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Jonas Ferdinand Gabriel Lippmann: The pioneer of color photography or *primus inter pares*

Jonas Ferdinand Gabriel Lippmann, a Luxembourgish-French physicist, is known for the innovation he brought to the color reproduction method in photography and for having produced the first color photographic plate. His method was based on the phenomenon of interference. His discovery enabled the total reconstitution of all wavelengths reflected by an object. Using an emulsion on a mercury surface, which reflects the incident light, both the received light and the reflected light produce standing waves that reproduce the original colors of the photographed object. This method is not practical because long exposure is necessary and no copies can be made. It also has no connection with modern methods. For this work, he was the Nobel laureate in physics in 1908. He was also known for his discovery of heliochromes, microscopic analyses, and of the Lippmann electrometer. In recognition of his work for developing the method of photographically reproducing colors based on the theory of wave interference, Lippmann was appointed Professor of Mathematical Physics at the Sorbonne. Lippmann enriched the field of scientific research with significant contributions to the fields of optics, thermodynamics, photochemistry, electricity, and astronomy.

The inventor of color photography was a member of the French Academy of Sciences in 1886 and was elected as its president in 1912.

1. The life of Lippmann or *lux aeterna*

Lippmann was born on 16 August 1845 in Hollerich, in Hollerich, in the Grand Duchy of Luxembourg. His mother, who was from Alsace, took care of his education, and his father was a tanner in the region of Lorraine. Later, the entire family moved to Paris, where Gabriel received his early education. In 1858, Lippmann followed the “Lycée Napoléon” (today known as Henri-IV). While at the “Lycée”, he was acknowledged for his attention to history, Latin and other languages such as English and German. During this

time at the “Lycée”, he was also interested in philosophy because of his teacher Nourisson. However, his physics teacher, Mr. d’Almeida, gave him a taste of the physical sciences. In 1870, d’Almeida and his friend Marcelin Berthelot had put such science in the service of the motherland. Almeida first proposed using microscopic photographs as a means of correspondence, which allowed the province to correspond with the capital using carrier pigeons. Under the influence of Almeida, Lippmann headed the scientific section of the “École normale” (normal school), which he entered in 1868 at the age of 23. He was only a few years older than his colleagues. He was first admitted to eligibility with good grades in mathematics and physics and a mark of 20 in composition in foreign languages. During these years at the “École normale”, Lippmann became much more interested in his personal scientific research than in his courses. The Deputy Director and Lecturer of Physics, Bertin, was interested by his inquisitive mind as a researcher. Lippmann was particularly interested in the oscillatory discharge of a capacitor. He realized that during this discharge, the current was not uniformly distributed in a straight section of the driver because of the increasing self-induction. This phenomenon is often referred to as the skin effect and plays a large role in the theory of electrical waves and wireless telegraphy. Such topics were not included in the aggregation programs and were thus slightly neglected by Lippmann. Lippmann was also more interested in scientific work, but he did not pass the final examination as a teacher at the “École normale”. He had no degree of worship. *How could one who did not want knowledge for its own sake and was independent of mind-relevant information clear a new area of knowledge?*

Between 1872 and 1875, Lippmann was charged by the French Government with several missions to visit Germany to study methods for teaching science, and he chose to work with Kühne and Kirchhoff in Heidelberg, and with Helmholtz in Berlin. These distinguished German researchers had always shown him the greatest kindness and

became interested in his work. In 1875, Lippmann returned to Paris; at first, he worked at home with a few instruments on loan from the “École normale”, but he subsequently worked at the Sorbonne University. He completed his thesis on electrocapillarity and defended it on 24 July 1875, achieving “summa cum laude” distinction. His thesis was entitled *Relations entre les phénomènes électriques et capillaires*, and Kirchoff served as the doctoral advisor. It must be mentioned that Herman von Helmholtz was also an academic advisor. After this beginning, as a “maître de conférences” (MdC), he was attached to the lab JAMIN until the end of 1878, when “maître de conférences” positions were created in the science faculties. Then, he had a stable position and some means to work. Lippmann remained as MdC until 1883. At that time, the mathematical physics chair became vacant following the death of Briot. Lippmann was then named a professor at the Sorbonne University and head of the laboratory of physics.

Lippmann taught at the Faculty of Science for over 40 years and many French and foreign scholars and students worked in the laboratory of Lippmann, where they produced original studies. One of his more interesting collaborations was with the young Polish student Marie Skłodowska (Curie), as well as with Maurice Couette and Pierre Curie.

Education was a major concern for Lippmann. He repeatedly set out his ideas on this concern in lectures and speeches.

2. Research activities or a success story of the color photography

As a passionate man of science, Lippmann chose to develop his own path in the “jungle” of knowledge and succeeded...

The scientific activity of Lippmann is distinguished by his contribution to several discoveries in physics such as piezoelectricity, time measurements, the coleostat, integral photography and color photography. Both during his time at the school and after leaving the school, Lippmann thought that there might be a relationship between electricity and capillarity. His intensive research led him to develop the capillary electrometer, or “Lippmann electrometer”. Lippmann also stated a theory of pyroelectricity, where crystals such as tourmaline that were subjected to heating or cooling exhibited electrical events at specific locations on their surface. In 1879, in a note entitled “Action magnetism moving about static electricity; inertia of static electricity”, he deduced that a moving magnet exerted a remote mechanical action on an electrified motionless body, and he concluded that static electricity had its own electrical inertia. The permanent color spectrum was obtained based on Zenker's explanation on reflection holography and Maxwell's electromagnetic theory. The Lippmann process, which yields colors, is a method for producing colored photographs of objects without using dyes, which is in contrast to the three-color processes. This method uses a layer of mercury in a special holder behind the photographic emulsion of an orthochromatic or panchromatic glass

plate. The emulsion side of the glass plate faces away from the lens and is in optical contact with the mercury mirror. Light rays that reflect off the mercury layer interfere with the incident light rays and form regular standing waves and latent images at different depths according to the colors. After the development, the film contains a series of layers of silver deposits where the light acted and intermediate places where silver was not reduced. The reflected lights from two layers add together to produce more light only if the two waves are in phase, which occurs when the distance between the layers is half of the wavelength of the light. The film appears with an identical color when it is viewed afterwards from the emulsion side due to the ordinary reflection, whereas the image appears negative due to the transmitted light (because the space between layers is determined by the light that falls on the film). The Lippmann method is a symmetrical two-step process of interference-mediated encoding and diffraction-mediated reconstruction to generate color photographs on a black-and-white medium.

Lippmann was an active member of the Academy of Sciences and its president. Moreover, he was a foreign member of the Romanian Academy, Royal Society of London, and Grand Ducal Institute of Luxembourg. He was a member of the “Société française de photographie” (1892) and its president (1896–1899). Lippmann was one of the founders of the “Institut d'optique théorique et appliquée” in France. In Luxembourg, in his tribute and recognition, the Centre for Public Research – University Center, which was created in July 1987 in Luxembourg City, changed its name on 31 May 1999 to that of Public Research Centre Gabriel Lippmann (1999–2014). However, the Public Research Centre – Gabriel Lippmann later merged with the Public Research Centre – Henri Tudor on 1 January 2015, and formed the Luxembourg Institute of Science and Technology (LIST).

Lippmann was a distinguished man with reserved manners, tender conscience and infinite scruples. His mother was a woman of rare distinction of mind and had a great influence on him. With her remarkable musical gifts, she developed in Lippmann a taste for classical music from childhood. From his father, a tanner, he obtained a sensitive colorist's eye to notice the effects of color degradation. This is the artist physicist! He took extreme pleasure in contemplating the effects of light in landscapes.

Lippmann was passionate about literature: he could recite full acts of plays from the classic French literature and from Shakespeare's ones. He could give a lecture on any novel by Walter Scott. The high culture of Lippmann was further refined in the circles that he frequented after his marriage (1888) to the daughter of Victor Cherbuliez (novelist and author). Miss Cherbuliez was a valuable collaborator and research associate to her husband in the study of colors in photographs; they realized together admirable photographs.

“Life is short and progress is slow,” said Gabriel Lippmann in 1908.

He died on 13 July 1921 while returning from a voyage to Canada. His research continued to live. The intelligence of Lippmann, which was an intelligent integral to fundamental physics, was a revolutionary strategy for progress in engineering and our society. Later, Denis Gabor became a Nobel laureate in Physics (1971) for developing the holographic method, which extended photography in the three-dimensional space. The works of Lippmann and Gabor enabled the evolution of two- and three-dimensional hologram studies by Yuri N. Denisyuk in 1962. A new technique to record Lippmann color holograms was described by Kubota: using three recording wavelengths that correspond to the three primary colors, using a holographic stereogram.

Lippmann, *sanctus sanctorum*, devoid of all ambition, lived only for research, and the idea of drawing some profit from his discoveries never occurred to him. Absorbed in his dream of a scholar, we must admire the disinterestedness of this scientist.

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11	Turbilly, Louis-François-Henri (11 August 1717–25 February 1776), French agronomist. La Tourrette, Marc Antoine Louis Claret de (11 August 1729–1793), French botanist. Bossut, Charles (11 August 1730–14 January 1814), French mathematician. Lowenörn, Paul de (11 August 1751–16 March 1826), Danish scientist. Rey, Jean Alexandre (11 August 1861–25 December 1935), Swiss engineer. Perrier de la Bathie, Marie Joseph Henri Alfred (11 August 1873–2 October 1958), French botanist. Klug, Aaron (11 August 1926), English chemist and Nobel laureate (1982). Carpentier, Alain (11 August 1933), French surgeon. Lions, Pierre-Louis (11 August 1956), French mathematician and Fields medal (1994).
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Klein, Johann Friedrich Carl (15 August 1842–23 June 1907), German mineralogist.
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Montagnier, Luc (18 August 1932), French biologist and Nobel laureate (2008).
Corvol, Pierre (18 August 1941), French medical doctor and biologist.
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25	Camus, Charles Étienne Louis (25 August 1699–4 May 1768), French mathematician. Rathke, Martin Heinrich (25 August 1793–15 September 1860), German embryologist and botanist. Dortet de Tessan, Urbain (25 August 1804–30 September 1879), French scientist. Douzou, Pierre Jules Louis (25 August 1926–19 June 2000), French biochemist. Abiteboul, Serge (25 August 1953), French scientist. Kontsevitch, Maxime Lvovitch (25 August 1964), Russian-French mathematician.
26	Montgolfier, Joseph Michel de (26 August 1740–26 June 1810), French inventor. Lavoisier, Antoine-Laurent (26 August 1743–8 May 1794), French chemist. Cauchy, Augustin Louis [baron] (26 August 1789–23 May 1857), French mathematician. Pouchet, Félix Archimède (26 August 1800–17 December 1849), French biologist. Weiss, Edmund (26 August 1837–21 June 1917), Austrian astronomer. Richet, Robert Charles (26 August 1850–3 December 1935), French physiologist and Nobel laureate (1913).
27	Brugnone, Giovanni (27 August 1741–3 March 1818), Italian veterinarian. Hufeland, Christoph Wilhelm (27 August 1762–25 August 1836), German physicist. Ariès, Louis Marie Joseph Emmanuel (27 August 1846–24 February 1923), French engineer and officer. Righi, Augusto (27 August 1850–8 June 1920), Italian physicist. André, Jean Marie Gustave (27 August 1856–11 May 1927), French scientist. Ciamician, Giacomo (27 August 1857–2 January 1922), Italian photochemist. Ramsey, Norman Foster (27 August 1915–4 November 2011), American physicist and Nobel laureate (1989).
28	Morand, Jean-François-Clément (28 August 1726–13 August 1784), French medical doctor and scientist. Bienaymé, Irénée-Jules (28 August 1796–19 October 1878), French statistician and probability mathematician. Thaxter, Roland (28 August 1858–22 April 1932), American mycologist. Holleman, Arnold Frederik (28 August 1859–11 August 1953), Dutch chemist. Blondel, André Eugène (28 August 1863–15 November 1938), French engineer. Germain, Paul-Marie Alfred Sosthène (28 August 1920–26 February 2009), French scientist.
29	Blane, Gilbert (29 August 1749–27 June 1834), Scottish physicist. Bonpland, Aimé Jacques Alexandre Goujaud (29 August 1773–11 May 1858), French explorer. Leclainche, Auguste Louis Emmanuel (29 August 1861–26 November 1953), French microbiologist. Lacassagne, Antoine Marcellin Bernard (29 August 1884–16 December 1971), French medical doctor and biologist.
30	Schröter, Johann Hieronymus (30 August 1745–29 August 1816), German astronomer. Serret, Joseph Alfred (30 August 1819–2 March 1885), French mathematician. Albrecht, Carl Theodor (30 August 1843–31 August 1915), German astronomer. Carpentier, Jules Adrien Marie Louis (30 August 1851–30 June 1921), French engineer. Van't Hoff, Jacobus Henricus (30 August 1852–1 March 1911), Dutch physicist and organic chemist. Nobel laureate in chemistry (1901). Rutherford of Nelson, Ernest (30 August 1871–19 October 1937), New Zealand physicist and Nobel laureate (1908). Gutton, Antoine Marie Camille (30 August 1872–19 August 1963), French engineer. Glowinski, Jacques (30 August 1936), French biologist and pharmacist.
31	Amontons, Guillaume (31 August 1663–11 October 1705), French physicist. Picault de La Rimbartière, Jean Charles François (31 August 1720–30 April 1757), French scientist. Duhamel, Jean Pierre François Guillot (31 August 1730–19 February 1816), French engineer. Necker, Louis (31 August 1730–31 July 1804), Swiss mathematician. Jean-Pierre-Joseph d'Arcet (31 August 1777–2 August 1844), French chemist. Chevreul, Michel-Eugène (31 August 1786–9 April 1889), French chemist. Heer, Oswald (31 August 1809–27 September 1883), Swiss geologist. Helmholtz, Hermann Ludwig Ferdinand von (31 August 1821–8 September 1894), German physicist. Stephan, Jean-Marie-Édouard (31 August 1837–31 December 1923), French astronomer. Forcrand de Coiselet, Hippolyte Robert de (31 August 1856–20 April 1933), French chemist.