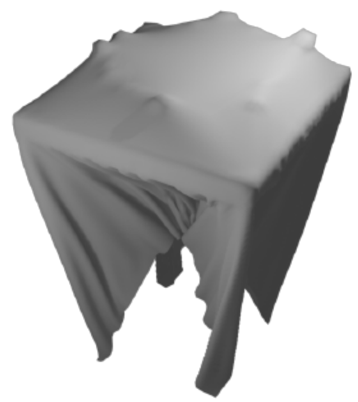
Para-images:

Cultural Ideas and Technical Apparatuses Beyond the Pictorial Surface



Keywords
para-images,
image theory,
algorithms,
computer simulation,
photography theory,
digital images,
media theory,
technical images,
apparatus,
post-internet,
CGI,
digital culture,
computer vision,
twenty-first-century media,
critical realism,
agential realism,
optics,
phenomenology,
representationalism,
phenomenological apparatus,
representational apparatus,
generative apparatus,
an image is the world

Author
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Title of thesis
Para-images:
Cultural Ideas and Technical Apparatuses
Beyond the Pictorial Surface

Degree
Master of Arts

Degree programme
Visual Culture, Curating
and Contemporary Art

Supervisor
Prof Bassam El Baroni

Thesis advisor(s)
Dr Daniel Rubinstein

Year of approval
2019

Number of pages
67

Language
English

Small, Zachary, et al. *"The First-Ever Image of a Black Hole Gets the Meme Treatment." Hyperallergic,* 12 Apr. 2019, hyperallergic.com/494359/the-first-ever-image-of-a-black-hole-gets-the-meme-treatment/.

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Abstract

Our world is hinged on images. The mass obsession with selfies and spectacles, the surveillance technology and Deepfake videos enabled by computer vision, the Event Horizon Telescope that produced the first image of a black hole, the simulations which climate change research relies on. Reality is being ever more entangled with image, yet images are increasingly detached from the physical world and escape human comprehension. It is obvious that the traditional understanding of images as a representation of the world, while valid, will no longer suffice to account for the intertwined relationship images has with our world.

Contemplating the ever-complex relationship between images and reality, the thesis proposes a new approach to understanding images in contemporary visual culture: para-images. The thesis employs Vilém Flusser's notion of counter vision to examine cultural ideas and technical apparatuses operating beyond the pictorial surfaces of seven images of water splashes. In the process, the thesis identifies agential realism and twenty-first-century media as two useful frameworks in formulating the triangular relationship among humans, images and the world. Attempting to answer the question 'What is left of an image if the pictorial surface is scratched away?', the thesis uncovers the often neglected ideological and technical infrastructures that make images possible in the first place. Situating images and machines at the same level of humans as entities with their own agencies, the image theory this thesis establishes concerns the entanglement of humans, machines, apparatuses, images and the world. In short, an image is the world, the world is an image.

Acknowledgement

I want to thank my supervisor Bassam El Baroni for the insights he has given me during my thesis. Dr Daniel Rubinstein has guided me through this thesis and pushed me to explore ideas beyond my comfort zone. For that, I want to sincerely thank him for his constructive criticism. I would recommend Joosung Kang to anyone who needs help with book design. He has been a professional graphic designer and a patient collaborator. I am grateful to Sophie Wright for proofreading the text. I want to thank Maija Tammi for being a reliable mentor. Thank you, Carlos Kynäslahti, for being my human iCloud. I want to thank Estelle Blaschke for generously sharing her paper. Last but not least, thank you to all the artists who gave me permission to use their work in the thesis publication: Jojakim Cortis and Adrian Sonderegger, Drew Nikonowicz, Michael Christopher Brown, Anna Ridler, Thomas Albdorf, Clare Strand and Emeric Lhuisset.

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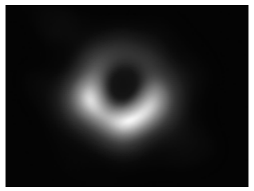
An Image is the World

On April 10, 2019, Director of the Event Horizon Telescope Project Shep Doeleman announced in a press conference that humans have captured the first-ever image of the most elusive and mysterious object in the universe: the black hole. More specifically, the image is of a supermassive black hole in the galaxy M87, 54 million light-years away from Earth. NASA declared that the image "makes history".[1] Among astrophysicists, the image is celebrated as a huge step forward in understanding the universe's most enigmatic object. But unlike many "extraordinary scientific feats" that went unnoticed, this image of a black hole went on to capture attention beyond the scientific community. The interest in the public sphere is unparalleled. Almost every major news outlet reported on the discovery. Through science and technology, humans have the ability to see the unseeable, to stare at a light-sucking abyss from an unfathomable distance. It seems that more than a remarkable achievement in astrophysics, the image symbolises something bigger than life.

2



The image[2] itself, however, is much less impressive. After almost 7 minutes of build-up, Doeleman unveiled the long-awaited image. The blurred image shows a fuzzy orange dough-nut-shaped ring against a dark background. After a round of applause, Doeleman promptly began explaining, to the press and many confused viewers like me who were watching the live-streaming of the conference, what we were seeing. The image, he said, depicts the event horizon of the black hole and the hot gas swirling around it. Doeleman asserted that the image is the strongest evidence that we have to date of the existence of a black hole. He went on to direct the viewer's attention to the shape of the shadow and the lighter patches of the ring underneath the black hole, few elements we can discern from the crude image, is consistent with Einstein's theory of relativity and their predictions.

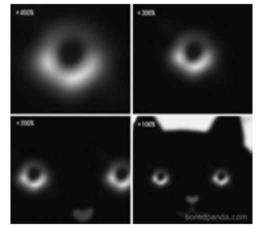
Within the online community, the image took on a vastly different narrative. Netizens were quick to mock the 'unimpressive'

1 Loff, Sarah. "Black Hole Image Makes History; NASA Telescopes Coordinate Observation." *NASA*, *NASA*, 10 Apr. 2019

2 Event Horizon Telescope collaboration et al., *Image of black hole at the center of galaxy M87*, 2019. Courtesy of EHT

image. In the typical social media manner, Reddit users offered their commentary in the form of memes. One meme[3] suggested the image is the eye of a low-res cat illustration, magnified at 400%. Another[4] is a four-panelled comic strip. The two panels on the left show American actor Tobey Maguire in character as Peter Parker in the 2000s' Spider-Man trilogy before and after putting on his glasses. In the panels next to them are the blurry black hole image and an in-focus, detailed photograph of a lit gas stove. These memes[5] highlighted the poor quality of the image and trivialized the scientific interpretation of the image.

4



5

The meaning of an image is ultimately flexible. What these two different reactions show, however, is that its meaning lies on something else other than the pictorial surface. The same blurred image that was hailed as a historic achievement in one community can be the mere punchline of a joke for another. Images are not inherently meaningful in themselves; underlying their meaningfulness is a worldview that makes the image possible in the first place. For Doeleman, the black hole image is informative despite its low resolution because of his trust in the ideas behind the image. The most obvious ones might be: His knowledge of astrophysics and black holes; Einstein's theory of general relativity; the development of telescopes; the Event Horizon Telescope project (an array of eight ground-based radio telescopes from around the world that act as a Earth-sized telescope to collect data from a single celestial target); very-long-baseline interferometry (the technique used to combine signals from multiple radio telescopes); work done by computer scientist Katie Bouman and the algorithm she developed to turn the data collected by the telescopes into an image; and the physical law of electromagnetic waves. For the memers, the image is a joke because they viewed the black hole image as a photographic image and, as such, it does not fit with their expectations of a digital photograph—

3 Small, Zachary, et al. "The First-Ever Image of a Black Hole Gets the Meme Treatment." *Hyperallergic*, 12 Apr. 2019

4 Black hole meme: *Magnified cat eyes*. 2019. Retrieved from DailyMemes. "Black Hole Memes." YouTube, 11 Apr. 2019

5 Black hole meme: *Tobey Mcguire*. 2019. Retrieved from DailyMemes. "Black Hole Memes." YouTube, 11 Apr. 2019

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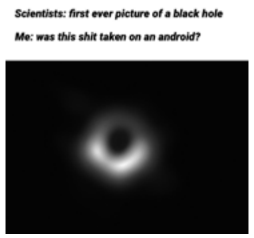

high-resolution and highly-detailed. It is a joke because it is a particularly poor image[6] in a time when even live-streaming is 1080p high-definition. Because a scientific image is expected to be 'informative'—in-focus, sharp and clear, leaving no ambiguity as to what is being depicted. Because, science—synonymous with reason and rationality—should provide answers with certainty.

Czech philosopher Vilém Flusser proposed a critical practice to examine vision which he coined "counter vision".[7] He suggested that instead of focusing on what is being looked at, we should move our point of inquiry to the reasoning and motivations behind certain kinds of image production, or as he put it, "inverting the visual intention".[8] Underpinned by the belief that the technical process is informative[9] in and of itself, counter vision looks back at where the image comes from, "turning the camera inside out"[10] to reveal how a specific vision becomes meaningful. A counter vision is not a critique of vision, but a "vision of vision".[11] If the intention of vision is the production of a meaningful image, the intention of counter vision is to see our being-in-the-world, not the world itself.[12]

Flusser's idea of counter vision is inextricably linked to two major concepts 'technical images' and 'apparatuses', which are crucial to his philosophy of photography. Counter vision is a way to reverse the vector of meaning and decode a technical image. Decoding in the Flusserian sense does not mean a semantic analysis of the image's content, but rather an examination of how the image is programmed. To him, the latter is a much more meaningful inquiry. In his book *Into the Universe of Technical Images*, he elaborates his position:

6 Black hole meme: *Was this shit taken on an android?*. Apr 10, 2019.

7 In an unpublished essay in collaboration with Andreas Müller-Pohle and Joan Fontcuberta

8 Flusser, Vilém. Countervision, In: "'To document something which does not exist.' Vilém Flusser and Joan Fontcuberta: A Collaboration", *Flusser Studies*, vol 13. May 29, 2017.

9 Flusser Vilém, et al. *Into the Universe of Technical Images*. University of Minnesota Press. 2011. p.45

10 Flusser, Vilém. Counter vision.

11 Ibid

12 Ibid

> *"The semantic and pragmatic dimensions of technical images are identical. To try to analyze what they show is to get lost in empty questions: Is the depicted house really out in the world, or is it just a surface? Or could the televised image of a politician be the performance of an actor imitating that figure? These are not good questions. They permit no answer relating to technical images because the questions assume a distinction between true and false, and in the universe of technical images, such distinctions have become superfluous. Technical images do not show us their meaning; they show us a way we may be directed. It is not what is shown in a technical image but rather the technical image itself that is the message. And it is a significant, commanding message."*[13]

This sentiment resonates with the ideas of his collaborator, Joan Fontcuberta. In his introduction to *Pandora's Camera*, a collection of essays on the technological transformation of photography, the artist emphasizes the "intentional" nature of the image:

> *"(Photography) is not reduced to its visibility: visibility is neither the one nor the determinant criterion; also involved are the processes that produce the image and the thoughts that sustain it..."*[14]

In both *Into the Universe of Technical Images and Towards the Philosophy of Photograph*, Flusser gives detailed descriptions of technical images. "A technical image is an image produced by apparatuses".[15] The Flusserian apparatus refers to technologies that abstract the world into images. The term implies a tension between the apparatus and the operator in the production of image – a "doubly involved" process.[16] For Flusser, the ordered world, which has previously been organized by texts and mathematical rules, has disintegrated into swarms of particles and quanta. What remains is a loose pool of discrete data points, moments and actions, where causality is ambiguous and meaning is undefined. An apparatus sees the particles as a field of possibility in which to function;[17] it is the human who gives the apparatus an intention to seek a certain pattern, resulting in an image with a particular aesthetic. A digital camera is capable of producing images of every exposure, every colour temperature at any shutter speed, but the photographs humans produce using a digital camera follow certain conventions. What we consider an

13 Flusser Vilém, et al. *Into the Universe of Technical Images*. 2011. p.48

14 Stein, Lisa. "Margin of Excess." *1000words Magazine*, 2018, pp. 32–41. Writing about Max Pinckers' project *Margin of Excess*, Stein referred to Fontcuberta's essay *Pandora's Camera*, which emphasises the intentional nature of images when discussing about the technological transformation of photography.

15 Flusser Vilém, et al. *Into the Universe of Technical Images*. 2011

16 Ibid.

17 Ibid.

‘informative’ photograph is one that is usually sharp, has good colour contrast, not too overexposed or underexposed… which makes up just a small portion of the images the camera is capable of capturing. In this way, Flusser’s concept of apparatus share similarities with that of Karen Barad, who defines an apparatus as the physical manifestation of a “boundary-drawing practice”[18] that reconfigures the different agencies of the world. Technical images, being products of apparatuses, inherit their properties. They are not surfaces but mosaics assembled from particles.[19] Technical images such as photographs, films and digital images, exist in an attempt to consolidate these particles in the world into images. As such, technical images are inherently grounded in physical reality. Technical images are ‘of reality’, whether the mosaics result in a comprehensible representation of reality or not, because they are the product of human’s interaction with reality. The world is the prerequisite of technical images; they cannot exist without it.

The apparatus is the key to differentiating between technical images and traditional images. With technical images, the world is transcoded through an apparatus onto an image. Like fingerprints, their significance is automatically reflected on their surface where the significance is the cause and the image is the consequence. This indexical process is sometimes confused with objectivity. On the contrary, the traditional image is symbolic by nature because “‘human beings’ place themselves between the images and their significance.”[20] In the case of a painting, the world is turned into symbols in the head of the painter and transferred to the surface through a paintbrush. To decode a traditional image, one has to get inside the head of the painter to understand how they encode the world. Hence, when analyzing paintings, it is common for researchers to study the painter’s biography. To decode a technical image, however, one has to look inside the apparatus because, in the gesture of ‘capturing an image’, the user is limited to carrying out the apparatus’ inner instructions. For example, the camera is programmed to produce photographs, and every photograph is a realization of one of the possibilities contained within the program of the camera. “The apparatus does as the photographer desires, but the photographer can only desire what the apparatus can do.”[21] In fact, an apparatus is not merely a piece of observing equipment; it is designed to simulate specific thought processes.“Apparatuses are black boxes that simulate thinking in the sense of a combinatory game using number-like symbols.”[22] Unless we flip the apparatus inside out

18 Barad, Karen Michelle. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press, 2007. p.140

19 Flusser Vilém, et al. *Into the Universe of Technical Images*. 2011.

20 Flusser, Vilém. *Towards a Philosophy of Photography*. Reaktion Books, 1983. p.15

21 Flusser Vilém, et al. *Into the Universe of Technical Images*. 2011. p.20

22 Flusser, Vilém. *Towards a Philosophy of Photography*. 1983. p.32

and examine the specific thought processes, we shall never understand the true meaning of an image.

Applying counter vision, this thesis inspects a series of technical images with renewed interest. Specifically, the thesis follows a lineage of images depicting water splashes. This ordinary yet little understood phenomenon has sparked the interest of scientists, artists and image-makers for centuries from Leonardo da Vinci to Arthur Mason Worthington to Harold Edgerton and contemporary MIT researchers. Its elusive nature makes it difficult to capture while its mesmerizing forms give the viewer an indescribable visual satisfaction once fixed in an image. The phenomenon somehow hits a sweet spot of being an appealing challenge for professionals and amateur image-makers alike. Images of a splash of water have been created in many different forms, time after time; as a drawing, as a photograph, as a digital image and as a simulation. They epitomize humankind’s long-term obsession with images and the intertwined relationship between humans, images and the world.

Looking at these images of water splashes through the lens of counter vision, we peek over the pictorial surface and examine the ‘para-image’. ‘Para’ is a prefix appearing in loanwords from Greek meaning ‘beyond’ or ‘beside’. Thus, a para-image is what is left when we scratch away the image surface. A para-image moves the focus away from the often seductive optical aspects of the image and examines different notions of images. This includes, but is not limited to: philosophy, cultural ideas, scientific theories and technological knowledge that sustains the image surface and give it meaning. It concerns perception, experience, production, dissemination and other aspects of images that are crucial to its agency. To put it another way, para-images are the results of apparatuses. This time, Giorgio Agamben’s definition of apparatus comes in handy, in which he defines it as “literally anything that has in some way the capacity to capture, orient, determine, intercept, model, control, or secure the gestures, behaviors, opinions, or discourses of living beings.”[23]

By frequently doing double-takes on these images, we see a pattern of how human beings situate themselves with images and the world. Apparatuses inspire certain way of image-making. The images in turn spark new thinking about images and sometimes new ontologies. This thesis unveils the para-images of seven depictions of water splashes by laying out ideas crucial to the significance of these images, as well as other images that operate in similar manners. In an attempt to give shape to these paradigms of thought, the thesis identifies, drawing on Agamben’s term, three apparatuses: (1) the

23 Agamben, Giorgio. *What Is an Apparatus?: and Other Essays*. Translated by David Kishik and Stefan Pedatella, Stanford University Press, 2009. p.14

representational apparatus (2) the phenomenological apparatus and (3) the generative apparatus.

The three apparatuses, although to some degree are informed by technology available at the time (e.g. cameras, computers, artificial intelligence, etc), are not limited to a particular era or medium. There is overlap among apparatuses; each can be seen as a commentary on others. A photograph may be given significance through different reasoning, as in the case of the black hole image. On the other hand, the same medium can switch between apparatuses. A digital image can be created with a representational intention[24] while a painting can be generative. A good example is Clare Strand's *The Discrete Channel with Noise: Algorithmic Painting; Destination.*[25] For the artwork, she let her husband picked a photograph from her archive, broke it down into a coded grids and filled in with a number corresponding to the brightness of the area. He would then communicate the number and she would fill up a canvas, painting grid by grid.

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Moreover, we cannot trace the apparatus back to a single point in time, nor can we easily attribute a linear causality among ideas. Ideas and images feed on each other. In fact, they are a loose pool of particles, which combine to form a partial picture when we begin to draw boundaries. After examining the three apparatuses, a blurry picture begins to appear, one that points to the displacement of human vision in the process of image-making and the ever-dissolving boundary between the image and the world. These will be further elaborated later on in the thesis, which is made up of a collection of essays contemplating the para-images of water splashes in different visual forms.

This thesis does not claim to provide an unambiguous and highly detailed para-image, but rather works to acknowledge the meaningfulness of a blurred-image, observed using a relevant apparatus. This thesis also does not discriminate between Flusser's, Agambem's and Barad's definition, using the term 'apparatus' flexibly. In many points of this thesis, an apparatus

24 RochlitzVR, *Rendering of Gothic Period using Blender*, circa 2017

25 Strand, Clare. *The Discrete Channel with Noise*. 2018. Courtesy of the artist.

refers to the boundary-drawing practice and the physical components of the image-making device, the technology and the cultural ideas surrounding it, the visual intention and everything else related to the production of an image. The three definitions are inseparable. An apparatus is both the ideology and the physical manifestation of those ideas. In short, this thesis refuses the reduction of technical images to their inscription as a visual form,[26] and apparatus to its technology.

Technical images have become a core component in our relationship with the world, or as Daniel Rubenstein elaborates in *Photography After Philosophy*: "Photography is the visual figuration of a new layer of consciousness—in which new relationships to space and time, and therefore new categories of thought, play, art and agency are emerging."[27] To talk about para-images is to problematize our conventional expectations and trust in images. Our relationships with images—whether it is one built on trust or skepticism—are emblematic of various kinds of epistemological, ontological and visualizing systems (Plato's or Descartes' or Kant's or Merleau-Ponty's or Foucault's or Baudrillard's or Flusser's or Hansen's or Barad's).[28] Which apparatus is dominant? Which apparatus has the hegemony to decide what type of image and aesthetics is meaningful? How do we formulate the triangular relationship between human beings, images and the world under each apparatus? How do we situate ourselves in it all? Images do not live in a vacuum; they are tied to our belief systems, to particular ways of relating to the world. The Flusserian apparatus can produce as many images as the program allows, but whether an image is meaningful or significant to us is supported by our worldviews. By investigating para-images, we excavate a world of ideas. In short: in every image, there is a world.

26 Lugon, Olivier. and Joschke, Christian."Transbordeur: Photography, History, Society Annual Journal." *Transbordeur Magazine, Transbordeur Magazine*

27 Rubinstein, Daniel. *Photography After Philosophy*. 2016. p.4

28 Barad. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. 2007. p.375

Chapter 1: Flat Ripples and Paper Moon

Representationalism

“When the water is impacted, it opens and the impacting drop bounces back. The water that was open, closes back as a wave converging toward the place where the drop jumped up. All this water in reflective motion impacts on itself and jumps (following the first drop) and climbs behind it as if embracing it.”[29] The Renaissance Man Leonardo DaVinci describes a water splash in his notebook. This ordinary phenomenon—in fact so ordinary that it is mundane—has been the interest of Western scientists and artists since time immemorial. It is a phenomenon that has been studied time after time for its sophisticated, fluid mechanics as much as for its elusive beauty.

Motivated by his interest in hydraulics and mechanics, DaVinci documented many fluid phenomena in texts and drawings dotted throughout his notebooks. In *Codex Atlanticus*, He made various crude drawings[30] to record his observations of the impact of a water drop as it collides with a body of water. One depicts a teardrop-shaped jet of water, another shows a side-view of the moment right after the impact, in which an organic, beaded form protrudes from a dark hole in the center of a rippled surface. *Codex Atlanticus* is the largest set of bound notes by DaVinci. Many of his notes written in the fifthteenth century still exist today, largely due to conservation efforts. *Codex Atlanticus*, along with its seven other cousins, including *Codex Leicester* and *Codex Madrid*, are highly sought after by collectors. There is not a shortage of buyers who would pay an obscene amount of money to get their hands on it, one of them being Bill Gates, who paid over $30 million for *Codex Leicester* in 1994 at a Christie’s auction.[31] It is not an overstatement to say that his notes have attained the status of a cult object: a tangible, paper Holy Grail.

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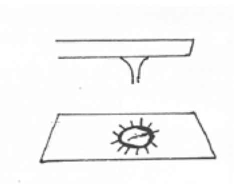

Flipping through the codex at the Warburg Institute in London, I stared in awe at the power that these drawings hold. The sketches are so simple, direct and nonchalantly drawn, yet

29 Macagno, Enzo. *Libro dell'acqua*. The University of Iowa, Iowa Institute of Hydraulic Research, 2006

30 DaVinci, Leonardo. *Drawings from Codex Atlanticus*. circa 1480

31 "Christie, Manson and Woods, sale 8030, 11 November 1994". *Christies.com*. 11 November 1994. Retrieved 23 July 2013.

they represent an unparalleled significance to the Western world. One can easily explain my wonder by attributing it to our obsession for objects, or the aura of DaVinci as an all-round genius—an image firmly constructed by Western rhetoric, but I believe its significance is not expressed simply by the monetary value a capitalistic system assigns to it. There is more about these manmade inscriptions that points to a fundamental belief system. At the minimum, the connection is strong enough for Enzo O. Macagno, a noted American hydraulician who has willingly spent decades compiling and deciphering fluid mechanics related texts and drawings from the codices. He published the findings in *Libro dell'acqua,*[32] from which I quote DaVinci’s description of a water splash.

When looking at a drawing from Western culture, we tend to subconsciously evaluate its realism, comparing what is depicted on its surface to our lived experience. For what reason do we believe a doodle by a famous man represents how water behaves? And why do we naturally assume a connection between the inscription and reality, when traditional images such as drawings are a personal system of encoded signifiers, construed by the author to depict the world? Before we move on to technical images and their apparatuses, we need to understand the para-images of surfaces and inscriptions.

If we are to find any connection between Plato's thinking and today's image culture, it would be in his dichotomy between the image and the real. In the *Allegory of the Cave,*[33] he argued that pure reason is the only way to enlightenment. He warned us about the phantasms of the caves. His idealism distinguishes essence from appearance, the intelligible from the sensible, ideas from images. He is famously skeptical of images. Plato characterised the distinction between the making of likeness (“eikons”) and the making of semblances (“phantasm”) in *Sophist*. The dialogue demonstrated that a phantasm is a deceitful copy of reality; an imitator that looks like reality but knows nothing of reality. His

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32 Macagno. *Libro dell'acqua*. 2006

33 Coxcie, Michiel. *Plato's Cave*, circa 16th century

theory establishes an oppositional tension between image and reality, in which images are malignant parasites preying on reality.[34] We do not know if Plato would have a different conception of images had he encountered a technical image, but his position with regards to the traditional image is clear—an image is an obstacle, blocking us from the true essence of the world.

This harsh critique of images poses a pesky intellectual challenge that every philosopher who succeeds him has had to confront if they wanted to use the technique of observation in their epistemology. As much as Plato wanted his fellow humans to pursue the true essence of things, we live in the visible world, in which images are an important medium to communicate our realities. Hence, to secure a trust in image surfaces, Western philosophy began a longstanding project that I like to call the 'rationalization of human sight'. Classical thinkers from Euclid to Descartes have attempted to provide alternative theories to rebuild the certainty of human sight and our trust in images.

One of their crucial undertakings was to put pure reason back into image. Euclid, though he was not motivated by this exact aim, brought mathematics into the study of light. At his time, nothing was deemed more rational than mathematics as a way of understanding reality.[35] In Euclidean optics, light rays are treated as geometrical problems. Euclid laid down seven postulates on the correlation between viewing angles and the size of the images. His theory of the viewing angle explains the reflective properties of light. Armed with these geometric principles, it is easy to work out the reflected image based on the knowledge that light rays travel in straight lines. Euclidean optics shows that our vision is no more than a point-to-point translation of light rays.

The ancient Greek understanding of human vision remains largely inaccurate. Euclid, Ptolemy and Plato asserted that vision occurs when rays emanate from the eyes and are intercepted by visual objects,[36] an idea known as intromission theory. The theory states that if an object was seen directly, it was by 'means of rays' coming out of the eyes and again falling on the object. This thinking was likely inspired by Greek mythology[37] and the observation of the gleaming 'fire' in animals' eyes at night. The view was accepted by mainstream thinkers until Arab mathematician Alhazen provided an alternative theory. He is the first scholar to explain that vision occurs when light bounces on an object and then is directed to one's eye.[38] Alhazen also published the 7-volume *Book of Optics* in

34 Plato. *Sophist*. 266d

35 "Plato on Mathematics." *MacTutor History of Mathematics Archive*

36 O'Regan, J. Kevin. "Ancient Vision." *J. Kevin O'Regan*

37 In ancient Greek mythology, Aphrodite made the human eye out of the four elements. She lit the fire in the eye which shone out from the eye and made sight possible.

38 J. Al-Khalili, "In retrospect: Book of optics", *Nature* 518. 2015. pp. 164–165

the eleventh century, in which the pinhole camera and the camera obscura are described.

Descartes built on the theories of his predecessors and further consolidated the connection between mathematics, geometry and optics. His illustration of a blind man[39] quite succinctly summarizes his optics. The illustration shows a blindfolded man walking with sticks and seeing with his hands. He compared the human eye to a camera obscura: an equipment in which the light that shone from an object travelled in a straight line into the apparatus, forming an image. "Rays of light are nothing other than the lines alone which this action tends."[40] For Descartes, the mechanics of light are universal to every pair of eyes. The mind's job is simply, as explained by the crossed sticks in his illustration, to invert the image formed by the camera obscura to form an upright image that humans are used to. Taking it one step further, Descartes alluded to the medieval distinction of light,[41] 'lux' and 'lumen', giving his optics extra metaphysical weight as he explains reflection and refraction. He characterised 'lux' as the light of the mind[42] and 'lumen' as the corporeal light that shines through objects. One could speculate that Descartes' interest in studying reflection and refraction was as much motivated by curiosity as by his metaphysical conception of light. His vocabulary is sprinkled with colourful metaphors that explore the connection between natural light and truth. Descartes equates truth with things that are clear and distinct,often using light as a synonym of reason. He explains that God is the truth because "it is manifest by the natural light that all fraud and deception depend on some defect".[43]

The invention of the camera obscura provided artists a new way to produce images. The world is now partially abstracted through an apparatus rather than directly translated by the human mind into a drawing. Drawings produced under this practice carry

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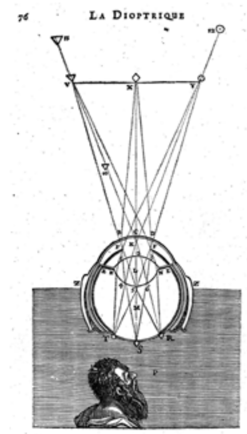

39 Illustrations from 1724 Edition of Descarte's La Dioptrique

40 Descartes, Rene. *La Dioptrique*. 1724

41 Descartes. *La Dioptrique*. 1724

42 Grosseteste, Robert, and Clare C. Riedl. *On Light (De Luce)*. Marquette University Press, 2000. "Light that extends along with itself the spirituality of the matter of the first body"

43 Garber, Daniel. *Descartes, René. In E. Craig (Ed.)*, Routledge Encyclopedia of Philosophy. London: Routledge. 1998, 2003. Retrieved September 12, 2019

the instruction of the apparatus. The popularisation of the camera obscura as a drawing aid during the Renaissance further imposed the philosophy of classical optics onto the pictorial surface.[44] Trust in the image surface continued to flourish with the invention of perspective and chiaroscuro during the Scientific Revolution of the sixteenth century. These techniques provided consistent rules to render the world onto image surfaces regardless of the viewer's position. Bruno Latour suggests that the invention of perspective is important because of "its logical recognition of internal invariances through all the transformations produced by changes in spatial location."[45] He concluded that the drawing technique creates an "optical consistency."[46] Linear perspectives established a two-way relationship between object and figure in which the world can be translated by the human illustrators in a fixed manner. Linear perspective and chiaroscuro supply a geometric stability to pictures, unifying the ways that traditional images in the Renaissance were made. The result is the rationalization of image surface.

> *"In the West, even if the subject of the printed text were unscientific, the printed picture always presented a rational image based on the universal laws of geometry. In this sense the Scientific Revolution probably owes more to Albrecht Dürer than Leonardo Da Vinci."* [47]

All these culminate to one concept: representationalism. Karan Barad summarises representationalism concisely as: "The assumption that language was a transparent medium that transmits a homologous picture of reality to the knowing mind finds its parallel in a scientific theory that takes observation to be the benign facilitator of discovery, a transparent lens passively gazing at the world."[48] Optical consistency fortifies the representational connection between image surface and the world it depicts. Behind every image surface is a dialogue with representation, in one way or another, aligning with or escaping from it, regardless of the author's intention. Every image surface bears the burden of representation.[49] Ironically, representationalism comes with a side effect: the suspension of reality. An image surface allows objects in the world to be isolated, translated onto a surface, examined and manipulated. A

44 Italian scholar Giambattista della Porta published a clear description of the camera obscura in a book entitiled *Magiae naturalis libri XX in quibus scientiarum naturalium divitiae et deliciae demonstrantur*

45 Latour, Bruno. "Drawing Things Together." *The Map Reader*, 2011, pp. 65–72

46 Summarising William M. Ivins and Samuel Y. Edgerton's analysis of linear perspective, Latour explain the term as "a regular avenue through space". The consistency allows the world to be transcribed onto a surface without much corruption.

47 Edgerton, S. "The Renaissance artists as a quantifier". In M.A. Hagen (Ed.) *The Perception of Pictures*, vol. 1, New York: Academic Press. 1980. p.190

48 Barad, Karen Michelle. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press, 2007. p.97

49 Tagg, John. *The Burden of Representation: Essays on Photographies and Histories*. Palgrave Macmillan, 2007.

subject and object dichotomy. The classical drawer suspends himself above reality, gazing into the world as an independent observer, exerting the power of vision over earthly beings.

Representationalism also extends to extraterrestrial beings: from the water drawings in DaVinci's notebook to the moon drawings of Galileo. Galileo's drawing[50] in 1609, a set of six watercolours, is widely regarded as the first realistic depiction of the topographical structure of the moon. His use of chiaroscuro accentuated the structure of lunar mountains and craters, debunking the common myth that the moon is a perfect sphere with patches of discoloration.[51] Yet, we have long been gazing up at our closest celestial neighbour and throwing guesses at its appearance. Different cultures popularize different interpretations of the moon's markings, even within Western culture, there have been controversies as to what the moon really looks like. Some cultures see the dark pattern as holes and fantasize a moon made of green cheese. The Haida people saw a boy trapped in the moon with a stick. The ancient Chinese identified a rabbit upon observing the markings and conceived a beautiful epic that ends with a goddess living in a moon palace.[52] Myths aside, Chinese scholars had less superstitious interest in the moon, focusing rather on tidal waves, the lunar cycle and other moon-related phenomena. These observations were mostly communicated through text.[53] There tends to be less emphasis on visual representations in epistemological literature compared to their Western counterparts. Representation remains by and large an artistic device reserved to paintings and fiction.

The seemingly inherent connection between image surface and reality in Western culture is constructed and historical. The investigation of the classical Western notion of the

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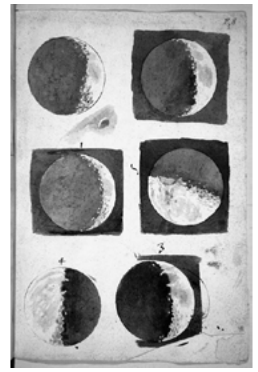

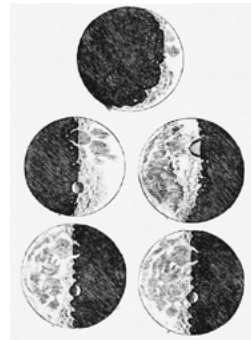

50 Galilei, Galileo. Drawings of the Moon, November-December 1609

51 Lynch, Michael, and Samuel Y. Edgerton. "Abstract Painting and Astronomical Image Processing." The Elusive Synthesis: Aesthetics and Science Boston Studies in the Philosophy of Science, 1996, pp. 103–124

52 The Fable of Chang-e, the Chinese goddess of the moon, can be traced back to classic text Huainanzi (《淮南子》：「姮娥竊以奔月，悵然有喪，無以續之。」).

53 Chinese classic text Lunheng (《論衡》) by Wang Chong mentioned the phenomenon of tidal wave (「濤之起也，隨月盛衰。」) Shen Kuo's Dream Pool Essay (《夢溪筆談》) proposed that the moon is a non-luminous body (「月本無光」).

image surface deserves an entire book on its own, but for now, the lyrics of a jazz classic succinctly summed up the para-images of the surface: "Said it is only a paper moon, sailing over a cardboard sea, but it wouldn't be make believe if you believed in me."[54]

54 Excerpt of the lyrics of *It's Only a Paper Moon* sung by Ella Fitzgerald. There are many interpretations as to what the lyrics mean. Some say paper moon refers to the illusion of romance. Others are reminded of carnival photos of people posing on a paper moon backdrop. Here, I want to emphasise the belief behind a representation.

Chapter 2: Catching Splashes in the Dark

Representational Apparatus

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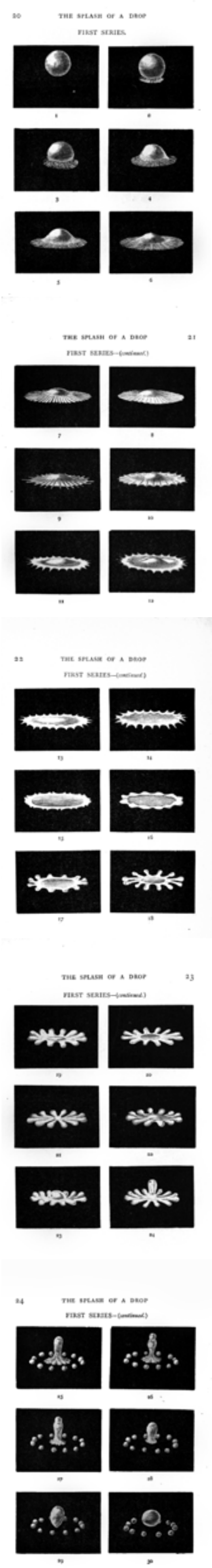

Arthur Mason Worthington spent most of his career studying water splashes. In the English physicist's book *The Splash of a Drop* published in 1895, he retold a school-boy account he had heard twenty years ago about the phenomenon: ink drops of the same size falling from the same height had always made the same mark.[55] What followed was decades of curious observations of the phenomenon, which materialized in a series of drawings. These drawings of liquid stretching,[56] perfectly symmetrical and sharp, are so elegant there is almost a painterly quality to them. They have the kind of Platonian beauty, one that associates truth with beauty.[57] Or perhaps this beauty is imagined: he is simply following the lineage of anatomists, botanists and microscopists before him, who took on the Baconian mission of documenting the world in its categories and its regularities.

In order to capture the fleeting phenomenon that occurs "in the twinkling of an eye,"[58] Worthington devised an elaborate observation setup. He designed a device consisting of a Leyden jar, a timing sphere and an observation platform of water drops made up of mechanical parts. Worthington conducted his experiment in a relatively dark room. When he dropped the timing sphere from above, breaking the electrical circuit within the device, the jar would produce a bright flash of light. In that split second, the splash revealed itself. For years, Worthington would rely on the afterimage burned onto his retina by the flash to illustrate the fascinating forms. By adjusting the height of the timing sphere in small increments, Worthington was able to produce a freeze-frame sequence of water splashes a thousandth of a second apart. Worthington probably learnt about afterimage through his working experience with Hermann Ludwig Ferdinand von Helmholtz in his Berlin laboratory.[59] Von Helmholtz is the father of neuroscience. In 1864, he published the first volume of his

55 Worthington, A. M. *Splash of a Drop*. 1895.

56 Worthington, A. M. *First Series*. Circa 1985. Drawings of a Drop of Mercury 0.15" in diameter falling 3" on to a smooth glass plate

57 Plato, *The Symposium*, Penguin Books, 1951.

58 Worthington, A. M. *The Splash of a Drop*. 1895. p.1. "The splash of a drop is a transaction which is accomplished in the twinkling of an eye..."

59 "Obituary Notice, Fellow: Worthington, Arthur Mason." *Monthly Notices of the Royal Astronomical Society*, vol. 77, Feb. 1917, p. 308.

pioneering work on visual perception, the *Handbook of Physiological Optics*. Central to his work is the study of the correlation between apperception and perception. As it turns out, very few sensations are one-to-one to perceptions. What one senses does not get directly translated into perception. The external object that creates a stimulus in the nervous system is interpreted and produces a vastly different perception that cannot be explained away simply by studying the sensory input. Helmholtz called this process transduction and sensory coding. One common phenomenon that Helmholtz studied is the afterimage. An afterimage is an image that continues to appear in the eyes after a period of exposure to the original image, sometimes as a result of colour fatigue. It happens to us often after prolonged looking at a colour, fatiguing a certain type of colour-processing cone cells in the retina. When we move our field of vision, those cone cells under-expresses themselves, resulting in a color patch of a complementary colour. Staring at a green rectangle for a long time will cause a magenta afterimage after the original stimulus is removed. An image continues to exist in our vision even though the stimuli has disappeared. His study of optical illusions reveal that the human eye is indeed not as optically reliable as Cartesian optics suggested. He concluded that vision is a form of unconscious inference based on previous experience.[60]

Cartesian optics are more idealistic than true to human vision. Scientists have discovered many more phenomena after Helmholtz, such as blind spots, visual hallucination and colour constancy, that cannot be explained by classical optics. French ophthalmologist Louis Émile Javal reported in the late nineteenth century that our eyeballs constantly make short, rapid movements (saccades) when reading along a line of text. A landmark study published in 1976 led by scientists John K. Stevens[61] in which subjects were anaesthetized but kept awake further investigate the phenomenon. With the experimental subjects' eyes open but unable to move, their vision actually faded when they could not re-stimulate neurons through eye movement. Saccades are essential to vision, yet curiously enough our vision is relatively stable despite the eyes' short and jerky motions. Psychologist and writer Susan Blackmore sums up the more modern understanding of vision quite well:

> *"Vision is an illusion in the following sense—to the extent that people believe that seeing means absorbing lots of information and building up a picture inside their heads that they then consciously experience they are wrong. SO vision is not the way it seems to be... neither*

60 von Helmholtz, Hermann. *Handbuch der physiologischen Optik*. 3. Leipzig: Voss. 1925

61 Stevens, John K., et al. "Paralysis of the Awake Human: Visual Perceptions." *Vision Research*, vol. 16, no. 1, 1976.

the show nor the observer can be found in the brain; it simply is not organized that way, and has no need of them." [62]

Light is also more complex than what previous philosophers had thought. The infamous double-slit experiment has offered explanations for a variety of hypotheses, first in Newtonian physics and later in quantum mechanics. There are many versions of the experiment, some are done with different emission sources and other times only as a thought experiment (gedanken), but the first, performed with light by Thomas Young in 1801, was conducted to demonstrate the wave theory of light. The corpuscular theory of light set forward by Descartes—an alternative to Young's—was the dominant theory of light propagation at the time. It states that light is made up of small discrete particles called 'corpuscles' travelling in straight lines. Young proved in his experiments that light can exhibit wave-like properties, as evidenced by the interference pattern on the screen. The discovery of diffraction by Francesco Maria Grimaldi two centuries earlier and Young's interference pattern provide a counter argument to classical optics where light is expressed in lines, figures and angles and calculated using the logical tool of geometry.

In Spring 1894, at the dawn of photography, Worthington decided to redo his experiment with a camera and finally succeeded in fixing the droplet's splash in pictures. Upon seeing the photographs, he finally realised how wrong he had been with his drawings. The water splashes were much less regular than he had presented in the drawings. The perfect symmetry was shattered. In his book, he confessed that he was blinded by his own judgement—an "Auto Splash":

> *"It remains only to speak of the greater irregularity in the arms and rays as shown by the photographs. The point is a curious and interesting one. In the first place I have to confess that in looking over my original drawings I find records of many irregular or unsymmetrical figures, yet in compiling this history it has been inevitable that these should be rejected, if only because identical irregularities never recur. Thus the mind of the observer is filled with an ideal splash—an 'Auto Splash'—whose perfection may never be actually realized."* [63]

Like many scientists of his time, Worthington's methodology was fashioned after the Baconian method. Put forward in Bacon's book *Novum Organum*, the method advocated methodical observation of facts as a means of studying and interpreting natural phenomena. Also known as empiricism, he postulated the dismissal of all prejudices and preconceptions by following three main steps: the description of facts, the tabulation and classification of those facts and hypothesis of causal relationship between the facts. In the nineteenth century, however, the new discoveries of inconsistent human vision and the duality of light both threaten the certainty of science. Human vision is an illusion permeated by subjective judgements. At this crucial moment, the not-so-coincidental invention of photography comes into science conveniently to reaffirm the certainty of Baconian knowledge.

Photography restores the optical consistency of the surface established by camera obscura and linear perspective in the fifteenth and sixteenth century while ensuring an unparalleled mechanical objectivity to document reality that a human subject cannot compete with. It is not surprising that since its developmental stage, when Henry Fox Talbot was experimenting with images produced solely by the action of light and chemistry in his backyard,[64] photography has been assigned this mission of objective representation. Fox Talbot named his first commercially published book illustrated with photographs *The Pencil of Nature*.[65] Photography symbolizes everything human vision is not. Mechanical seeing counteracts the flaw of the human eye. Its fast shutter freezes time, its long exposure reveals imperceptible movements. Or as Fox Talbot put it: "The eye of the camera would see plainly where the human eye would find nothing but darkness."[66]

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Underpinned by this representational demand, it is a natural development that photography's automatic nature is highlighted in the early writings of photography. It is in fact a central idea mainstream photo theorists must engage with at the infancy of photography. Before digital photography, photography was thought to be unique because it is THE 'unmediated' image. Theorists have given this characteristic many names. Susan Sontag called it "trace",[67] Rosalind Krauss used "indexicality"[68]

62 Blackmore, Susan. "A Grand Illusion." Consciousness, 2005, pp. 50–65

63 Worthington, A. M. *The Splash of a Drop*. 1895, p.74

64 Henry Fox Talbot, Wim. *A Cascade of Spruce Needles*, 1839 (photogenic drawing negative)

65 Henry Fox Talbot, William. *The Pencil of Nature*. Longmans, London. 1844.

66 Henry Fox Talbot. *The Pencil of Nature*. 1844

67 Sontag, Susan. *On Photography*. Penguin Classics, 2014.

68 Krauss, Rosalind. *"Notes on the Index: Seventies Art in America."* October 3 1977. 68-81.

and Roland Barthes named it a " message without a code."[69] A photograph, they argue, simply registers what is in front of the camera. An image is drawn automatically by nature. For the first time, the image of the world is formed automatically, without the creative intervention of man.[70] The photographic subject 'touches' the light-sensitive surface and leaves an imprint of its presence, thus producing an image that is free of style, free of code. It is "the object itself."[71] It is what supports the idea of a "truth claim", the term coined by Tom Gunning to describe the prevalent belief that traditional photographs accurately depict reality. A new optical consistency, now rooted in the indexicality and visual accuracy of photographs, rekindles the connection between surface and reality— realism, a Western obsession that keeps haunting images even today. It gives the entire tradition of documentary photography, from Dorothea Lange's work of the Great Depression and Robert Capa's photographs of the Second World War right through to modern photojournalism, weight and significance.

Photographic vision, in its early years, emblematized a distrust in the human eye. For a long time, the aesthetic of photography has been defined as the antithesis of human vision. Unlike inconsistent human vision, the camera translates whatever in front of it onto an image in a one-to-one fashion. The camera renders time and space in a much higher resolution than the human eye. It freezes quick motions, it magnifies microstructures. A camera is thought to be a prosthetic to human vision, capturing what the human eye *cannot* see. Thus, photographs are expected to be in-focus, sharp and highly detailed. In a nutshell, photography is, like many exhibition titles[72] have suggested, seeing the invisible.

Looking backwards, the stroboscopic photographs of Berenice Abbott,[73] commissioned by MIT, that document the principles of physical science, and Harold Edgerton's high-speed photography of splashes and bullets[74] seem like a logical developments in the medium's history. For more than forty years, Harold Edgerton and James R. Killian worked as a team: one taking the photographs and the other writing about the 'meaning of the pictures.' In the introductory essay of their photobook *Flash! Seeing the Unseen by Ultra-high speed photography*, Killian boasted about the superiority of their

69 Barthes, Roland. 1977, *The Rhetoric of the Image in Heath, Stephen (Trans) Image, Music, Text.* New York: Hill and Wang. p32

70 Bazin, Andre, and Hugh Gray. "The Ontology of the Photographic Image." *Film Quarterly*, vol. 13, no. 4, 1960, pp. 4–9.

71 Ibid.

72 *Once Invisible* (1967), an exhibition of science photographs curated by John Szarkowski, opens at the Museum of Modern Art, NY; *Beyond Vision* (1984), an exhibition and book by John Darius for Britain's National Museum of Photography, Film and Television includes 100 photographs that "provide information inaccessible to the human eye."; *Brought to Light: Photography and the Invisible 1840–1900* (2009), an exhibition curated by Corey Keller, opens at the San Francisco Museum of Modern Art.

73 Abbott, Berenice. *A Gold Ball Bouncing Along a Hard Flat Board, Loses Energy. Where Has All the Energy Gone?* 1958-61.

74 Edgerton, Harold E. *Bullet through Apple*. 1964

technology over a conventional camera[75] and that high-speed photography shows that "beyond the horizon of human vision lies a whole world of such unseen rapid motion."[76] The electric spark, lasting about one millionth of a second, allowed them to access a superhuman temporal resolution. The technique not only enabled the duo to freeze water splashes in a motion arc, but also to literally capture the blink of an eye.[77]

In his essay, Killian continued to highlight the capability of high-speed photography by recounting the effort photography's pioneer Fox Talbot had exerted to make a 'still' picture of moving objects. Fox Talbot, who patented his method of instantaneous photography in 1851, created an 'unblurred' picture of a clipping from the London Times by using a studio setup that combined a rapidly revolving disk and a spark-producing Leyden battery. The method formed the basis of 'stroboscopic seeing', in which a flash unit[78] creates pulses of light at miniscule intervals, allowing a moving object (a rotating fan for example) to appear momentarily frozen in time to the naked eye. Stroboscopic photography is a technique of time manipulation, and as such it acquires the aesthetics of stillness. The genius of a 'still' photo is emphasised repeatedly in the essay.

> *"It is the genius of high-speed photography, both still and motion, to reduce and clarify the fuzzy world of the transient and fast...They provide a unique and literal transcript of that time world beyond the threshold of our eyes."* [79]

Killian credited the invention of stroboscope in 1832 to the Belgian physicist Joseph Plateau and Austrian mathematician Simon von Stampfer. Plateau made many original contributions to physiological optics. His thesis was a remarkable study of the

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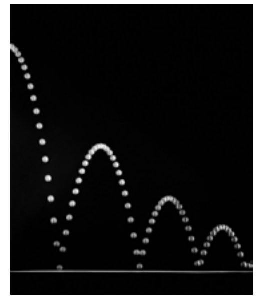
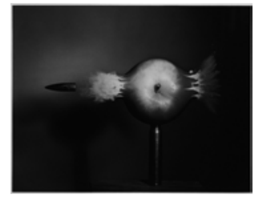


74



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75 Edgerton, Harold E. *A Mechanical Shutter in Action*. circa 1939. A series of pictures, taken at the rate of 4,200 per second, on a high-grade mechanical shutter. (scanned from Flash! Seeing the Unseen by Ultra-high speed photography.

76 Edgerton, Harold Eugene, and James Rhyne Killian. *Flash! Seeing the Unseen by Ultra High-Speed Photography*. C.T. Branford Co., 1954

77 Edgerton, Harold E. *Quick As A Wink*. circa 1939

78 Directions for assembling a single-light high-speed photography devised by Harold E. Edgerton

79 Edgerton, *Flash! Seeing the Unseen by Ultra High-Speed Photography*. 1954. p.22

properties of the impressions which light can exercise on the eye, studying the effect of colour on the human retina and the distortion of moving images. In 1829, his passion for experimentation pushed him to carry out a very dangerous experiment of directly staring at the sun for approximately twenty-five seconds.[80] It was rumoured that the experiment was related to his eventual blindness in 1843. He retained reasonable vision until two years before his blindness. Within those two years, he suffered "from blurring of vision with many black spots floating about in front his sight."[81] Often called the 'martyr of science', Plateau lost his sight in the pursuit to master human vision. As he learnt about the physiology of the eye, his retina slowly detached, the remnants forming black spots, blocking his own vision.

Time manipulation creates its own blindness. The emphasis of a sharp picture devalues ambiguous surfaces. Shot after shot, the experiment continues until a sharp image is produced. Motion blur is unacceptable, fuzzy images are discarded. After staring at Edgerton's *Milk Drop Coronet*,[82] I see the afterimage of Worthington's "Auto Splash":an ideal splash whose perfection may never be realized.[83]

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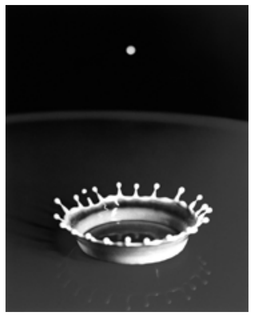
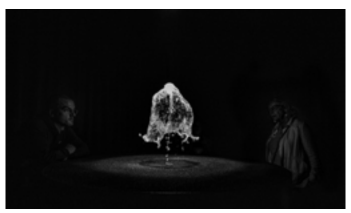


80 "Joseph Plateau (1801 - 1883)." *Museum Voor De Geschiedenis Van De Wetenschappen*

81 "Joseph Antoine Ferdinand Plateau." Joseph Plateau (1801-1883), *MacTutor History of Mathematics Archive*

82 Edgerton, Harold. *Milk Drop Coronet*. 1957

83 Worthington, A. M. *The Splash of a Drop*. 1895.



Chapter 3: Staged Facts and Real Fictions

Critical Representationalism

The blindness representationalism produced points to the times when images fail. Not the technical kind of failure that forbids an apparatus from making an image, but rather the imaginary kind that deters one from producing certain kinds of images. Representations metamorphosized into a representational regime, where the world is understood as a picture[84] and a picture is only meaningful when it aligns with the rigid framework of rationality and objectivity. This philosophy is expressed in the aesthetics of early documentary photography — sharp and detailed. With this in mind, a historical exploration of 'failed images'— blurred images, under and overexposed images and staged photography — can reveal the representational crises in different forms. Alternative photographic practices, often overlooked in mainstream photographic discourses, challenge the notion of the camera as the embodiment of an objective recording device. The practice of spirit photography in the 1860s exemplifies a constitutive feature of photography in general. The blurred imprint in the photograph, created by double exposure or the layering of negatives to produce the illusion of a ghost, is not just another niche photographic practice. Its spectral qualities call into question the visual expectation of a photograph, for what caught on camera is not the image itself but our gazes, our intentions going into the production and reading of the image.

> *"Vision recognises a presence, but this presence wavers between the transparency of immateriality and materiality. For people interested in ghosts, this wavering indicates a metaphysical certainty: the existence of ghosts. For people interested in photographic images, this wavering indicates a visual and phenomenological uncertainty. We do not know what the status is of what we see. It embodies in ontological wavering."* [85]

This photographic uncertainty is not a mere rhetorical figure of speech. Research led by Helmholtz, Plateau and others in physiological optics has proven that human vision is highly inconsistent and easily fooled by optical illusions. Our perception is dependent on personal experience, memory and other environmental factors. The external object that is sensed and created a stimulus in the nervous system does not always translate into the perception of that very same object. The simple fact that our eyes can see our noses all the time yet our brains rendered it invisible in our field of vision[86] would make anyone reevaluate Cartesian optics. The wave properties of light also pose challenges on the 'objective' camera as diffraction limits the ability of a lens to resolve an image. The greater the diffractions, the less determinate the boundaries of an image are. That is to say, in addition to lens distortions, the resolution is compromised because of the very fact that photography draws with light.

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Olafur Eliasson's piece *Big Bang Fountain*, made in 2014 and exhibited at his 2019 retrospective at Tate Modern, directs the viewer's thought to the very question of perception. Inside a dark, square room, a fountain is set up in the centre. Water—dyed blue and illuminated by a strobe light—is pumped up before the viewer in quick bursts. The strobe light catches the bust at the apex of the trajectory, freezing the globular form before it is pulled down by gravity.[87] Rather than letting the viewer experience the entire motion of the water, only a chosen moment is revealed. The installation alludes to Edgerton's high-speed photography, in which motion is frozen using the high-frequency pulse of the flash. In Eliasson's, however, the stroboscopic seeing is slowed down to a human temporality, as it is designed for the human eye rather than the fast shutter of the camera. Some might be mesmerized by the spectacular visual form of water splash; others might see the photographic connection, but more fundamentally, the work reflects the condition of human perception. Humans do in fact perceive our physical environment in glimpses. Yet despite the blinking, the saccades and all the other small movements our eyes make, our field of vision remains relatively stable. Our perception of reality is an image our brain has construed by interweaving and reprocessing discrete sensual data. *Big Bang Fountain*'s strobe light flashes every two seconds, Edgerton's every millionth of a second; human vision operates in the timeframe between these two extremes. There are many layers to *Big Bang Fountain* but at the very least, the installation guides viewers to the realization that "the eye is not a camera that forms and delivers an image, nor is the retina simply a keyboard that can be struck by fingers of light."[88]

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84 Heidegger M. The Age of the World Picture. In: *Tauber A.I. (eds) Science and the Quest for Reality. Main Trends of the Modern World.* Palgrave Macmillan, London, 1977

85 Alphen, Ernst van. *Failed Images: Photography and Its Counter-Practices.* Valiz, 2018. p.136

86 Mach, Ernst. *Self-Portrait by Ernst Mach.* 1886.

87 Eliasson, Olafur. *Big Bang Fountain.* 2014, Tate Modern, London. Photo: Anders Sune Berg

88 Gibson, James J. The Ecological Approach to Visual Perception. *Psychology Press*, 2015

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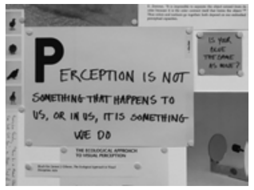

At the same exhibition, a blue memo asks "Is your blue the same as mine?",[89] a typical question about human perception that has been a main interest of physiological optics. This very question has fuelled a decades-long enquiry to reorganize the relationships between knowledge, reality and human perception. That enquiry is phenomenology. A philosophical phenomenon is seldom the work of a few geniuses, nor is it confined to a certain period. The mainstream narrative identifies Western philosophers Hegel, Husserl, Merleau-Ponty and Heidegger as main proponents of the ideology. In his book *Phenomenology of Spirit*. Hegel critiqued "Absolute Knowledge";[90] the idea that knowledge is an instrument and a medium that presupposes distinction of ourselves from the knowledge itself. The classical notion of knowledge takes for granted that the absolute truth stand on one side and humankind stands on the other, independent from the absolute. Hegel proposes an alternative notion of knowledge by bringing human consciousness into the discourse. He suggested that there is no way to 'know' without the mind somehow interacting with the world under investigation. The subject and object are tied up and knowledge is not completely separate from ourselves. The fact that we cannot know without our consciousness and perception brings uncertainty to knowledge.

The Hegelian argument that pure knowledge does not exist is further elaborated by Husserl whose work reflects on everyday experience to uncover its underlying structure. His thesis is a reflective study of how things appear to our conscious awareness, and how the world appears to us. He, continuing Hegel's argument on knowledge, critiqued the idea of natural attitude;[91] the belief that the world is 'out there' and separable from our experience. Merleau-Ponty, who shares an intellectual proximity with Husserl, summarizes phenomenology in his book *Phenomenology of Perception* as " a manner or style of thinking, that existed as a movement before arriving at complete awareness

89 Eliasson, Olafur. *Expanded Studio*, 2019. Tate Modern, London. Photo: Sheung Yiu

90 Hegel, Georg Wilhelm Friedrich. *Phenomenology of Spirit*. Clarendon Press, 1977.

91 Merleau-Ponty, M., and Colin Smith. *Phenomenology of Perception: (5. Impr.)*. Routledge & Kegan Paul. New York: The Humanities Press, 1970

of itself as a philosophy."[92] Merleau-Ponty further explained this style of thinking by borrowing Husserl's call to the "things themselves",[93] to return humankind to a world which precedes knowledge from the world "of which knowledge always speaks, and in relation to which every scientific schematization is an abstract and derivative sign-language, as is geography in relation to the countryside in which we have learnt beforehand what a forest, a prairie or a river is."[94]

Husserl's phenomenology heralded a drastic shift from the way representationalism situates humankind in relation to knowledge and reality. Under phenomenology, the subject-object dichotomy dissolves. New findings in perception reveal the absurdity of the notion of an independent observer. Human vision is a product of its environment. This scepticism of absolute knowledge extends to the 'objectivity' of the camera, leading to a rethinking of the 'truth claim' of photography. While bringing uncertainties to knowledge, phenomenology brings the same uncertainty to the previously naturalized connection between photography and reality.

In order to return to the things themselves, Husserl prescribed a regimen he called phenomenological reduction. It entails a paradigmatic change in the manner we engage with the world, with 'things'. The regimen attempts to undo our habits of 'understanding' the world through theories and concepts—as we have been conditioned to do since the scientific revolution and through the Enlightenment without our acknowledgement. Instead, Husserl advocated 'epoché', or the suspension of judgement. By letting go of these intellectual constructions, we can begin experiencing the world, engaging with 'things' through our perception. Underpinning this mode of thinking is the acknowledgement that the objectivity of science is compromised by the very framework of science itself and the psychological assumptions of the scientist. To borrow Husserl's framework on our discourse of images, "to the things themselves"[95] means throwing the picture away and reaching our hands for the objects. It also means that we should experience an image as an object. It is not a mere representation of a 'world out there'.

Applying phenomenology to our context, photographic reduction[96] switches the focus from the photographic image to photographic activities (i.e. the interaction between the photographer, the act of photographing, the camera and the production of the photograph) in an attempt to reconstruct a new understanding of a photograph. Photographic reduction acknowledges that the camera reduces the perceptual world

92 Ibid. p.12

93 Ibid. p.14

94 Ibid. p.16

95 Ibid.

96 Cheung, Chan-Fai, et al. *Kairos: Phenomenology and Photography*. Zeta Books, 2012.

into a photographic frame. For a photographer to produce a photograph, they must see through the viewfinder of the camera and perceive the world as a surface. Seeing the world as a picture is "in essence a restricted seeing and not seeing in a natural attitude."[97] The representational apparatus fortifies the connection between the image and reality by the rationalization of sight through the geometrification of optics.[98] When the certainty of classical optics was challenged by physiological optics, the indexicality of photography provided a new argument to justify the relationship. Phenomenology acknowledges that the status quo of a photograph as the representation of reality is a social construct. The phenomenological apparatus asks: What separates a photograph from reality despite its indexicality and its mechanical reproduction?

Canadian artist Jeff Wall was at the forefront of rethinking the pictorialist tradition and photography theory in late twentieth century. Although he refused the rudimentary reading of the photographic surface as a direct representation of reality, he admitted that photography also cannot escape the mechanics of representations. A photograph cannot respond to the phenomenological enquiry in the same way modernist art does because photography cannot find an alternative to depiction.

> *"Photography constitutes a depiction not by the accumulation of individual marks, but by the instantaneous operation of an integrated mechanism. All the rays permitted to pass through the lens form an image immediately, and the lens, by definition, creates a focused image at its correct focal length. Depiction is the only possible result of the camera system, and the kind of image formed by a lens is the only image possible in photography. Thus, no matter how impressed photographers may have been by the analytical rigour of modernist critical discourse, they could not participate in it directly in their practice because the specificities of their medium did not permit it."* [99]

What photography can do instead is to put into play "its own necessary condition of being depiction-which-constitutes-an-object."[100] Photography approaches the kind of reflexivity made mandatory for modernist art by critically examining representationalism. This involves stretching representation to its limit to unveil what is compromised in the act of translating the world onto a surface and to question the implication of reality itself. For Jeff Wall, he chose to rework the tradition of reportage practised by documentary photographers like Robert Frank or Garry Winogrand. Meticulously

97 Ibid. p.21
98 Referring to Classical optics, which is hugely based on Euclidean geometry and Cartesian optics
99 Wall, Jeff. *Jeff Wall: Selected Essays and Interviews*. The Museum of Modern Art, 2007. p.40
100 Ibid.

restaging 'decisive moments' using non-professional actors in real settings, he reinvigorates the concept of the tableau in photography, which had a long hiatus as modernists fixated on photograph's unique ability to record the world in the early twentieth-century.[101] His work *Mimic*[102] depicts a staged scene of racial abuse that he witnessed on a Vancouver street in which a white man made a 'slant-eye' gesture towards an Asian pedestrian.

102

To be clear, staged photography is nothing new to photography. In fact, as long as there has been photography, there has been staged photography.[103] Soon after announcing his invention of the calotype, Fox Talbot had the idea of making some "delightful pictures" by asking servants to dress up and stand in for him.[104] Wall, in contrast, recreated his scene with an entirely different intention to Fox Talbot's. He is not presenting a fiction to his viewers, rather his tableau is a staged reality. One cannot make a simple conclusion as to whether the photograph depicts reality or not based on the reasoning of the representational apparatus. The photograph depicts the real world not because of the 'traces' left on the light-sensitive surface. As a matter of fact, the "that-has-been"[105] registered on the photographic surface is not the exact moment that the racial abuse occurred. However, racial abuse is, in fact, part of our reality and has manifested in an incident which Wall himself witnessed. The realism of Wall's photograph does not stem from its signs because there is no 'real' referent. Its realism stems from a fiction that is real. What Wall attempted to do, as Cindy Sherman also explored in her *Untitled Film Stills*,[106] is to renounce the residual trust we have in the mechanical eye and put the last blow in representationalism. It is an answer to the artistic problem.

104

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101 Weiss, Marta Rachel. *Making It up: Photographic Fictions*. Thames & Hudson, 2018. Introduction
102 Wall, Jeff. *Mimic*, 1982
103 Weiss, *Making It up: Photographic Fictions*. 2018.
104 Henry Fox Talbot, Willian. and Jones, Calvert Richard, *The Fruit Sellers*, 1845
105 Barthes, Roland. *Camera Lucida: Reflections on Photography*. The Noonday Press, 1988. Also called the photograph's noema.
106 Sherman, Cindy. *Untitled Film Still #45*, 1979

"The public believed that the photograph could not lie, and it was easier for the photographer if he believed it too, or pretended to. Thus he was likely to claim that what our eyes saw was an illusion and what the camera saw was the truth," [107]

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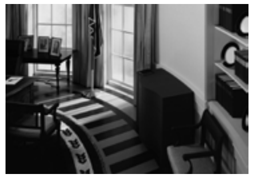

Thomas Demand's photographs work with a similar logic. The German sculptor creates large-scale photographs of life-size paper models depicting architectural spaces in which historical events took place. In his work such as *Tunnel* [108] and *Presidency II*,[109] the "that has been" is nothing but paper cardboard. The true oeuvre of Demand does not lie on the photographic surface as much as in his meticulous construction of the spaces. To create a convincingly real photograph, Demand had to painstakingly arrange every piece of paper for the camera. This involves closely following Cartesian perspectivalism. In building the scene, he ironically conformed to a rational, optical model of photographic representation, placing the sculpted shapes in the correct positions in order to fit the three-dimensional space seamlessly onto a flat surface. Demand was forced to create duplicates of a number of his sculptures when he first started because "he found that the camera lens introduced distortions that altered the formal relationship he wanted to see in his sculpture."[110] Roleplaying as "a perspectivalist painter using a camera obscura to reproduce the observed world,"[111] a practice closely associated with Cartesian optics, Demand reflected back on the picture of modernist representation. In the process, he scrutinized the truth claim of photography grounded in indexicality and representationalism. He and Wall are two of many prominent voices within critical representationalism.

The tension between the staged and the real continued to be a major motif of contemporary photography and beyond.

107 Szarkowski, John. *The Photographer's Eye*. The Museum of Modern Art, 2012. p.8

108 Demand, Thomas. *Tunnel*. 1999.

109 Demand, Thomas. *Presidency II*. 2008.

110 Nieberding, William J. *"Photography, Phenomenology and Sight: toward an Understanding of Photography through the Discourse of Vision."* The Ohio State University, 2011.

111 Jay, Martin. *Downcast Eyes: the Denigration of Vision in Twentieth Century French Thought*. Univ. of California Press, 2009. p.70

The Iranian film *Close Up* directed by Abbas Kiarostami brilliantly explored the blurred boundary between documentary and fiction. The film tells the story of the real-life trial of a man who impersonated filmmaker Mohsen Makhmalbaf, conning a family into believing they would star in his new film. Kiarostami hired the people involved to star in his film, this time a real one, to reenact the whole event. The whole cast played as themselves in a sequence of fictional events, which in turn is based on what has happened—a real fiction. Like Demand's work, the captivating part of the work lies in the production of the image. Kiarostami shot the movie in forty days without any scripts. The actors went on set with their own 'scripts' based on how they remember the events. In some shots, one of the characters did not know that he was in front of a camera whereas the other one did. Kiarostami described *Close Up* years later as "a film that made itself".[112] More than showing the futility of distinguishing facts from fiction, the director turns the mechanism of representation inside out.

Even war photographers became self-aware of the representational apparatus, reexamining their practices with a critical eye. Photographers are more willing to point out the fictionality in the superficial realism of their photographs. Staged photography, which had once been considered a taboo, has been adopted by many documentary photographers. In general, photographers who work with reality as their material are less certain about the problematic word 'documentary' and tend to describe their work as visual narratives. Or they might simply not find the label relevant to their work anymore. The work of French photographer Emeric Lhuisset certainly does not fit into simple categories. In *Theatre of War*,[113] lhuisset worked with Kurdish guerrilla groups that were at war on the Iraq/Iran border. Frustrated by the inability to capture stories he collected from witnesses through interviews, he asked them to reenact the events in front of the camera. Once again, we can see the photographer's scepticism

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112 *"Abbas Kiarostami."* The Guardian, Guardian News and Media, 28 Apr. 2005

113 Lhuisset, Emeric. *Theatres of War* .2011-12. Courtesy of the artist.

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of truth claim. We can look at the project *Libyan Sugar*[114] by war photographer Michael Christopher Brown who lost two of his colleagues, Tim Hetherington and Chris Hondros, in a military attack during their job documenting the Libyan Revolution. Rather than offering a documentary account of the war, the photographer characterised his project as a road trip through a war zone. Layered with diaristic photographs, journal entries, and correspondence with family and colleagues, Brown told a story about the intertwined relationship between the photographer and the war, the observer and the events that transpired in front of him. It is hard not to doubt how anyone could claim to be an unaffected 'observer' of war, seeing how traumatizing the experience of war is, even to a Magnum photographer—to someone who has the privilege to choose to leave the war zone when they want. Or we can look back at Emeric lhuisset's *Chebab*[115] in which the photographer has decided to give up his auteurship once and for all and strapped a body camera to a soldier. The final work is a 24-hour loop of the war as experienced by forefront fighter in real life, without editing, without the excitement and the blood, without the exaggerated drama of a composed image; simply war as it is.

All these attempts by photographers exemplify an awareness of the representational apparatus. The notion of an independent observer and mechanical objectivity is an imagined one. The subject-object dichotomy is being questioned and replaced by intersubjectivity. The rationalization of sight and the independent human subject began to separate from representation through the regimen of phenomenological reduction. Representation itself is scrutinized in new lights, leading to a reformulation of the logic behind Tom Gunning's truth claim. "Now, representation is re-presentation: the subject's deferral of what presences in order to present it again, but this time on the subject's terms, according to the subject's sovereign will."[116] The interest in the photographic surface has shifted to photographers and their photographic process. Phenomenology gave photography a new insight into its own para-images. The criticality towards representationalism is embodied in different experimentations of the medium. One obvious approach involves exploring the surrealistic potential of photography, in a similar way that "Surrealists had discarded art's claim to provide representative 'resemblances' of the external world in favour of repetitive 'similitudes' that circulate a series of visual and linguistic signs without any external referents."[117]

114 Brown, Michael Christopher. *At a morgue, he was killed during fighting in Benghazi. Banghazi, Libya*. March 20, 2011. Courtesy of the artist
Brown, Michael Christopher. *Photographer Michael Christopher Brown at Hikma hospital after being hit by the mortar. Misrata, Libya*. April 20, 2011. Courtesy of the artist
115 Lhuisset, Emeric. *Chebab*, 2012. Courtesy of the artist.

116 Kleinberg-Levin, D. M. *Sites of vision: The discursive construction of sight in the history of philosophy*. Cambridge, Mass: MIT Press. 1999. p.403
117 Jay, Martin. *Downcast Eyes: the Denigration of Vision in Twentieth Century French Thought*. Univ. of California Press, 1993. p.400

Chapter 4: Ready-made Photoshoot

Phenomenological Apparatus: Image as Experience

The National Science and Media Museum in Bradford, England held exhibition in its Wonderlab called *Can you capture a splash?* The exhibition panel introduces Harold Edgerton's milk coronet and his endeavour in refining his time-freezing high-speed photography. The wall-text reads: "This high-speed camera takes photos 40 times faster than the blink of an eye. It's able to capture detail you can't see." On the side is an installation consists of a simple photo studio setup with a clear acrylic box, a control panel and a huge monitor.

Exhibits in science museums tend to follow a certain design principle. A panel explains the scientific theories behind the exhibition in brief terms. The exhibition usually has an obvious point of interaction, whether it is a huge button, a handle or levers, so even though the visitors may have no patience reading, they can still play. A science museum exhibition is first a toy before anything else and the one in front of me is no exception. Two young teens got in before me and instinctively began turning the knob on the panel. As a boy pressed the button, the acrylic box let out a flash and without them realizing it, a photo appeared on the monitor. A coloured photo of a ripple. It seems that he had missed the water splash at the apex of its motion. Without missing a beat, the pair turned the knob, adjusting the delay of the flash in milliseconds and pressed the second time.

Another flash. Another photo. A lot was happening in between. The teens hardly paid attention, but any photographer who has tried to capture a water splash would know. After the button was pressed, the machine let out a controlled drop of water, the water fell until it reached the black cup filled to the brim with water. It triggered the shutter and a twinkling of an eye later, a flash is produced. If the delayed time is set right, the camera will capture a beautiful water splash frozen at its peak. Unfortunately, the delay of the flash this time was too early—'nothing' was captured. The photograph did capture the water ripple on the cup, but other than that nothing of human interest. The teens compared the result with Edgerton's infamous photo of milk coronet on the side, noticeably dissatisfied and continued their quest to freeze a water drop.

The Speedlite in the box kept flashing. The teens carefully adjusted the delay time. They kept on going, trying to get that sharp, in-focus perfect shot. But the details that they were promised never came. After what must have been the thirtieth shot, the young photographers were visibly frustrated. They quickly decided to move on, disinterested in both the photo setup and the phenomenon itself. After all, there were more toys to fiddle with in the lab. And to be fair, they could not see the water drop with their naked eyes anyway. At least not with the blinding flash.

It is not particularly radical anymore in today's digital culture to say that the

image is an experience in itself, maybe even more important than the first-hand experience with the real thing. Professor Hiroaki Ota, a Japanese psychiatrist working in France, was the first to diagnose a peculiar psychological condition among Japanese tourists— Paris Syndrome (パリ症候群).[118] The syndrome is a result of an extreme shock realising that Paris is very different from their expectations. The city of light looks duller than it is in the movies. The Eiffel Tower does not look as photogenic as it is in the postcards. In serious cases, the disappointment can turn into anxiety, acute delusions and hallucinations. It is still unknown why Japanese tourists are especially susceptible to Paris Syndrome. First diagnosed in 1986, the syndrome would not surprise photo theorists like Susan Sontag, who had already warned us about the effect of photography on the real in *On Photography*, published in 1977:

> *"Knowing a great deal about what is in the world (art, catastrophe, the beauties of nature) through photographic images, people are frequently disappointed, surprised, unmoved when they see the real thing. For photographic images tend to subtract feeling from something we experience at first hand and the feelings they do arouse are, largely, not those we have in real life. Often something disturbs us more in photographed form than it does when we actually experience it."* [119]

That same sentiment was felt by tourists heading to Lapland, Finland in the winter of 2018. They were expecting to arrive at a winter wonderland only to be disappointed by the region's lack of snow.[120] Knowing that the historic low-level of snow cover could never match the tourists' expectations, tour companies cancelled the trips to Lapland. "The pictures I have seen look terrible," one tourist said. Another complained: "We paid for a once in a lifetime trip to magical Lapland with our daughter, based on a TUI brochure of snowmobiles and husky rides."

Reality is often disappointing, especially when we are constantly comparing it to a photograph. You may have travelled to Lapland, but unless your trip matches with what is depicted on an image, that experience of travelling will be inauthentic. Never have we ever carried so many expectations of cities we have never visited and cared so much about an authentic experience. In *I Know I Will See What I Have Seen Before* (2015),[121] Thomas Albdorf asked: can one know a place without ever having set foot there? To answer these questions, he gave himself a mission to create photographs of the popular

118 Wyatt, Caroline. *"Europe | 'Paris Syndrome' Strikes Japanese."* BBC News, BBC, 20 Dec. 2006
119 Sontag, Susan. *On Photography*. Penguin Classics, 2011
120 Bateman, Tom. *"Tourists Turned off by Finland's Unusual 'Black' Lapland Cancel Holiday Jaunts."* Yle Uutiset, 22 Nov. 2018
121 Albdorf, Thomas. *Focus test*, 2015. Courtesy of the artist.

121

tourist destination—the Alps— from behind his computer screen. Using an extensive selection of sourced image from tourist brochures and Heimatfilms, he recreated the cliché majestic mountain landscapes in his studio and in Photoshop. He then tested his creations with image recognition software and discovered tricks to hack the software. For example, the software recognises an image as a waterfall when the human eye clearly sees a handful of dust being thrown onto a dark cloth. Albdorf reveals the way images construct spaces. A repetition of images creates an idea of a place, which promotes the production of a certain image of the place, which in turn consolidates the experience of it. The cycle repeats itself until we can only see what we have already witnessed a thousand times over and created a reality of that place. Moreover, a photograph is a projection—like lighthouses. They should not be understood as "representations of things out in the world but as signposts directed outward."[122] A photograph is first and foremost a fiction about reality that often gets confused with reality. Similar to how image recognition software misidentifies a handful of dust as waterfalls, human misdecode the photogenic mountain landscape as the Austrian Alps.

The main takeaway here is not that photography is fraudulent and photographers are malicious scammers out to trick unsuspecting tourists. It is not useful to hold onto the Platonic binary framework of the 'real' and the 'copy' and put judgement on an image according to its similitude to reality. The discourse on images should move beyond:

> *"Photoshop is everywhere. It's on your phone and it's in your computer, and everybody has the experience of photoshopping somebody into a group picture, so that the photographer can be in the image. We know! and yet we still have the idea, this ideal, this nearly indestructible belief in the mimetic photograph. We're only slowly arriving at the moment when the manipulated image is part of our perception. Not just in worried newsrooms and anxious scientific-journal headquarters–not (to not just) in the sense of a dreaded onslaught of fraud."* [123]

122 Flusser Vilém, et al. *Into the Universe of Technical Images*. University of Minnesota Press, 2011. p.48

As experience is increasingly mediated and abstracted, "'Authentic' experience becomes both elusive and allusive as it is placed beyond the horizon of present lived experience, the beyond in which the antique, the pastoral, the exotic, the other fictive domains are articulated."[124] Our experience is not replaced by the myth cultivated by photography; it is supported by it. American photographer Drew Nikonowicz explores the notion of authentic experience in *This World and Others Like It* (2017).[125] Experimenting with different forms of media and their representations, from the nineteenth-century geological surveys of pioneers such as Timothy H. O'Sullivan[126] to analog large-format photographs to re-photographed digital images,[127] the series is a photographic investigation on the mechanics of seeing. Nikonowicz does not distinguish between 'straight' photography from computer generated photographs or documentary photography from internet archives. In his project, the photographer uses mapping software to create landscapes and 'rephotographed' them from within the software. There is no real representation of the external world: all are equally valid embodiments of an experienced reality. To him, the world we experience via our screen is as real as the physical reality that surrounds us.[128] Rather than a representation of the world, images embody an experience of the world, and one cannot neatly categorize experience into real and fake, lived and mediated; one can only speak of the authenticity of the experience.

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123 Monteith, Matthew. *"The Lives of Images: Peter Galison in Conversation with Trevor Paglen."*, Issue 211: Curiosity, Aperture Magazine, 15 May 2013, pp. 33–39

124 Stewart, Susan. *On Longing: Narratives of the Miniature, the Gigantic, the Souvenir, the Collection*. Duke University Press, 2007.

125 Nikonowicz , Drew. 2014-11-05 11:31:54 AM 38°56'53.53" N 092°19'34.22" W 00749, from the project *This World and Others Like It*. 2017. Courtesy of the artist.
Nikonowicz , Drew. 2012-05-01 04:59:27 PM 38°59'08.83" N 092°22'47.89" W 00741, from the project *This World and Others Like It*. 2017. Courtesy of the artist.

126 O'Sullivan, Timothy H., *Cañon de Chelle. Walls of the Grand Cañon about 1200 Feet in Height*, 1873.

127 Nikonowicz , Drew. 2016-09-27 01:04:00 PM 45°44'24.92" N 012°16'02.23" E 00120, from the project *This World and Others Like It*. 2017. Courtesy of the artist.

128 Nikonowicz, Drew, and Paula Kupfer. *This World and Others like It*. Fw:Books, 2019.

The reason for this shift in the dialectics between the image and the real is informed by a fundamental change in image production and dissemination. A meaningful conclusion from the mechanical reproduction of art in the early twentieth century is not the lost aura of the original image,[129] but rather the democratization of image production. While in antiquity the technique of painting and drawing was confined to a privileged few, the modern age heralded an age of amateur image-making, beginning with the invention of portable cameras in the late nineteenth century and more recently with a culture driven by social media and smartphones. The important implication behind Kodak's now-classic advertising slogan "You press the button, we do the rest," is not that everyone can own a picture, but rather that everyone can make one. With the advent of smartphone cameras, everyone is an image hunter. We find ourselves role-playing photographers, going out in the wild in search of the perfect shot. Our natural vision fuses with the photographic vision, one that obsessively looks for the best angle to translate the 3D world in front of us onto a flat surface. The world is constantly perceived with the intention of making an image – the Heideggerian world picture.

Sociologist Nathan Jurgenson called this our "documentary vision."[130] The constant image-sharing of social media has had a great phenomenological effect on human perception. Social media platforms provide a virtual stage, giving users incentives to perform for a potential audience of millions. This performance, mediated through images that oscillate between staged and real, permeates our lives. In this process of perceptual image-making and image-sharing, our natural vision has slowly been replaced by "documentary vision", leading us to "view our present always as a potential past".

> *"Facebook and the rest of the new and social media influence us most powerfully when not logged-in and staring at some glowing screen. Instead, the biggest role social media plays in our life is phenomenological; that is, it changes how we experience the world even when logged off."*

Our lived experience is not validated if it is not documented. Wedding albums, travel photos, themed park portraits become the norms of how we 'access' experience. Images are Claude Glass,[131] an old mirror-device that allowed users to stand facing away from the world in order to view a more "picturesque" version of it. The demand for body

129 Benjamin, Walter, and James Amery. Underwood. *The Work of Art in the Age of Mechanical Reproduction*. Penguin Books, 2008.

130 Jurgenson, Nathan. *"Experiencing Life Through the Logic of Facebook."* Cyborgology, 27 Oct. 2011

131 A Claude glass from around 1775. Courtesy of Victoria and Albert Museum, London. Claude glass is a convex, tinted mirror designed to soften and frame the landscape.

from the world in order to view a more "picturesque" version of it. The demand for body cameras speaks volumes about the desire to document every lived moment for future idealization. All the world's a 'stage' gains a new meaning. We are *both* the directors and the audiences of the movies that we call life. We live our own lives vicariously through the images we make. Images and lived experiences become inseparable. They fuse with human perception and form our memories. This new relationship between humans and images, the world and its representation is symptomatic of new media, as Mark Hansen succinctly puts it:

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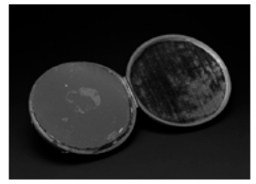

> *"Whereas the technical media characteristic of the nineteenth and twentieth centuries, for example, photography and cinema, primarily address human sense perception and experiential memory (and I say "primarily' to indicate both that there is no technical necessity involved here and that there are significant exceptions), twenty-first-century media directly shape the sensory continuum out of which perception and memory arise."* [132]

It was said that approximately 1.2 trillion digital photos were taken in 2017.[133] More than three billion images are shared on social media every day. This overcrowding of digital images on the Internet leaves traces in our physical reality. Like dust, they accumulate. The phantasms form a hologram. Rather than mere representation, they have become a part of our lives, a lens which we see through. Images become moments, which is what the iPhone calls our photos. These moments are in turn a part of a collection, dated and archived, sorted by years, searchable and editable. If you want, your smartphones can quickly compile them into your memories—curated by advanced algorithms, created automatically on demand, length and music adjustable with a mere tap.

132 Hansen, Mark B. N. *Feed-Forward: on the Future of Twenty-First-Century Media*. University of Chicago Press, 2015. iBooks. p.38

133 Lee, Ed. *"Our Best Photos Deserve to Be Printed."* InfoTrends, 12 Sept. 2018

When told “you have something on your face”, the common thing to do today is to take out your smartphone, turn on the front-facing camera and consult the screen. Images become mirrors and selfies become our faces. After the popularization of smartphones and social media, the word selfie very quickly entered the English lexicon. The Oxford Dictionary defines selfie as “a photograph that one has taken of oneself...and shared via social media,”[134] putting an extra emphasis on the dissemination of images. The selfie effect,[135] a term coined by the plastic surgeon and researcher Boris Paskhover, describes the distortive effects of short distance photographs on nasal appearance. His research shows that a photo taken at an arm’s length makes the base of the nose appear approximately 30% wider compared to a photograph taken at 5 feet, a standard portrait distance.[136] Consequently, this distortion is catching many selfie-takers off guard and even driving some to consult plastic surgeons to make their noses ‘look’ smaller. According to a 2017 poll by the American Academy of Facial Plastic and Reconstructive Surgeons,[137] 55% of facial plastic surgeons reported seeing patients who wanted surgery to help them look better in selfies.

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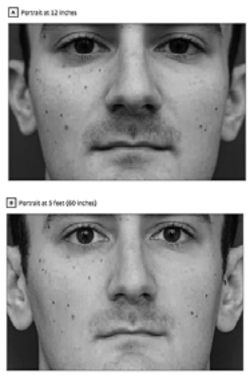

The repeated consensus among photographers is that a portrait should be shot with a telephoto lens at some distance from the subject. A wide lens exaggerates spatial distance, making the foreground appear much bigger and closer to the lens. Often neglected, distortions are inherent to any image taken by an apparatus. In order to make the world looks right to the camera, photographers employ different techniques to match the final image to what is being observed. That is part of their professionalism. But as images merge with the perception of self, the representation merges with its referent. We change our nose to look better in a selfie. We stage our lives for photographs. How we look in an image feels more important than how we are in the ‘real world’. The imitation creates its own reality.

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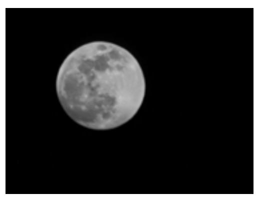

> *“It is even possible that by looking carefully at the selfie we can discern the future shape of our own species not as individuals connected to each other via social fabric, governed by self-interest and competition, but as nodal points formed from the cross-fertilization between human and artificial intelligence.”* [138]

This process repeats and continues until the distinction between the two is irrelevant. The man who dreamt about a butterfly does not know if he has dreamt the butterfly or if the butterfly has dreamt him. In Jean Baudrillard’s frequently-quoted work *Simulacra and Simulations*, he examined the notion of the image by reversing the Platonic dichotomy of the real and the copy. By driving the emphasis away from the question of imitation, Baudrillard proposed that many contemporary social phenomena should be understood by examining how the signs of the real are being substituted for the real itself. In the first essay of the book *The Precession of Simulacra*, he listed four progressively abstract philosophical orientations towards images, beginning with the Platonic notion of image as a representation of the world and ended with his concept of simulacra. Images, he proclaimed, are simulacra that do not owe us reality. Their realism does not guarantee a connection with reality. As a matter of fact, in the postmodern world, oftentimes they have no relation to reality whatsoever. The raison d'être of a selfie is not to truthfully represent our faces; we take a selfie exactly for everything else but that—the Snapchat filters and the beautification. We perceive ourselves through photos. We reshape our nose to look better in selfies. Representations are stacked over other representations—and underneath all of these layers, there is no original referent. The illusionary trickery of images is no longer possible because “the real is no longer possible.”[139] Seen against the backdrop of Baudrillardian simulacra, the Huawei moon photo scandal[140] is anything but surprising.

For a long time in Chinese, the words ‘elephant’, ‘similitude’, ‘phenomena’ and ‘image’ have shared the same character. The Chinese etymology dictionary Kangxi Dictionary[141] explains: real-life encounter of elephant is rare in ancient China. People more often saw its drawing than a real elephant. The drawing becomes the only way for

134 *“Selfie”*. Oxford dictionary Third Edition, June 2014

135 Ward, Brittany, et al. *“Nasal Distortion in Short-Distance Photographs: The Selfie Effect.”* JAMA Facial Plastic Surgery, vol. 20, no. 4, Jan. 2018, p. 333., doi:10.1001/jamafacial.2018.0009.

136 Example of Nasal Size Distortion in a Short-Distance Photograph and Derived Model, Courtesy of researchers

137 *“The American Academy of Facial Plastic and Reconstructive Surgery (AAFPRS).”* The Grants Register 2018, 2018, pp. 29–29.

138 Rubinstein, Daniel. *“Keeping Up With the Cartesians: on the Culture of the Selfie With Continual Reference to Kim Kardashian”*. In: Public, Private, Secret: On photography and the configuration of self. Edited by Charlotte Cotton. 2018

139 Baudrillard, Jean, and Sheila Faria. Glaser. *Simulacra and Simulation*. University of Michigan Press, 2018. p.19

140 Chen, Vincent. *The Moon as captured by the Huawei P 30 Pro’s ’Moon Mode*, 2019

141 Kangxi Dictionary, “又【韓非子・解老篇】人希見生象也，而得死象之骨，按其圖以想其生也，故諸人之所以意想者，皆謂之象也。”

people to grasp the idea of the elusive animal. The representation of the elephant per se becomes the perception of one. That is the earliest acknowledgement I know of of an image as a phenomenological phenomenon, a phenomenon that is as real as, if not realer than, the real.[142]

142 Massumi, Brian. *Realer than real: The Simulacrum According to Deleuze and Guattari*. From Copyright no.1, 1987, p. 90–97.

Chapter 5: The Reconstructed Water Splash

Phenomenological Apparatus: Image as Event

We live in a world where images play multiple complex roles. More than depictions of our experience, images shape our experience. The traditional understanding of an image as a window to the world, while still valid, is no longer useful to address the complex, intertwined relationship that it has with our world. The philosophy of perception establishes a new way of seeing. Images are not mere representations; they engender their own realities. The compound effect of simultaneous image-taking and image-sharing facilitated by social media, for example, has had a fundamental impact on human perception.

Sociologist Nathan Jurgenson coined the term 'documentary vision' to describe this perceptual change, a new type of vision where we view our every living moment as a potential past to be shared in the future. Documentary vision blurs the line between experience and its documentation, between the image and the world. Jurgenson elaborated his observation:

> *"The line and the causality between the person and their documentation on social media has been upended, twisted over, turned inside out, blurred and imploded into a state of mutual coexistence without clear division or causal precedence. We need to begin our analysis of social media documentation with the assumption that experience and documentation are not separate, but mutually co-determining. The causality goes both ways: Life has now become as subservient to the document as the document is subservient to life."* [143]

The conceptual fallacy of viewing online and offline as two separate spheres is falling apart. So is the dichotomy of the image and the world. Contemporary objects live through a cycle. It is experienced, translated into an image, experienced yet again online and reincarnated back into an object in the physical world.

Contemporary architecture lives in this cycle. Thomas Heatherwick's *Vessel*, currently under construction in New York, was designed under the instructions of his client to be a spectacle.[144] The elaborate $200million staircase to nowhere, when finished, would be a 46 metre-high goblet as tall as it is high, nicely fitting into the square frame of Instagram. Increasing number of clients come in to architecture firm asking for picture-perfect buildings, driving the industry towards a populist approach to design. The industry, in turn, internalized Instagram aesthetics. Australian architect Scott Valentine wrote an Instagram design guide,[145] detailing ways to build "a visual sense of amazement". In the guide, the architect suggests different ways a restaurant can design space that is more photographable and inviting for guests "to take the main stage".

143 Jurgenson, Nathan. *"Experiencing Life Through the Logic of Facebook."* Cyborgology, 27 Oct. 2011

144 Wainwright, Oliver. *"Snapping Point: How the World's Leading Architects Fell under the Instagram Spell."* The Guardian, Guardian News and Media, 23 Nov. 2018

145 Valentine, Scott. *"Designing Instagrammable: Understanding the Psychology of Instagram."* Valé, Valé, 9 Jan. 2018

While throughout history, there have been buildings or architectural elements, such as Michealangelo's mural in the Sistine Chapel, that are designed to fit a single perspective, never have representations held so much power over architectural reality. Man-made structures before technical images, the Great Wall, The Pantheon, the Aztec pyramids, despite being spectacular to look at, seem to primarily serve a utilitarian purpose, whether it be military or religious. Now representations themselves has become the end goal of a building. The snake bites its tail.

Near the end of the guide, Valentine reminds designers to consider the "six universal truths of influence", highlighting the connection between social psychology of Instagram and design. An architecture becomes a potential 'photogenic experience'. It doesn't matter if artists take them into account during the design process; the architecture will be perceived as one. Emperor Huizong of the Chinese Song Dynasty, who, driven by his passion for the arts built the Imperial Painting House, would have been dumbfounded if he were to experience Instagrammable architecture. The Imperial Painting House he built had nurtured a generation of talented Chinese artists who went out to make some of the most famous pieces of ink paintings, but he probably would not have imagined erecting a building simply for the sake of representation itself—the Debordian spectacle, a "capital to such a degree of accumulation that it becomes an image".[146]

Images become an integral part of spectacles. Guy Debord famously said: "The spectacle is not a collection of images, but a social relation among people, mediated by images."[147] The founding member of the Situationist International has already observed in the last century that everything that was directly lived has been ingested into a representation. This accumulation was composed of the discrete images detached from life, separated from their original context, and reunited as an autonomous world apart from lived experience.[148] The causality between images and events is reversed. The images rule the workers, and the world is constructed for the images. The boom of pop-up museums, exhibition spaces built to provide visitors with giddily colourful backdrops for foolproof photogenic Instagram photos,[149] proves once again this inverse relationship between the world and its representation. The Museum of Ice Cream, a museum equivalent of carnival cutout photo boards, is indeed so successful that it has forced major art

146 Debord, Guy. *Society of the Spectacle*. Black and Red, 1977. p.427

147 Debord, Guy. *Society of the Spectacle*. Black and Red, 1977

148 Jay, Martin. *Downcast Eyes: the Denigration of Vision in Twentieth Century French Thought*. Univ. of California Press, 1993. p.427

149 Pardes, Arielle. *"The Rise of the Made-for-Instagram Museum."* Wired, Conde Nast, 27 Sept. 2017
Haigney, Sophie. *"The Museums of Instagram."* The New Yorker, The New Yorker, 16 Sept. 2018

institutions to reconsider their approach to social media.[150] Director of Digital at the Jewish Museum of New York Jia Jia Fei acknowledged their impact in a TED Talk on Art in the Age of Instagram, saying: "The world has seen an increase in these 'spectacle' exhibitions that have really taken on a new dimension online." Artworks that are not designed for Instagram, such as Yayoi Kusama's Infinity Mirrored Room and the Rain Room at MoMA, have taken on a life of its own online.

The reversed causality is made more apparent by the advent of smartphones and social media. The notion of audience and social engagement is magnified. The Shakespearean proverb "all the world's a stage"[151] takes on a contemporary twist in the age of social media. The site of image production and the site of image dissemination merges. While in the past, paintings tended to be made in the studio or in a patron's house and films in movie sets, in a smartphone-driven digital culture, photographs are taken whenever and wherever one likes. The fictions that had been confined to the studio have overflowed into the real world. The movie set expands infinitely. Prank videos, Vlogs, Youtube challenges[152] and extreme selfies,[153] we "do it for the views." We perform for the cameras, creating spectacle after spectacle to fight for attention in the 24/7, all-encompassing online reality TV show. In the process, the causality of event and its representation becomes cyclical as the online and offline world fuses into one.

Images become events. In his project *Dawn Breaking – A Museum Film Project* (2018) at Shanghai's Long Museum West Bund, Chinese video artist Yang Fudong literally turned museums into stages. He moved his film production into museums and other exhibition spaces. He led a crew of actors and production team to shoot a historical period film about the Song dynasty in two large scale sets constructed within the museum, in front of an audience, over the course of a month. At the end of each day, Yang edited a video documentation of the day's filming. Interspersed with quotations by Nietsche and mistakes that happened during the shooting, these dailies serve as a video diary detailing the director's psychological commentary on his process. The weeks-long filming process materializes in dozens of dailies and towards a final, edited film.[154] The dailies are shown in various combinations, assembled into a continuous film and individually on different flat screens, alongside the live movie set, creating an immersive video installation.

150 Davis, Ben. *"State of the Culture, Part I: Museums, 'Experiences,' and the Year of Big Fun Art."* Artnet News, 2 Jan. 2018

151 Shakespeare, William. *As You Like it. Act II, Scene VII [All the world's a stage]*.

152 Caitlin, Dewey. *"A Comprehensive Guide to YouTube's Dumbest and Most Dangerous Teen Trends."* The Washington Post, 30 July 2014

153 *"Selfie Deaths: 259 People Reported Dead Seeking the Perfect Picture."* BBC, 4 Oct. 2018

154 Fudong, Yang. Video still, *Dawn Breaking – A Museum Film Project*, 2018

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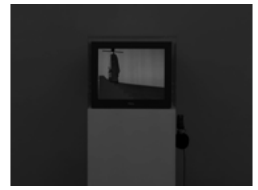


Intending to avoid attributing any fixed meaning to his work, Yang did not explicitly reference any specific ideas in the press release nor the exhibition handouts, though the phenomenological underpinning of the film is undeniable. By revealing the structure of film production, the performance within the museum created a "simultaneity of art-making and art-viewing." Yang described the project in an interview:[155] "The viewer gets to be the director: they can see how things change onset, and then predict how the film will turn out." The collapse of the distance between film production and screening parallels the Instragramification of image production, where the intention of representation is flipped inside out. Built to create the illusion of time-travelling, movie sets were constructed as a backdrop of a representation—the final film, but in Yang's work, they are given a life of their own. They are built for the exhibition audience as much as they are built to complete the final film. The life-size movie sets elaborately setup in the museums become a reality themselves, which generate another representations. The representation itself becomes the subject of representation. One cannot tell which representation among the 36 roughly-edited dailies and the polished final film is more 'meaningful' in Yang's Museum Film Project. The final film and the dailies homogenize in a holistic artwork, just as multi-million blockbusters and amatuer Vlogs and every representation in between becomes 'content' on social media. A representation does not necessitate a real referent; it feeds on each other and generates more representations in the process. Images become viral, videos comment on each other, photographs reference other photographs. Yang created a microcosm of image culture in our contemporary society—Baudrillard's hyper-reality—in which the dichotomy of the image and the real ceases to be important, and simulation begins to precede and engender reality.

The Swiss artist-duo Jojakim Cortis and Adrian Sonderegger have been recreating iconic photographs, including

155 Rappolt, Mark. *"Feature: Yang Fudong."* ArtReview, Summer 2019

156

157

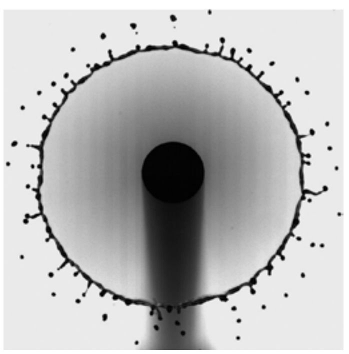
Harold Edgerton's infamous photo *Milk Drop Coronet*,[156] since 2012. For their project *Iconen*, the duo build meticulous dioramas from scratch, some can take as long as three months to recreate and occupy the entirety of their studios.[157] After photographing every detail of their set, the artists mercilessly destroy the painstakingly miniature diorama they worked so hard to put up. Nothing is left behind in their studio; only the representations remain.

156 Cortis, Jojakim & Sonderegger, Adrian, *Making of "Milk Drop Coronet,"* (by Harold Edgerton, 1957), 2016

157 Mufson, Beckett. *"These Artists Make Hyper-Realistic Dioramas of History's Most Iconic Photos."* Vice, 19 June 2018

Chapter 6: False Colour Universe

Generative Apparatus: Image as Dataset



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In 1957, Computer pioneer Russell Kirsch and his colleagues successfully created the first ever digital image.[158] That image is of a baby's face, the face of the scientists's three-month-old son. More precisely speaking, it is of a scanned photograph of his son Walden. In the black-and-white digital image, Walden is divided into a mosaic of various brightnesses. He is cut up into 30976 squares, transcoded into values of brightness by a scanner and reconstructed into a 176×176 pixel image through a computer program. The result is a cute yet eerily disturbing image, one that is excavated from the uncanny valley. It triggers an uneasiness in viewers who cannot completely grasp what they are looking at. They can recognize what is being represented in the image, yet it is not a photograph; it is a digitalization of a photograph, a representation of a representation. With its invention, a new type of technical images emerges—a digital image. A digital image is different from a photograph. Its indexicality does not come from the 'that-has-been' visible to human eyes in the world, it comes from the data transcoded by the scanner. The rest of the history of the digital image as we know it can be understood as merely different manifestations of this single event. Although many of us have become accustomed to the digital image as an everyday artefact, there are still moments, such as when we encounter a DeepDream image[159] or an AI-generated fake face on ThisPersonDoesNotExist.com,[160] that rekindle the same uneasiness.

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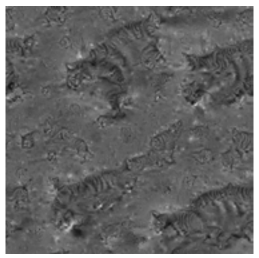

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The fragmentation of image — the conception of image as assemblage of pixels — is a rather recent development that can find its roots in computer science. Almost a century ago, Ada Lovelace developed the world's first machine algorithm for an early computing machine that only existed on paper.[161] She suggested programs that would allow an Analytical Engine, an invention by Cambridge mathematics professor Charles Babbage, to calculate Bernoulli numbers, establishing the idea of mechanical computing. Later in the twentieth century, Alan Turing's

158 First digital image created by Russell Kirsch in 1975

159 Mordvintsev, Alex. *Cats*, 2015. It is one of the first DeepDream images produced.

160 Wang, Philip. *Thispersondoesnotexist.com*, Dec 2018

161 *"Ada Lovelace: The First Computer Programmer."* Mental Floss, 13 Oct. 2015

Turing Machine[162] demonstrated that numbers can be encoded on tapes (in binary), where mathematical tasks (such as additions) can then be computed physically. His model of mechanical computing, which many regarded as an early prototype of modern computers, reified the notion of a 'thinking' machine. The idea is further expanded in the Church-Turing Thesis,[163] which hypothesizes that all mathematical functions can be effectively computed by a Turing machine. The interpretation of the thesis is highly contested, but it engenders a philosophical debate regarding pure computation and physical computation: whether all pure computation, from geometry to human cognitive processes, can be embodied within a computer.[164] The thesis provides an intellectual incentive to break our world down into bits of encodable information for computation. More broadly speaking, it establishes the computer as a universal apparatus, an apparatus that sees the world as a field of possibility made up of particles in which to function.[165] It is under this historical background that the first digital image was conceived. Each of the 30976 pixels embodies the intention to break down the world into a discretized system of computable problems. The fragmentation of the image echoes the fragmentation of the world.

The question "Can machines think?" that Alan Turing asked himself soon inspired many other questions. The American sci-fi writer Philip K. Dick famously asked "Do Androids Dream of Electric Sheep?" while neuroscientist David Marr investigated the question "Can machines see?" Marr believed that human vision can be simulated by computers.[166] Deconstructing human vision into computable problems, he laid the foundations of the computational theory of vision and machine vision.[167]

In computational optics, vision is defined as "a process that produces from images of the external world a description that is useful to the viewer and not cluttered with irrelevant information."[168] The notion of light as truth is taken out of the picture. A good vision is not necessarily a truthful one. Rather a good vision is reflected by the usefulness of the representation it produces, which in turn depends upon how well suited it is to a particular visual intention. Therefore, to Marr, advanced vision, like human vision, is not inherently superior to the simpler vision of rabbits and house flies.

162 A Turing machine is essentially a theoretical state machine made up of a head that reads and writes data and a tape that stores data.

163 Alan Turing developed the thesis with his teacher and mathematician Alonzo Church. There are various equivalent formulations of the Church-Turing thesis. A common one is that every effective computation can be carried out by a Turing machine.

164 Galton, Antony. *The Church-Turing Thesis: Its Nature and Status*. Department of Computer Science, University of Exeter, 1992. p.161

165 Flusser, Vilém. *Towards a Philosophy of Photography*. Reaktion Books, 1983

166 Marr, David. *Vision: a Computational Investigation into the Human Representation and Processing of Visual Information*. MIT Press, 2010.

167 Ibid. p.16

168 Ibid. p.31

Under the paradigm of computational vision, human visual perception is divided into three main groups of questions:[169] (1) computational theory, which examines the mechanism and intention of visual perception, what is computed and why; (2) representations and algorithm, which analyzes the process of visual perception and how an algorithm can transform sensations into representations; and (3) apparatus, which looks at the hardware implementation of visual perception, the physical device. For example, in reading a line of text, a useful human vision (1) discerns individual alphabets, combines them into words and sentences and extracts meaning from the text. The process is operated through (2) edge detection, which extracts the text from the page and then identifies each shape into alphabets. Lastly, visual sensation began physically (3) at the eyeball, where signals are transmitted through the optic nerve to the visual cortex to be interpreted and constructed into an image. Marr shifted the focus away from the classical ontological anxiety towards a more practical approach to vision. Instead of "What is vision and what is an image?", he asked, "How can vision be formulated into a computable question for a machine to create a useful representation with the least amount of irrelevant information?"

His theory of computational optics signalled an algorithmic turn[170] in the thinking of vision and images; a development in image culture that I like to call, and to quote Heather Dewey-Hagborg, "generative representationalism."[171] The 'truth claim' of generative representationalism, emerging after mechanical representationalism, lies not in the Cartesian metaphysics of light nor the indexicality of the light-sensitive surface but in data and algorithms. Generative representationalism encompasses two levels of seemingly contrasting approaches towards the image. On a superficial level, it suggests that the world can be disassembled into particle-like pixels, turned into a 2D-matrix of data points then recombined by the computer to a human-understandable visual image.

The Opportunity rover, part of NASA's Mars mission program, is equipped with thirteen sensors to survey Mars' geology. The digital photographic plate, or the CCD, precisely measures the quantity and quality (wavelengths) of photons that hits it. The thirteen carefully chosen color filters, considered particularly useful for seeing specific geological features, allow the collection of different types of data in the same shot.[172] This data is then color-coded in red, blue and green channels and recombined into a photogenic image of Mars' landscape.[173]

169 Ibid. p.25

170 Uricchio, William. *"The Algorithmic Turn: Photosynth, Augmented Reality and the Changing Implications of the Image."* Visual Studies, vol. 26, no. 1, 2011, pp. 25–35.

171 Dewey-Hagborg, Heather. *"Generative Representation."* Generative Representation | u n t h i n k i n g . p h o t o g r a p h y

172 Vertesi, Janet. *Seeing like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*. The University of Chicago Press, 2015.

173 Mars Exploration Rover Opportunity, *Downward Slope, sol 131*, June 6, 2004

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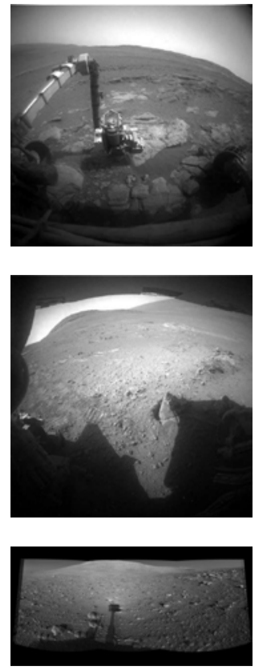

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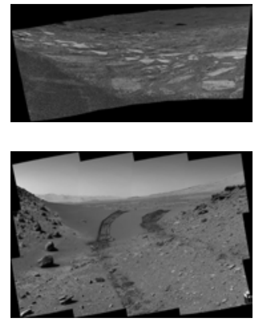

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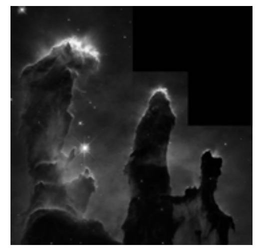

The *Pillars of Creation*,[174] a photograph taken by the Hubble Space Telescope of elephant trunks of interstellar gas and dust in the Eagle Nebula, is composed of 32 images from four different cameras. Each camera captured light of different wavelengths emitted by different elements in the cloud. The data is then represented in different colors in the composite image: green for hydrogen, red for singly ionized sulfur and blue for double-ionized oxygen atoms.[175] Using this technique, NASA is able to create awe-inspiringly colourful photos of parts of the universe where an optical telescope would simply see a dull haze. These picturesque, false color universes exemplify the practice in which digital images operate in a similar way to photographs. Pixels are forced into the mould of a photographic surface, on which a human-centric realism is maintained. At this level, the aesthetic of digital images is still largely defined by the human eye.[176]

But the digitalization of images also points to a fundamental reformulation in the relationship between the image, the world and the humans that live among them. For the scientists studying Cercidilla, a crater ejecta on Mars' Victoria Crater, the realism of the image captured by the Opportunity rover does not stem from the visual representation of the rock. The lighting and geometry of the photo were more important to them than compositional differences in studying the crater's staritography because the previous contains data in the pixels that allows scientists to measure the exact, shapes, sizes, and depths of the crevices on the cliff face.[177] The referent of a digital image is not the event or object depicted but data itself. It signifies a huge shift in the understanding of an image.

> *"Insofar as it makes any sense to talk of a digitally produced image as some kind of 'copy' of the data out of which it is made, it is a visible copy of an invisible original, since it is the digital data*

174 Hubble Telescope, *Pillars of Creation*, 1995. Courtesy of Hubble Heritage Team/ESA/NASA

175 Hubble news release, *"Embryonic Stars Emerge from Interstellar."* Hubble Site

176 Manovich, Lev. *The Language of New Media*. MIT Press, 2010. p.182

177 Vertesi, Janet. *Seeing like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*. The University of Chicago Press, 2015. p.77

that plays the role of the original here, rather than the situation or event that is depicted, which is its more distant, shadowy source." [178]

A digital image is an "artefact soup"[179] and, as such, requires a skilled vision to translate it into something meaningful. This vision could belong to an expert or be embodied by image-processing algorithms, such as in the case of images of Cercidilla. The production of a 'meaningful' digital image works under a stretched temporality; its focus moves from the 'click of a shutter' in analog photography to image processing. Or to reiterate this idea another way, by using Osborne's terminology, the event of capture and the event of visualization[180] now happen in an extended timeline. This stretched temporality is evident in popular digital photography, where one of the most common convention photographers are told to follow is to always shoot in RAW. This golden rule is often underpinned by the reasoning that the RAW format gives photographers more data to 'work' with,' so that during the post-production process, there is more leeway for adjustments in image-editing software. Understood this way, digital photographs are Wittgenstein's gestalt figures.[181] They are ambiguous pictures that need the interpretation of an external agent to further narrow down a few meanings from multiple possibilities.[182] Although sometimes coincidentally photogenic and pleasing to the human eye, "we have to remember that it is not only image quality that distinguishes digital from analog, it is data, the code itself."[183]

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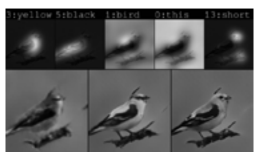

Another interpretation of generative representationalism is similar to the first level but without the final product: a visual image that is intelligible to humans. Here, a digital image is not merely a surface of visual representation for the human eye but rather as a datamap, a 3D point cloud[184] or a textural pattern. An image is simultaneously a matrix of data and a visual representation generated by data. The pattern-recognition machine WiSARD, developed by scientist Igor Aleksander in the 1980s, could recognize individual human faces. It is the world's first patented artificial neural network machine. In a 1983 BBC documentary,[185] his colleagues took turns sitting in front of a camera connected to the computer. Pixelated monochrome images of their faces flashed onto the computer screens and, following a slight delay, the computer recognized them. "Hello, Bruce," the computer said in a monotonous voice. Another man entered. This time the computer 'saw' a face that was not in the system and shouted: "Intruder! Intruder!"

185

It almost seemed as though Aleksander's machine has answered Marr's question:"Can machines see?" But it would be a mistake to call what the machine did seeing. Computer vision, a love-child of machine-learning and photography, is "pure statistic."[186] For a computer to 'see', or to perform semantic segmentation,[187] it carries out an algorithm developed using deep learning. Deep learning is a training process which involves a neural network comprising an input image, layers and output results. Layers of simple feature detectors and high-level feature detectors are trained on millions of human-labeled images. This process involves people painstakingly identifying objects and circling them from the image pixel by pixel. The machine 'learns' by back-propagating errors until the network gets the answer right. When the computer can pick up the pattern, it can begin to identify the elements of a photograph autonomously. To put it in another way, the machine computes the relationship between the questions (the input image) and the answers (the identifier). The

178 Osborne, Peter. *Infinite Exchange: The Social Ontology of the Photographic Image*. Philosophy of Photography, vol. 1, no. 1, Jan. 2010, p.65

179 Vertesi. *Seeing like a Rover: How Robots, Teams, and Images Craft Knowledge of Mars*. p.77

180 Ibid, p.64

181 Jastrow, Joseph. *'The duck/rabbit'*, 1900. Wittgenstein used this image to illustrate "the dawning of aspect": a change in the organization of visual experience. A picture can be 'seen as' a duck or a rabbit, just as the world can be seen in one way or the other.

182 Ibid, p.79

183 Steyerl, Hito. *"In Defense of the Poor Image."* e-Flux

184 A point cloud is a set of data points in space. Usually a result a 3D scanning, the assemblage of data points gives the impression of a 3D space.

185 Video still of the 1983 BBC Documentary

186 Süsstrunk, Sabine. Panelist, Panel discussion. Symposium *"A Mass Stake: From Photo Dissemination to Archive Management"*, 3rd July 2019, Les Rencontres d'Arles, Arles, France

187 Semantic segmentation is a computer vision jargon referring to an image analysis task that discerns elements of an image e.g. decipher an assemblage of blue and white pixels as 'sky'.

result is pattern recognition. Computer vision, thus, is the process of which the machine associates certain combinations of patterns with a specific semantic conclusion. A computer isn't seeing: it is merely using brute force to solve a computable problem which humans called vision. Anna Ridler explores the crucial practice of labelling in computer vision in her work *Myriad (Tulips)* (2018).[188] The photographer created her own dataset by hand-labelling over 10,000 of photographs of Tulips into categories: "red or other colours", "budding or blooming", "strips or no strips". Experimenting with labelling, she found a way to control the images generated by the neural network.

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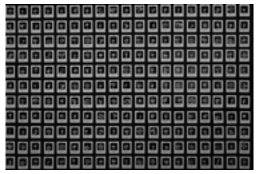

The recent advent of computer vision has highlighted the process of labelling, but this practice of injecting data into images has its roots much deeper in the past. Photography researcher Estelle Blaschke described the coexistence of data and images by looking at the development of image storage medium. The invention of microfilm and Eastman Kodak's Recordak system[189] in the 1920s pioneered an efficient way to store and reproduce documents on 16mm and 35mm film rolls. Contracts, patents and other important papers were photographed onto microfilm. In the event of damage or loss of the original document, the photographic record could be used to reproduce the document using an enlarger embedded in Kodak's system. Subsequently, the large amount of data stored in films called for an image retrieval system.[190] In 1932, German chemist and engineer Emanuel Goldberg proposed a method for using optics and the photoelectric cell to retrieve indexed documents stored on film. His method involves dots or alphanumeric code on microfilms, a 'search template' and a 'light-bulb selector'. For the retrieval of the document, the search template is put in front of the film reel, which is illuminated and turned at high-speed until both match. The use of the data that is encoded onto film is the basis of the

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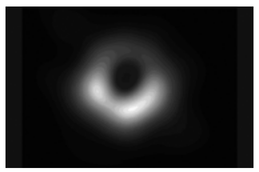

188 Ridler, Anna. *Myriad (Tulips)*, 2018. Courtesy of the artist

189 Recordak Corporation. *Ad print of Eastman Kodak Recordak microfilm systems catalog*, 1968, retreived online

190 Blaschke, Estelle. *"From Microform to the Drawing Bot: The Photographic Image as Data."* Grey Room, vol. 75, 2019, pp. 60–83., p.34

image 'search engine'.

Retrieval technologies kept improving to adapt to the dominant medium of later eras. The inception of Miracode, used in Kodak's Business Systems,[191] not only boosted the speed and accuracy of the retrieval, but also extended the scope of information that could be retrieved. The code de-materializes the mechanical retrieval systems that were largely based on microfilm, minicard and hand-written indexes. The advancement in image-retrieval technology made possible the invention of image banks, such as Corbis images, in the 1990s. The Bill-Gates-backed pioneering image bank heralded the evolution from index cards to digital metadata. With digital metadata, the amount of data stored behind the visible surface increased substantially. The labelling of images becomes the foundation on which Google Image search and newer image banks such as Getty Images and EyeEm are based on, which in turn makes the compilation of training datasets for computer vision much more efficient. Data becomes an integral part of a digital image, perhaps as important as, if not more important, than the visual representation. It defines the meaning of an image and even the existence of an image, for it determines whether the image can be retrieved from an archive or whether it will be forever lost in the ocean of images.

We have reached a full circle that begins with Igor's seeing machine, continues onwards with a brief historical review on the coexistence of data and image only to return to computer vision. What defines the invention of computer vision as a watershed moment in our image culture is not that the machines can see, but rather the development of the invisible infrastructure that enables it—data and algorithms. Digital images are infused with data, data to be read and computed by machines through an opaque process incomprehensible to humans. Some describe them as 'black-box algorithms'. The process is imprinted in the psychedelic colours and uncanny eyes of a DeepDream image of Van Gogh's *Starry Night*.[192] We instantly identify the famous painting

192

191 The system is an updated Recordak adapted to modern office management

192 Google AI, *A Vincent van Gogh-inspired Google Deep Dream painting*, circa 2016

in the image, but what Google engineer Alexander Mordvintsev showed is something else. The alien textures on the images are the traces of computer vision, the process of how computers recognize patterns. Mordvintsev explored computer vision through the Flusserian counter vision. DeepDream gave us a rare glimpse of the inside of the apparatus; one that is slowly slipping out of human comprehension. Perhaps the uneasiness that catches us off guard when we look at a DeepDream image is down to the fact that we are, consciously or unconsciously, becoming self-aware that images are increasingly detached from human perception.

We are no longer the sole producers of images, nor are we the sole audience of images. Self-driving cars, facial recognition, Microsoft's text-to-image drawing bots;[193] all are trained with image datasets to identify other images. These technologies imply that more and more images are produced by, and created for, machines. Speaking about his latest project *A Study of Invisible Images*, in which he tackles the topic of computer vision, Trevor Paglen attempts to broaden the contemporary discourse on photography. "The traditional discourses that we have to think about photographs seem useless today," he says in an interview.[194] Surveying the territory of 'machine vision', Paglen shone light on what he terms 'invisible images'—images made by machines for other machines—to unveil the 'black-box algorithms' behind the pictorial surfaces. The images Paglen shown ranged from completely abstract, eerily human-like[195] to photogenic.

195

One of these 'invisible images' might have been found at the Fluid Dynamics of Disease Transmission Laboratory at MIT.[196] To build a model of spray physics, Lydia Bourouiba led a group of researchers to capture high-speed video footage of water splashes[197] on different surfaces, such as leaves. The photogenic slow-motion crown-splash video is reminiscent of Harold Edgerton's *Milk Drop Coronet*, but unlike Edgerton, these videos are not made for the human eye. The imagery captured by the state-of-the-art high-speed camera was sent to the image-analysis algorithms developed by the team. The algorithms automatically extract and measure the features of the fluid breakup processes, such as the rim thickness of the splash, features that are otherwise indiscernible by humans. With the aid of the algorithms, the researchers discovered a pattern through analysing videos of droplets. The machine deciphers the hidden information of an image that is invisible to the human subject.

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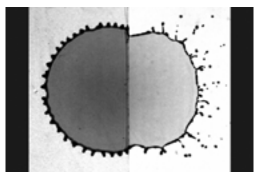

Artist Zachery Norman reversed Bourouiba's visualizing logic by injecting data into the image. Behind every trippy false-colour image in *Endangered Data* (2017) is a year's worth of measurement of meteorological data stored in the respective measuring station depicted in each of his image. Following the footsteps of scientists, librarians and laypeople who have taken up the task of backing up publicly available government datasets after the 2016 election results—driven by the fear that the incoming US president and climate denier Donald Trump would destroy the evidence of human-induced global warming—Norman injects data into his image using a cryptographic technique known as steganography. The technique, used to store or hide information within the pixels of digital images, creates the distinctive appearance of the image.[198] In this way, Norman presents two landscapes in a single digital image: one that is visible to human eyes and one that is accessible only to machines. His six books, which is a small facet of a much larger ecology of machine-generated and machine-readable images, prompts us to reassess our mastery over representation. We can find the same line of thought in Paula Kupfer's introduction to Drew Nikonowicz's work *This World and Others Like It*.

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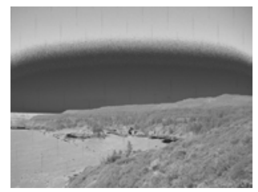

193 The Microsoft's drawing bot was trained on datasets that contain paired images and captions, which allow the models to learn how to match words to the visual representation of those words. The GAN, for example, learns to generate an image of a bird when a caption says bird and, likewise, learns what a picture of a bird should look like.

194 Bridle, James. *"Episode 2: Machine Visions"*, New Ways of Seeing, 24th April 2019

195 Paglen, Trevor. *"Fanon" (Even the Dead Are Not Safe) Eigenface*, 2017

196 Chu, Jennifer, and MIT News Office. *"New Theory Describes Intricacies of a Splashing Droplet."* MIT News, 16 May 2018

197 Fluid Dynamics of Disease Transmission Laboratory, *Droplet's Rim*, 2019, Courtesy of the researchers

198 Norman, Zachery. From the project *Endangered Data*, 2017.

"Within the contemporary wilderness, robots have replaced photographers as mediators producing images completely dislocated from human experience. This suggests that now the sublime landscape is only accessible through the boundaries of technology."

What can we make out of all this talk about images and data? Willian Uricchio's notion of 'the algorithmic turn' quite succinctly crystallises the algorithmic intervention between the viewing subject and the object viewed. He suggests that the union of image and data heralded a new way of representing the world, a way that "refracts the subject-centered world charted by Descartes."[199]

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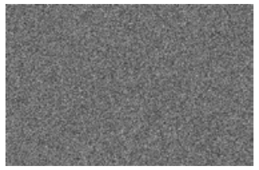
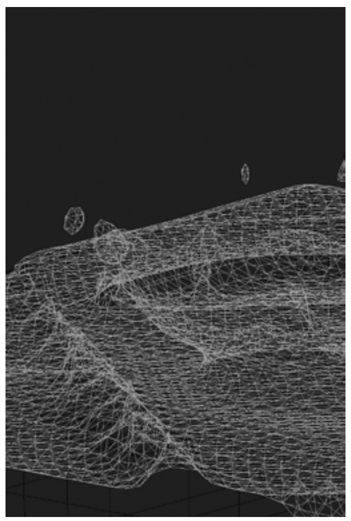


Uricchio's view is mirrored in *The Babel Image Archives*,[200] a webpage that claims to contain all the possible images in the world. The web application permutes 4096 colours on a pixel grid with 416 rows and 640 columns. The title is a homage to Jorge Luis Borges' short story *The Library Of Babel*, which describes a universal library containing every possible permutation of 410 pages of letters, thus everything that ever has been or ever could be written. Since the whole process is randomized, what the user usually gets is a noisy "artefact soup", although in some very rare occasions, the colours and the pixels might just align in the right pattern to form a digital representation of Van Gogh's *Starry Night*, or the face of Kirsch's three-month-old son. *The Library Of Babel* teaches us about infinity just as much as it teaches us that a 'meaningful' image is just one of the infinite possibilities an apparatus can produce. To the apparatus, an "artefact soup" is no less important than the face of an infant. They are all serendipitous combinations of colored pixels, readable and computable by machines—one of the many possibilities of the apparatus.

For a long time, the image an apparatus produced was largely defined by human sight. The significance of an image depends on how people find meaning in them. With each refresh, the website reassigns a new colour to each pixel on the grid, churning out as many images as the apparatus can possibly produce, only this time it does not matter what the human subject desires.

199 Uricchio, William. *"The Algorithmic Turn: Photosynth, Augmented Reality and the Changing Implications of the Image."* Visual Studies, vol. 26, no. 1, 2011, pp. 25–35.

200 Babelia, *babelia #5882212427991338*, 2019. The image of black hole can be found at babelia #2480667808...6607719849 of the library



Chapter 7: Grey Fluid in Black Boxes

Generative Apparatus: Simulation

201

After clicking on the 'bake' button in the interface, the grey sphere suspended in midair began to slowly descend. The sphere on the screen hits another square slab, the 'water tank', equally grey and suspended. At first, a small protrusion rises up from the dent it has made on the 'water tank', then a few seconds later, as the computer finish rendering another frame, the protrusion extends. The motion continues, the protrusion reaches its climax and there it is: a splash inside a computer.[201]

How is a simulated water splash different from a 'real' one? What is the relationship between a computer simulation and our lived world? We might be tempted to conclude that because the water splash on the screen resembles, for example, Edgerton's photograph of a milk coronet, a simulation is related to our lived world in the same way a camera captures an image—a direct transcription of the world. Thus, we may assume that the computer will simulate a water splash using the same laws that govern physical phenomena. Given the same input (the size and height of the water drop, the size and depth of the water tank), the computer would simulate a replica of the 'real' water splash repeatedly and without deviation. However, as we have learnt from previous chapters, a representational perspective only provides a very limited understanding of an image. On the software interface, there is no size, height, depth, gravity nor any of the other common properties used in physics equations, replacing them instead are 'optimization', 'grid levels', 'slip type' and 'fluid particles'.

Examining the apparatus at its technical limits is often helpful for regaining a clear view of the image. The simulated water splash is a technical image. Beyond the assemblage of pixels on the screen lies a unique para-image. Among many other 'particles', making up the para-image are two foundational concepts of simulation: 'parametrics' and 'cellular automata'.[202] Parametrics relates to the human effort to translate observations from our

201 A sequence of a water splash generated from fluid simulation in Blender

202 Keller, Evelyn Fox. *Making Sense of Life: Explaining Biological Development with Models, Metaphors, and Machines.* Harvard University Press, 2003.

lived experience into a computer-readable format. It involves the discretization of worldly phenomena into computable information bits as well as other necessary algorithmic techniques to maintain a stable simulation. 'Cellular automata' describes the machine's ability as a "universe synthesizer".[203] The autonomy of simulation to self-evolve according to simple rules,[204] however, often creates unpredictable results. Parametrics and cellular automata are two parts of a feedback loop that makes simulations possible. Humans leverage on the machine's brute force computing power to solve differential equations; machines rely on algorithms developed by humans to maintain stability. Parametrics construct the algorithmic treatments that encode the physical world for the model to synthesize results, but at the same time, they provide an ad-hoc algorithmic solution to patch technical errors. This combination of human and machine agency formulates a new relationship between the world and the image, one that is recursive, iterative and contingent.

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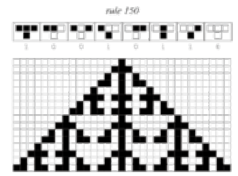

The endeavour of Norman Phillips and Akio Arakawa to model the Earth's atmosphere using computer simulation exemplifies the intertwined relationship between humankind and machines in the production of an image. Both meteorologists were searching for an approach to modelling, experimenting with different ways of translating the physical phenomenon into computable problems in the 1950s. Phillips developed his simulation based on six equations from theoretical models of atmospheric wind and pressure relations.[205] His simulation ran as expected initially, but the dynamic of his atmosphere remained unstable. The system 'exploded' into chaos in merely 4 weeks.[206] This signals a fundamental gap between theory and discrete simulation models that forbids the direct imitation of physical phenomena. Phillips' model was successful in two ways: he

203 Ibid

204 A cellular automaton is a collection of "colored" cells on a grid of specified shape that evolves through a number of discrete time steps according to a set of rules based on the states of neighboring cells. Fox-Keller uses the term to describe the nature of simulation.

205 Lenhard, Johannes. *"Computer Simulation: The Cooperation Between Experimenting And Modeling*"*. Philosophy Of Science, vol 74, no. 2, 2007, pp. 176-194. University Of Chicago Press

206 Ibid

formulated the right primitive equations (theory[207]) and devised the subsequent connections among them (model). However, his focus of transcoding human knowledge into the computer has not yielded him a stable simulation.

Phillips' failure shows that the production of a successful computer simulation is more than theory and model. The process necessitates both human and machine intelligence, and an approach that treats both parties as active agents. A computer simulation involves both the human transcoding of physical phenomena into computable data and the synthesis of a virtual environment through the machine's cellular automata. Contrary to Phillips' work, Arakawa's approach emphasises the simulation's ability to imitate phenomena in the atmosphere rather than solving theoretical equations.[208] Despite being well-versed in mathematics, he permitted contradictions in the primitive equations in order to better imitate the atmosphere. He introduced additional unempirical mathematical artefacts (treatment and solver) to ensure the system would remain stable in the long-term. Surprisingly, his quasi-empirical approach allowed him to produce a stable and usable simulation.

These patchwork algorithms, referred to as 'discretization scheme'[209] and 'parametrics',[210] are now standard when building computer simulations. Sometimes, a "parameter is a kind of proxy—a stand-in for something that cannot be modelled directly but can still be estimated, or at least guessed."[211] Other times, they act as lubricants that overcome computational friction[212] by simplifying physical processes too small to be modelled directly. Parameters such as 'cloud fraction'[213] and 'eddy viscosity'[214] allow the simulation to stay relatively consistent in simulating larger-scale meteorological phenomena, without overcrowding the computer with irrelevant calculations. However, the parameters have no theoretical foundation. In other words, many parameters are not physically based, but these numerical artefacts are crucial to the stability of the simulation. Paul E. Edwards summarizes the use of parameters:

207 The five components of simulation Winsberg identified are: Theory, Model, Treatment, Solver and Results

208 Johannes. *"Computer Simulation: The Cooperation Between Experimenting And Modeling*"*.

209 Winsberg, Eric B. *Science in the Age of Computer Simulation*. University of Chicago Press, 2010.

210 Edwards, Paul N. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. MIT Press, 2013.

211 Ibid.

212 Paul N Edwards uses the term computational friction to refer to the resistance that opposes the transformation of data into knowledge. It includes the physical and economic limits on processor speed and memory capacity as well as human work involved in programming and operating the computer.

213 Scientists would assign a "cloud fraction" to estimate the percentage of each grid box covered by clouds, rather than calculating it directly from convection columns, condensation nuclei, and their other physical causes. The simplification of the physical phenomenon makes it more manageable for computer to execute simulation.

214 The parameter is used in meteorologist Robert Wilhelmson's thunderstorm simulation. Eddy viscosity is a mathematical tool scientists invented to approximate the effect of tiny-scale vortices that is unresolvable by computational grid. The parameter allows the simulation to stay relatively consistent with accurate representation of the larger-scale meteorological phenomenon, without overcrowding the computer with irrelevant calculations.

> *"Modelers develop parameterizations by reviewing observational data and the meteorological literature. They identify the range of observed values and try to find relationships between small-scale processes and the large-scale independent variables in their models. When they succeed in finding such relations, they call the resulting parameters 'physically-based'. Often, however, they do not find direct links to large-scale physical variables. In this quite common case, modelers invent ad-hoc schemes that provide the models with the necessary connections."* [215]

Among computer programmers, the ad-hoc parameters are referred to as 'Kluge'. A Kluge is a colloquial term that describes sections of code that were functional but unprincipled, inelegant, and ill-understood.[216] A simulation combines two seemingly contrasting methodologies; part of the process is grounded in empirical experience and theoretical models in physics. Another part of the process relies on parameters. By forging nonexistent connections between real-life phenomenon and virtual variables, these contingent mathematical schemes serve as the operational backbone of simulations.

The parameterization of the world and the autonomy of simulation dissolve the conventional epistemological paradigm that divides the scientifically-sound from the imaginary, 'real' from 'fictional'.[217] Underpinned modern computer simulation is the acceptance of uncertainty—both in the physical world and in computation. Edward Lorenz learnt that chaos is in the nature of many world phenomena as he was experimenting with meteorological simulations. He later summarized his findings in chaos theory which describes the unpredictability of chaotic systems. Many phenomena are, in fact, not deterministic. Alan Turing's halting problem[218] proves that there are problems unsolvable by deterministic machines such as computers. It is uncertain whether

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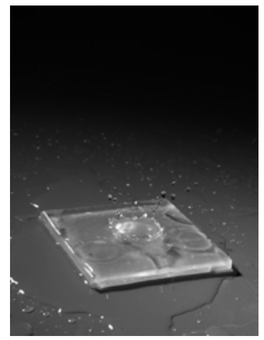


215 Edwards. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. p.341

216 Winsberg, *Science in the Age of Computer Simulation*. p.109

217 Yiu, Sheung. Water Splash on Water Splash. 2019.

218 In computability theory, the halting problem is the problem of determining, from a description of an arbitrary computer program and an input, whether the program will finish running, or continue to run forever.

a programme will provide answers. What we can do at that moment is to throw educated guesses. The second-best response to this uncertainty is parameterization.

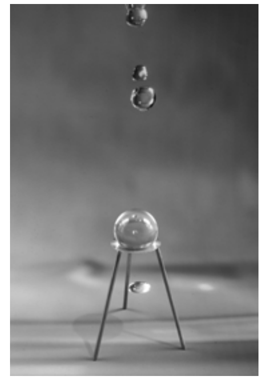
Parameterization signifies the limit of human knowledge. It entails accepting and absorbing fictionality into a world in which empiricism and logic are held as the virtues of truth. Parameterization is a counterpoint to the Cartesian subject. The rise of simulation has engendered a re-evaluation of the human-centric nature of almost every concept; the notion of the world, reality, knowledge, technology, apparatuses and images. Replacing it is a posthuman understanding of image ecology grounded in uncertainty and human-machine symbioses. We need to work with machines to access our reality through images. Our intelligence is neither superior nor inferior to that of a machine; the two simply have different roles in the practice. We work symbiotically as one apparatus. Simulation obliterates the notion of an all-knowing human subject and the idea of absolute knowledge. Rather, it leans towards a pragmatic theory of truth, "a reliability without truth".[219] This pragmatism has materialized in the contemporary development of AI and computer vision in which we partially disengage from theories and accept inexplicable elements—such as black-box algorithms—as long as they spit out meaningful results.

Just as telescopes have a limit to their resolving power,[220] simulation, like any other apparatus, has a limit to its 'resolution'. We tend to think that simulation is a computationally generated version of the real world based on the same principle, but simulation is indeed its own universe governed by a different set of rules, driven by the human desire to imitate our world. To borrow Flusser's lexicon, computer simulation is the world abstracted, on one hand by theories (linear texts that abstract the physics of the lived world), and on the other by algorithmic modelling (linear text that abstract the 'physics' of the virtual world). The image is not a deterministic one, rather it might be a coincidental resemblance. A simulated image is a mirage, a refraction of our world.

Likewise, the simulation of a water splash conjured up by my computer belongs to a new type of technical image; one that reformulates a relation between the image and the world unlike any other that came before it.[221] This gesture of image-making is "doubly self-involved, from an intricate opposition and collaboration between the inventor and the manipulator of the apparatus and an opposition and collaboration between an apparatus and a human being."[222] For one, whereas a photograph refers to a 'there-has-been' in the world and digital image refers to data, the referent of a simulation is a mathe-

219 Winsberg, *Science in the Age of Computer Simulation*
220 The ability of optical equipment to discern two close together images as being separate.
221 Yiu, Sheung. Photo Installation. 2019.
222 Flusser Vilém, et al. *Into the Universe of Technical Images*. University of Minnesota Press, 2011. p.20

221


223


matical model. In Flusser's *Into The Universe of Technical Images,* the philosopher characterizes five "rungs" of knowledge transmission throughout human history wherein each rung the mediation reaches a new level of abstraction. These "rungs" can be briefly summarized diagrammatically as: actions – objects – traditional images – linear text – technical images.[223] The traditional image is an observation of an object, and the technical image is a concept computed in an apparatus.[224] In the fifth rung: "Texts have recently shown themselves to be inaccessible. They don't permit any further pictorial mediation. They have become unclear. They collapse into particles that must be gathered up. This is the level of calculation and computation, the level of technical images."[225] A simulation occupies a new level of abstraction outside of the five rungs. The sixth rung, as Marcel Cadaval Pereira called it, is the age of virtual interactive media. This level of abstraction features "non-existent (virtual) tools manipulated by multiple characters, generating multiple possible results."[226] At this level, images are work-in-progress objects which do not have a static final form. They are always subject to change from the reaction-loop between human and the apparatus. A water splash can shapeshift into any other water splash calculable by the model as the user changes the data input. A simulated crown splash depicts a discrete instance created by a mathematical model. It is neither a direct representation of the real-world water splash nor of the whole mathematical model.

For another, we shall focus back on the first part of Pereira's definition of the sixth rung — "non-existent (virtual) tools manipulated by multiple characters".[227] Referencing Windberg's simulation timeline, we can deconstruct the production of a simulation into multiple agencies: (1) a theorizing agent that transcodes observations in the real world into physical properties e.g. mass and velocity, (2) an agent, usually human, that trans-

223 Pereira, Marcel Cadaval et al., *The Sixth Rung*, Flusser Studies 22, p1-12
224 Flusser, *Into the Universe of Technical Images*
225 Flusser, *Into the Universe of Technical Images*
226 Pereira, *The Sixth Rung*
227 Pereira, *The Sixth Rung*. p.10

lates these theories into computable programming language, (3) a modelist that sets and adjusts certain parameters based on both physics theories set by the first agent and the performance of the model and (4) a computing agent, commonly the computer, that executes a large amount of calculations. Every agent in this non-exhaustive list interacts with one another, meaning that they all take feedback from each other and adjust their input accordingly. A simulation is created when all of these interacting agents manipulate a mathematical model or a program. A simulated image is an artefact created , either intentionally or accidentally, to visualize an instance of the mathematical model that has been given certain input conditions. The image is no longer an end in itself; rather, it is a mean to an end. Additionally, while the meaningfulness of a photograph is mostly defined by humans, a simulated image exemplifies a new apparatus—both in the Flusserian and Agambien sense—that requires humankind and machines to work together to create meaning. The image is a product of the interactive relations between the user and the model. It records a water splash that lives between the physical world and the virtual world—a refracted water splash. A simulated image is a visual embodiment of uncertainty. Similar to a mirage, it shows a projection of the world that is beyond our horizon.

The World is an Image

Viewing images through counter vision in the last seven chapters, we have demonstrated the complexity of images in our times. We have peeked beyond the surface to examine the non-pictorial aspects of an image in order to make sense of the triangular relations between humans, images and the world. As we switch between the representational, the phenomenological and the generative apparatuses, a blurry para-image begins to emerge. This para-image points to the dissolution of two dichotomies. Firstly, we are less certain where human agency ends and machine agency begins in the production of image. Humans are no longer the sole producer of the image. The generative apparatus implies that humankind needs to work with machines to decipher the meaning of an image. An anthropocentric perspective is less helpful in understanding the complexity of contemporary images. Secondly, the boundary between image and reality has become blurred. The phenomenological and the generative apparatuses have shown that images engender their own realities. Rather than the window from which we see the world, an image is the world.

An image is not a map that leads to the demise of the nation it represents.[228] The relationship between the image and the world is not quite exactly as Baudrillard lays out in his notion of simulacra.[229] A detachment from the Platonic representational model of images, Baudrillard used 'simulacra' to describe the postmodern tendency of images to stand in for the real. However, in this rhetoric where the copy replaces the real, the hierarchy of the real over the copy—that underlined the Platonic discourse of images—lingers. Baudrillard's hyperreality described a dystopian world where the copy preys on the real, and as the copy is further removed from its original referent, the world is left with unattainable idealistic representations. His view suggested an ontological difference between the image (the copy) and the world (the real). However, as I have argued, the relationship between the image and the world would be better understood not as two separate entities, but as one entangled body.

Going back to "the image itself",[230] the last seven chapters have elaborated on the three different apparatuses that sustain the significance of certain images, and subsequently provide a contemporary formulation of the relationship between humans, images

228 Here, I am referring to Jorge Luis Borges's *On the Exactitude of Science*, in which he told a story of an empire so enamoured with representing its cities that its maps eventually cover its entire territory, leading to its demise.
"In that Empire, the craft of Cartography attained such Perfection that the Map of a Single province covered the space of an entire City, and the Map of the Empire itself an entire Province. In the course of Time, these Extensive maps were found somehow wanting, and so the College of Cartographers evolved a Map of the Empire that was of the same Scale as the Empire and that coincided with it point for point. Less attentive to the Study of Cartography, succeeding Generations came to judge a map of such Magnitude cumbersome, and, not without Irreverence, they abandoned it to the Rigours of sun and Rain. In the western Deserts, tattered Fragments of the Map are still to be found, Sheltering an occasional Beast or beggar; in the whole Nation, no other relic is left of the Discipline of Geography."

229 Baudrillard, Jean, 1929-2007. *Simulacra And Simulation*. Ann Arbor. University of Michigan Press, 1994.

230 Merleau-Ponty, M., and Colin Smith. *Phenomenology of Perception: (5. Impr.).* Routledge & Kegan Paul. New York: The Humanities Press, 1970. p.14. In his book, Merleau-Ponty describes Husserl's directive to phenomenology as 'descriptive psychology', or to return to the 'things themselves'

and the world. Through employing three different "boundary-drawing practices",[231] namely the representational, the phenomenological and the generative apparatuses, we have encircled cultural ideas, technological apparatuses, artworks, scientific theories and other particles that combine to form para-images of seven depictions of water splashes. We began with Da Vinci's Drawing and Worthington's photograph, two examples that are emblematic of representationalism—an apparatus that purports the idea of image as a representation of reality. This view is first espoused by the rationalization of sight established by Euclid followed by the invention of perspective during the Renaissance, and later by the invention of photographic cameras.

Representationalism faced a crisis in the late nineteenth century as human vision was put under scrutiny by physiological optics and absolute knowledge by phenomenology. The epiphany that the world we know is not absolute but a perceived conjecture unstabilized the representational logic behind the truth claim of images. Eliasson's *Big Bang Fountain* (2014) exemplifies this view. Following the lead of phenomenologists, photographers return to "the image itself", treating the image as an object. The readymade Edgerton's photoshoot at Bradford's National Science and Media Museum and Jojakim Cortis and Adrian Sonderegger's recreation of the milk coronet challenge us to rethink the dichotomy of the real and the image. The lived world is as constructed as the photographs of Thomas Demand. The world becomes a stage where every moment is a photogenic experience. We live our lives vicariously through our own images. With it, the distinction between the thinking subject and the observed object dissolves. Baudrillard's notion of simulacra and Debord's spectacle are key to making sense of the contemporary image culture we live in.

The last two chapters focus on the generative apparatus, from which we examine digital images and simulations. MIT's research images of water splashes demonstrate the image-as-data approach. With the advent of computer vision, humans are no longer the sole producer and sole audience of images. In fact, a new strand of image emerges—"invisible images",[232] images with a message that is undecipherable by humans alone. This finally brings us to fluid simulation, which entails a fundamental shift in the ontology of realism and our relationships with machines. Parameterization signifies a fictionality in reality; a reliability without truth. I analogize a computer simulation to a mirage. It is a refraction of reality. It is partly based on the lived world, yet is also

231 Barad's definition of apparatus

232 *Trevor Paglen Shows Us How Computers See The World (HBO)*, YouTube, uploaded by Vice News, July 25, 2017.

governed by an ad-hoc scheme of mathematical modelling. Its autonomy brings unprecedented interactivity to an image. The technical images it produces are manifestations of the interaction between humans and machines.

Viewing the image through three apparatuses side-by-side, we are then able to break away from the Platonic model of images that binds us to the world of representation and objective reproduction. In every apparatus lies a different agenda; images enter different circuits and the distinction between the real and the copy becomes irrelevant. The image has a life of its own. More than a representation, it is the reality; it engenders reality. Reality is not 'real' but a well-tempered harmony of simulations. Put in another way, the image is 'realer than real'. As Deleuze elaborates:

> *"Simulation does not replace reality… but rather it appropriates reality in the operation of despotic overcoding, it produces reality on the new full body that replaces the earth. It expresses the appropriation and production of the real by a quasi-cause."* [233]

If images are, as Flusser said, "signposts directed outward",[234] then we should not be distracted by their signs, but rather turn our eyes to the directions they point towards. One direction is the dismantling of anthropocentrism in the discourse of images. On one hand, phenomenology challenges us to scrutinize the notion of absolute knowledge. Rationality and objectivity which prioritize an independent human subject comes into questions as human vision is more complex than it was once thought. Images are objects of human perception rather than representations of reality.

On the other hand, the emergence of new media restructures the mediation of human experience. The traditional McLuhanian idea[235] that media is a prosthetic of human sensory organs no longer holds. The cellular automata of simulation, or the capacity to perform according to its own laws, marks the moment "in the history of technical media in which human experience is left behind."[236] Parametrics, data and algorithms break down the world into bytes, which are then fed into the machines as their sensory inputs. The result is that computers now mediate a world rendered through its own perception, one that is incomprehensible by humans. Once the technical inscription of human experience, the media now gains an agency. Today mediation entails a task of "composing the relations between technical circuits and human experi-

233 Massumi, Brian. *Realer than real: The Simulacrum According to Deleuze and Guattari.* From Copyright no.1, 1987, p. 90-97.

234 Flusser, Vilém, et al. *Into the Universe of Technical Images.* University of Minnesota Press, 2011.

235 McLuhan, Marshall, et al. *The Medium Is the Massage.* Penguin, 2008.

236 Hansen, Mark B. N. *Feed-Forward: on the Future of Twenty-First-Century Media.* University of Chicago Press, 2015. iBooks. p.42

ence."[237] An image is a medium no longer restricted to tracing human experiences, but one that includes "everything that happens when machines interact with other machines in today's complex media networks, everything that happens when human interface with these networks and also, of course, everything that happens when human self-reflect on these interactions."[238]

> *"What transpires is a doubling or splitting of media's operationality: on one hand, twenty-first-century media mediate the sensory continuum in which all experience, human included, occurs; on the other, twenty-first-century media function as media for humans—as media in its traditional sense—when and insofar as they presentify the data of sensibility in ways that humans can perceive."*

The twenty-first-century-media Hansen describes implies that humans are not the sole producers and sole audience of images any more; there are instances when we must work with machines to complete certain images and, by extension, our lived experience. The human experience is just one of the many experiences new media is capable of mediating. In some cases, an image is produced for us to understand the machine's experience. For example, a visualization of a simulated model. In this process, human vision is displaced from the throne of visual culture and epistemological structure. Replacing it is a stereoscopic vision, where humans and machines must collaborate as an apparatus to negotiate and decipher the meaning of an image.

Another direction these technical images point towards is a new understanding of reality, which Barad aptly named "agential realism".[239] Underpinning this non-representational realism is the blurry boundaries between the human subject and the observed object. This idea, raised by phenomenologists in the early twentieth century, become the focus of debate in a vastly different discourse— quantum physics. Heisenberg's uncertainty principle and Niel Bohr's thought experiments highlight the interaction of the apparatus with the measured object. Bohr disproves the notion of an independent reality. The reality of the measured object, in Bohr's case the position or momentum of a particle, depends on the apparatus set-up. The momentum of a particle can be determined by a moving apparatus but not a non-moving apparatus. Theoretical concepts are not idealistic in nature but rather a consequence of a specific physical arrangement. That is to say, the apparatus, the observer and the observed are entangled. There is no clarity

237 Ibid, p.43

238 Ibid

239 Barad, Karen Michelle. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Duke University Press, 2007.

between the object and the agencies of observations. The world is not a combination of independent realities but the result of the intra-actions of various agencies. In Barad's own words:

> *"In my agential realist account, scientific practices do not reveal what is already there; rather, what is 'disclosed'' is the effect of the intra-active engagements of our participation with/in and as part of the world's differential becoming. Which is not to say that humans are the condition of possibility for the existence of phenomena. Phenomena do not require cognizing minds for their existence; on the contrary, 'minds'' are themselves material phenomena that emerge through specific intra-actions. Phenomena are real material beings. What is made manifest through technoscientific practices is an expression of the objective existence of particular material phenomena. This is, after all, a realist conception of scientific practices. But unlike in traditional conceptions of realism, 'objectivity' is not preexistence (in the ontological sense) or the preexistent made manifest to the cognitive mind (in the epistemological sense). Objectivity is a matter of accountability for what materializes, for what comes to be. It matters which cuts are enacted: different cuts enact different materialized becomings."* [240]

The image, being a worldly object, operates under the same framework. Images are not representations of the world, they are part of the world. They are the product of apparatuses, "boundary-drawing practices —specific material (re)configurations of the world—which come to matter."[241] They themselves are also apparatuses and phenomena. This is not merely a theoretical invention, or meant to be a cheap provocation, but a lived reality. Our obsession with selfies and spectacles, the surveillance technology and Deepfake videos enabled by computer vision, the Event Horizon Telescope that produced the first image of a black hole, the simulations which climate change research relies on: all of these images point to an entangled web of images, humans and the world. Like the particle in Bohr's experiment, the 'reality' of the image depends on the arrangement of agencies. Under a representational apparatus, an image is a mirror of the world. Seen through a phenomenological apparatus, an image affects the perception of self and reality. In a generative apparatus, an image is a manifestation of the interaction between humans and machines.

An image is an object. The traditional understanding of image as a window to the world no longer suffices, failing to grasp the complexity of images in contemporary

240 Ibid. p.361
241 Ibid. p.140

visual culture. More than a pictorial surface, an image is a manifestation of our interactions with the world through an apparatus. An image is both an object and a representation. It has its own agency and 'intra-acts' with other entities in the world. An image is the Soviet battle tank IS-3 for Joseph Stalin: one moment it is put on a WWII memorial pedestal, admired as a historical display; the next moment it is driven off from the pedestal and promptly goes to war.[242]

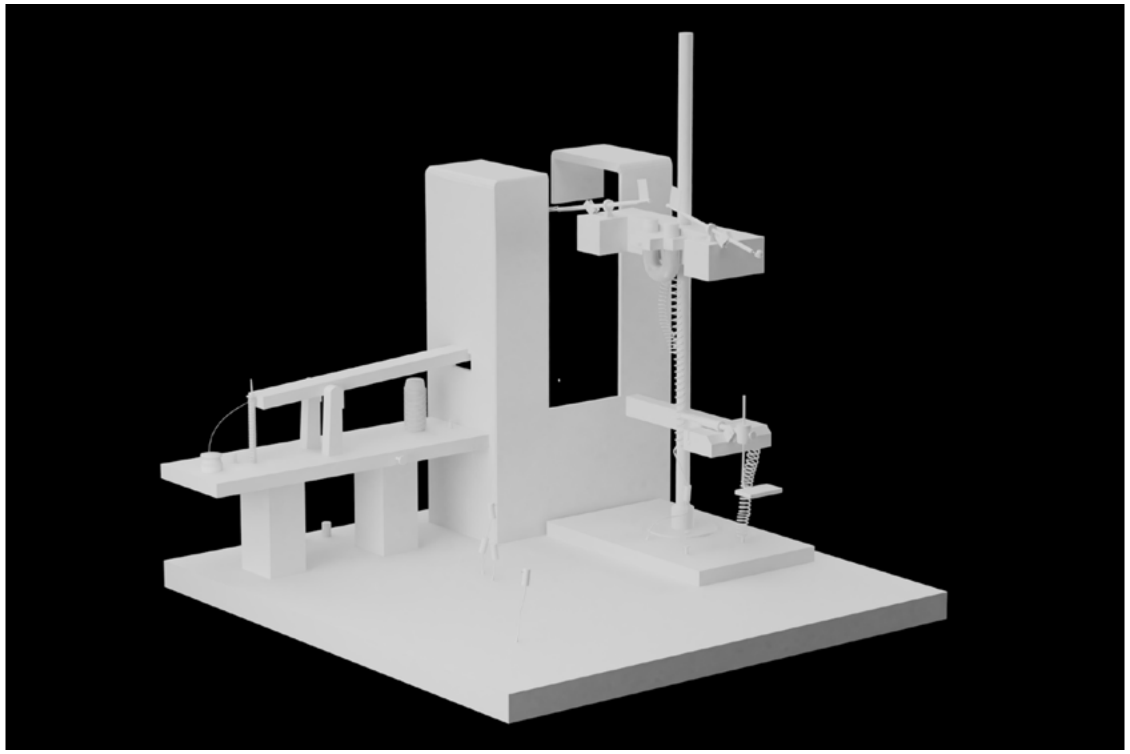
The discourse on images should not stop at the visible part of an image. Para-images reveal that behind every image is an invisible belief system. This belief system determines what kind of images are created and what images have a significant relationship to us. It is also indicative of the configurations of different agencies, ideas and technical apparatuses that sustain our reality. They are manifestations of the structure of the world as it is, and they are the only way in which the world is.[243] That is, the world is an image.

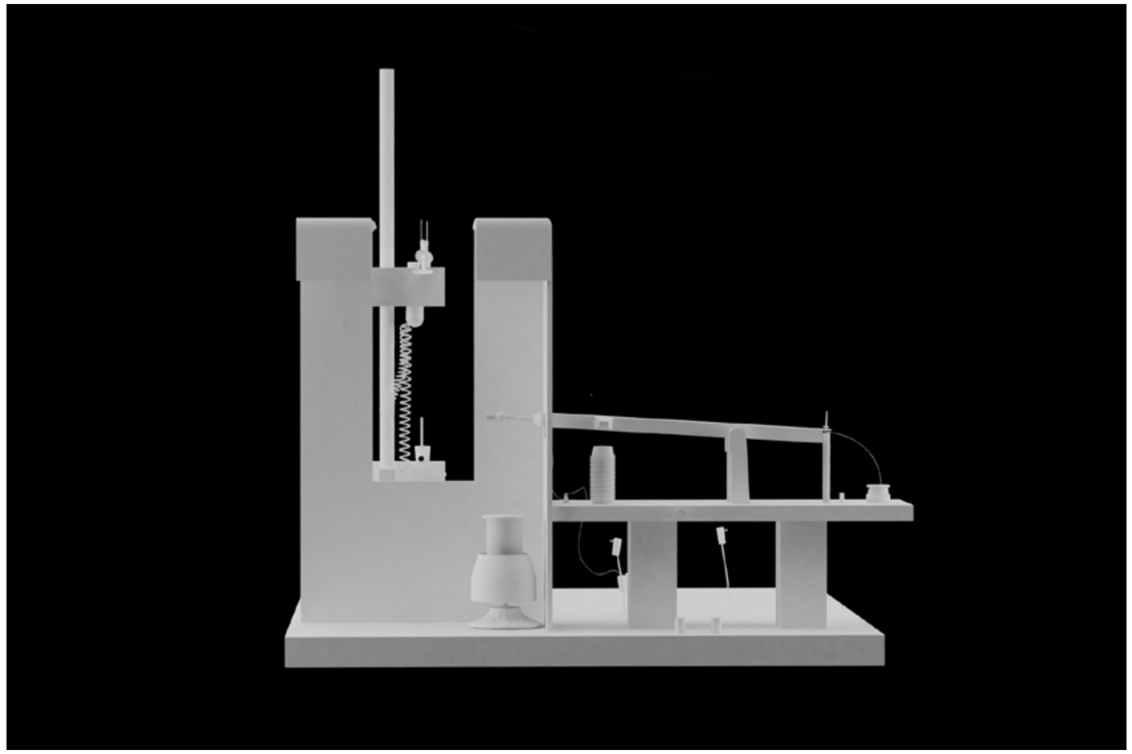
242 Steyerl, Hito. *"A Tank on a Pedestal: Museums in an Age of Planetary Civil War."* e-Flux, Feb.
243 Hansen, Mark. *"Logics of Futurity, or on the Physicality of Media"* 2014 School of Criticism and Theory public lecture series, 30 June 2014, Cornell University.

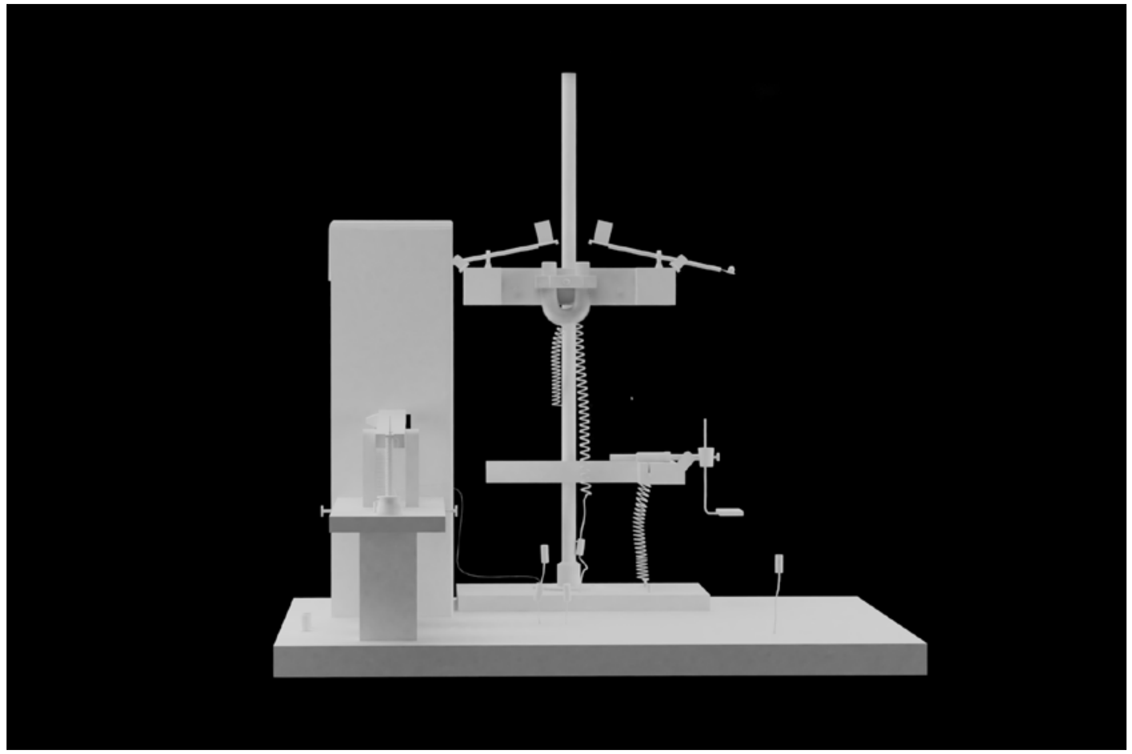
The Twinkling of an Eye

"When the water is impacted, it opens and the impacting drop bounces back. The water that was open, closes back as a wave converging toward the place where the place jumped up. All this water in reflective motion impacts on itself and jumps (following the first drop) and climbs behind it as if embracing it."

Codex Atlanticus, Leonardo Da Vinci





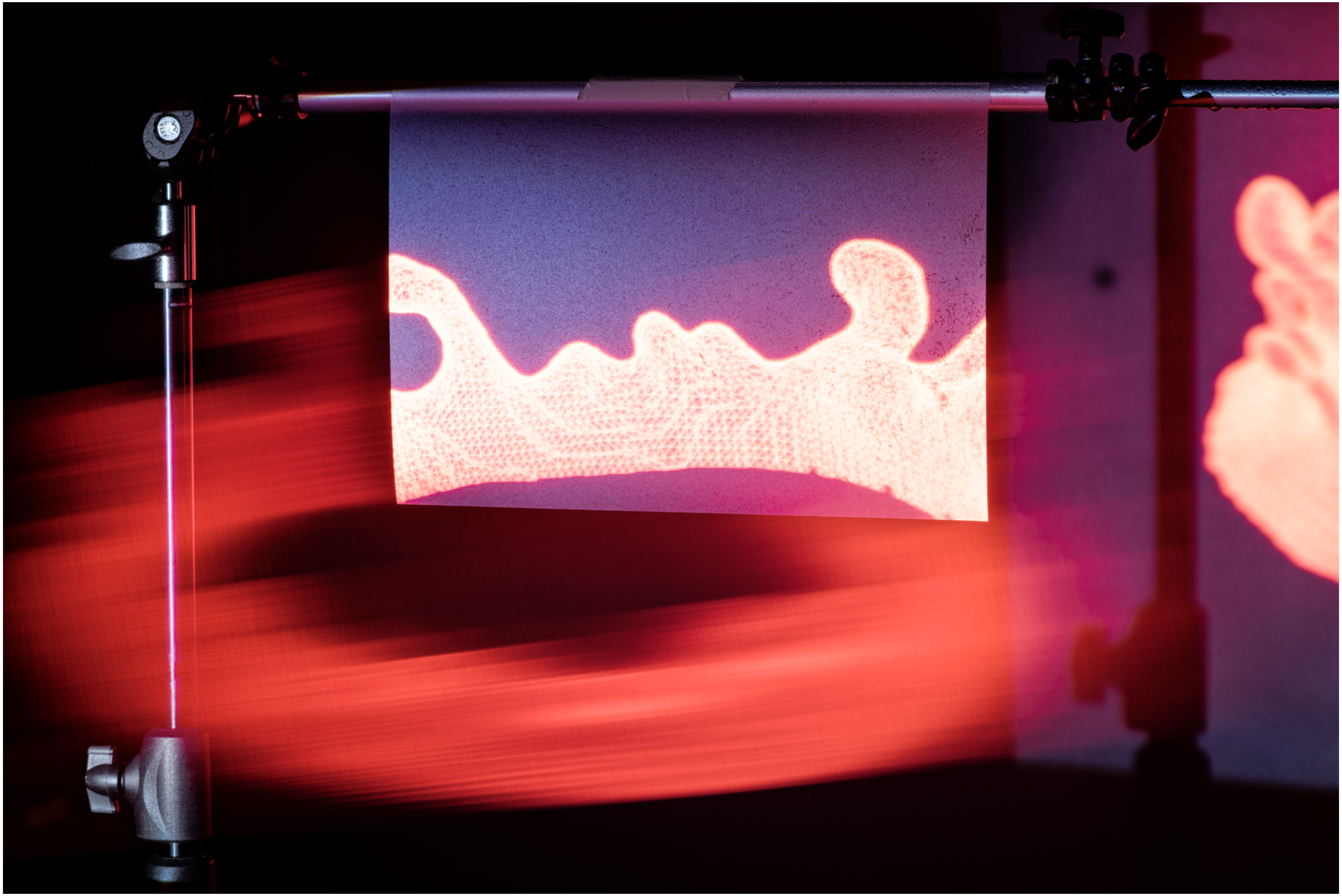


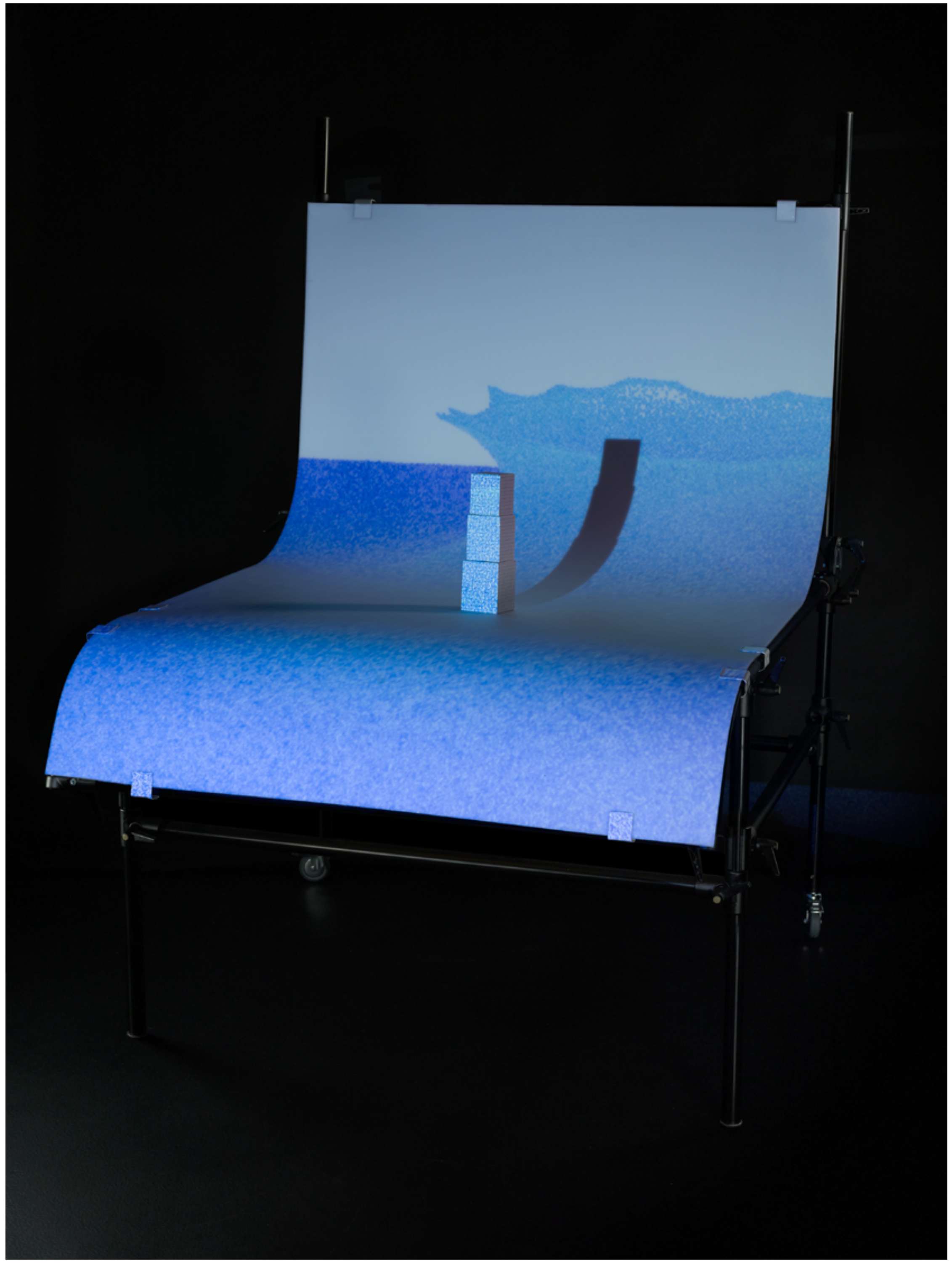
"The splash of a drop is a transaction which is accomplished in the twinkling of an eye."

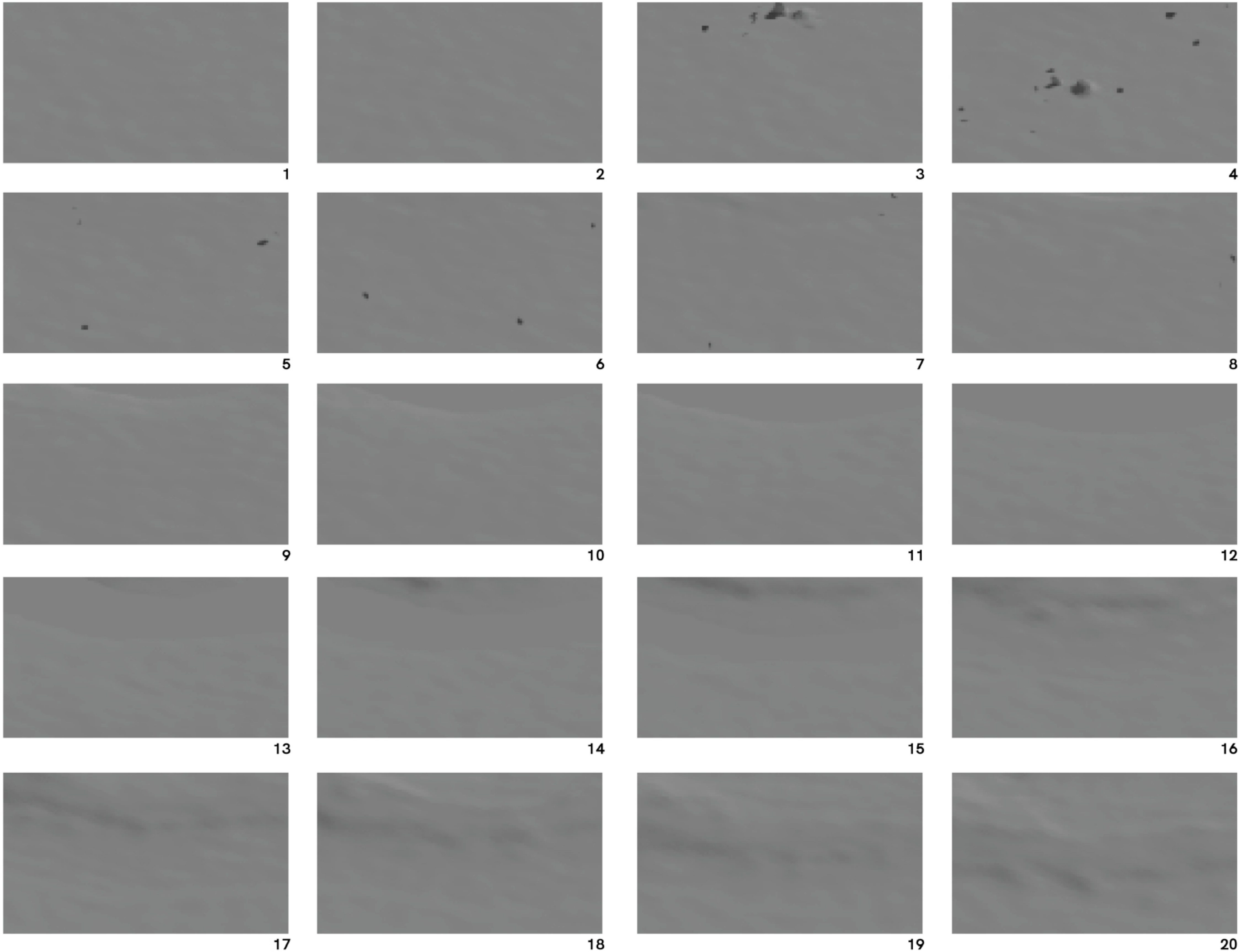
The Splash of a Drop, Arthur Mason Worthington

"The modern stroboscope has achieved these desiderata, and under its revealing light it is now possible to see the exquisite splash formations with the unaided eye, to photograph them in daylight, and to take motion pictures for ultraslow projection."

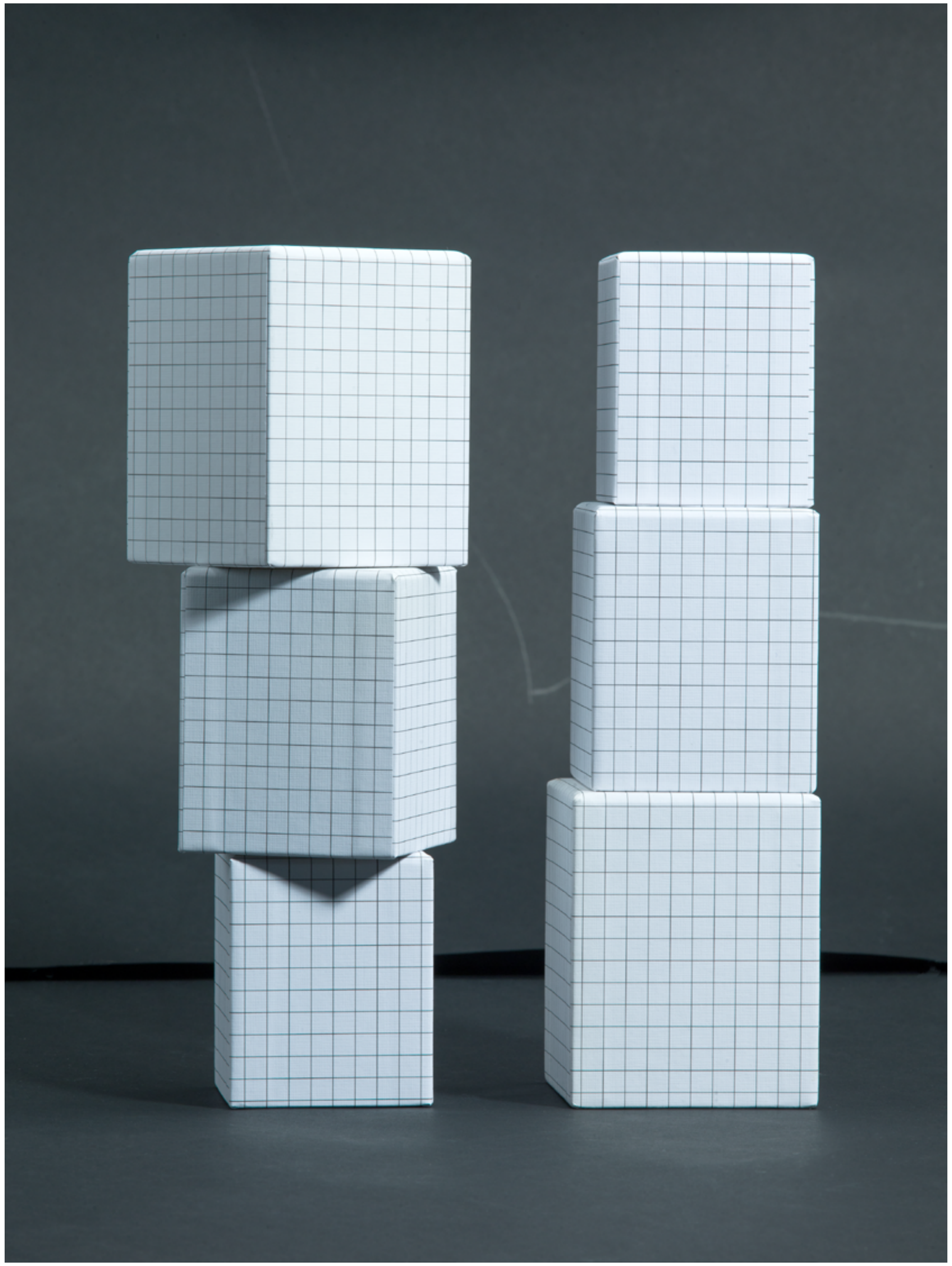
Harold Edgerton and James Rhyne Killian, Flash!
Seeing the Unseen by Ultra High-Speed Photography







resolution 150
height 10
size of waterdrop 0.5
speed 0.5



"As a single raindrop falls to the ground, it can splash back up in a crown-like sheet, spraying smaller droplets from its rim before sinking back to the surface — all in the blink of an eye."

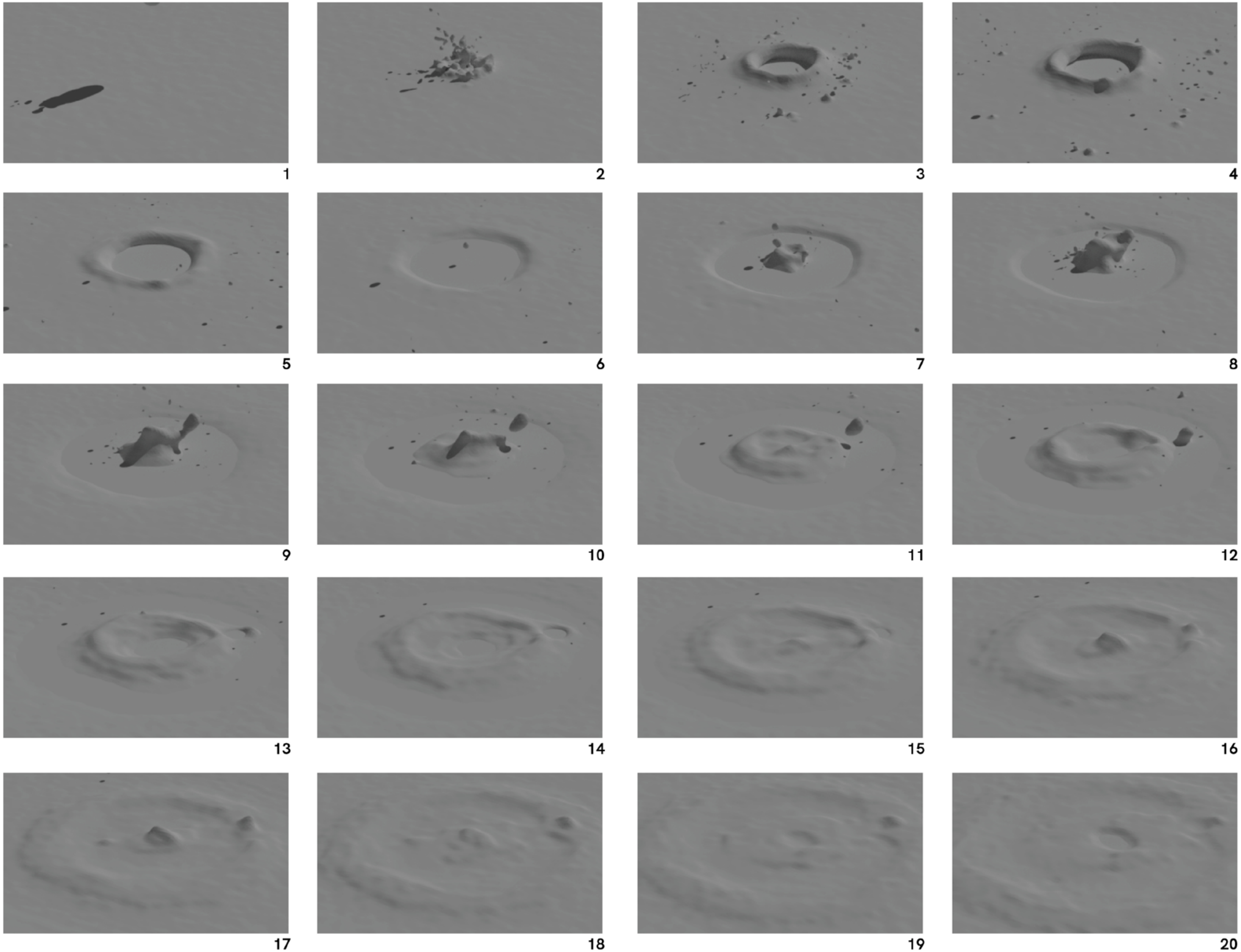
Jennifer Chu, MIT News "New theory describes intricacies of a splashing droplet

"Think of a fluid as a collection of boxes or cells. Each box has various properties, like velocity and density. These boxes interact with their neighbours, affecting their velocity and density. A real-world fluid can be seen as having a huge number of absolutely minuscule boxes, all interacting with their neighbours a zillion times a second.

Of course, a real computer can't handle a zillion interactions per second, nor can it handle a zillion little boxes, so we have to compromise. We'll break the fluid up into a reasonable number of boxes and try to do several interactions per second."

Mike Ash, Fluid Simulation for Dummies



resolution 150
height 10
size of waterdrop 0.5
speed 0.5

"Please note that the normal real-world viscosity (the so-called dynamic viscosity) is measured in Pascal- seconds (Pa.s), or in Poise units (P, equal to 0.1 Pa.s, pronounced pwaz, from the Frenchman Jean-Louis Poiseuille, who discovered the laws on "the laminar flow of viscous fluids"), and commonly centiPoise units (cP, equal to 0.001 Pa.s, sentipwaz). Blender, on the other hand, uses the kinematic viscosity (which is dynamic viscosity in Pa.s, divided by the density in kg.m-3, unit m2.s-1). The table below gives some examples of fluids together with their dynamic and kinematic viscosities."

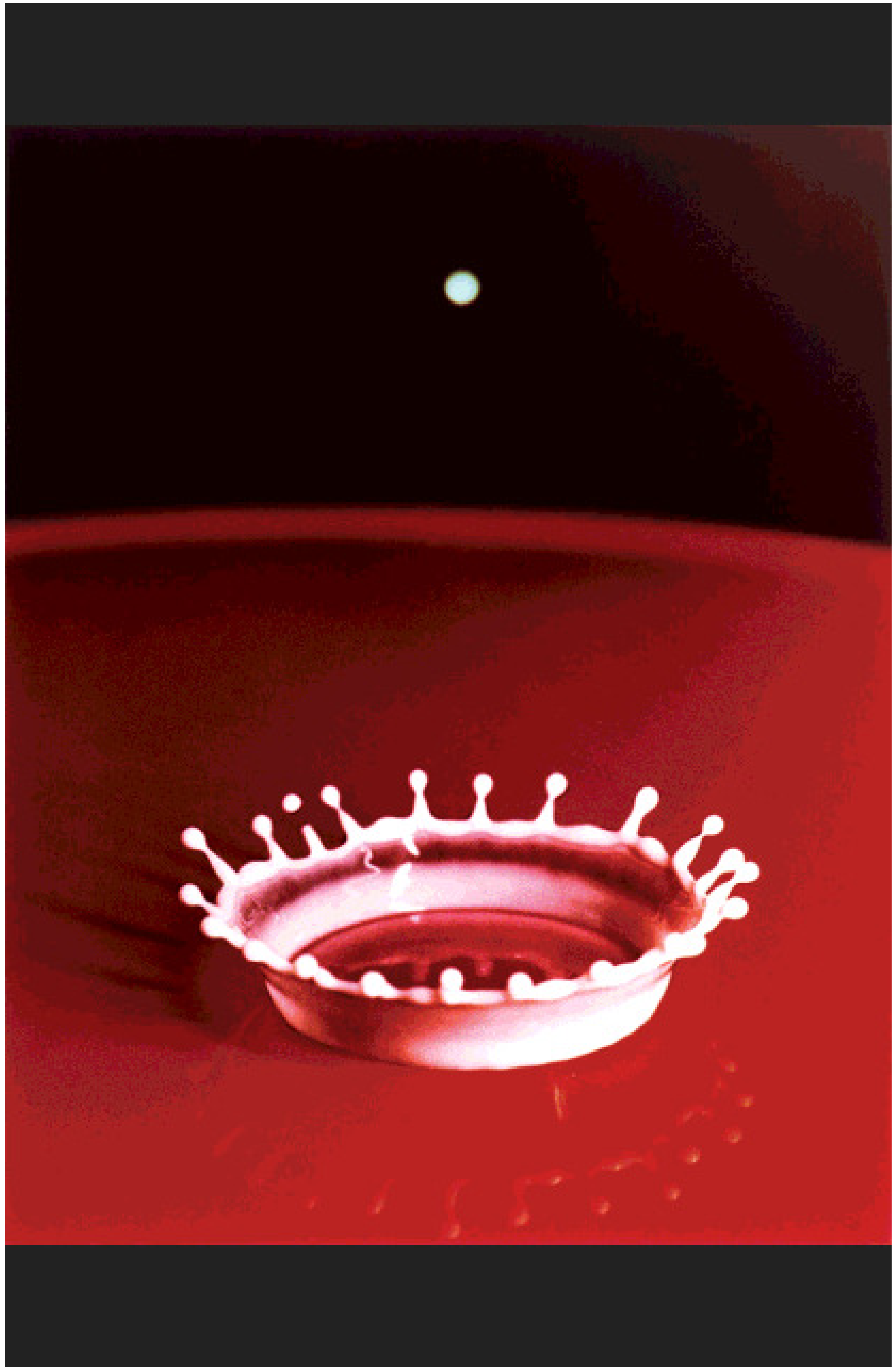
Blender Manual

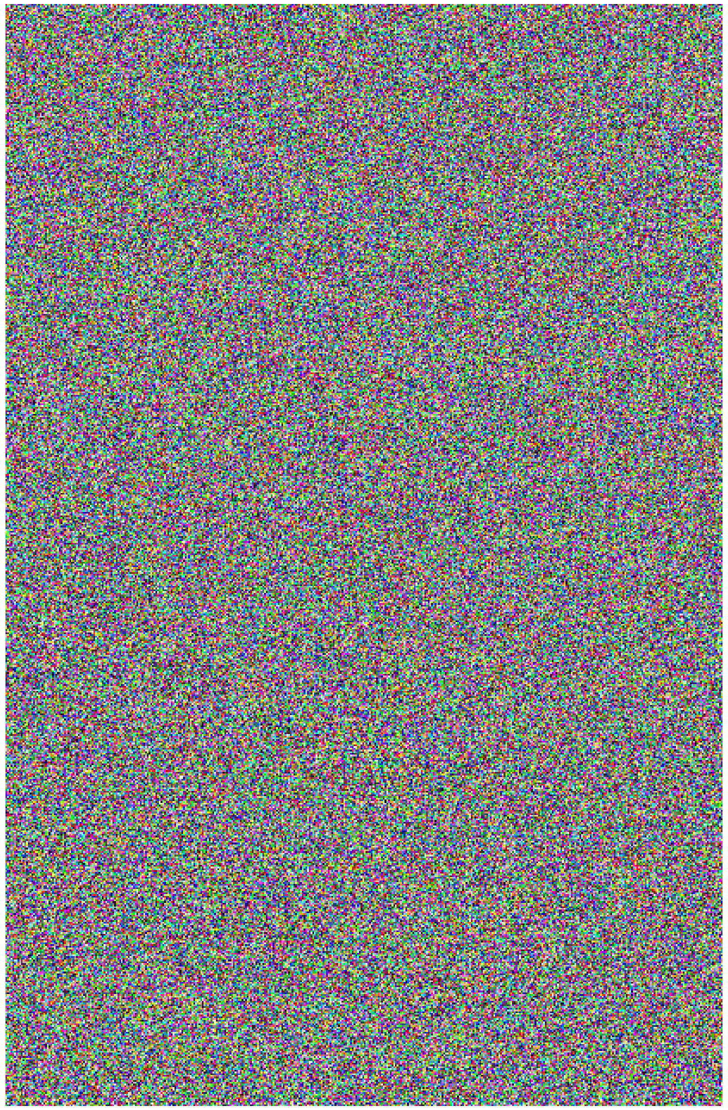
"

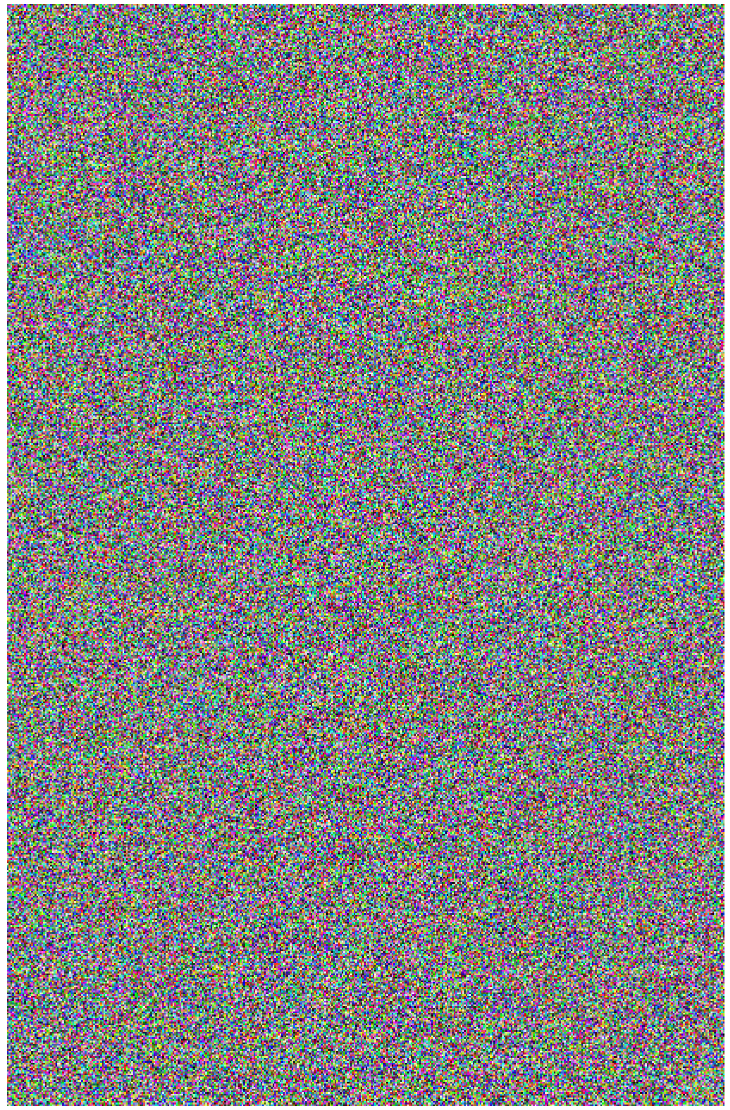
```
struct FluidCube {
        int size;
        float dt;
        float diff;
        float visc;

        float *s;
        float *density;

        float *Vx;
        float *Vy;
        float *Vz;

        float *Vx0;
        float *Vy0;
        float *Vz0;
} ;
typedef struct FluidCube FluidCube;
```

"

Mike Ash, Fluid Simulation for Dummies







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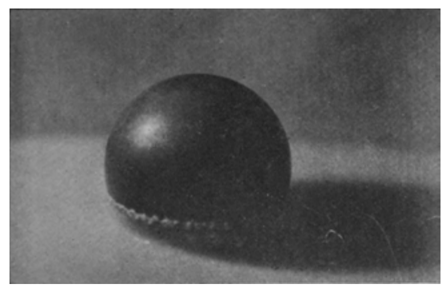
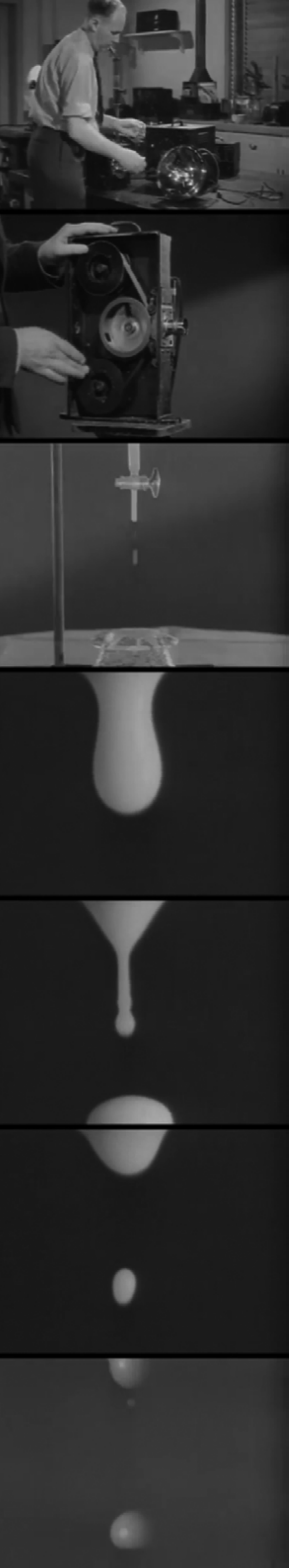
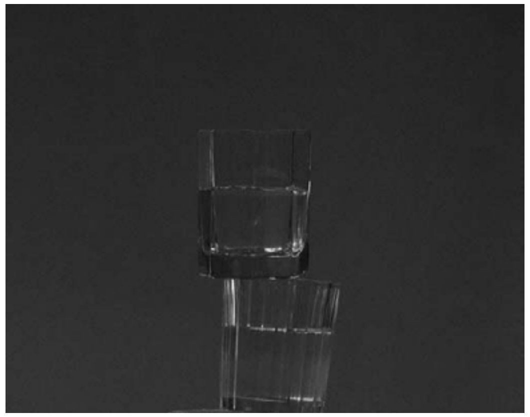
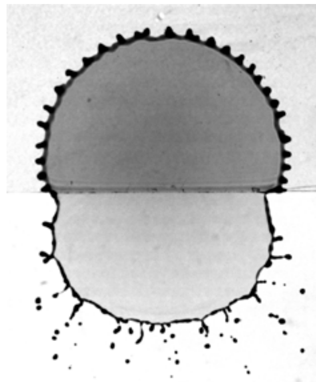
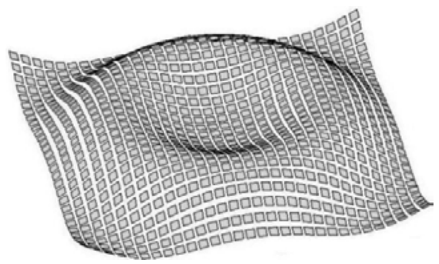
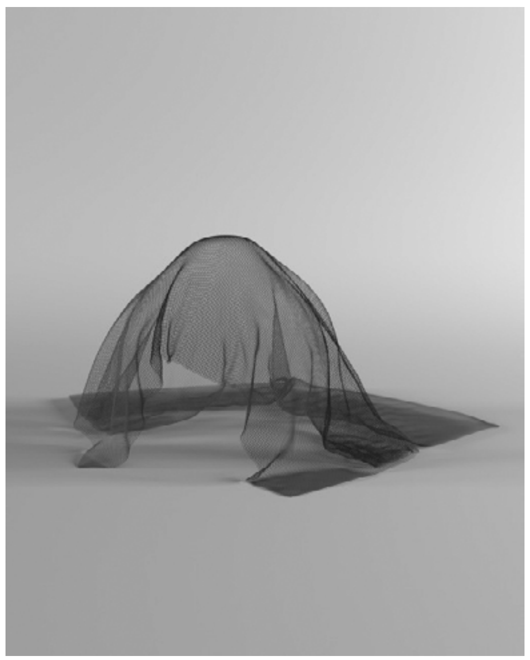


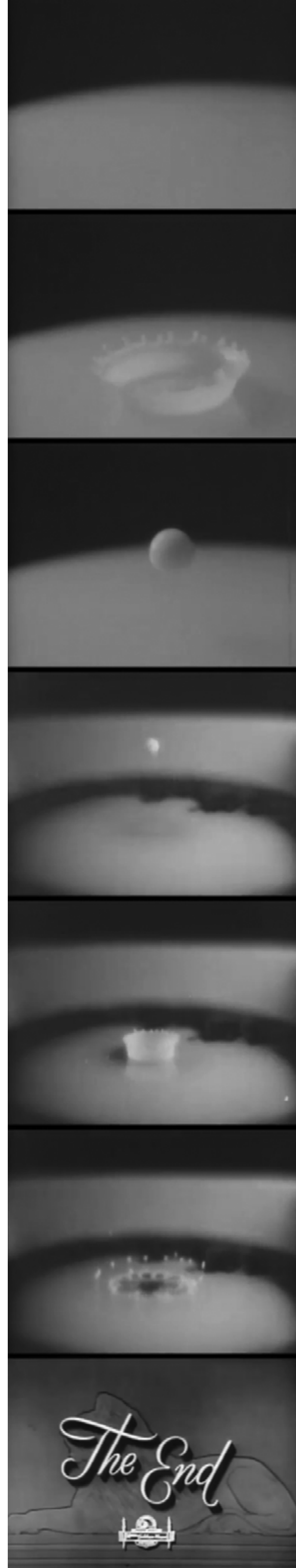






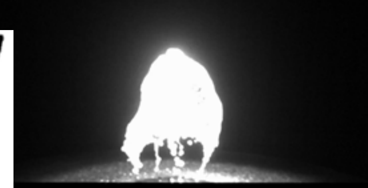


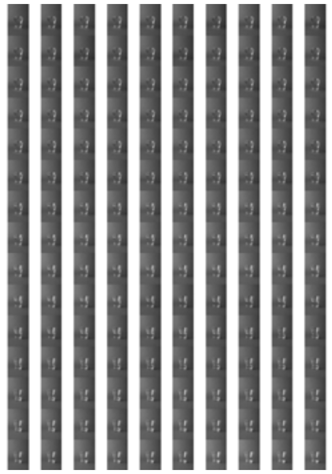


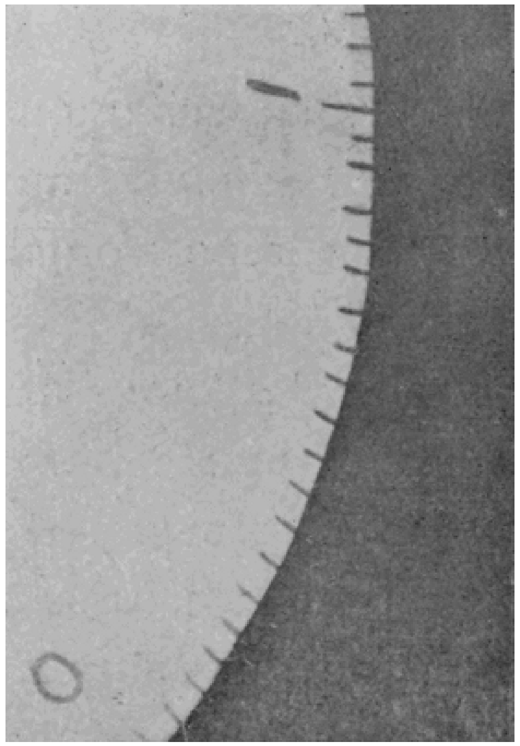

The End

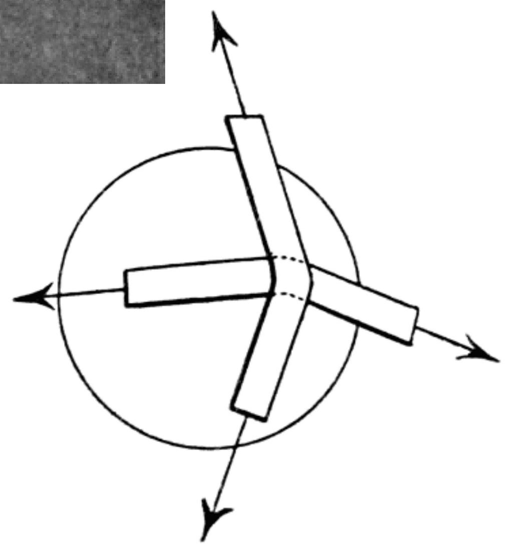

Bluestone

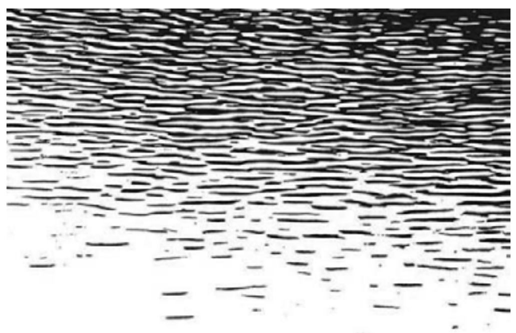

A
A

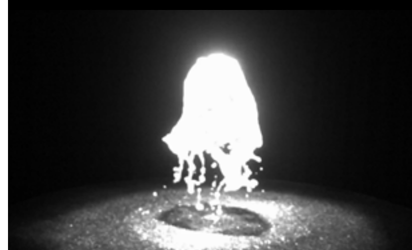




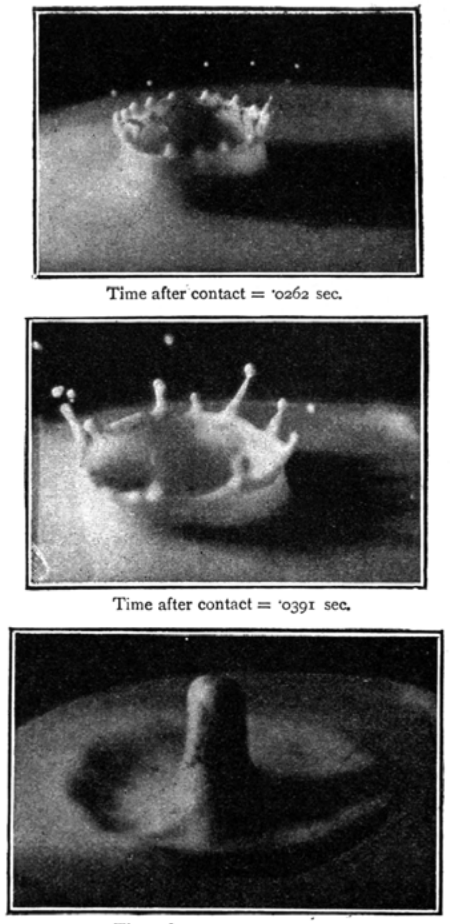


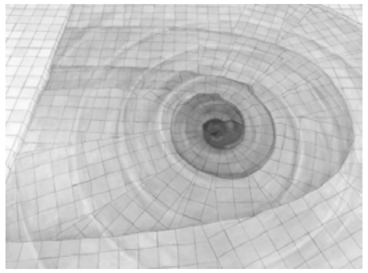


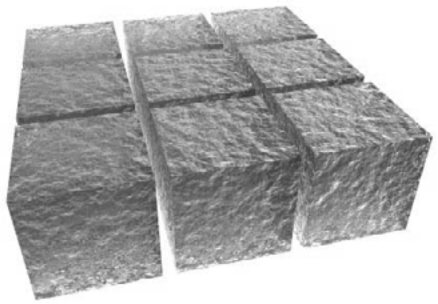




INSTANTANEOUS PHOTOGRAPHS OF THE SPLASH OF A WATER-DROP FALLING ABOUT 16 INCHES INTO MILK.







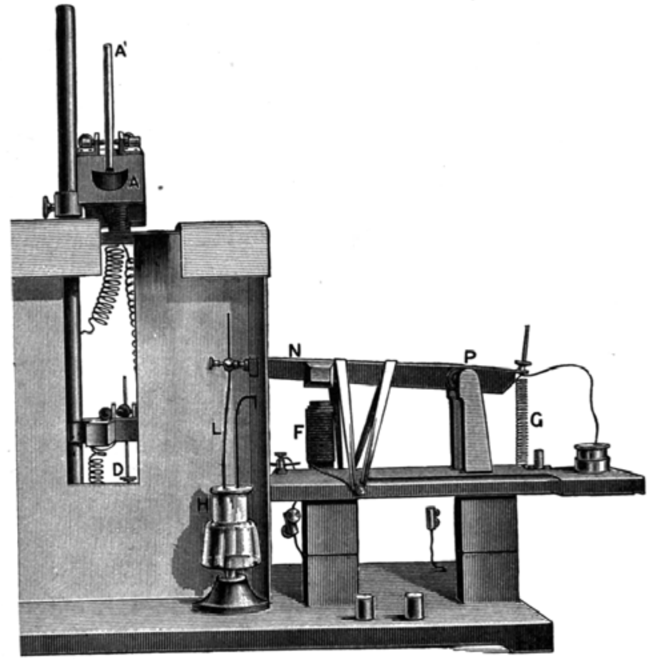
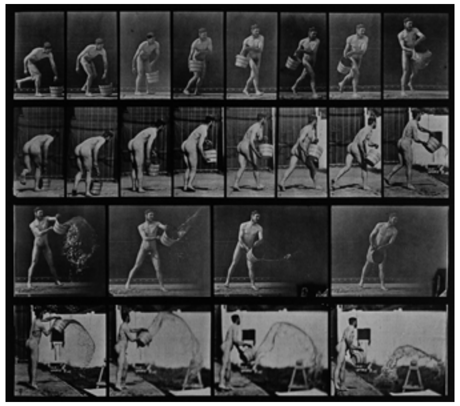


Fig. 2.



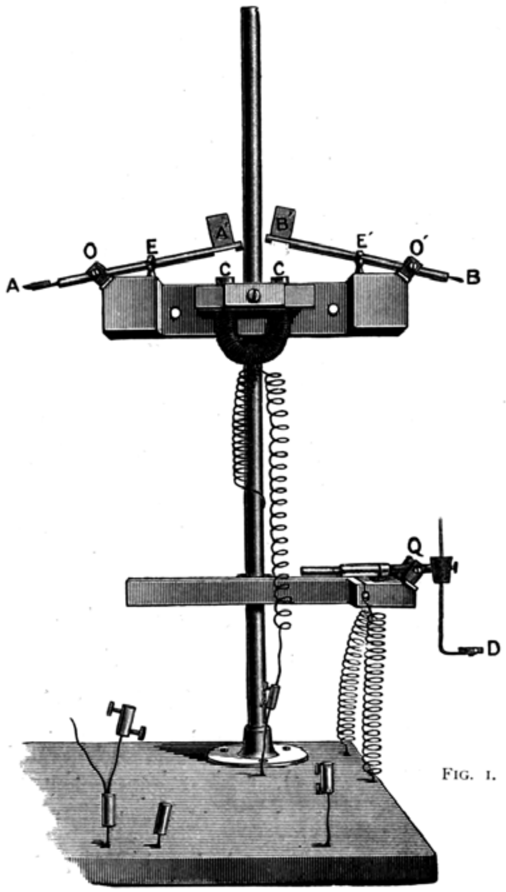
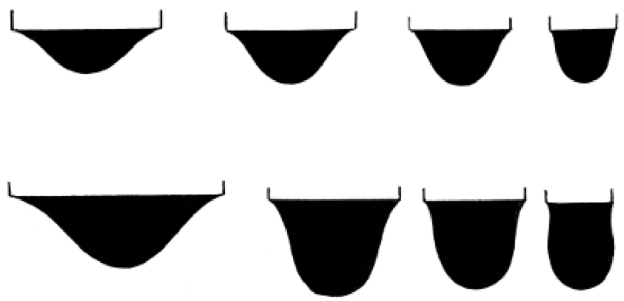
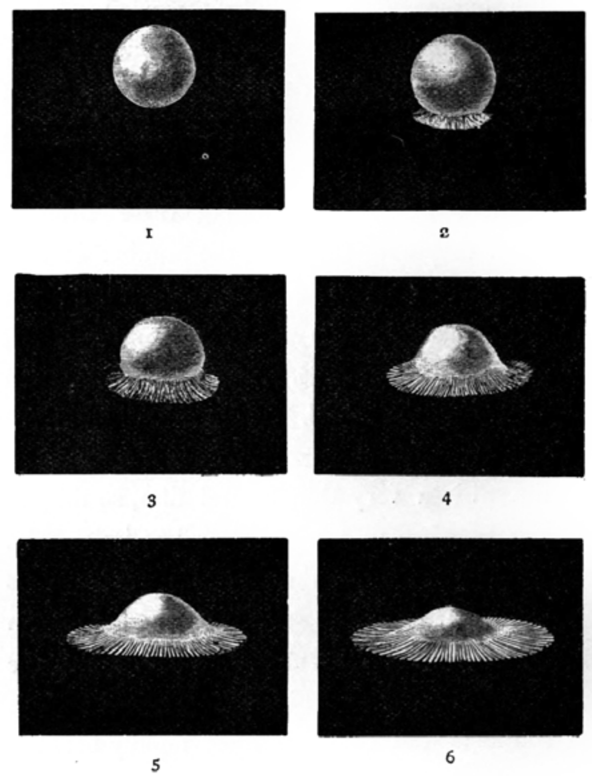


Fig. 1.



FIRST SERIES.



FIRST SERIES—(*continued.*)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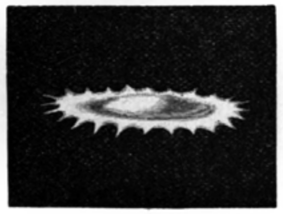
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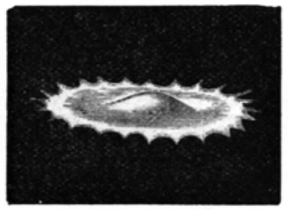
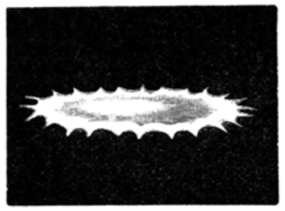

12

FIRST SERIES—(*continued.*)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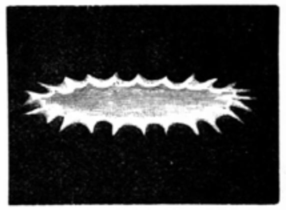
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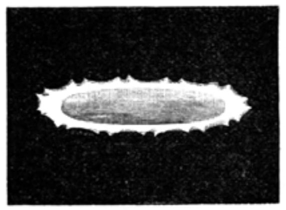
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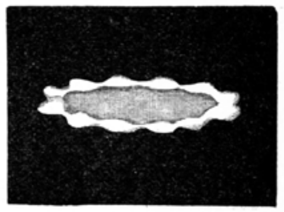
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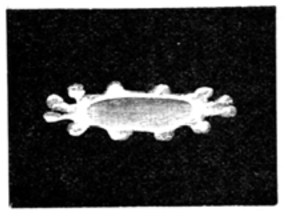
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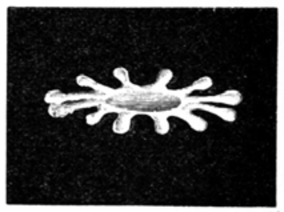
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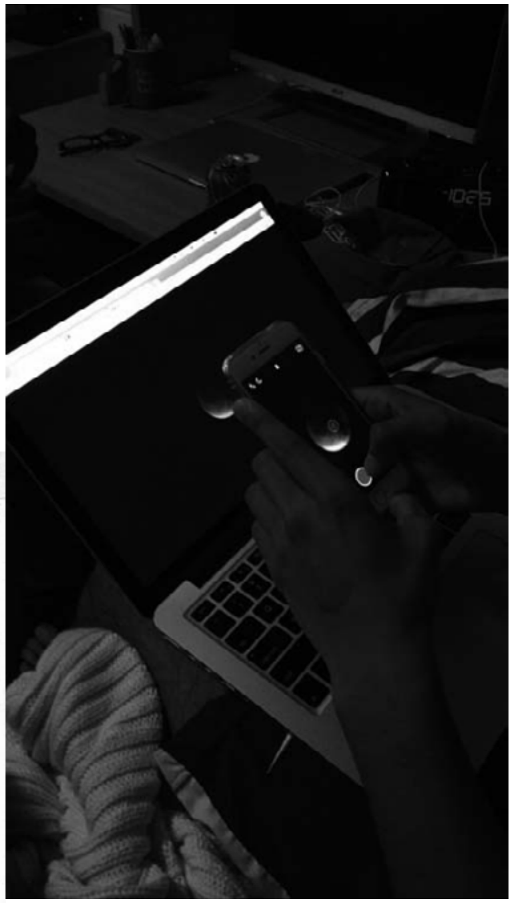
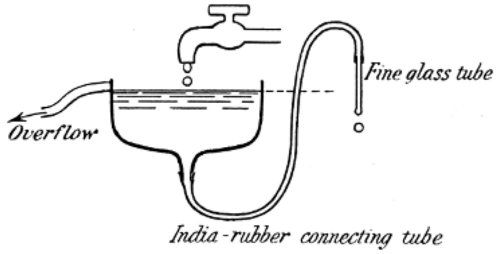
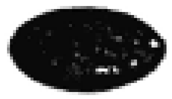
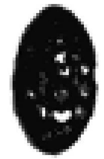
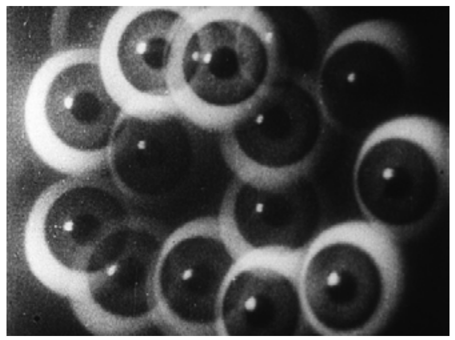


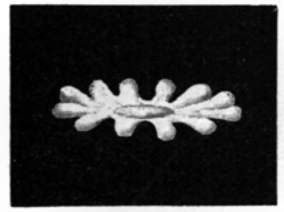








FIRST SERIES—(*continued.*)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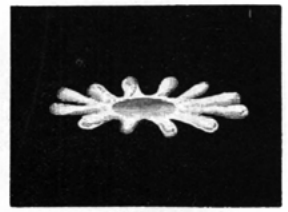
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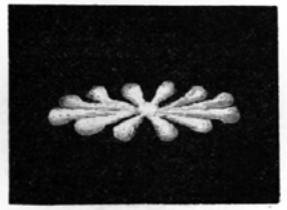
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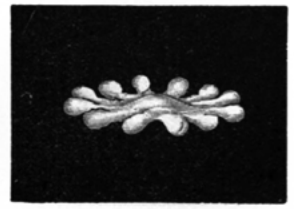
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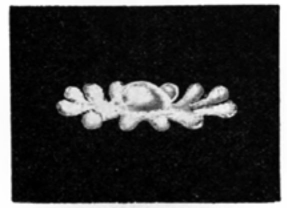
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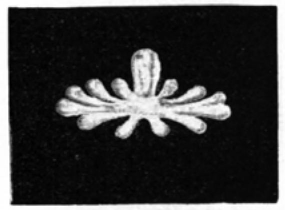
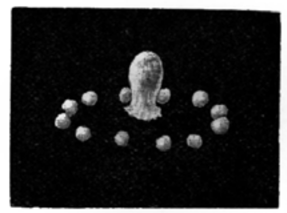

24

FIRST SERIES—(*continued.*)


25


26


27


28


29


30

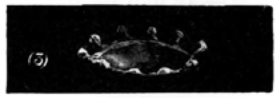
SERIES III.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

Diameter of Drop, $\frac{1}{5}$ inch. Height of Fall, 1 ft. 5 in.

τ = 0 sec.

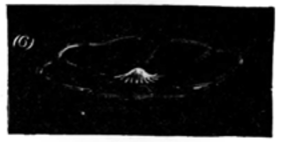
τ = ·0314 sec.



τ = ·0317 sec.

τ = ·0389 sec.

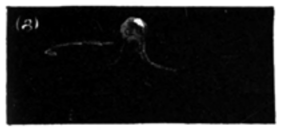
τ = ·0498 sec.



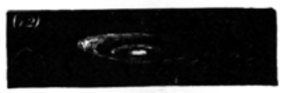
τ = ·0551 sec.

τ = ·0759 sec.

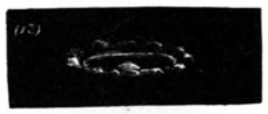
SERIES III.—(*continued.*)

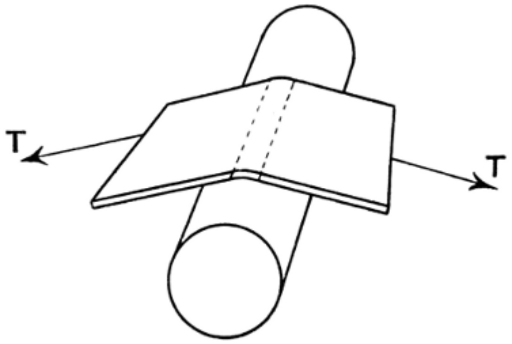


τ = ·0301 sec.



τ = ·295 sec.



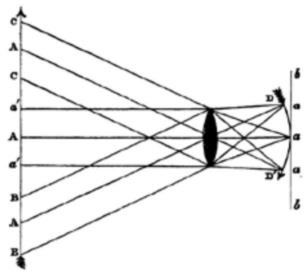


tory power of the surfaces so produced that their peculiarities belong. The adjoining figures represent the varieties.

30.

1 is termed a plano-convex lens.
2 is a double convex lens.
3 is formed of parts of two circles of different diameters, and is called a meniscus lens, or concavo-convex.
4 is a plano-concave lens.
5 is a double concave lens. And
6 is a concavo-convex lens, formed of parts of the inner surfaces of two dissimilar circles.

It is not necessary to examine the laws of refraction for all these forms; the phenomena will be fully understood by an examination of a few leading points. Whatever may be the form of a lens, the incident rays parallel to its axis pass through without suffering refraction, as A A A, *a a a*, Fig. 31.



31.

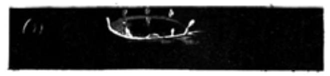
All other rays must have a certain amount of obliquity, and these all consequently suffer refraction, as the rays *d d*. Now

83.

SERIES IV.

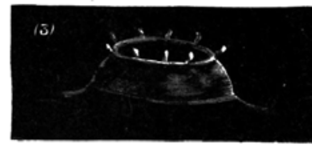
The Splash of a Drop, followed in detail by Instantaneous Illumination.

Diameter of Drop, $\frac{1}{4}$ inch. Height of Fall, 4 ft. 4 in.

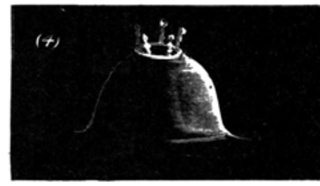


τ = 0 sec.

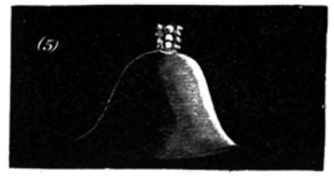
τ = ·0021 sec.



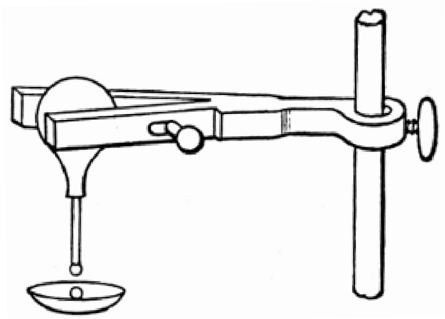
τ = ·0042 sec.



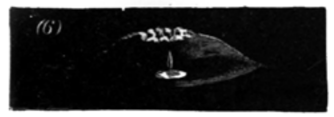
τ = ·0165 sec.



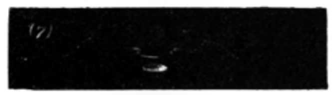
τ = ·0206 sec.



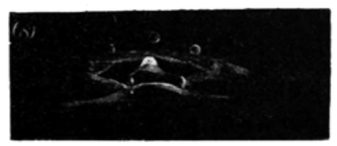
SERIES IV.—(*continued.*)



τ = ·0443 sec.

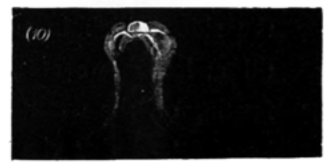


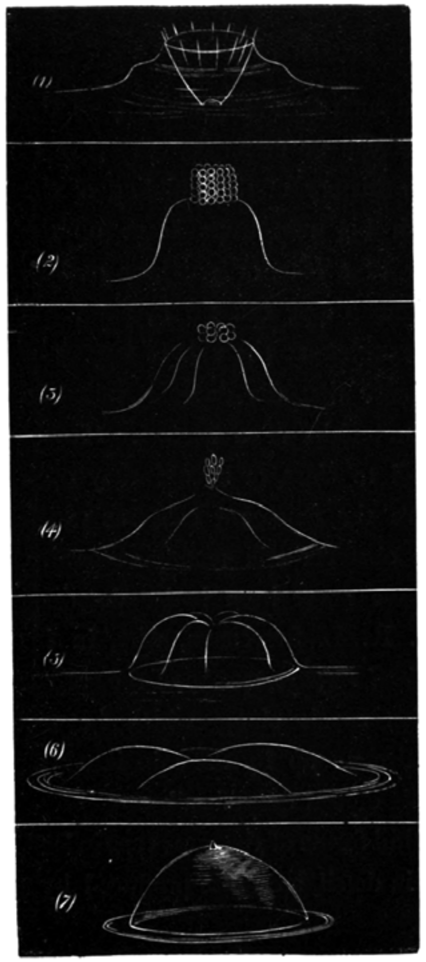
τ = ·0482 sec.



τ = ·0595 sec.

τ = ·0707 sec.

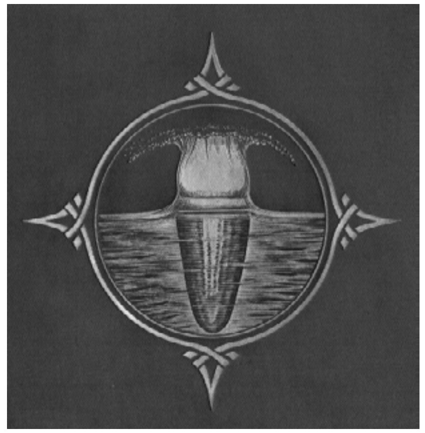




SERIES V.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

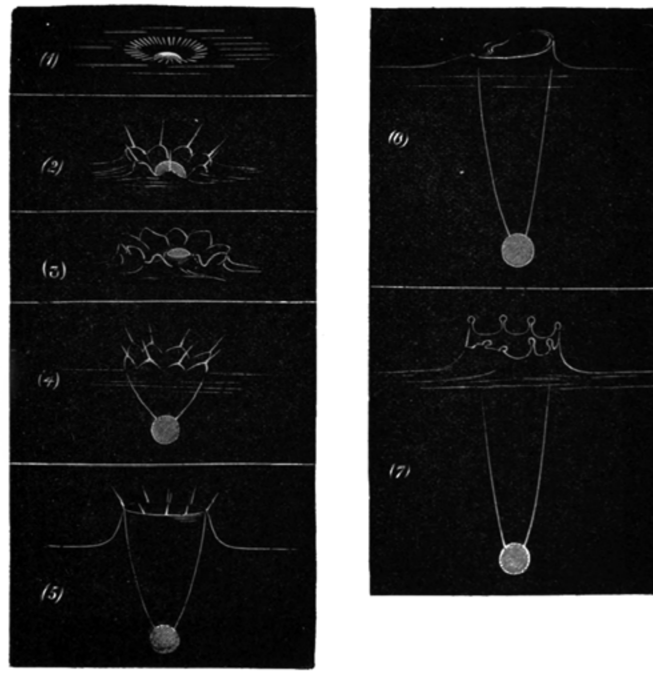
The Size of Drop and Height of Fall are the same as before, but the hollow shell (see figs. 4 and 5 of the previous Series) does not succeed in opening, but is left as a bubble on the surface. This explains the formation of bubbles when *big* raindrops fall into a pool of water.



SERIES VIII.

The Splash of a Solid Sphere—(continued.)

When the sphere is *rough* or *wet*.



The psychic activities that lead us to infer that there in front of us at a certain place there is a certain object of a certain character, are generally not conscious activities, but unconscious ones. In their result they are equivalent to a *conclusion*, to the extent that the observed action on our senses enables us to form an idea as to the possible cause of this action; although, as a matter of fact, it is invariably simply the nervous stimulations that are perceived directly, that is, the actions, but never the external objects themselves. But what

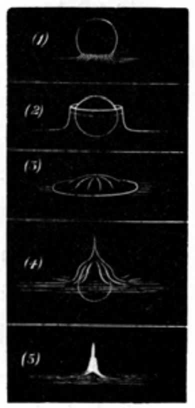
the patient has been paying more attention to visual phenomena. No doubt, also, there are cases where one eye has gradually become blind, and yet the patient has continued to go about for an indefinite time without noticing it, until he happened one day to close the good eye without closing the other, and so noticed the blindness of that eye.[1]

SERIES VI., VII.

Splash of a Solid Sphere (*a marble ½ inch in diameter falling 2 feet into water*).

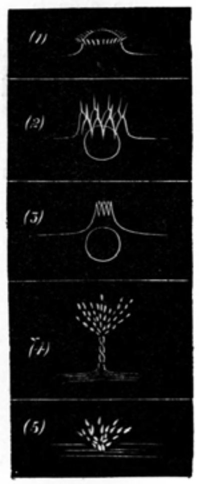
SERIES VI.

When the sphere is *dry* and *polished*.



SERIES VII.

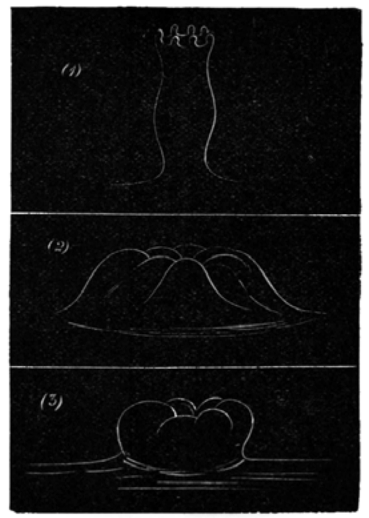
When the sphere is *not* well *dried* and *polished*.



SERIES IX.

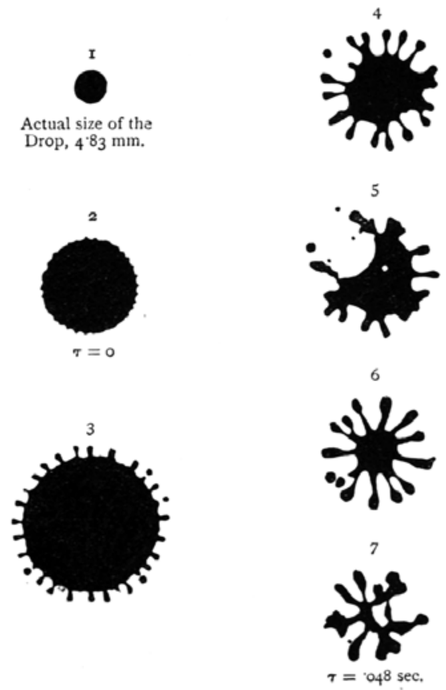
The Splash of a Solid Sphere—(continued.)

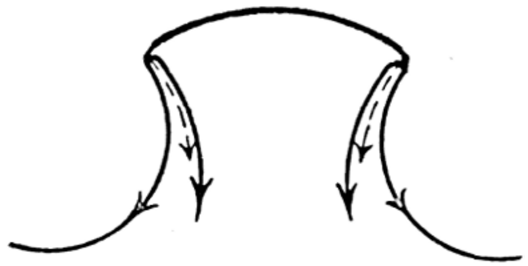
When the sphere is rough or wet, and falls above 5 feet.

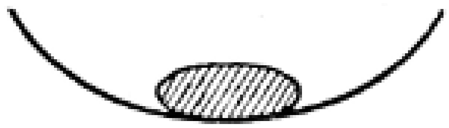


SERIES X.

(1) *Instantaneous Shadow Photographs* (*life size*) *of the Splash of a Drop of Mercury falling* 8 *cm. on to the Photographic Plate.*

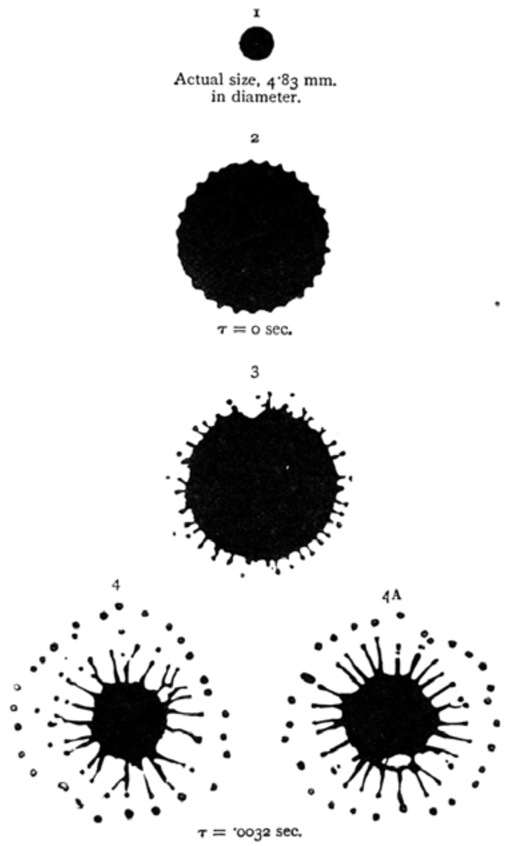






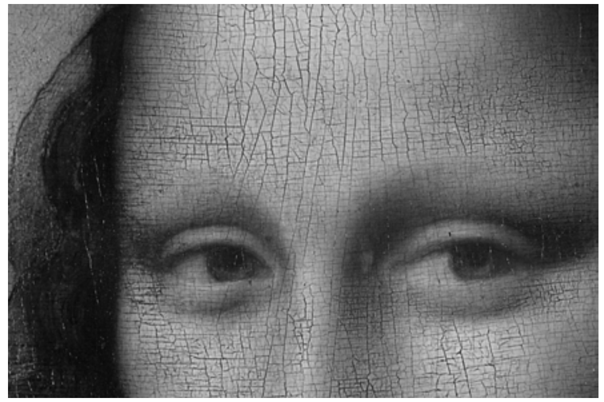
SERIES XI.

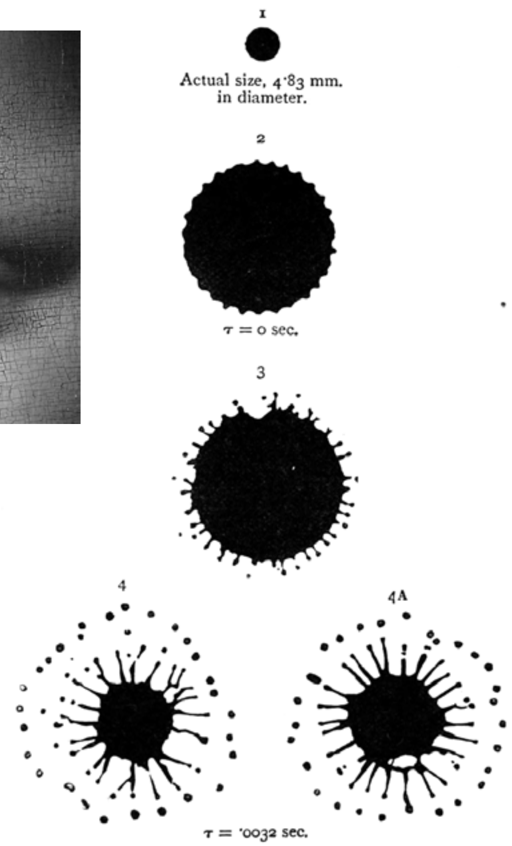
(2) *Instantaneous Shadow Photographs* (*life size*) *of the Splash of a Drop of Mercury falling* 15 *cm. on to Glass.*



SERIES XI.

(2) *Instantaneous Shadow Photographs* (*life size*) *of the Splash of a Drop of Mercury falling* 15 *cm. on to Glass.*



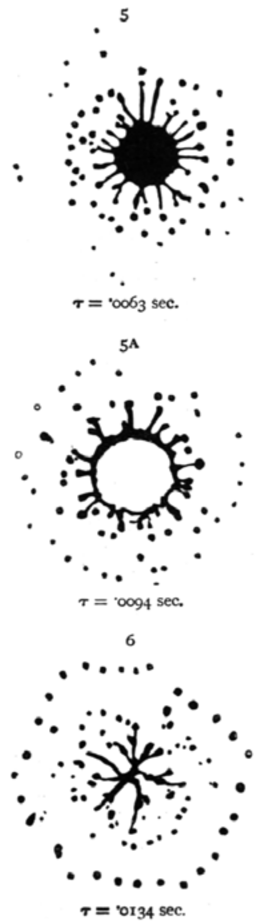



```
class FluidSimulationMeshStats_t(ctypes.Structure):
    _fields_ = [("enabled", c_int),
                ("vertices", c_int),
                ("triangles", c_int),
                ("bytes", c_uint)]
```

```
class FluidSimulationTimingStats_t(ctypes.Structure):
    _fields_ = [("total", c_double),
                ("mesh", c_double),
                ("advection", c_double),
                ("particles", c_double),
                ("pressure", c_double),
                ("diffuse", c_double),
                ("viscosity", c_double),
                ("objects", c_double)]
```

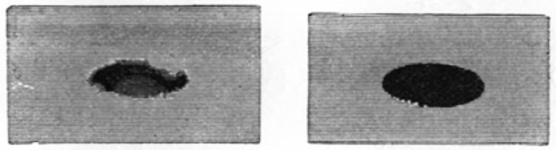
```
class FluidSimulationFrameStats_t(ctypes.Structure):
    _fields_ = [("frame", c_int),
                ("substeps", c_int),
                ("delta_time", c_double),
                ("fluid_particles", c_int),
                ("diffuse_particles", c_int),
                ("surface", FluidSimulationMeshStats_t),
                ("preview", FluidSimulationMeshStats_t),
                ("surfaceblur", FluidSimulationMeshStats_t),
                ("foam", FluidSimulationMeshStats_t),
                ("bubble", FluidSimulationMeshStats_t),
                ("spray", FluidSimulationMeshStats_t),
                ("foamblur", FluidSimulationMeshStats_t),
                ("bubbleblur", FluidSimulationMeshStats_t),
                ("sprayblur", FluidSimulationMeshStats_t),
                ("particles", FluidSimulationMeshStats_t),
                ("obstacle", FluidSimulationMeshStats_t),
                ("timing", FluidSimulationTimingStats_t)]
```

SERIES XI—(*continued.*)

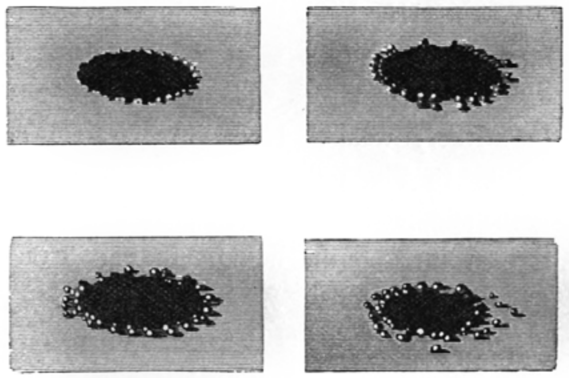


SERIES XII.

Engravings from Instantaneous Photographs ($\frac{15}{17}$ of the real size) of the Splash of a Drop of Mercury, 4·83 mm. in diameter, falling 8·9 cm. on to a hard polished surface.

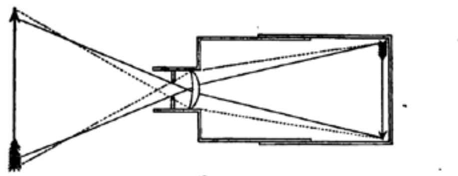


τ = 0 sec.



τ = ·0195 sec.

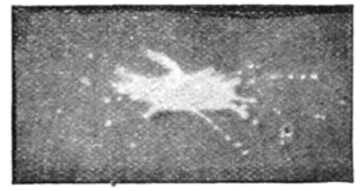
If, instead of a darkened room, we substitute a darkened box (Fig. 43), the same effect will be seen. Suppose, in the first place, the box to be without the lens, the rays would pass from the external arrow in nearly right lines through the opening, refracted only in passing the solid edges of the hole, and form an image on the back of the dark box. The lens refracts the rays still more, and a smaller, but a more perfectly defined picture, is the result.



43.

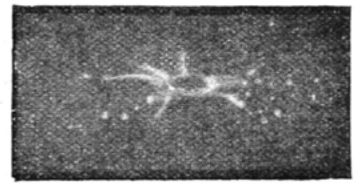
SERIES XIII.—(*continued.*)

7



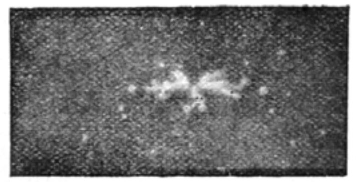
τ = ·0128 sec.

8



τ = ·0149 sec.

9

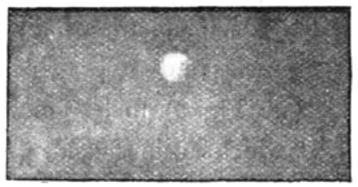


τ = ·0149 sec.

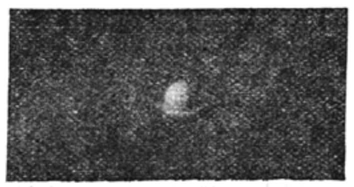
SERIES XIII.

Engravings of Instantaneous Photographs ($\frac{14}{15}$ of the real size) of the Splash of a Drop of Milk falling 20 cm. on to smoked glass.

1



2

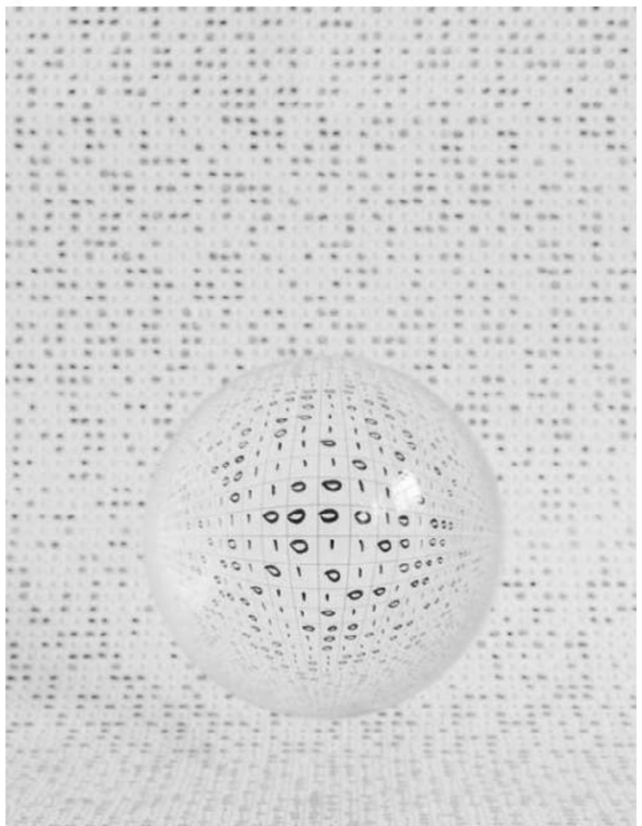


τ = 0 sec.

3

τ = ·0025 sec.

(It was not found possible to reproduce satisfactorily the missing figures of this series.)

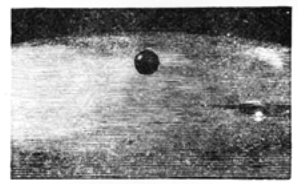


SERIES XIV.

Engravings of Instantaneous Photographs of the Splash of a Drop of Water falling 40 cm. into Milk.

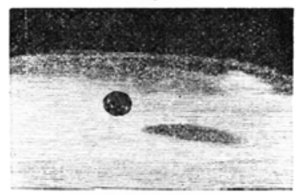
Scale about $\frac{8}{10}$ of actual size.

1

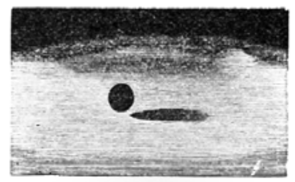


2

3

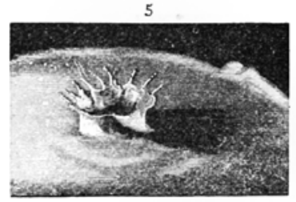


4

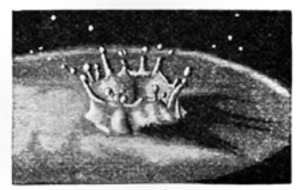


τ = 0 sec.

5



6



τ = ·0036 sec.

SERIES XIV.—(*continued.*)

7

8

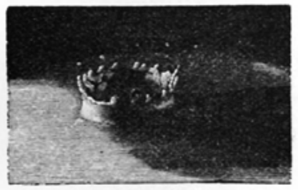
τ = ·0163 sec.

9

10

τ = ·0182 sec. τ = ·0197 sec.

11

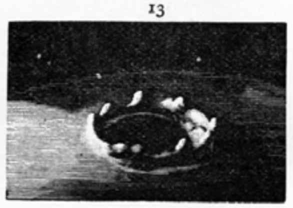


12

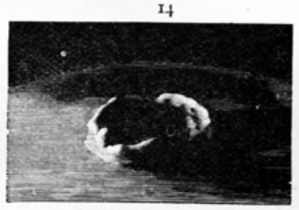
τ = ·0262 sec. τ = ·0391 sec.

SERIES XIV.—(*continued.*)

13



14



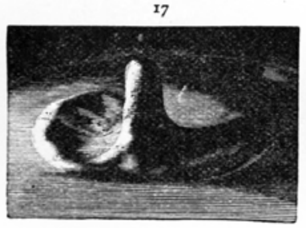
τ = ·0514 sec. τ = ·0601 sec.

15

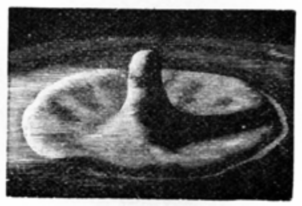
16

τ = ·080 sec.

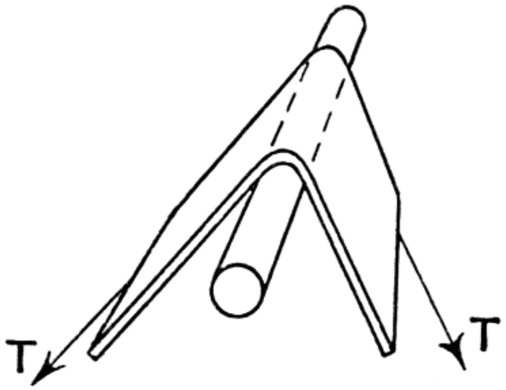
17



18



τ = ·101 sec.



THE ROMANCE OF SCIENCE

THE SPLASH OF A DROP

BY

PROF. A. M. WORTHINGTON, M.A., F.R.S.

Being the reprint of a Discourse delivered at the Royal Institution of Great Britain, May 18, 1894.

PUBLISHED UNDER THE DIRECTION OF THE GENERAL LITERATURE COMMITTEE.

LONDON:
SOCIETY FOR PROMOTING CHRISTIAN KNOWLEDGE,
NORTHUMBERLAND AVENUE, CHARING CROSS, W.C.;
43, QUEEN VICTORIA STREET, E.C.
BRIGHTON: 129, NORTH STREET.
NEW YORK: E. & J. B. YOUNG & CO.
1895.

THE SPLASH OF A DROP

THE splash of a drop is a transaction which is accomplished in the twinkling of an eye, and it may seem to some that a man who proposes to discourse on the matter for an hour must have lost all sense of proportion. If that opinion exists, I hope this evening to be able to remove it, and to convince you that we have to deal with an exquisitely regulated phenomenon, and one which very happily illustrates some of the fundamental properties of fluids. It may be mentioned also that the

recent researches of Lenard in Germany and J. J. Thomson at Cambridge, on the curious development of electrical charges that accompanies certain kinds of splashes, have invested with a new interest any examination of the mechanics of the phenomenon. It is to the mechanical and not to the electrical side of the question that I shall call your attention this evening.

The first well-directed and deliberate observations on the subject that I am acquainted with were made by a school-boy at Rugby some twenty years ago, and were reported by him to the Rugby Natural History Society. He had observed that the marks of accidental splashes of ink-drops that had fallen on some smoked glasses with which he was experimenting, presented an appearance not easy to account for. Drops of the same size falling from the same height had made always the

same kind of mark, which, when carefully examined with a lens, showed that the smoke had been swept away in a system of minute concentric rings and fine striæ. Specimens of such patterns, obtained by letting drops of mercury, alcohol, and water fall on to smoked glass, are thrown on the screen, and the main characteristics are easily recognized. Such a pattern corresponds to the footprints of the dance that has been performed on the surface, and though the drop may be lying unbroken on the plate, it has evidently been taking violent exercise, and were our vision acute enough we might observe that it was still palpitating after its exertions.

A careful examination of a large number of such footprints showed that any opinion that could be formed therefrom of the nature of the motion of the drop must be largely conjectural, and it occurred to me about eighteen

years ago to endeavour by means of the illumination of a suitably-timed electric spark to watch a drop through its various changes on impact.

The reason that with ordinary continuous light nothing can be satisfactorily seen of the splash, is not that the phenomenon is of such short duration, but because the changes are so rapid that before the image of one stage has faded from the eye the image of a later and quite different stage is superposed upon it. Thus the resulting impression is a confused assemblage of all the stages, as in the photograph of a person who has not sat still while the camera was looking at him. The problem to be solved experimentally was therefore this: to let a drop of definite size fall from a definite height in comparative darkness on to a surface, and to illuminate it by a flash of exceedingly short duration at any desired stage, so as to

exclude all the stages previous and subsequent to the one thus picked out. The flash must be bright enough for the image of what is seen to remain long enough on the eye for the observer to be able to attend to it, and even to shift his attention from one part to another, and thus to make a drawing of what is seen. If necessary the experiment must be capable of repetition, with an exactly similar drop falling from exactly the same height, and illuminated at exactly the same stage. Then, when this stage has been sufficiently studied, we must be able to arrange with another similar drop to illuminate it at a rather later stage, say $\frac{1}{1000}$ second later, and in this way to follow step by step the whole course of the phenomenon.

The apparatus by which this has been accomplished is on the table before you. Time will not suffice to explain how it grew

out of earlier arrangements very different in appearance, but its action is very simple and easy to follow by reference to the diagram (Fig. 1).

A A′ is a light wooden rod rather longer and thicker than an ordinary lead pencil, and pivoted on a horizontal axle O. The rod bears at the end A a small deep watch-glass, or segment of a watch-glass, whose surface has been smoked, so that a drop even of water will lie on it without adhesion. The end A′ carries a small strip of tinned iron, which can be pressed against and held down by an electro-magnet C C′. When the current of the electro-magnet is cut off the iron is released, and the end A′ of the rod is tossed up by the action of a piece of india-rubber stretched catapult-wise across two pegs at E, and by this means the drop resting on the watch-glass is left in mid-air free to fall from rest.

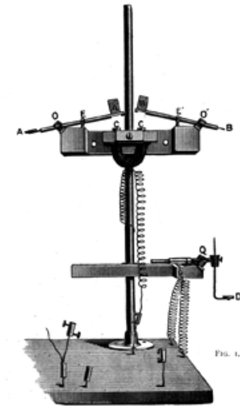


FIG. 1.

B B′ is a precisely similar rod worked in just the same way, but carrying at B a small horizontal metal ring, on which an ivory timing sphere of the size of a child's marble can be supported. On cutting off the current of the electro-magnet the ends A′ and B′ of the two levers are simultaneously tossed up by the catapults, and thus drop and sphere begin to fall at the same moment. Before, however, the drop reaches the surface on which it is to impinge, the timing sphere strikes a plate D attached to one end of a third lever pivoted at Q, and thus breaks the contact between a platinum wire bound to the underside of this lever and another wire crossing the first at right angles. This action breaks an electric current which has traversed a second electro-magnet F (Fig. 2), and releases the iron armature N of the lever N P, pivoted at P, thus enabling a strong spiral spring G to lift a

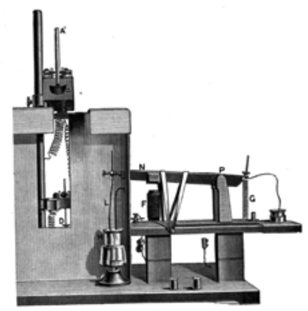


FIG. 2.

stout brass wire L out of mercury, and to break at the surface of the mercury a strong current that has circulated round the primary circuit of a Ruhmkorff's induction coil; this produces at the surface of the mercury a bright self-induction spark in the neighbourhood of the splash, and it is by this flash that the splash is viewed. The illumination is greatly helped by surrounding the place where the splash and flash are produced by a white cardboard enclosure, seen in Fig. 2, from whose walls the light is diffused.

It will be observed that the time at which the spark is made will depend upon the distance that the sphere has to fall before striking the plate D, for the subsequent action of demagnetizing F and pulling the wire L out of the mercury in the cup H is the same on each occasion. The modus operandi is consequently as follows:—The observer, sitting

in comparative but by no means complete darkness, faces the apparatus as it appears in Fig. 2, presses down the ends A′ B′ of the levers first described, so that they are held by the electro-magnet C (Fig. 1); then he presses the lever N P down on the electro-magnet F, sets the timing sphere and drop in place, and then by means of a bridge between two mercury cups, short-circuits and thus cuts off the current of the electro-magnet C. This lets off drop and sphere, and produces the flash. The stage of the phenomenon that is thus revealed having been sufficiently studied by repetition of the experiment as often as may be necessary, he lowers the plate D a fraction of an inch and thus obtains a later stage. Not only is any desired stage of the phenomenon thus easily brought under examination, but the apparatus also affords the means of measuring the time interval between

B

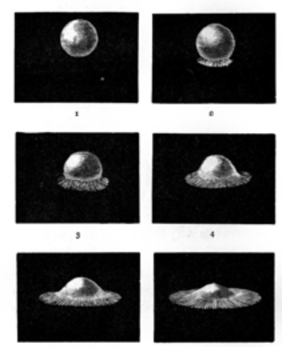
any two stages. All that is necessary is to know the distance that the timing sphere falls in the two cases. Elementary dynamics then give us the interval required. Thus, if the sphere falls one foot and we then lower D $\frac{1}{4}$ inch, the interval between the corresponding stages will be about ·0026 second.

Having thus described the apparatus, which I hope shortly to show you in action, I pass to the information that has been obtained by it.

This is contained in a long series of drawings, of which a selection will be presented on the screen. The First Series that I have to show represents the splash of a drop of mercury 0·15 inch in diameter that has fallen 3 inches on to a smooth glass plate. It will be noticed that very soon after the first moment of impact, minute rays are shot out in all directions on the surface. These are after-

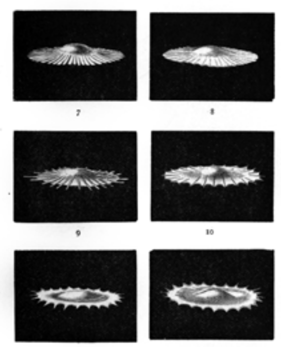
wards overflowed or united, until, as in Fig. 8, the outline is only slightly rippled. Then (Fig. 9) main rays shoot out, from the ends of which in some cases minute droplets of liquid would split off, to be left lying in a circle on the plate, and visible in all subsequent stages. By counting these droplets when they were thus left, the number of rays was ascertained to have been generally about 24. This exquisite shell-like configuration, shown in Fig. 9, marks about the maximum spread of the liquid, which, subsiding in the middle, afterwards flows into an annulus or rim with a very thin central film, so thin, in fact, as often to tear more or less irregularly. This annular rim then divides or segments (Figs. 14, 15, 16) in such a manner as to join up the rays in pairs, and thus passes into the 12-lobed annulus of Fig. 16. Then the whole contracts, but contracts most rapidly between

FIRST SERIES.



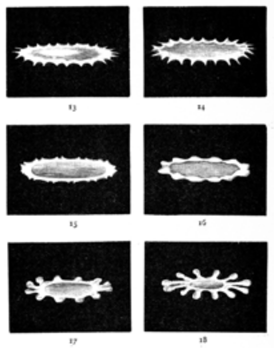
1 2 3 4 5 6

FIRST SERIES—(*continued.*)

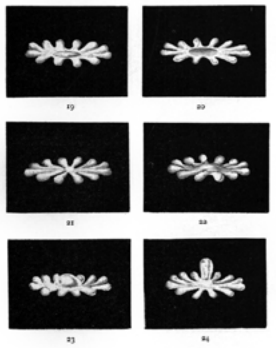


7 8 9 10 11 12

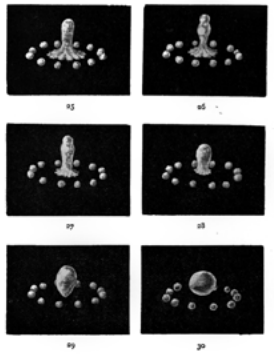
FIRST SERIES—(continued.)



FIRST SERIES—(continued.)



FIRST SERIES—(continued.)



the lobes, the liquid then being driven into and feeding the arms, which follow more slowly. In Fig. 21 the end of this stage is reached, and now the arms continuing to come in, the liquid rises in the centre; this is, in fact, the beginning of the rebound of the drop from the plate. In the case before us the drops at the ends of the arms now break off (Fig. 25), while the central mass rises in a column which just fails itself to break up into drops, and falls back into the middle of the circle of satellites which, it will be understood, may in some cases again be surrounded by a second circle of the still smaller and more numerous droplets that split off the ends of the rays in Fig. 9. The whole of the 30 stages described are accomplished in about $\frac{1}{10}$ second, so that the average interval between them is about $\frac{1}{300}$ second.

It should be mentioned that it is only in

rare cases that the subordinate drops seen in the last six figures, are found lying in a very complete circle after all is over, for there is generally some slight disturbing lateral velocity which causes many to mingle again with the central drop, or with each other. But even if only half or a quarter of the circle is left, it is easy to estimate how many drops, and therefore how many arms there have been. It may be mentioned that sometimes the surface of the central lake of liquid (Figs. 14, 15, 16, 17) was seen to be covered with beautiful concentric ripples, not shown in the figures.

The question now naturally presents itself, Why should the drop behave in this manner? In seeking the answer it will be useful to ask ourselves another question. What should we have expected the drop to do? Well, to this I suppose most people would be inclined, arguing from analogy with a solid, to reply

that it would be reasonable to expect the drop to flatten itself, and even very considerably flatten itself, and then, collecting itself together again, to rebound, perhaps as a column such as we have seen, but not to form this regular system of rays and arms and subordinate drops.

Now this argument from analogy with a solid is rather misleading, for the forces that operate in the case of a solid sphere that flattens itself and rebounds, are due to the bodily elasticity which enables it not only to resist, but also to recover from any distortion of shape or shearing of its internal parts past each other. But a liquid has no power of recovering from such internal shear, and the only force that checks the spread, and ultimately causes the recovery of shape, is the *surface tension*, which arises from the fact that the surface layers are always in a state of extension and always endeavouring to contract.

Thus we are at liberty when dealing with the motions of the drop to think of the interior liquid as not coherent, provided we furnish it with a suitable elastic skin. Where the surface skin is sharply curved outwards, as it is at the sharp edge of the flattened disc, there the interior liquid will be strongly pressed back. In fact the process of flattening and recoil is one in which energy of motion is first expended in creating fresh liquid surface, and subsequently recovered as the surface contracts. The transformation is, however, at all moments accompanied by a great loss of energy as heat. Moreover, it must be remembered that the energy expended in creating the surface of the satellite drops is not restored if these remain permanently separate. Thus the surface tension explains the recoil, and it is also closely connected with the formation of the subordinate rays and arms. To explain this it

is only necessary to remind you that a liquid cylinder is an unstable configuration. As you know, any fine jet becomes beaded and breaks into drops, but it is not necessary that there should be any flow of liquid along the jet; if, for example, we could realize a rod of liquid of the shape and size of this cylindrical ruler that I hold in my hand, and liberate it in the air, it would not retain its cylindrical shape, but would segment or divide itself up into a row of drops regularly disposed according to a definite and very simple numerical law, viz. that the distances between the centres of contiguous drops would be equal to the circumference of the cylinder. This can be shown by calculation to be a consequence of the surface tension, and the calculation has been closely verified by experiment. If the liquid cylinder were liberated on a plate, it would still topple into a regular row of drops,

but they would be further apart; this was shown by Plateau. Now imagine the cylinder bent into an annulus. It will still follow the same law,[1] *i. e.* it will topple into drops just as if it were straight. This I can show you by a direct experiment. I have here a small thick disc of iron, with an accurately planed face and a handle at the back. In the face is cut a circular groove, whose cross section is a semicircle. I now lay this disc face downwards on the horizontal face of the lantern condenser, and through one of two small holes bored through to the back of the disc I fill the groove with quicksilver. Now, suddenly lifting the disc from the plate, I release an annulus of liquid, which splits into the circle of very equal drops which you see projected on the

[1] See Worthington on the "Spontaneous Segmentation of a Liquid Annulus," *Proceedings Royal Society*, No. 200, p. 49 (1879).

screen. You will notice that the main drops have between them still smaller ones, which have come from the splitting up of the thin cylindrical necks of liquid which connected the larger drops at the last moment.

Now this tendency to segment or topple into drops, whether of a straight cylinder or of an annulus, is the key to the formation of the arms and satellites, and indeed to much that happens in all the splashes that we shall examine. Thus in Fig. 12 we have an annular rim, which in Figs. 13 and 14 is seen to topple into lobes by which the rays are united in pairs, and even the special rays that are seen in Fig. 9 owe their origin to the segmentation of the rim of the thin disc into which the liquid has spread. The proceeding is probably exactly analogous to what takes place in a sea wave that curls over in calm weather on a slightly sloping shore. Any one may notice

how, as it curls over, the wave presents a long smooth edge, from which at a given instant a multitude of jets suddenly shoot out, and at once the back of the wave, hitherto smooth, is seen to be furrowed or "combed." There can be no doubt that the cylindrical edge topples into alternate convexities and concavities; at the former the flow is helped, at the latter hindered, and thus the jets begin, and special lines of flow are determined. In precisely the same way the previously smooth circular edge of Fig. 8 topples, and determines the rays and lines of flow of Fig. 9.

Before going on to other splashes I will now endeavour to reproduce a mercury splash of the kind I have described, in a manner that shall be visible to all. For this purpose I have reduplicated the apparatus which you have seen, and have it here so arranged that I can let the drop fall on to the horizontal condenser

plate of the lantern, through which the light passes upwards, to be afterwards thrown upon this screen. The illuminating flash will be made inside the lantern, where the arc light would ordinarily be placed. I have now set a drop of mercury in readiness and put the timing sphere in place, and now if you will look intently at the middle of the screen I will darken the room and let off the splash. (The experiment was repeated four or five times, and the figures seen were like those of Series X.) Of course all that can be shown in this way is the outline, or rather a horizontal section of the splash; but you are able to recognize some of the configurations already described, and will be the more willing to believe that a momentary view is after all sufficient to give much information if one is on the alert and has acquired skill by practice.

The general features of the splash that we

have examined are not merely characteristic of the liquid mercury, but belong to all splashes of a liquid falling on to a surface which it does not wet, provided the height of fall or size of the drop are not so great as to cause complete disruption,[1] in which case there is no recovery and rebound. Thus a drop of milk falling on to smoked glass will, if the height of fall and size of drop are properly adjusted, give forms very similar to those presented by a drop of mercury. The whole course of the phenomenon depends, in fact, mainly on four quanities only: (1) the size of the drop; (2) the height of fall; (3) the value of the surface tension; (4) the viscosity of the liquid.

The next series of drawings illustrates the splash of a drop of water falling into water.

[1] Readers who wish a more detailed account of a greater variety of splashes are referred to papers by the author. *Proceedings Royal Society*, vol. xxv. pp. 261 and 498 (1877); and vol. xxxiv. p. 217 (1882).

In order the better to distinguish the liquid of the original drop from that into which it falls, the latter was coloured with ink or with an aniline dye, and the drop itself was of water rendered turbid with finely-divided matter in suspension. Finally drops of milk were found to be very suitable for the purpose, the substitution of milk for water not producing any observable change in the phenomenon.

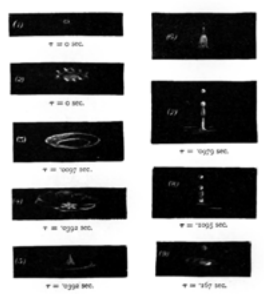
In Series II. the drop fell 3 inches, and was ⅙ inch in diameter.

[In most of the figures of this and of succeeding series the central white patch represents the original drop, and the white parts round it represent those raised portions of the liquid which catch the light. The numbers under each figure give the time interval in seconds from the occurrence of the first figure, or of the figure marked $\tau = 0$.]

SERIES II.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

Diameter of Drop, ⅙ inch. Height of Fall, 3 inches.



It will be observed that the drop flattens itself out somewhat, and descends at the bottom of a hollow with a raised beaded edge (Fig. 2). This edge would be smooth and circular but for the instability which causes it to topple into drops. As the drop descends the hollow becomes wider and deeper, and finally closes over the drop (Fig. 3), which, however, soon again emerges as the hollow flattens out, appearing first near, but still below the surface (Fig. 4), in a flattened, lobed form, afterwards rising as a column somewhat mixed with adherent water, in which traces of the lobes are at first very visible.

The rising column, which is nearly cylindrical, breaks up into drops before or during its subsequent descent into the liquid. As it disappears below the surface the outward and downward flow causes a hollow to be again formed, up the sides of which an annulus of

milk is carried, while the remainder descends to be torn again a second time into a vortex ring, which, however, is liable to disturbance from the falling in of the drops which once formed the upper part of the rebounding column.

It is not difficult to recognize some features of this splash without any apparatus beyond a cup of tea and a spoonful of milk. Any drinker of afternoon tea, after the tea is poured out and before the milk is put in, may let the milk fall into it drop by drop from one or two inches above it. The rebounding column will be seen to consist almost entirely of milk, and to break up into drops in the manner described, while the vortex ring, whose core is of milk, may be seen to shoot down into the liquid. But this is better observed by dropping ink into a tumbler of clear water.

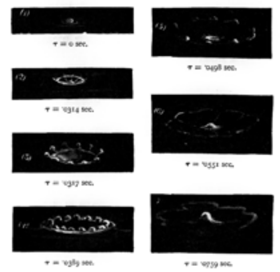
Let us now increase the height of fall to 17 inches. Series III. exhibits the result.

All the characteristics of the last splash are more strongly marked. In Fig. 1 we have caught sight of the little raised rim of the hollow before it was beaded, but in Fig. 2 special channels of easiest flow have been already determined. The number of ribs and rays in this basket-shaped hollow seemed to vary a good deal with different drops, as also did the number of arms and lobes seen in later figures, in a somewhat puzzling manner, and I made no attempt to select drawings which are in agreement in this respect. It will be understood that these rays contain little or none of the liquid of the drop, which remains collected together in the middle. Drops from these rays or from the larger arms and lobes of subsequent figures are often thrown off high into the air. In Figs. 3 and 4 the drop is clean gone below the surface of the hollow, which is now deeper and larger than before.

SERIES III.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

Diameter of Drop, ⅙ inch. Height of Fall, 1 ft. 5 in.



SERIES III.—(continued.)

The beautiful beaded annular edge then subsides, and in Fig. 5 we see the drop again, and in Fig. 6 it begins to emerge. But although the drop has fallen from a greater height than in the previous splash, the energy of the impact, instead of being expended in raising the same amount of liquid to a greater height, is now spent in lifting a much thicker adherent column to about the same height as in the last splash. There was sometimes noticed, as seen in Fig. 9, a tendency in the water to flow up past the milk, which, still comparatively unmixed with water, rides triumphant on the top of the emergent column. The greater relative thickness of this column prevents it splitting into drops, and Figs. 10 and 11 show it descending below the surface to form the hollow of Fig. 12, up the sides of which an annular film of milk is carried (Figs. 12 and 13), having been detached from the

central mass, which descends to be torn again, this time centrally into a well-marked vortex ring.

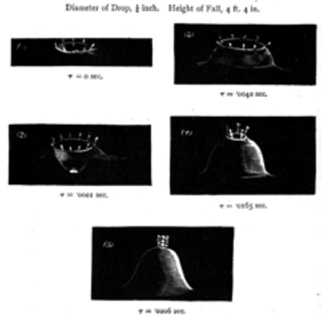
If we keep to the same size of drop and increase the fall to something over a yard, no great change occurs in the nature of the splash, but the emergent column is rather higher and thinner and shows a tendency to split into drops.

When, however, we double the volume of the drop and raise the height of fall to 52 inches, the splash of Series IV. is obtained, which is beginning to assume quite a different character. The raised rim of the previous series is now developed into a hollow shell of considerable height, which tends to close over the drop. This shell or dome is a characteristic feature of all splashes made by large drops falling from a considerable height, and is extremely beautiful. In the splash at present

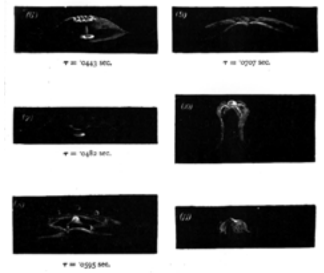
SERIES IV.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

Diameter of Drop, ⅕ inch. Height of Fall, 4 ft. 4 in.

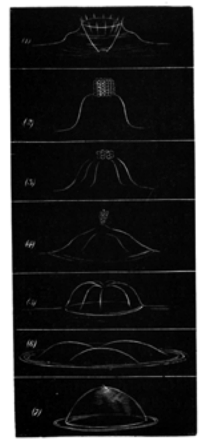


SERIES IV.—(continued.)



under consideration it does not always succeed in closing permanently, but opens out as it subsides, and is followed by the emergence of the drop (Fig. 8). In Fig. 9 the return wave overwhelms the drop for an instant, but it is again seen at the summit of the column in Fig. 10.

But on other occasions the shell or dome of Figs. 4 and 5 closes permanently over the imprisoned air, the liquid then flowing down the sides, which become thinner and thinner, till at length we are left with a large bubble floating on the water (see Series V.). It will be observed that the flow of liquid down the sides is chiefly along definite channels, which are probably determined by the arms thrown up at an earlier stage. The bubble is generally creased by the weight of the liquid along these channels. It must be remembered that the base of the bubble is in a state of oscillation, and that the whole is liable to burst at any



SERIES V.

The Splash of a Drop, followed in detail by Instantaneous Illumination.

The Size of Drop and Height of Fall are the same as before, but the hollow shell (see figs. 4 and 5 of the previous Series) does not succeed in opening, but is left as a bubble on the surface. This explains the formation of bubbles when *big* raindrops fall into a pool of water.

moment, when such figures as 6 and 7 of the previous series will be seen.

Such is the history of the building of the bubbles which big rain-drops leave on the smooth water of a lake, or pond, or puddle. Only the bigger drops can do it, and reference to the number at the side of Fig. 5 of Series IV. shows that the dome is raised in about two-hundredths of a second. Should the domes fail to close, or should they open again, we have the emergent columns which any attentive observer will readily recognize, and which have never been better described than by Mr. R. L. Stevenson, who, in his delightful *Inland Voyage*, speaks of the surface of the Belgian canals along which he was canoeing, as thrown up by the rain into "an infinity of little crystal fountains."

Very beautiful forms of the same type indeed, but different in detail, are those produced by a

drop of water falling into the lighter and more mobile liquid, petroleum.

It will now be interesting to turn to the splash that is produced when a solid sphere, such as a child's marble, falls into water.

I found to my great surprise that the character of the splash, at any rate up to a height of 4 or 5 feet, depends entirely on the state of the surface of the sphere. A polished sphere of marble about 0·6 of an inch in diameter, rubbed very dry with a cloth just beforehand and dropped from a height of 2 feet into water, gave the figures of Series VI., in which it is seen that the water spreads over the sphere so rapidly, that it is sheathed with the liquid even before it has passed below the general level of the surface. The splash is insignificantly small and of very short duration.[1] If

[1] Photographs obtained since this was written show that much may happen after the stages here traced.

SERIES VI., VII.

Splash of a Solid Sphere (a marble ⅗ inch in diameter falling 2 feet into water).

Series VI.	Series VII.
When the sphere is *dry and polished.*	When the sphere is *not* well *dried* and *polished.*

SERIES VIII.

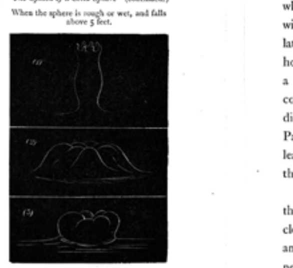
The Splash of a Solid Sphere—(continued.)

When the sphere is *rough* or *wet.*

SERIES IX.

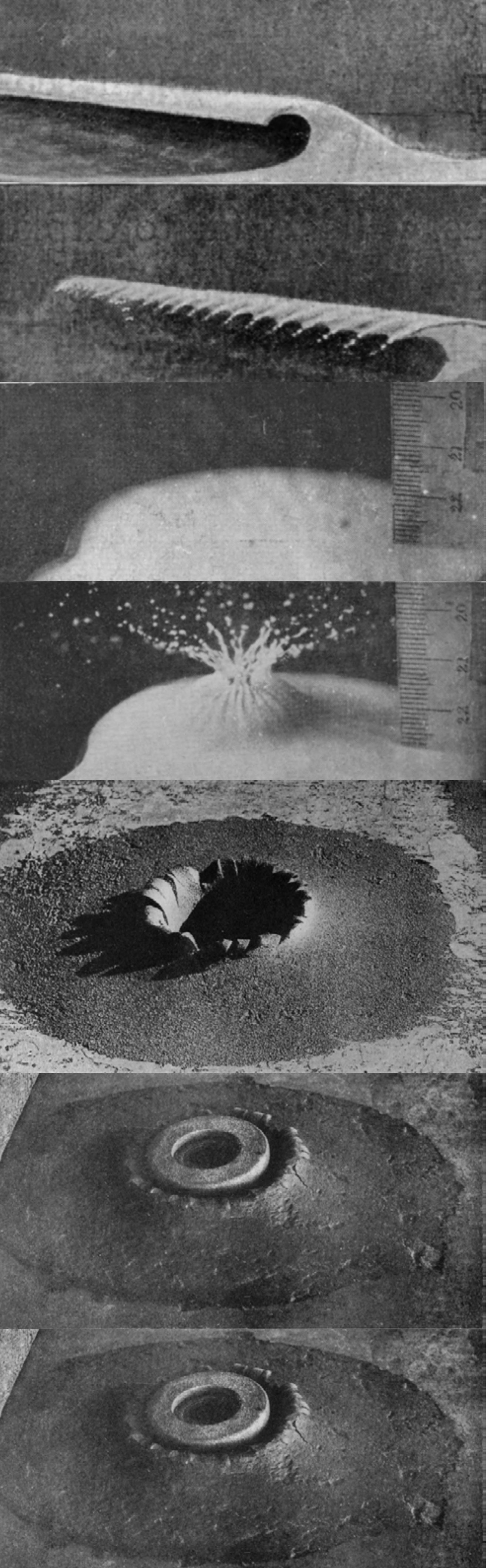
The Splash of a Solid Sphere—(continued.)

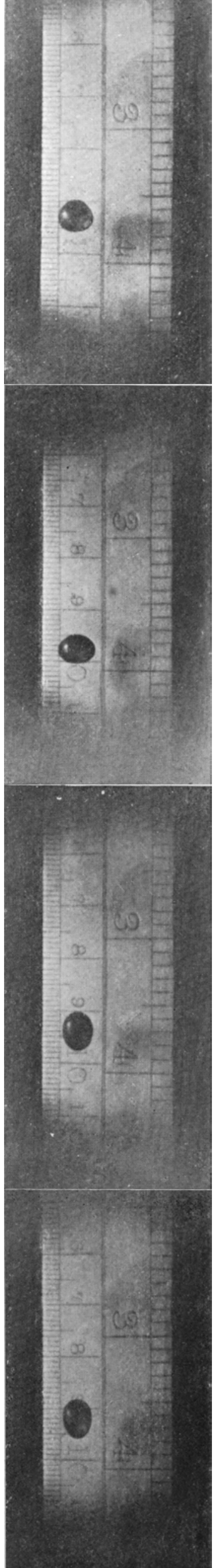
When the sphere is rough or wet, and falls above 5 feet.

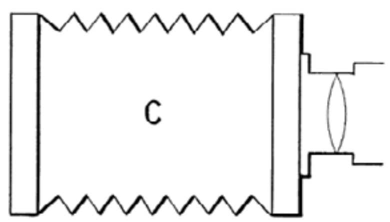


the drying and polishing be not so perfect, the configurations of Series VII. are produced; while if the sphere be roughened with sand-paper, or *left wet*, Series VIII. is obtained, in which it will be perceived that, as was the case with the liquid drop, the water is driven away laterally, forming the ribbed basket-shaped hollow, which, however, is now prolonged to a great depth, the drop being followed by a cone of air, while the water seems to find great difficulty in wetting the surface completely. Part of this column of air was carried down at least 16 inches, and then only detached when the sphere struck the bottom of the vessel.

Figs. 6 and 7 show the crater falling in, but this did not always happen, for the walls often closed over the hollow exactly as in Figs. 4 and 5 of Series IV. Meanwhile the long and nearly cylindrical portion below breaks up into bubbles which rise quickly to the surface.



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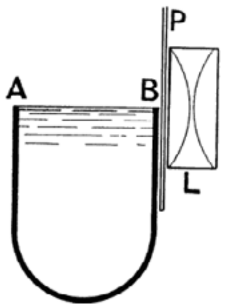
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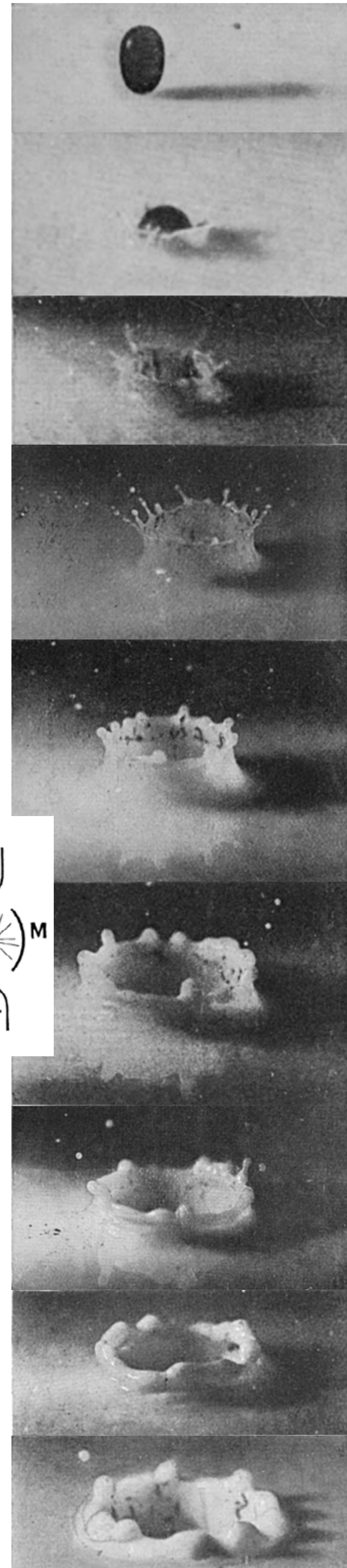
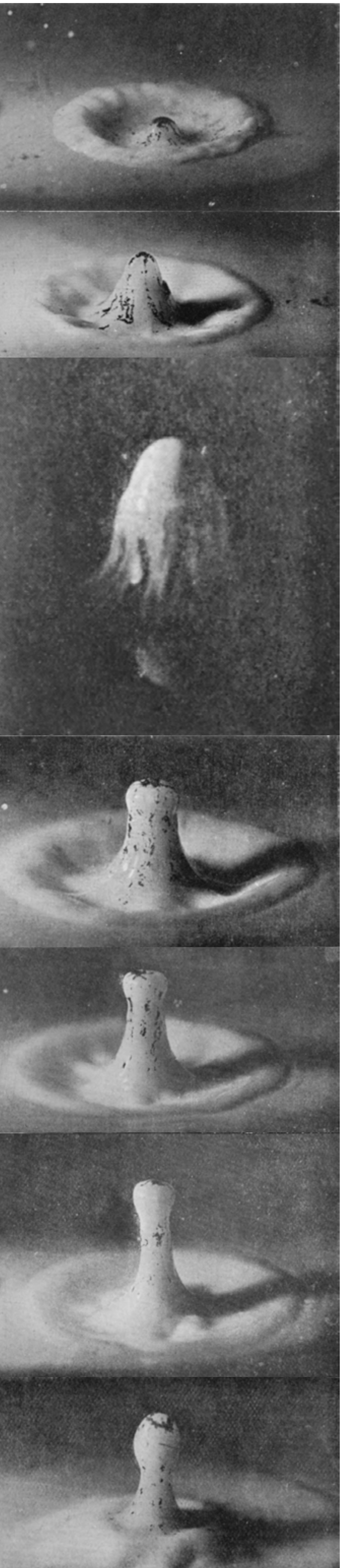
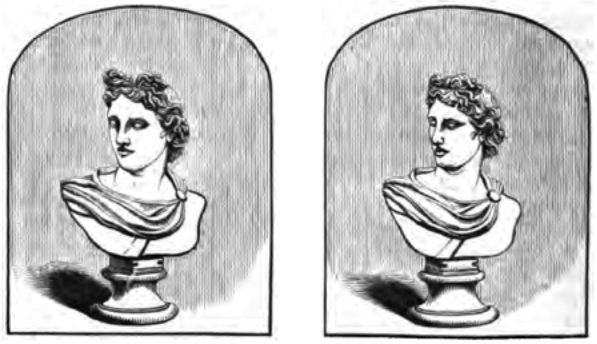
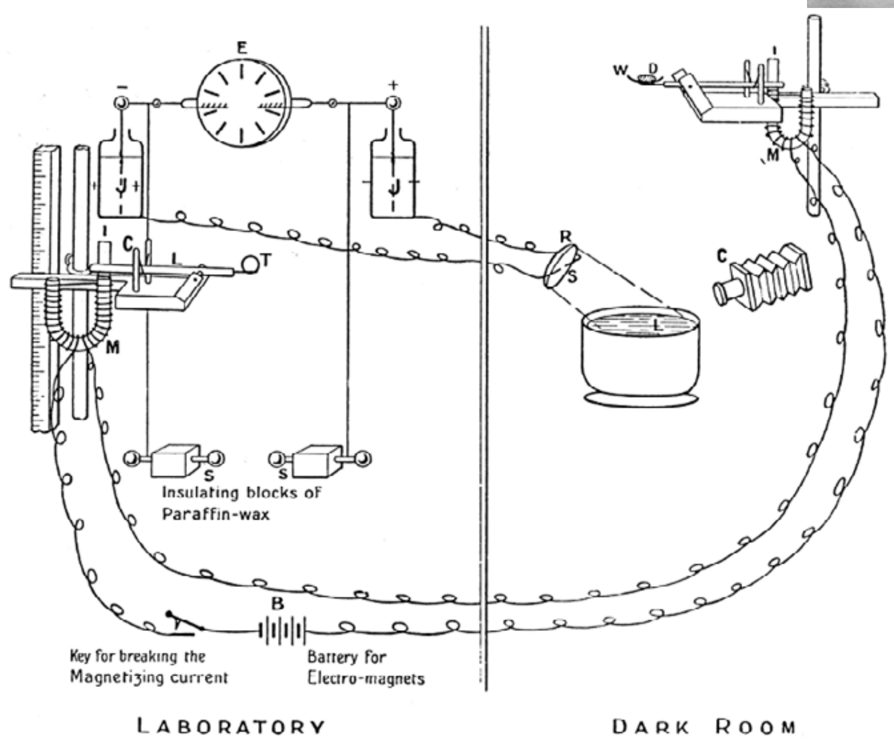


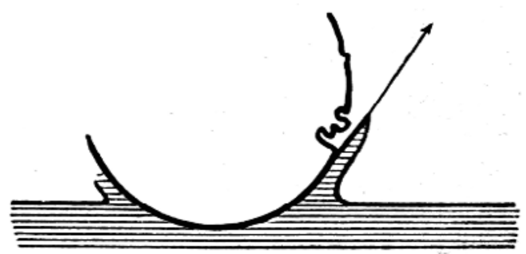


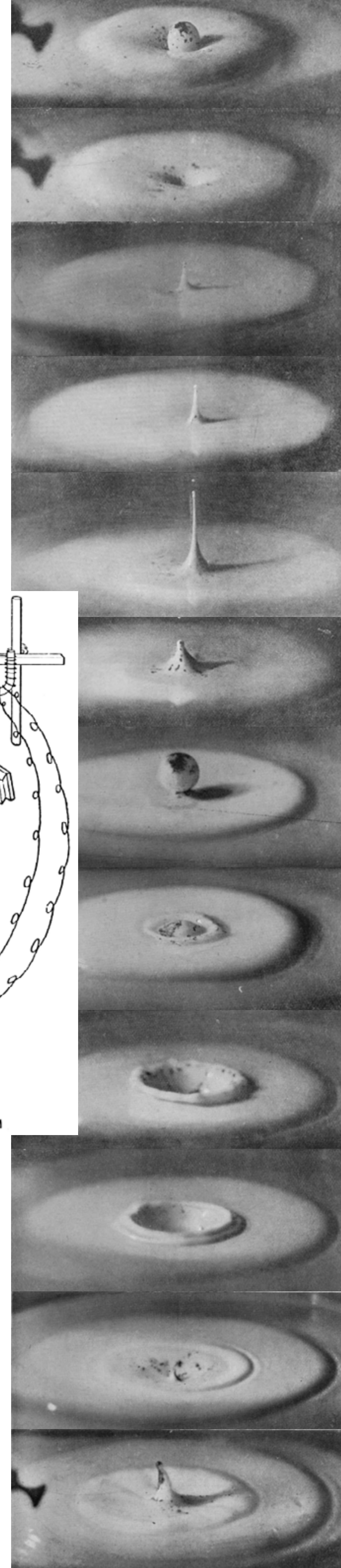


86.


E
Insulating blocks of
Paraffin-wax
Key for breaking the
Magnetizing current
Battery for
Electro-magnets
LABORATORY
DARK ROOM

85.





By increasing the fall to 5 feet we obtain the figures of Series IX. The tube of Fig. 1 corresponds to the dome of Series IV. and V., and is not only elevated to a surprising height, but is also in the act of cleaving (the outline being approximately that of the unduloid of M. Plateau). Figs. 2 and 3 show the bubble formed by the closing up of this tube, weighed down in the centre as in Figs. 5 and 6 of Series V. Similar results were obtained with other liquids, such as petroleum and alcohol.

It is easy to show in a very striking manner the paramount influence of the condition of the solid surface. I have here a number of similar marbles; this set has been well polished by rubbing with wash leather. I drop them one by one through a space of about 1 foot into this deep, wide, cylindrical glass vessel, lighted up by a lamp placed behind it. You see each marble enters noiselessly and with

hardly a visible trace of splash. Now I pick them out and drop them in again (or to save trouble, I drop in the place of these other wet ones), everything is changed. You see how the air is carried to the very bottom of the vessel, and you hear the "φλοῖσβος" of the bubbles as they rise to the surface and burst. These dry but rough marbles behave in much the same way.

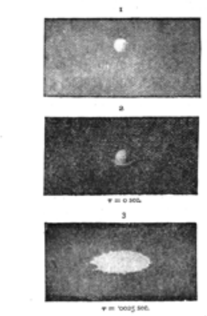
Such are the main features of the Natural History of Splashes, as I made it out between thirteen and eighteen years ago. Before passing on to the photographs that I have since obtained, I desire to add a few words of comment. I have not till now alluded to any imperfections in the timing apparatus. But no apparatus of the kind can be absolutely perfect, and, as a matter of fact, when everything is adjusted so as to display a particular stage, it will happen that in a succession of

observations there is a certain variation in what is seen. Thus the configuration viewed may be said to oscillate slightly about the mean for which the apparatus is adjusted. Now this is due both to small imperfections in the timing apparatus and to the fact that the splashes themselves do actually vary within certain limits. The reasons are not very far to seek. In the first place the rate of demagnetization of the electro-magnets varies slightly, being partly dependent on the varying resistance of the contacts of crossed wires, partly on the temperature of the magnet, which is affected by the length of time for which the current has been running. But a much more important reason is the variation of the slight adhesion of the drop to the smoked watch-glass that has supported it, and consequently of the oscillations to which, as we shall see, the drop is subjected as it de-

scends. Thus the drop will sometimes strike the surface in a flattened form, at others in an elongated form, and there will be a difference, not only in the time of impact, but in the nature of the ensuing splash; consequently some judgment is required in selecting a consecutive series of drawings. The only way is to make a considerable number of drawings of each stage, and then to pick out a consecutive series. Now, whenever judgment has to be used, there is room for error of judgment, and moreover, it is impossible to put together the drawings so as to tell a consecutive story, without being guided by some theory, such as I have already sketched, as to the nature of the motion and the conditions that govern it. You will therefore be good enough to remember that this chronicle of the events of a tenth of a second is not a mechanical record but is presented by a fallible

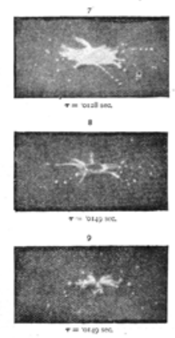
SERIES XIII.

Engravings of Instantaneous Photographs (1½ of the real size) of the Splash of a Drop of Milk falling 20 cm. on to smoked glass.



(It was not found possible to reproduce satisfactorily the missing figures of this series.)

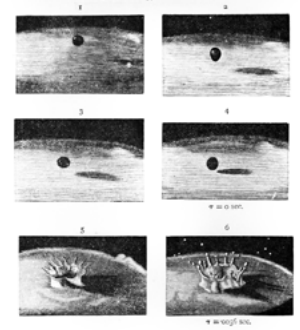
SERIES XIII.—(*continued.*)



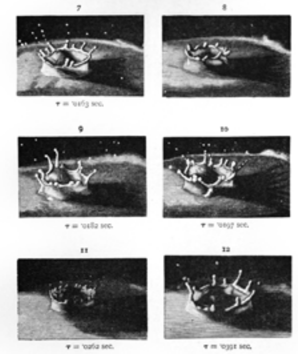
SERIES XIV.

Engravings of Instantaneous Photographs of the Splash of a Drop of Water falling 40 cm. into Milk.

Scale about ⅔ of actual size.



SERIES XIV.—(*continued.*)



human historian, whose account, like that of any other contemporary observer, will be none the worse for independent confirmation. That confirmation is fortunately obtainable. In an attempt made eighteen years ago to photograph the splash of a drop of mercury, I was unable to procure plates sufficiently sensitive to respond to the very short exposures that were required, and consequently abandoned the endeavour. But in recent years plates of exquisite sensitiveness have been produced, and such photographs as those taken by Mr. Boys of a flying rifle bullet have shown that difficulties on the score of sensitiveness have been practically overcome. Within the last few weeks, with the valuable assistance of my colleague at Devonport, Mr. R. S. Cole, I have succeeded in obtaining photographs of various splashes. Following Prof. Boys' suggestion, we employed Thomas's cyclist plates, or occasionally the less

sensitive "extra-rapid" plates of the same makers, and as a developer, Eikonogen solution of triple strength, in which the plates were kept for about 40 minutes, the development being conducted in complete darkness.

A few preliminary trials with the self-induction spark produced at the surface of mercury by the apparatus that you have seen at work, showed that the illumination, though ample for direct vision, was not sufficient for photography. When the current strength was increased, so as to make the illumination bright enough for the camera, then the spark became of too great duration, for it lasted for between 4 and 5 thousandths of a second, within which time there was very perceptible motion of the drop and consequent blurring. It was therefore necessary to modify the apparatus so as to employ a Leyden-jar spark whose duration was probably less than 10-

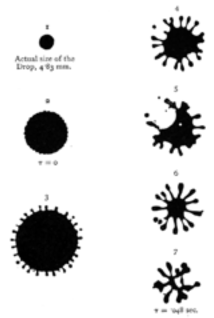
millionths of a second. A very slight change in the apparatus rendered it suitable for the new conditions, but time does not permit me to describe the arrangements in detail. It is, however, less necessary to do so as the method is in all essentials the same as that described in this room two years ago by Lord Rayleigh in connection with the photography of a breaking soap-film.[1] I therefore pass at once to the photographs themselves.

The first two series (X. and XI.) may be described as shadow photographs; they were obtained by allowing a drop of mercury to fall on to the naked photographic plate itself, the illuminating spark being produced vertically above it, and they give only a horizontal section of the drop in various stages, revealing the form of the outline of the part in contact

[1] A detailed account of the optical, mechanical, and electrical arrangements employed, written by Mr. Cole, will be found in *Nature*, vol. l., p. 222 (July 5, 1894).

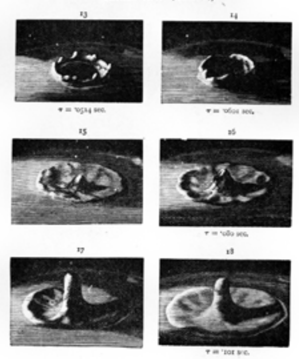
SERIES X.

(1) *Instantaneous Shadow Photographs (life size) of the Splash of a Drop of Mercury falling 8 cm. on to the Photographic Plate.*



Actual size of the Drop, 4·83 mm.

SERIES XIV.—(*continued.*)



new points that the photographs have so far revealed.[1]

With respect to these photographs,[2] the credit of which I hope you will attribute firstly to the inventors of the sensitive plates, and secondly to the skill and experience of Mr. Cole, I desire to add that they are, as far as we know, the first really detailed objective views that have been obtained with anything approaching so short an exposure.

Even Mr. Boys' wonderful photographs of flying bullets were after all but shadow-

[1] The black streaks, seen especially in Figs. 11, 15, and 16, are due to particles of lamp-black carried down by the drop from the surface of the smoked watch-glass on which it rested.

[2] Three of these photographs, viz. Nos. 11, 12, and 17, are reproduced full size, as a frontispiece, by a *photographic* process, to enable the reader to form a more correct idea than can be gathered from the engravings, of the amount of detail actually obtained, though even in these reproductions much is inevitably lost.

photographs, and did not so strikingly illustrate the extreme sensitiveness of the plates, and I want you to distinguish between such and what (to borrow Mr. F. J. Smith's phrase) I call an "objective view."

It remains only to speak of the greater irregularity in the arms and rays as shown by the photographs. The point is a curious and interesting one. In the first place I have to confess that in looking over my original drawings I find records of many irregular or unsymmetrical figures, yet in compiling the history it has been inevitable that these should be rejected, if only because identical irregularities never recur. Thus the mind of the observer is filled with an ideal splash—an "Auto-Splash"—whose perfection may never be actually realized.

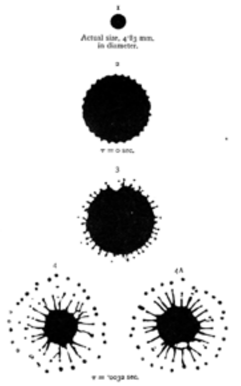
But in the second place, when the splash is nearly regular it is very difficult to detect

irregularity. This is easily proved by projecting on the screen with instantaneous illumination such a photograph as that of Series X., Fig. 6. My experience is that most persons pronounce what they have seen to be a regular and symmetrical star-shaped figure, and they are surprised when they come to examine it by detail in continuous light to find how far this is from the truth. Especially is this the case if no irregularity is suspected beforehand. I believe that the observer, usually finding himself unable to attend to more than a portion of the rays in the system, is liable instinctively to pick out for attention a part of the circumference where they are regularly spaced, and to fill up the rest in imagination, and that where a ray may be really absent he prefers to consider that it has been imperfectly viewed.

This opinion is confirmed by the fact that

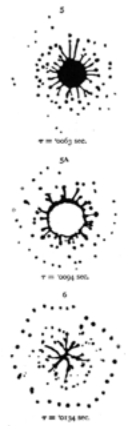
SERIES XI.

(2) *Instantaneous Shadow Photographs (life size) of the Splash of a Drop of Mercury falling 15 cm. on to Glass.*



Actual size, 4·83 mm. in diameter.

SERIES XI.—(*continued.*)



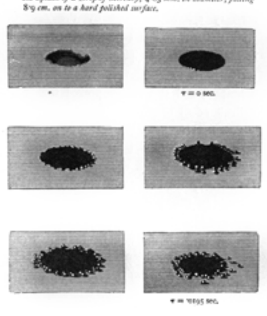
with the plate, but of course telling nothing about the shape of the parts above. The first series corresponds to a mercury splash very similar to that first described, and the second to the splash of a larger drop such as was not described. In each series, the tearing of the thin central film to which allusion was made is well illustrated. I think the first comment that any one would make is that the photographs, while they bear out the drawings in many details, show greater irregularity than the drawings would have led one to expect. On this point I shall presently have something to say.

Comparing the first set of drawings (pp. 20—24) with the photographs of Series X., it will be seen that

Photograph	2	corresponds to drawing		4 or 5
"	3	"	"	9
"	4	"	"	18
"	6	"	"	20
"	7	"	"	24

SERIES XII.

Engravings from Instantaneous Photographs (1½ of the real size) of the Splash of a Drop of Mercury, 4·83 mm. in diameter, falling 8·9 cm. on to a hard polished surface.



in several cases, I have been able to observe with the naked eye a splash that was also simultaneously photographed, and have made the memorandum "quite regular," though the photograph subsequently showed irregularity. It must, however, be observed that the absolute darkness and other conditions necessary for photography are not very favourable for direct vision.

And now my tale is told, or rather as much of it as the limits of the time allowed me will permit. I think you will agree that the phenomena are very beautiful, and that the subject, commonplace and familiar though it is, has yet proved worthy of an hour's attention.

THE END.

Richard Clay & Sons, Limited, London & Bungay.

but the irregularity of the last photograph almost masks the resemblance.

Series XII. gives an objective view of a mercury splash as taken by the camera. Only the first of this series shows any detail in the interior. The polished surface of the mercury is, in fact, very troublesome to illuminate, and this splash proved the most difficult of all to photograph.

Series XIII. shows the splash of a drop of milk falling on to a smoked glass plate, on which it runs about without adhesion just as mercury would. Here there is more of detail. In Fig. 4 the central film is so thin in the middle that the black plate beneath it is seen through the liquid. In Fig. 8 this film has been torn.

Series XIV. exhibits the splash of a water drop falling into milk. The first four photographs show the oscillations of the drop about

66 THE SPLASH OF A DROP

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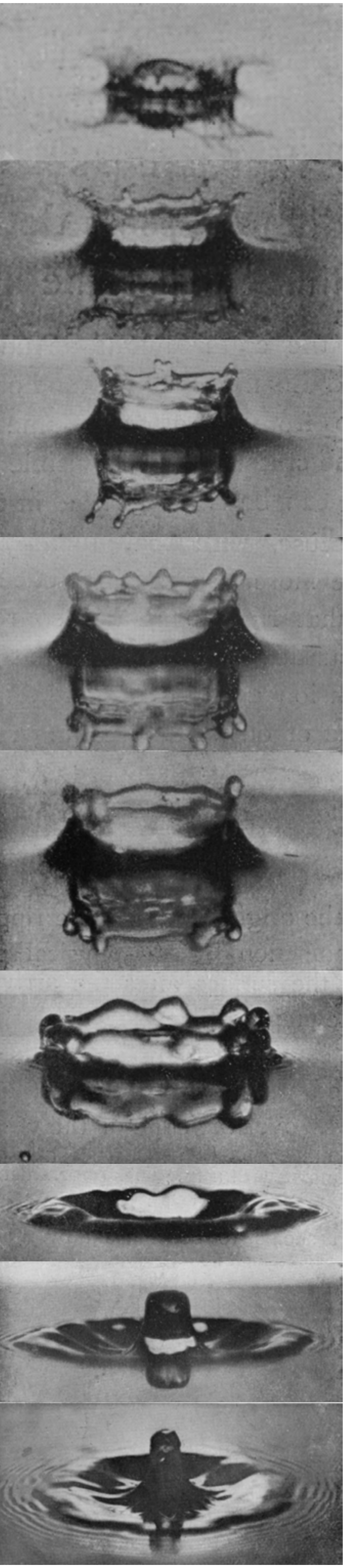
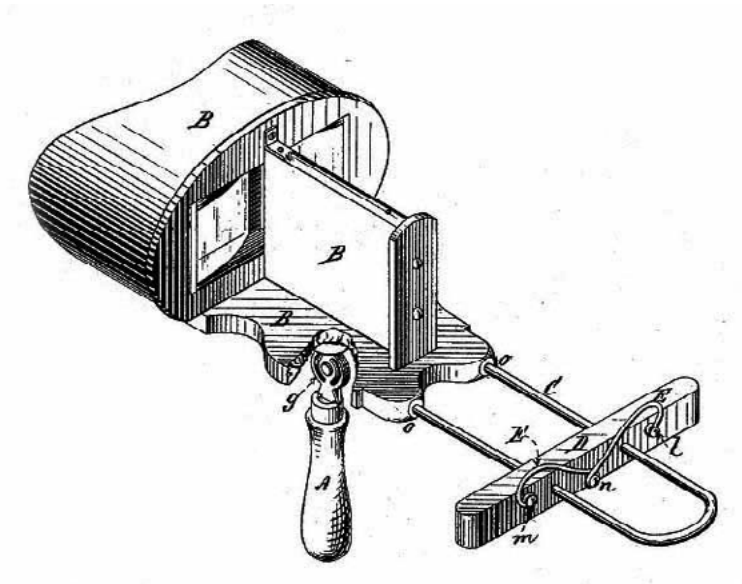
Series XIV. exhibits the splash of a water drop falling into milk. The first four photographs show the oscillations of the drop about

a mean spherical figure as it approaches the surface.

In the subsequent figures it will be noticed that the arms which are thrown up at first, afterwards segment into drops which fly off and subside (see Fig. 8), to be followed by a second series which again subside (Fig. 11), to be again succeeded by a third set. In fact, so long as there is any downward momentum the drop and the air behind it are penetrating the liquid, and so long must there be an upward flow of displaced liquid. Much of this flow is seen to be directed into the arms along the channels determined by the segmentation of the annular rim. This reproduction of the lobes and arms time after time on a varying scale goes far to explain the puzzling variations in their number which I mentioned in connection with the drawings. I had not, indeed, suspected this, which is one of the few





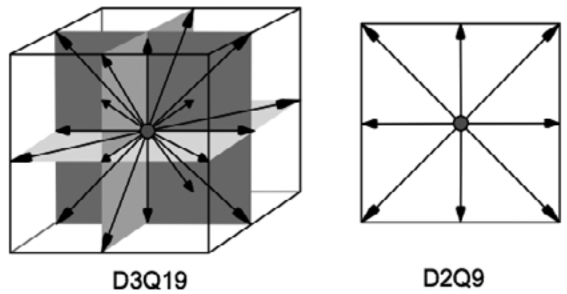


Figure 2: The velocities of the D3Q19 and D2Q9 LBM models.

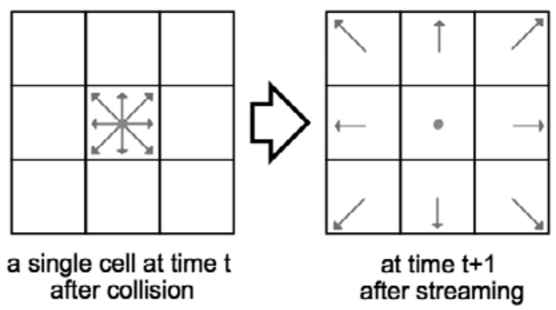
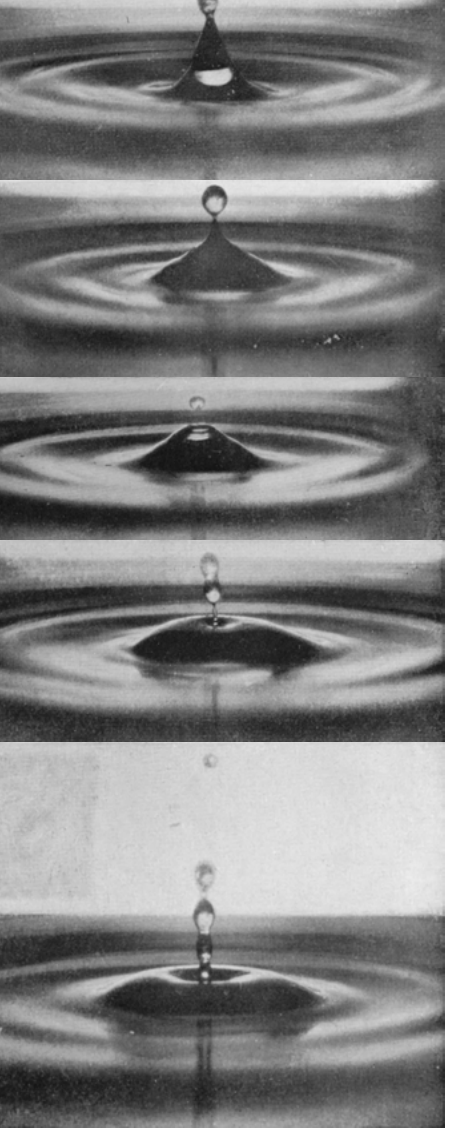
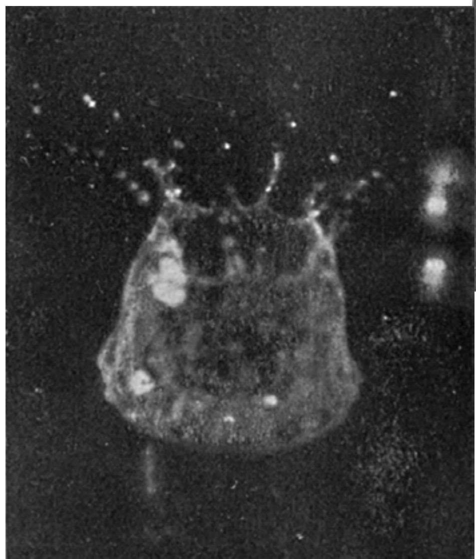
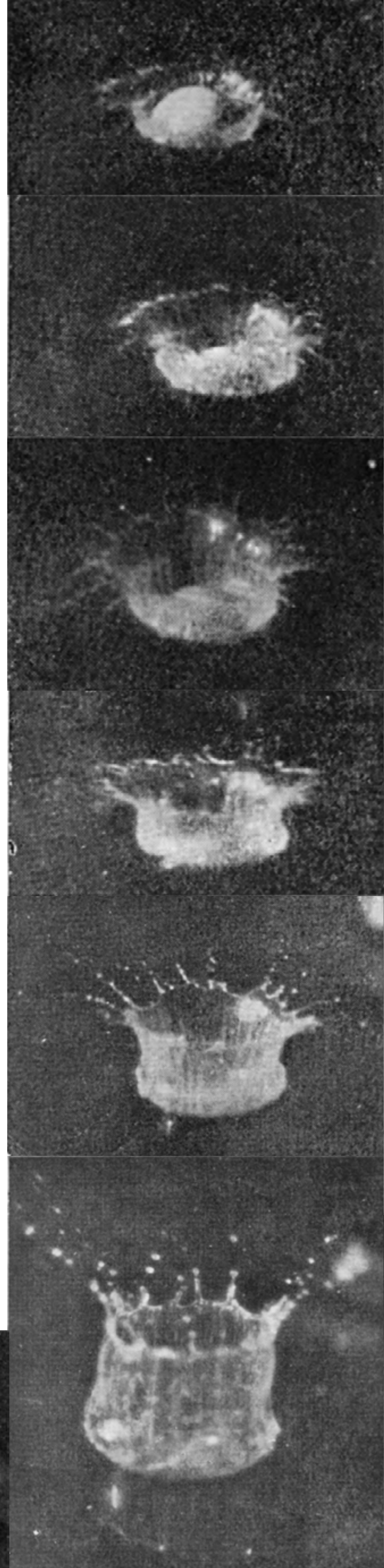
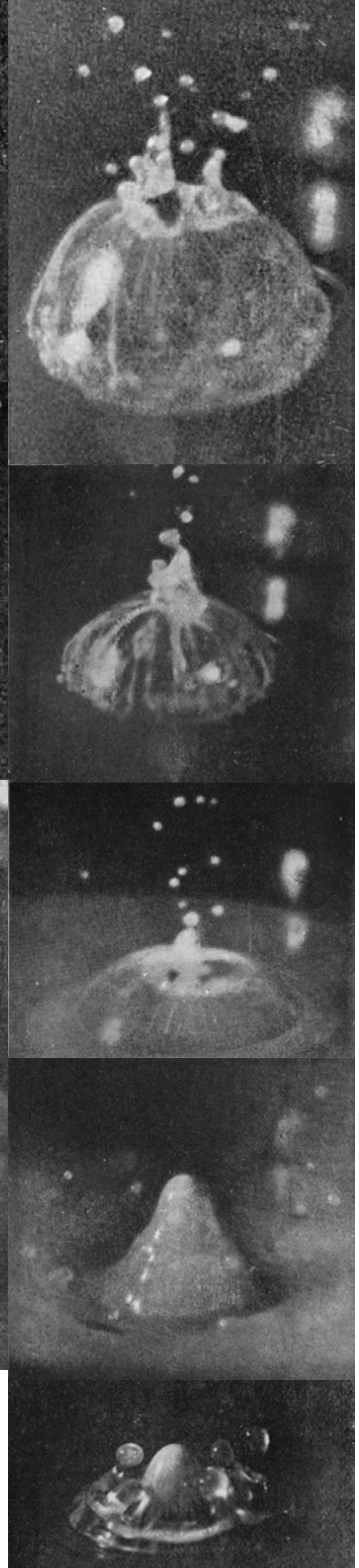


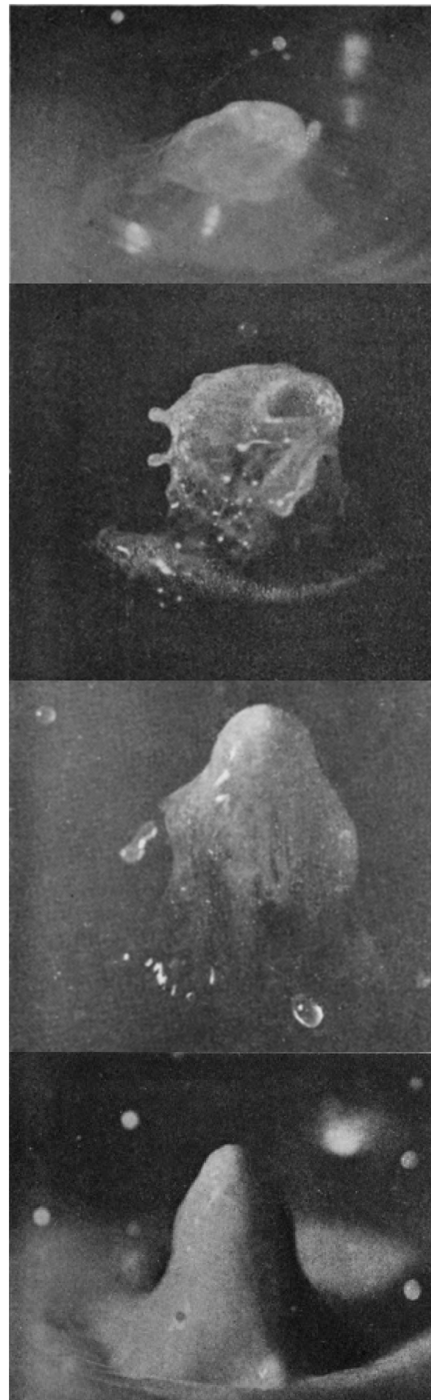
Figure 3: The distribution functions of a single cell at time before and after the streaming step.

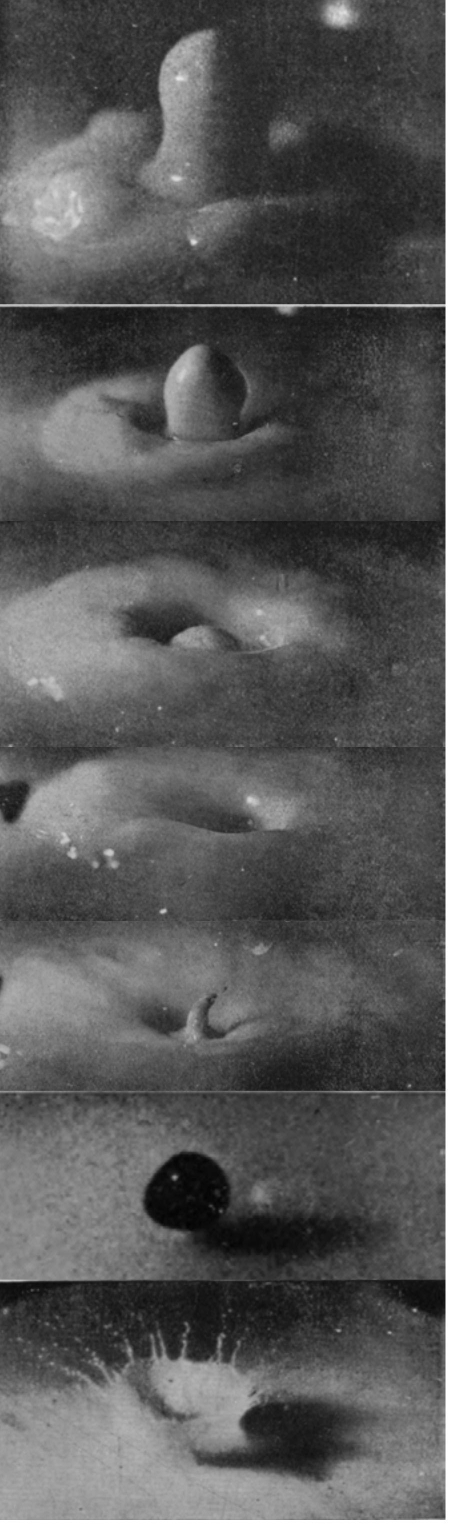


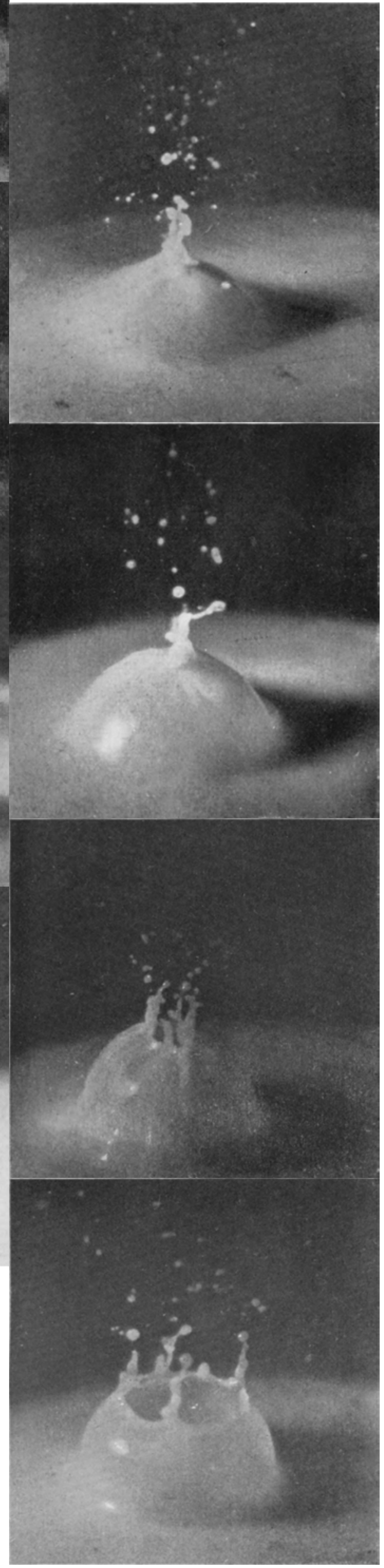




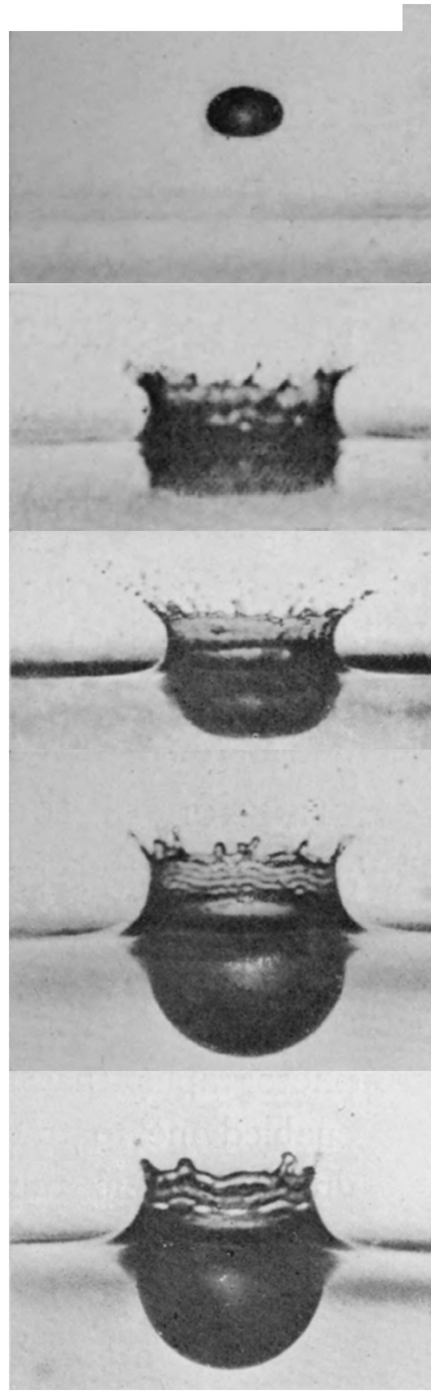


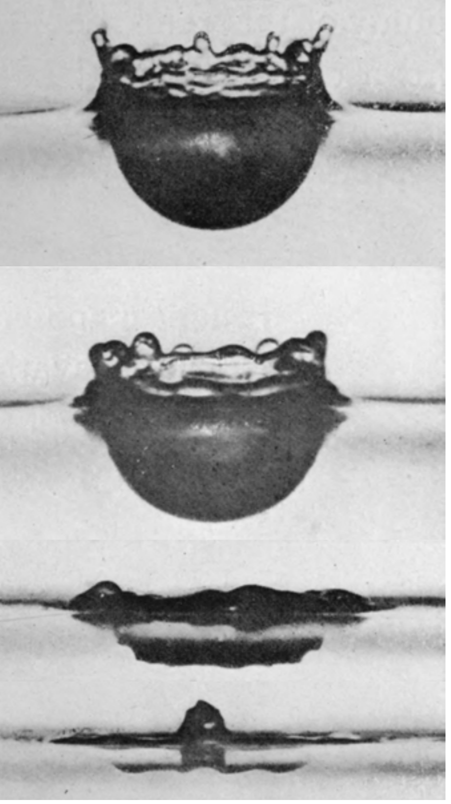


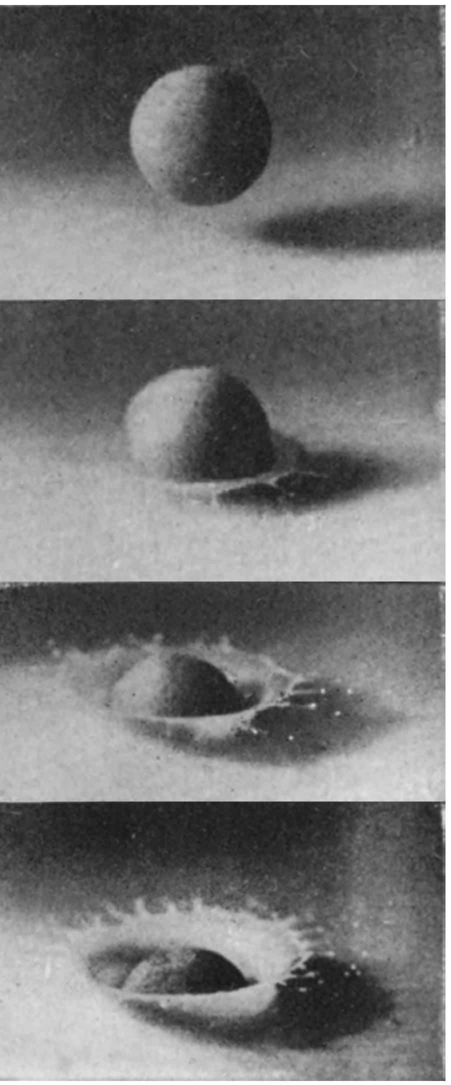


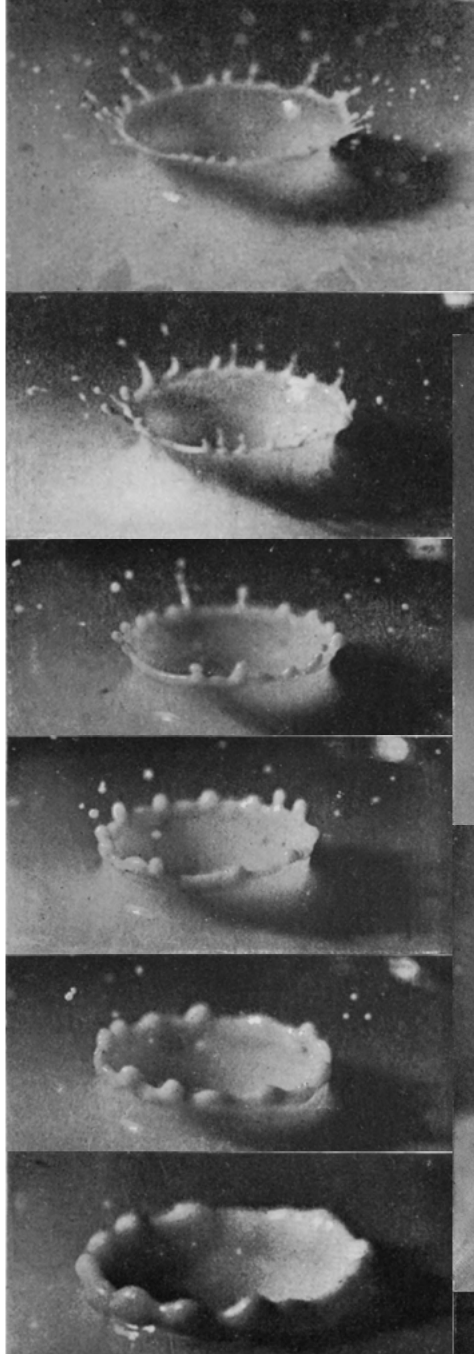


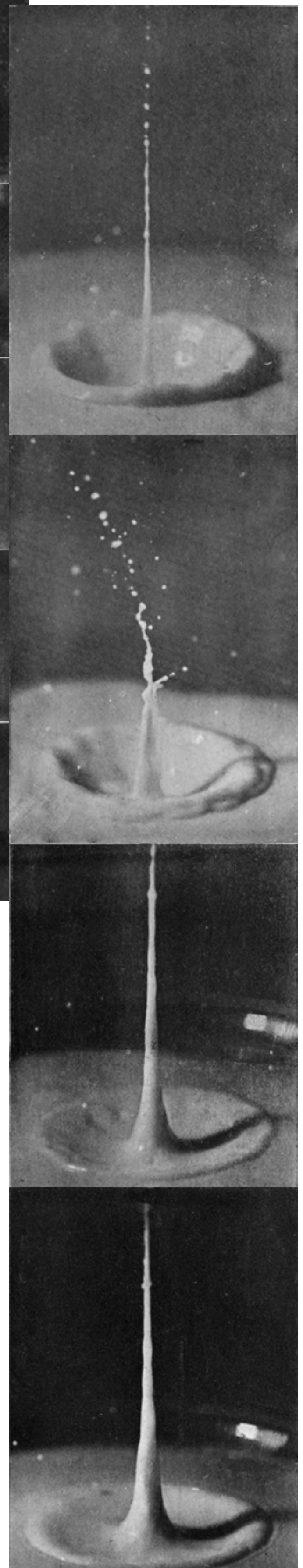
3 The Lattice-Boltzmann method

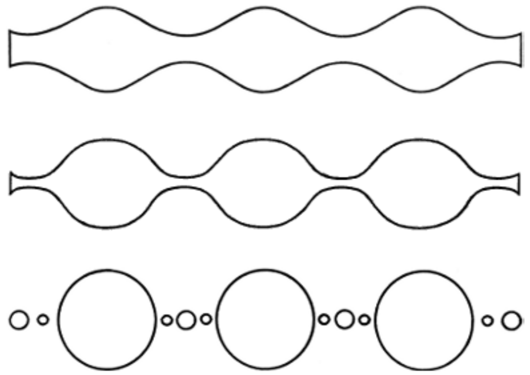


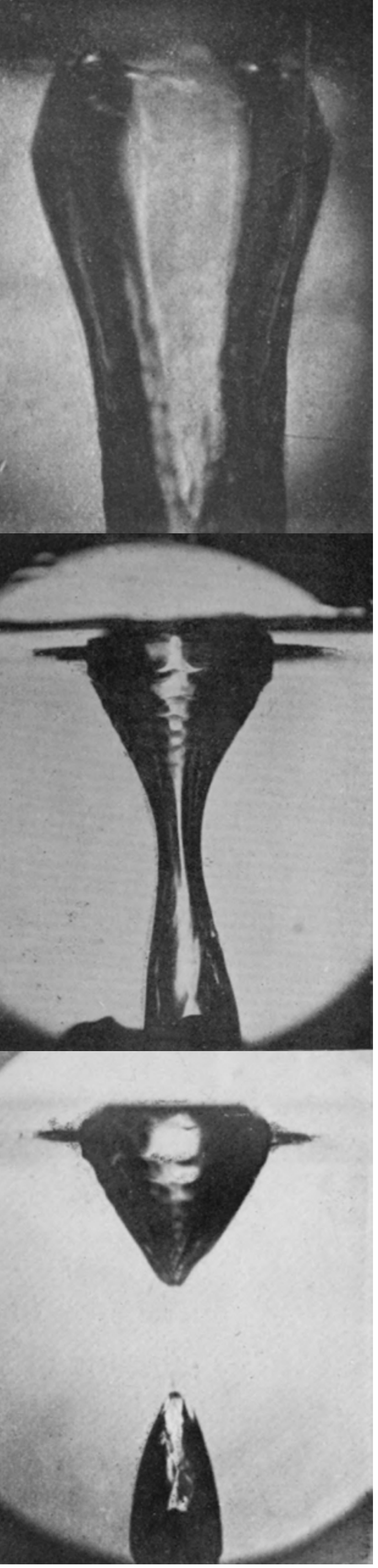


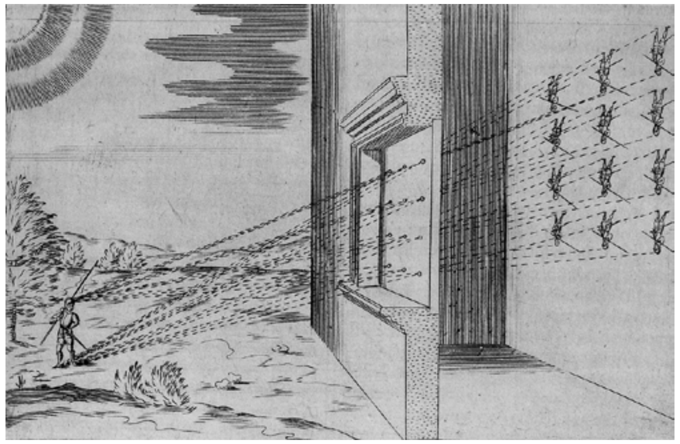


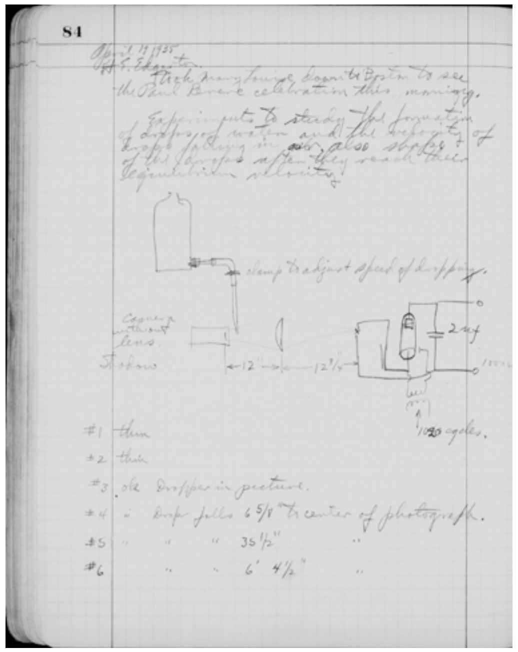











84

the Paul Revere celebration this morning.

Experiments to study the formation of drops of water and the velocity of drops falling in air, also shapes of the drops after they reach their equilibrium velocity.

clamp to adjust speed of dropping.

Camera without lens.

Shadow

12"

12 1/4"

2 uf

#1 thin

#2 thin

#3 ok Dropper in picture.

#4 " Drop falls 6 5/8" to center of photograph.

#5 " " " 35 1/2" "

#6 " " 6' 4 1/2" "

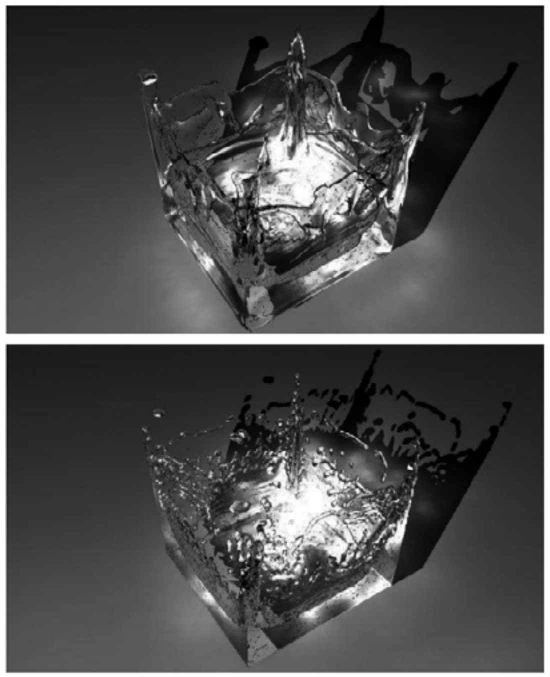
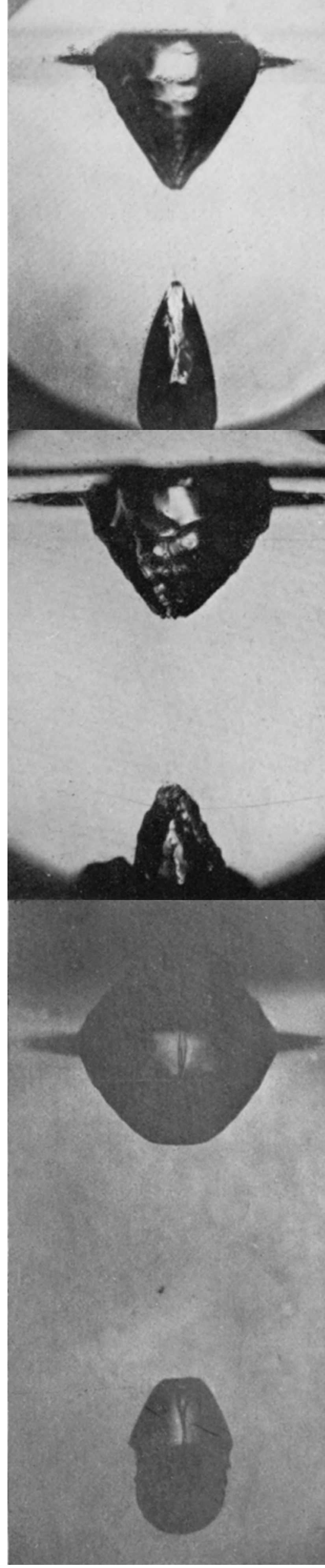
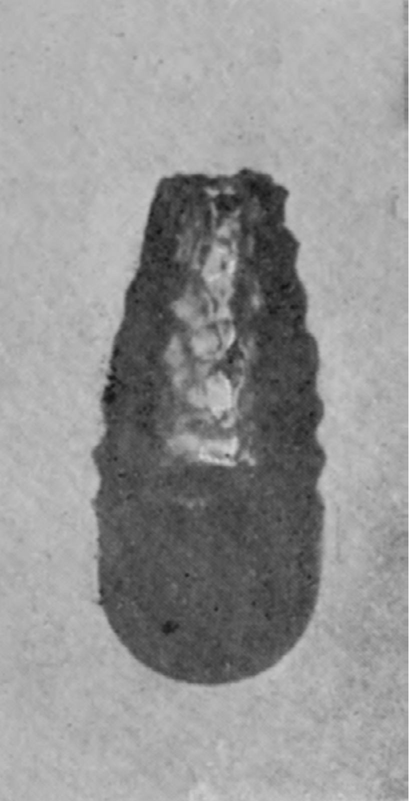
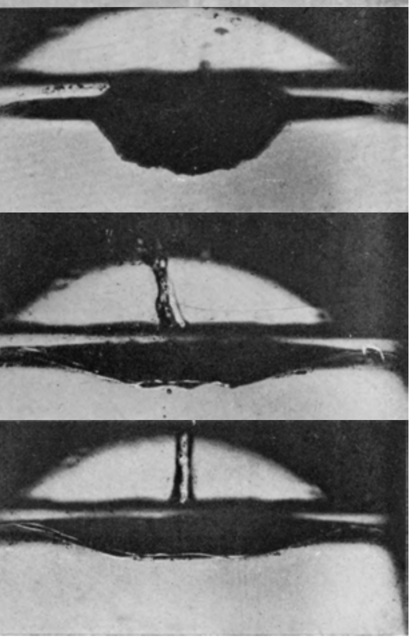
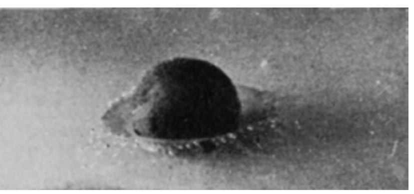


Figure 4: A square drop of fluid is falling down into a container. The upper picture is taken from a simulation using level sets, while the simulation of the lower picture uses the mass tracking algorithm.







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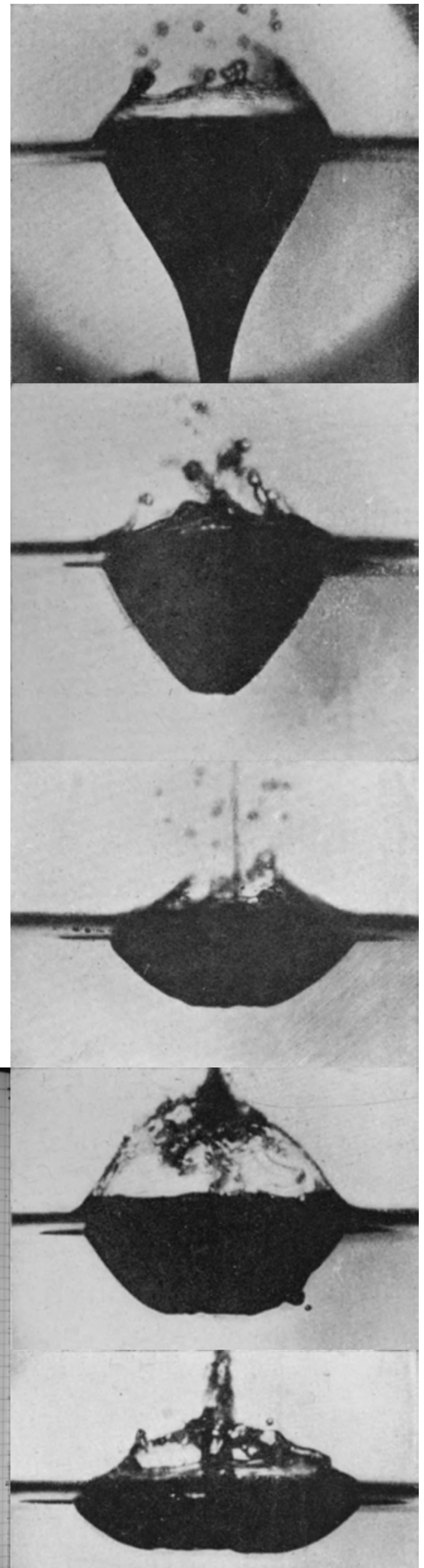

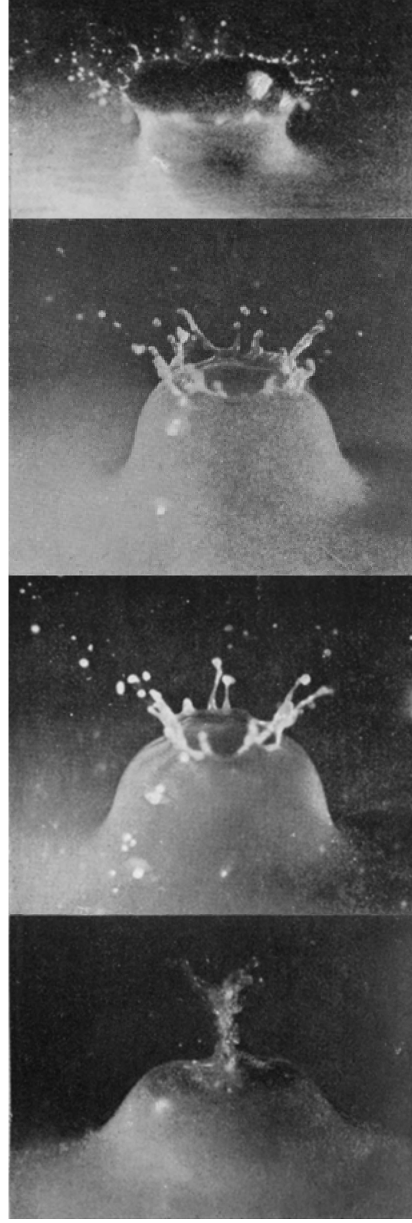

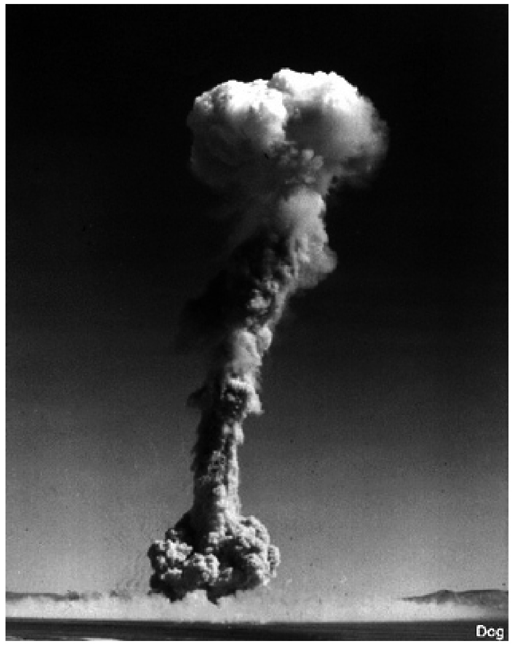
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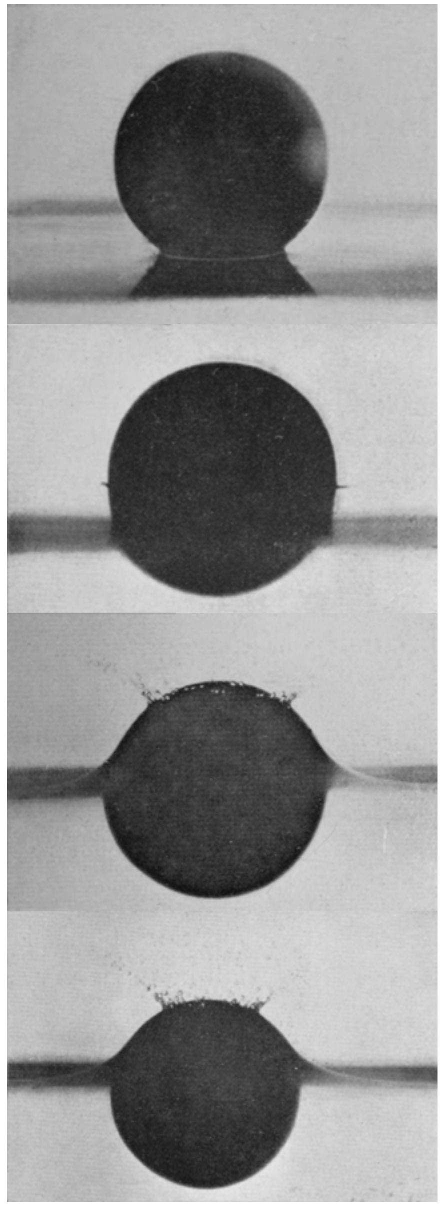

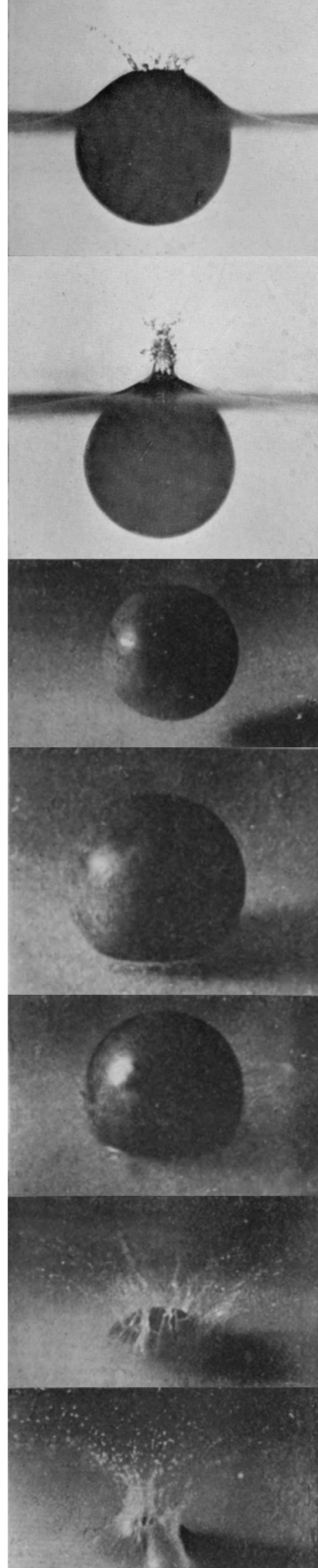

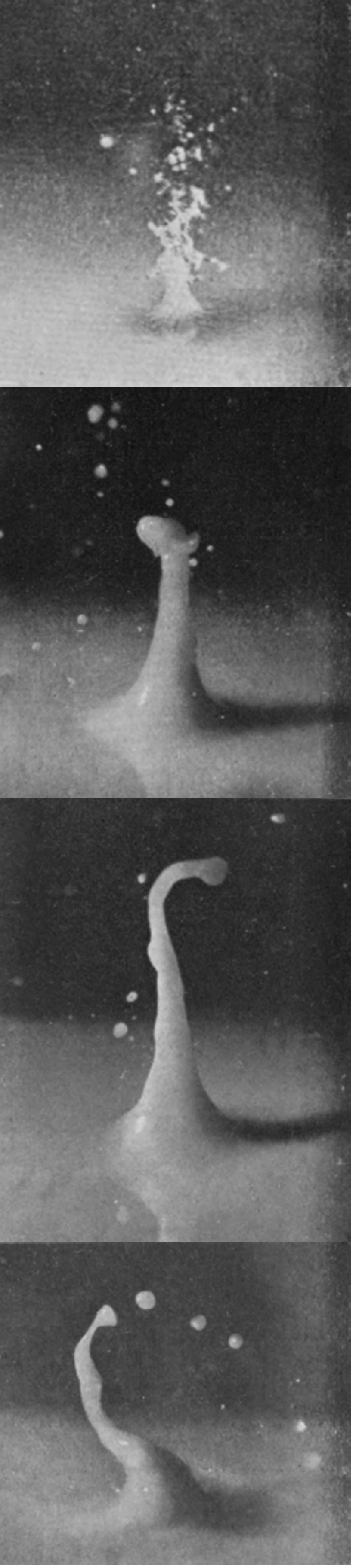

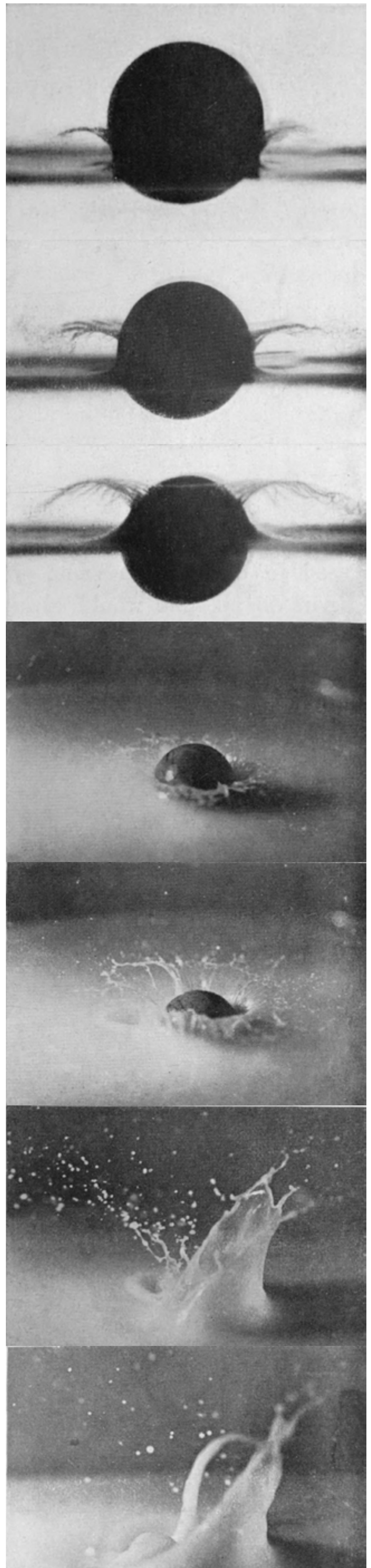

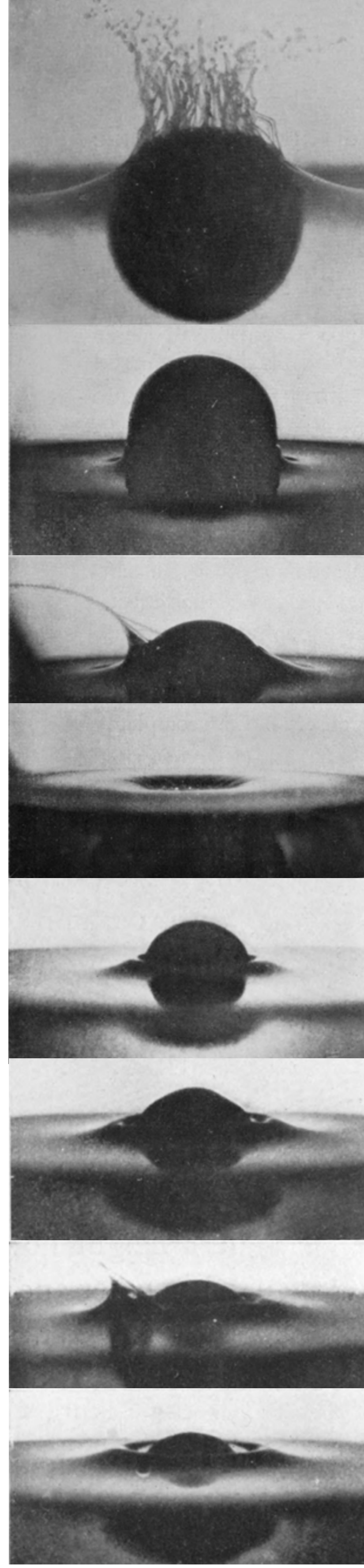

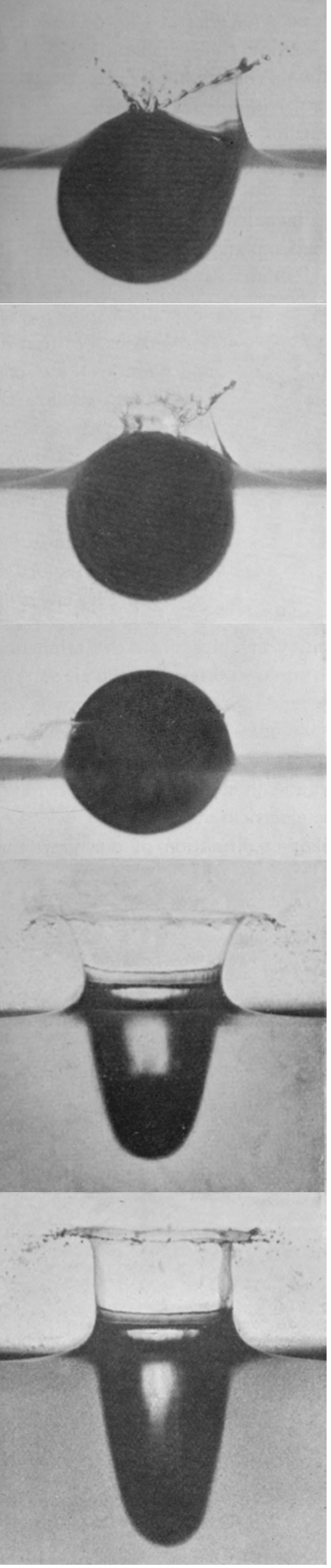
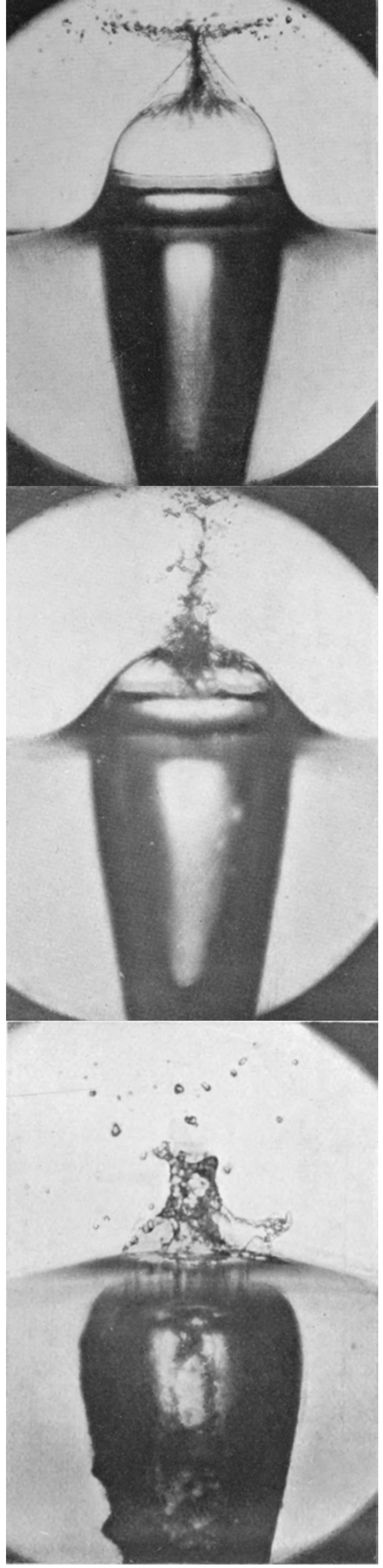
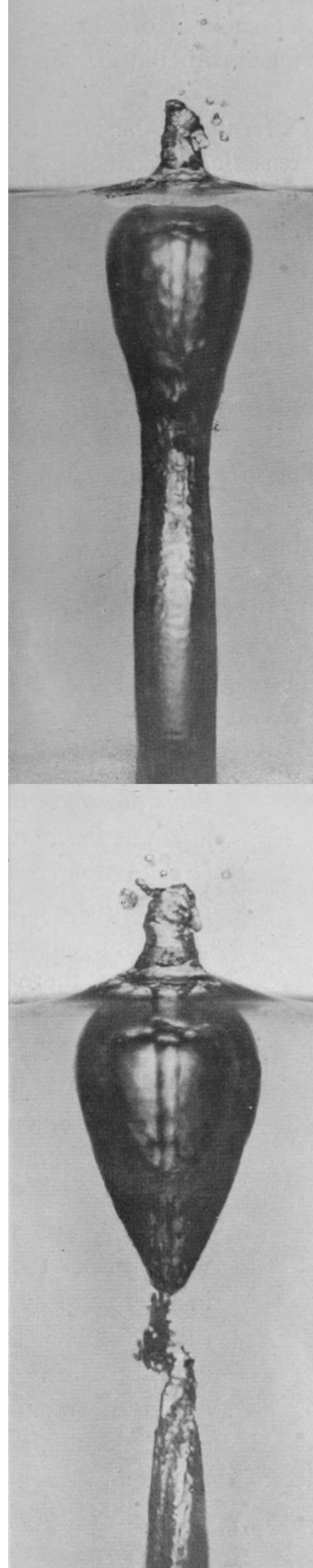

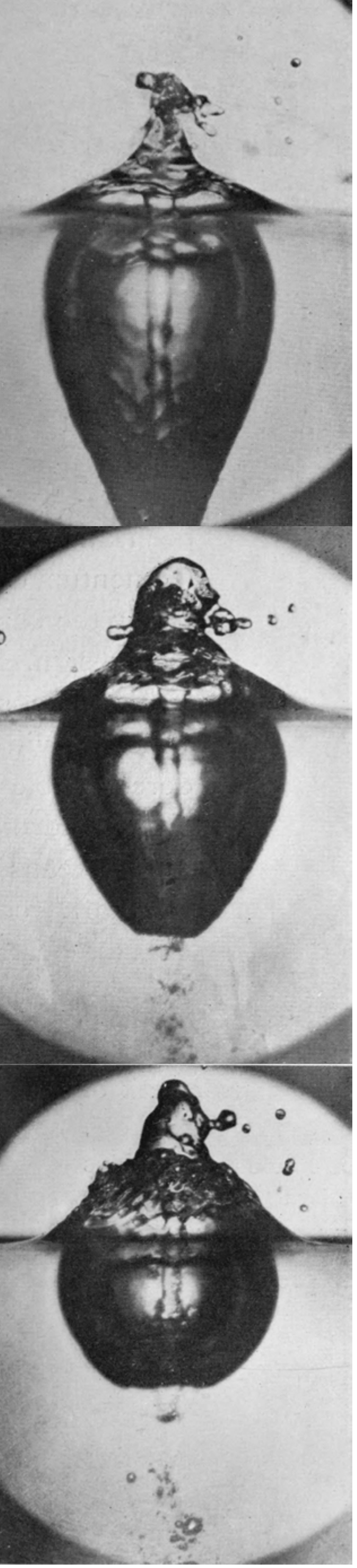

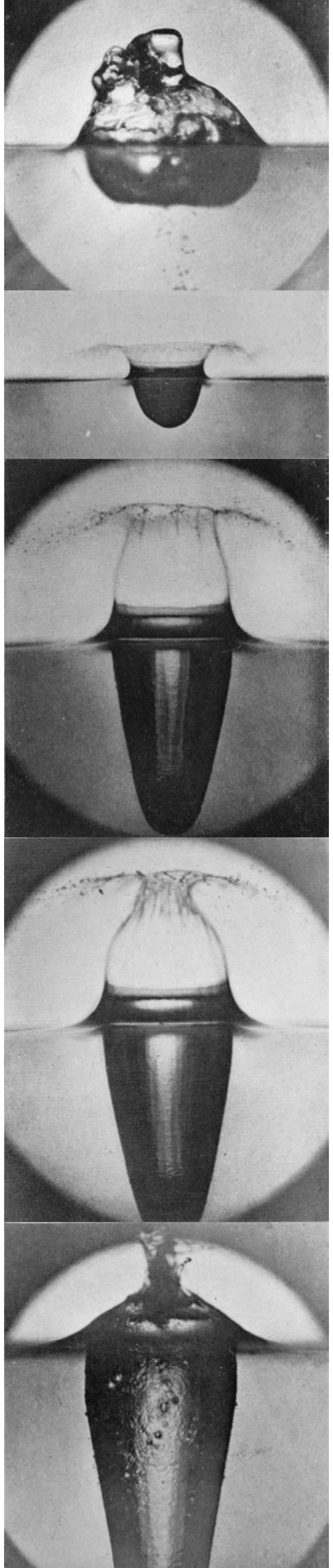

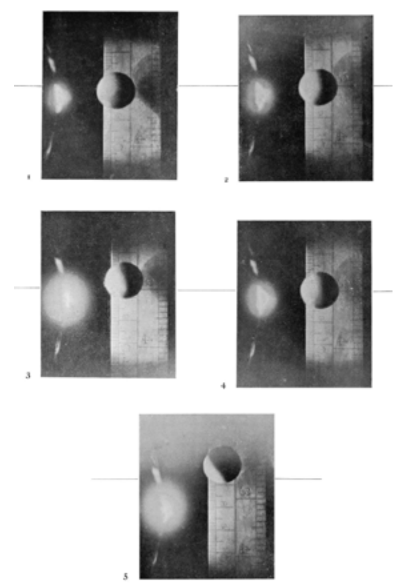

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Author
Sheung Yiu
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Publishing
Sheung Yiu

Proof Reading
Sophie Wright

Design
Joosung Kang
www.joosungkang.com

ISBN 978-952-94-2588-4

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