The three physicists

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The three PHYSICISTS

Chris DeWitt, José Edelstein, and Bayram Tekin

Since 1951, the Prize of the Three Physicists has been awarded by the École Normale Supérieure in honor of Henri Abraham, Eugène Bloch, and Georges Bruhat—successive directors of the university's physics laboratory. These are their stories.

As the daughter of two physicists, Bryce DeWitt and Cécile DeWitt-Morette, I was always aware of the profound impact of the Holocaust on the lives of 20th-century scientists. Countless Jewish physicists and mathematicians—Albert Einstein, Lise Meitner, Emmy Noether, Edward Teller, Victor Weisskopf, and Eugene Wigner among them—or those married to Jews, such as Enrico Fermi, had to abandon their native European countries with the rise of the Third Reich. Others, such as Nobel laureate Georges Charpak and Fields Medalist Alexander Grothendieck, were sent to concentration or internment camps—Charpak to Dachau in Germany and Grothendieck with his mother to the Rieucros Camp in southern France.

Many of the physicists who managed to find safe havens nonetheless suffered immeasurably. Nobel laureate Walter Kohn, for example, managed to get out of Austria as a teenager on a Kindertransport, but both of his parents were killed by the Nazis. Other Jews, such as French astrophysicists Évry Schatzman and Jean-Claude Pecker, survived the Holocaust by first fleeing Paris to the unoccupied zone in southern France, known as the "free zone," and then by assuming false identities. But Schatzman's father was killed in Auschwitz-Birkenau, as were both of Pecker's parents.

FIGURE 1. THE PHYSICS LABORATORY of the École Normale Supérieure. Built in 1937, it has undergone several renovations and an expansion. (Photo courtesy of Sébastien Balibar.)

There were also casualties of Nazi barbarism among the families of other prominent scientists. Max Planck's son Erwin was executed for attempting to assassinate Adolf Hitler, and Louis Cartan, the physicist son of Élie Cartan, was beheaded by the Nazis for being in the French Resistance. The tragic cases are countless.

Because of my mother's own experiences during World War II and the bombing of her family home in Normandy on D-Day, my sisters and I were raised on stories about the war and its aftermath. But some war stories are often forgotten, overlooked, or only told on certain occasions in hushed and somber tones. The story told here is one of them. I stumbled on it almost haphazardly because one of the protagonists was the father of my mother's close friend and coauthor, French mathematician Yvonne Choquet-Bruhat.

This is not a story to be relegated to a footnote. The shared tragic fates of French physicists Henri Abraham, Eugène Bloch, and Georges Bruhat deserve to be known. Passionate about their scientific endeavors and teaching—and committed to the future of France—the three men were betrayed by the Vichy government when the pestilence of fascism swept through France.

The three men were successive directors of the famous physics laboratory of the École Normale Supérieure, one of France's most prestigious institutions: The original entrance to the university is shown on page 43, and the facade of the physics lab is shown in figure 1. For more than three decades during the scientific revolutions of quantum mechanics and relativity, first Abraham, then Bloch, and finally Bruhat led the lab. They are known in the French physics community as *les trois physiciens*, the three physicists.[1,2]

Chris DeWitt

University under threat

On 4 August 1944 in Paris, the Gestapo burst onto the campus of the École Normale Supérieure (ENS).[3] Germany's defeat was inevitable at the time, but its leaders were still determined to carry out the "final solution"—the Nazi plan to exterminate the Jewish people—at any cost. They were looking for a literature student suspected of being part of the French Resistance, but the ENS's deputy director, Georges Bruhat, and secretary general, Jean Baillou, refused to divulge his whereabouts.

Five months earlier Bruhat, shown in figure 2, had already been arrested for defending several employees who were apprehended by the Gestapo for having sheltered Allied parachutists in the cellars of the ENS, but he was eventually released. This time the Germans were utterly brutal: They detained the men's wives, Berthe Hubert Bruhat and Aline Baillou, and threatened to kill the women the following day if their demands regarding the student's whereabouts were not met (reference 3, page 274; reference 4, page 71, French ed.). Yvonne Choquet-Bruhat pleaded with the Germans to allow her to take her mother's place, but they refused.

The Gestapo did not carry out its threats against the women, but Georges Bruhat and Jean Baillou were taken just south of Paris to the Fresnes Prison, which the Germans used to hold and torture captured British agents and members of the French Resistance. As the Allied forces approached Paris, the Germans hurriedly killed or transferred their prisoners. One of the last trains out of Fresnes embarked for Germany on 15 August. It was carrying Bruhat and Baillou. Paris was liberated the following week.

Bruhat had no self-pity. He resolutely supported the morale of other prisoners and taught them the physics of the Sun. He was transferred to the Sachsenhausen concentration camp, where the eldest of Joseph Stalin's children was murdered the year before, along with several tens of thousands of mostly political prisoners. Some survivors recounted that in Sachsenhausen, Bruhat gathered a group of students, engineers, and imprisoned officers eager for intellectual activity. But tragically, he became ill with bronchopneumonia and died in the camp hospital on

New Year's Eve when most of France was already liberated. Baillou, who was younger and stronger, managed to survive and return to Paris in the spring of 1945.

Once Bruhat entered the Gestapo's insane machinery, there was no way out. None of his captors knew that this man, weakened by the inhumane conditions of his detention, was a remarkable physicist, a professor revered by his students, and the author of four volumes of a colossal general-physics course— translated into several languages and an obligatory reference work in many European universities. But the story of Georges Bruhat and his fate cannot be told without beginning with those of two other French physicists: Henri Abraham and Eugène Bloch.

The great inventor

Abraham, shown in figure 3, was born in Paris on 12 July 1868; he was the fifth of six children in a Jewish family. He entered the ENS as a student in 1886. Like many French physicists of his day, Abraham began his career by teaching at a prestigious high school, Louis-le-Grand, which is a short walk from the ENS and counts among its alumni such giants as Henri Poincaré, Victor Hugo, and Jean-Paul Sartre. He also taught for a period at the secondary school where he himself had been a student—the Collège Chaptal, which also counts among its alumni Alfred Dreyfus, the French Jewish officer who was falsely accused of treason because of virulent anti-Semitism.

Abraham was interested in Heinrich Hertz's proof of the existence of the electromagnetic waves predicted by Maxwell's equations. In his doctoral thesis, he decided to verify another of Maxwell's predictions—namely, that the propagation speed of the waves must be equal to the ratio of units of electric charge defined in the two unit systems (electrostatic and electromagnetic) then in use. In 1892 Abraham obtained a precise result, within 1% of the results found by J. J. Thomson at the University of Cambridge. At the time, few knew the connection between electromagnetic waves and light. The overall agreement between the two measurements helped confirm electromagnetic theory and placed Abraham, at the age of 24, on the same level as the best experimental physicists of the era. The rest of Abraham's scientific career was devoted to verifications and applications of electromagnetic theory.

In 1912 Abraham became a tenured professor at the University of Paris, and he took over the management of the ENS physics laboratory. His career was interrupted by World War I, during which he was assigned to the military telegraph service with other high-caliber scientists such as Bloch, Bloch's brother Léon, and Léon Brillouin. Working from the ENS, they invented a series of new radio-transmission devices.

Abraham is credited with improving the US's three-electrode lamps by perfecting the technique used to obtain a high and durable vacuum; the lamps were provided to all the Allied armies. Shortly afterwards, he and Eugène Bloch built the first radio amplifiers that used the lamps. They later developed many electronic devices essential to radio-transmission and ultimately the success of the Allied war effort. In addition, Abraham was in charge of the "Walzer apparatus," a remarkable submarine sonar detector that he jointly developed with Charles Fabry and Paul Langevin. For his achievements, Abraham was decorated with membership in the military Legion of Honor.

Abraham was a prodigious inventor and respected teacher. He had a particular interest in recording rapid phenomena. His mastery of vacuum techniques and his use of the newly established intercontinental radio-wave-transmission system to obtain an even more precise value of the speed of electromagnetic waves made him vital to the French scientific community. He served as the secretary-general of the French Physical Society, expanded the ENS physics lab during his tenure, and kept it running during the Great Depression before retiring in 1937. The great inventor was so involved in designing the plans and technical layout of the new lab that the director of the ENS suggested adding an architecture certificate to the long list of Abraham's degrees.

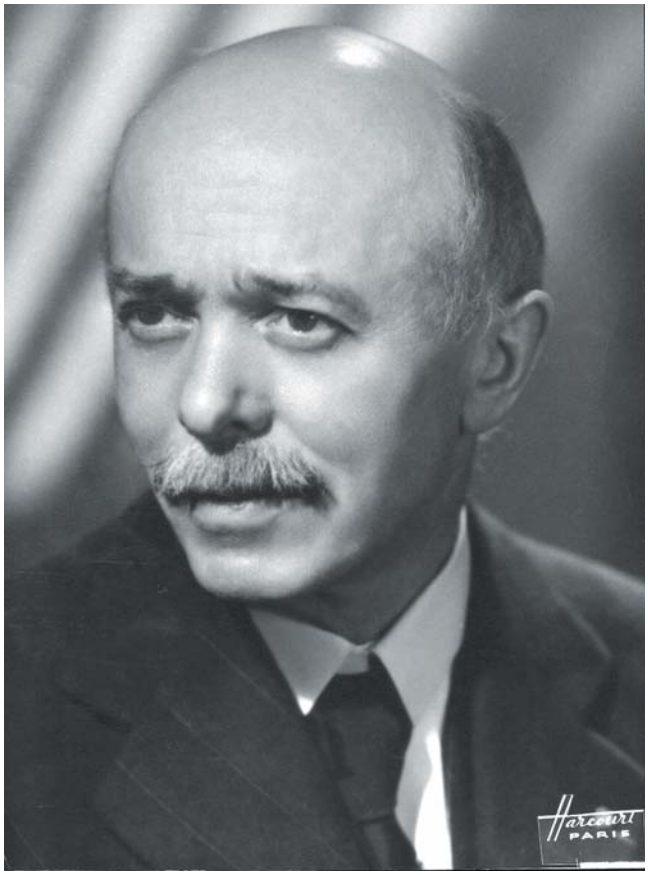

FIGURE 2. GEORGES BRUHAT (1887–1945). This portrait was taken at Studio Harcourt, Paris, circa the 1930s. (Courtesy of the École Normale Supérieure.)

On 1 September 1939 Nazi Germany invaded Poland, and on 10 May 1940 it attacked France and the Low Countries. Abraham left Paris, on orders to follow the technical section of the artillery to Bordeaux. After the June 1940 armistice between Germany and France, he joined his family in Aix-en-Provence. In 1942, German troops moved into the rest of France; Abraham was arrested on the night of 23 June 1943. He was taken to Marseille with his eldest daughter, who did not want to leave her sick father. They were transferred to Drancy, a town northeast of Paris with an internment camp through which most French Jews and other deportees passed before being sent to extermination camps in Germany and Poland. The father and daughter briefly stayed there before being transferred to Auschwitz. On arrival, Abraham was most likely sent directly to the gas chambers.

Under the spell of the quantum

Bloch, shown in figure 4, was born on 10 June 1878, two years after his older brother, Léon, in the small town of Soultz, in

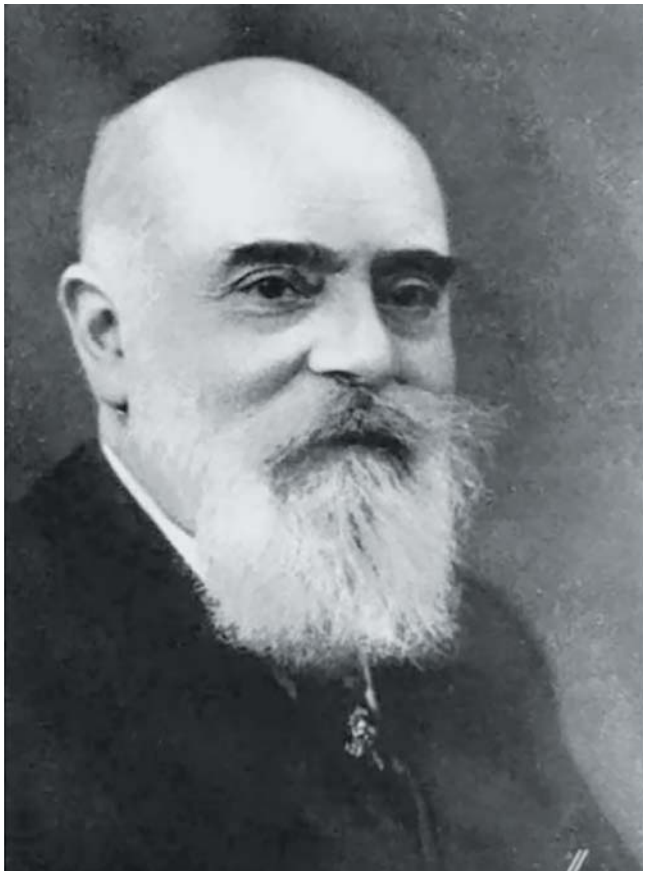

FIGURE 3. HENRI ABRAHAM (1868–1943). This portrait was taken at Studio Harcourt, Paris, circa 1935. (Taken from ref. 1; available on Wikimedia Commons.)

FIGURE 4. EUGÈNE BLOCH (1878–1944). (Courtesy of the École Normale Supérieure.)

Alsace. They were born only a few years after the annexation of Alsace by Germany. Because their father wanted a French education for his sons, he sold his small silk weaving factory and settled in Paris. The two brothers excelled at Louis-le-Grand, the high school where Abraham taught, and they both later entered the ENS. They explored different fields, such as philosophy and botany, before devoting themselves to physics. After being a teacher at the Lycée Saint-Louis for more than a decade—in the middle of which he was assigned to the military telegraph service with Abraham—Eugène became a physics and chemistry professor at the ENS in 1920.

Bloch was a tremendous teacher. He prompted Alfred Kastler to study Arnold Sommerfeld's work in the then-nascent field of quantum mechanics. Bloch's classes were clear and clever. In a 10-year period he wrote four books: on the kinetic theory of gases, on thermionic phenomena, on his applied-physics experience in the military telegraph service, and, most notably, on quantum theory. His early book on quantum mechanics[5] was considered "the bible" among French physicists in subsequent decades.

Bloch carried out his first research in the flourishing arena of atomic physics, in which he focused on the connection between ionization and phosphorescence. That work spurred his interest in ionization produced by UV light—the photoelectric effect discovered by Hertz in 1887. Bloch was one of the first to demonstrate the importance of operating with monochromatic light. His publications of 1908 and 1910 lent support to the theoretical explanation of the photoelectric effect proposed by Albert Einstein in 1905; that theory ultimately earned Einstein the Nobel Prize.

Because of his background in handling UV, Bloch devoted the rest of his career to spectroscopy. Beginning in 1912, he worked to provide precise experimental data for the new quantum theory. With remarkable ingenuity, he developed the first spectrograph with a concave, reflective, and vacuum network that worked from the near-UV down to wavelengths of 20 nm. The tables of wavelengths, made with the spectrograph on 30 chemical elements and their variously charged ions, are still in use.

Bloch succeeded Abraham as director of the physics lab and oversaw the completion of its new building, on which they had both worked, in 1937. Three years later the Vichy regime decreed that Jews could no longer hold public office, and so Bloch had to leave. In October 1941 he and his brother, Léon, quickly abandoned Paris and managed to secretly cross the demarcation line and take refuge in Lyon, which was in the "free zone." They were warmly received by their colleagues in the University of Lyon's laboratory.

Léon wrote a satirical pamphlet addressed to Philippe Pétain, the head of state of the Vichy regime, for which he was arrested. The arrest ultimately saved his life. Eugène, meanwhile, took refuge in different places under a false identity. He unsuccessfully tried to cross the Swiss border and ended up hiding in the mountains. On 24 January 1944, Bloch was arrested by the

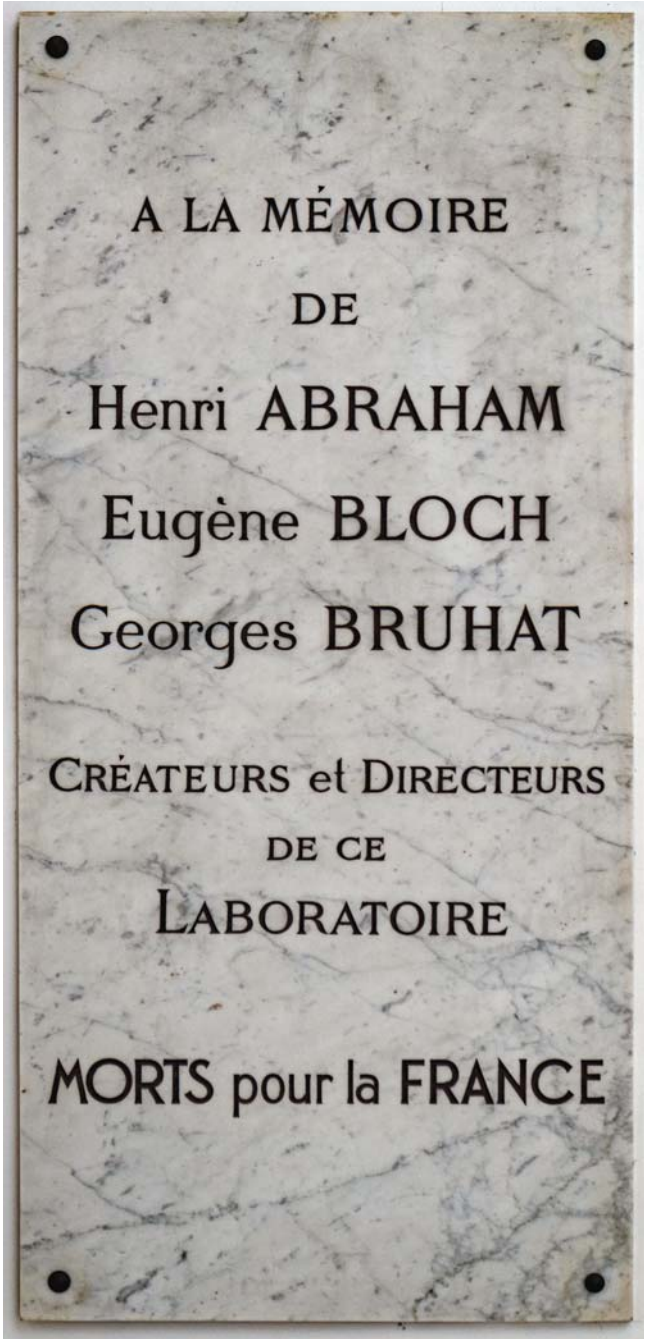

FIGURE 5. A MEMORIAL for the three physicists. The plaque resides at the entrance to the École Normale Supérieure physics lab. (Photo courtesy of Sébastien Balibar.)

Gestapo and sent to Drancy. A few weeks later, he was deported to Auschwitz, where he met the same fate as Abraham.

Master of light

The three founding directors of the ENS physics lab followed each other in age by about a decade. Bloch was born 10 years after Abraham, and Bruhat was born on 21 December 1887, nine years after Bloch. Bruhat entered the ENS in 1906 and completed his doctoral thesis in 1914, shortly before World War I began. While completing his thesis work on the anomalous dispersion of molecular rotatory power under Aimé Cotton, he taught at the Lycée Buffon on Paris's Left Bank. Bruhat entered the French Army in 1915 and received the Croix de Guerre for his contributions to the acoustic detection of cannons.

After the war, Bruhat was appointed to the University of Lille, a few hundred kilometers north of Paris, and he was promoted to full professor in 1921. Shortly thereafter, in 1922, his wife, Berthe, a philosophy professor, gave birth to their daughter Jeanne, and then in 1923 to Yvonne, who also became a physicist. It was not until 1927 that Bruhat obtained a chair in stellar physics in Paris at the Sorbonne. His preference for that area of astronomy led him to write two high-level popularizations, *Le soleil* (The Sun)[6] and *Les étoiles* (The Stars).[7] His son, the mathematician François Bruhat, was born in 1929. Soon after Abraham's retirement, Bruhat became the deputy director of the ENS physics lab under Bloch; and when Bloch was dismissed under the Vichy regime's anti-Semitic laws, Bruhat, who was not Jewish, became the lab's acting director.

Bruhat was a world-class expert in optics and specialized in anisotropic crystalline media, which became important to the development of solid-state physics after World War II. He prepared various experiments with circularly polarized visible and UV light and studied phenomena such as circular dichroism and birefringence by compression. Bruhat was interested in thermodynamics. And despite being an experimentalist, he was also an accomplished theorist. In 1926 he was awarded a prize from the Becquerel Foundation for his work in theoretical physics.

In addition to his important contributions to different fields of physics, Bruhat left a precious legacy to the scientific community. He was a prolific writer of textbooks, and in the span of a decade he wrote a four-volume treatise covering electricity (1924), thermodynamics (1926), optics (1930, with the sixth edition published in 1965 by Kastler), and mechanics (1934). Together, they constituted his course in general physics. The optics book, undoubtedly the most complete, continues to serve as a reference for many aspects of experimental optics. French physicists still regard those volumes as among the most important books in their education; they simply call them les Bruhats.

In the summer of 1944, ENS director Jérôme Carcopino, who had collaborated with the Vichy regime, decided to flee Paris in anticipation of the arrival of the Allied forces. He put Bruhat, then deputy director of the ENS, in charge of the ENS. And that's why Bruhat was confronted by the Gestapo about the whereabouts of the literature student. Bruhat's daughter Yvonne never got a chance to say goodbye to her beloved father (private communication with Chris DeWitt).

Bruhat's family held on to hope that he would eventually return home. Yvonne continued with her studies while trying to obtain information about her father's whereabouts. Because she was Catholic at the time, she turned to the chaplain of the ENS for assistance. The chaplain asked, "Your father, was he a practicing Catholic?" When Yvonne responded that he was not, the chaplain said, "Well then, I will pray for him" (reference 4, page 72, French ed.). It was not until the spring of 1945 that the new director of the ENS informed the family that Georges Bruhat had eventually succumbed to the filth and disease of the concentration camp.

Le prix des trois physiciens

In the first few years after World War II, the fate that had befallen the three physicists went virtually unmentioned. In

particular, few acknowledged Bruhat's selfless and courageous refusal to cede to Nazi demands. The silence was due, at least in part, to the fact that in the war's aftermath, the French placed everyone into three categories: members of the Resistance; Jewish victims of the Holocaust; or reviled collaborators.

But Bruhat did not fit neatly into any of those categories, and some people even spread rumors that because he had not joined Charles de Gaulle in the UK, he must have been a Nazi collaborator. That was false, of course. He had felt a duty to remain in Paris to keep the lab running and to help students escape the Nazis and find jobs under assumed names. Like Abraham and Bloch, he paid with his life.

To rectify the void in history and to honor the three great physicists, Hélène Bloch, Eugène's widow, provided seed money for a prize known simply as le prix des trois physiciens, "the prize of the three physicists." Inaugurated in 1951, it is awarded annually (and primarily) to physicists affiliated with the ENS. For recipients, the prize is considered not only recognition that one's work has been of great value but also a treasured jewel within the ENS family. Indeed, the laureates regard the prize as more than an award of great respect; they see it as a legacy to carry forward in the fight against present-day elements of racism and fascism.

Beginning with Jean Cabannes in 1951, the laureates have included J. Robert Oppenheimer in 1958; Nobel laureates Louis Néel in 1963, Claude Cohen-Tannoudji in 1986, and Walter Kohn in 2002; Edith Falgarone in 2018; and, most recently, Vincent Hakim in 2019. (The full list is available at www.phys.ens.fr/spip.php?article2180.)

To commemorate the three physicists, the ENS has installed a plaque (see figure 5) at the entrance to the physics lab, which each of them had helped design or build. It is meant to remind ENS students that the three physicists represented the very best of France. The three men were united in death as they were in life. Their lab stands today as the product of their mutual accomplishments and as a reminder of the Nazis' brutal crimes against humanity.

The idea for this article originated from conversations one of us (DeWitt) had with Jean-Claude Pecker and Yvonne Choquet-Bruhat to whom this article is dedicated. We are grateful to Sébastien Balibar and Christophe Salomon, both physicists of the École Normale Supérieure, and to Daniel Choquet, the grandson of Georges Bruhat and son of Yvonne Choquet-Bruhat. Without their valuable assistance, this article would not have been possible.

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