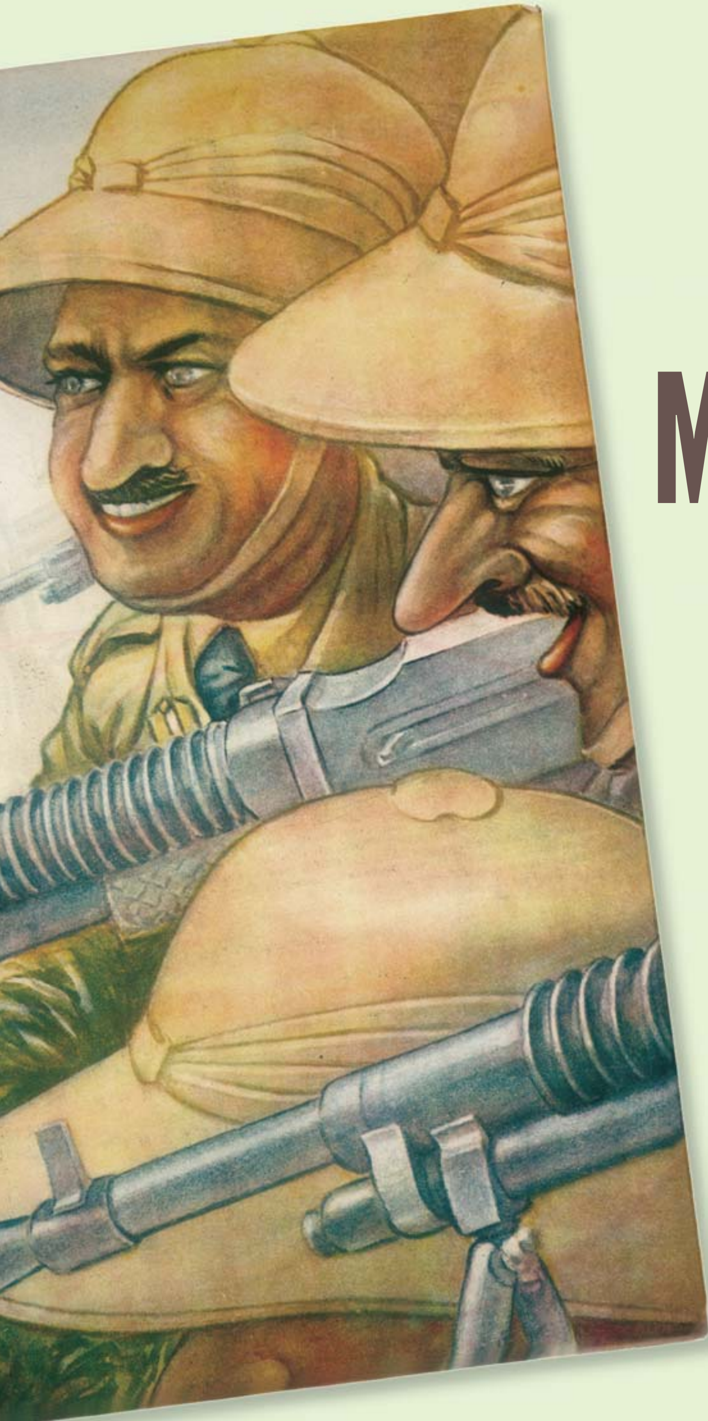
THE 1919 BRITISH MASSACRE of civilians in the Amritsar district of northwestern India became a catalyst for action against colonial rule. The incident, wrote Indian physicist Meghnad Saha in horror, "degraded us before the whole world." This World War II–era propaganda poster was meant to foment resistance to British rule. (Courtesy of King's College London.)



Soma Banerjee is an assistant professor of history at the University of Idaho in Moscow.

MEGHNAD SAHA: Physicist and nationalist

Somaditya Banerjee

Deeply committed to the cause of Indian independence, Saha occasionally detoured from his physics to conduct a revolutionary mission or pen a populist manifesto.

Meghnad Saha (1893–1956) was an Indian physicist who did much of his work in the last decades of British colonial rule. In the 1920s he made important contributions to the theory of thermal ionization and its application to stellar spectra. He would continue to be a leader in modern physics in colonial and postcolonial India and to earn international renown. His story is particularly noteworthy for at least two reasons. First, he was born in an obscure village in Bengal, to a lower-caste family with no educational background; he had to work hard to transcend the stereotypes associated with his social status. Second, he saw his work as facilitating the process of decolonization, a goal that was finally achieved with the Indian Independence Act of 1947.

Norwegian astrophysicist Svein Rosseland, in the introduction to his well-known *Theoretical Astrophysics: Atomic Theory and the Analysis of Stellar Atmospheres and Envelopes* (Clarendon Press, 1936), remarked on the importance of Saha's contributions:

> Although Bohr must thus be considered the pioneer in the field [of atomic theory], it was the Indian physicist Megh Nad Saha who (1920) first attempted to develop a consistent theory of the spectral sequence of the stars from the point of view of atomic theory. . . . The impetus given to astrophysics by Saha's work can scarcely be overestimated, as nearly all later progress in this field has been influenced by it and much of the subsequent work has the character of refinements of Saha's ideas.

Early life

Saha was born in 1893 in Seoratali, in the Dacca (now Dhaka) district of what is now Bangladesh. He was the fifth of eight children born to Jagannath Saha, a poor shopkeeper, and his wife, Bhubaneshwari Devi. His elder brother failed in high school, so his father decided that Meghnad and his brother should work at selling groceries. However, Meghnad's mother and uncle intervened and allowed him to continue his high school education. In 1905 he went to the city of Dacca where, in preparation for college, he attended the Government Collegiate School with a full scholarship. It was an eventful year in the history of India: George Nathaniel Curzon partitioned Bengal into Muslim-majority East Bengal (which included the Dacca district) and Hindu-majority West Bengal. That event sparked off a nationalist movement manifested by protests all over Bengal. When the British lieutenant governor of Eastern Bengal and Assam, Joseph Bampfylde Fuller, visited Dacca, the citizens there organized a boycott. All students who participated in the protests—Saha among them—were expelled. As a consequence, he lost his scholarship; his brothers helped him survive.

FIGURE 1. DACCA COLLEGE as it was in 1904, a few years before Meghnad Saha arrived there. (Photograph by Fritz Kapp.)

In 1911 Saha graduated from Dacca College (shown in figure 1) with the equivalent of a US high school degree. He ranked first in physics and mathematics but third in the whole intermediate science examination. He then joined Presidency College at the University of Calcutta, where he worked toward a bachelor's of science degree in mixed mathematics, which he received in 1913. While at Calcutta, Saha boarded at the Eden Hindu Hostel (see figure 2), which was college housing. There he experienced painful discrimination because he belonged to the *shudra*, the lowest tier of the Indian caste system. The system was particularly problematic in the early 20th century in India; unfortunately, prejudice persists in parts of the country even today. When Saha was at the Eden Hindu Hostel, some students objected to eating in the same dining hall with him because of his caste status. Some Brahmins (the highest, priestly caste) also prevented him from making an offering to the goddess of learning, Mother Saraswati.

Saha and Satyendra Nath Bose (of Bose–Einstein fame) were classmates at Presidency College, whose faculty included the well-known chemist and entrepreneur Prafulla Chandra Ray, internationally acclaimed physicist cum plant physiologist Jagadish Chandra Bose (see figure 3), and famous mathematician Devendra Nath Mallik. Those mentors at Presidency inspired Saha to use science as a tool to promote nationalism and revive ancient India's intellectual past. In an example of the spirit of the times, J. C. Bose, in his 1902 book *Response in the Living and Non-Living*, linked nationalism and science and dedicated the work "to my countrymen, who will claim the intellectual heritage of their ancestors."

Saha's transition from graduate student to professional physicist was a remarkable process. Several unforeseen events—for example, a departmental transfer and the opportunity to teach a graduate seminar—helped him get acquainted with the latest research in theoretical physics. European scientific literature was limited, and few advanced books were available in Calcutta (now Kolkata) libraries due to World War I. Fortunately, Saha got help from Paul Johannes Brühl, an Austrian scientist at the Bengal Engineering College who provided him with an English translation of the *Treatise on Thermodynamics* by Max Planck and *Die theoretischen und experimentellen Grundlagen des neuen Wärmesatzes* (*The New Heat Theorem: Its Foundation in Theory and Experiment*) by Walther Nernst. In addition, Saha read *A History of Hindu Chemistry from the Earliest Times to the Middle of the Sixteenth Century A. D.*, written by his mentor Ray, and also familiarized himself with papers by Niels Bohr and Arnold Sommerfeld on the quantum theory of the atom.

The scientist

At Presidency College, Saha learned the German language from a chemist who had returned from studies in Vienna. He could hardly have expected to use his German skills in Bengal, but he nonetheless judged the effort spent learning the language as valuable in itself. He earned the nickname *Eigenschaften* ("attributes"), in part for his knowledge of German. Ultimately his effort paid off: In 1919, when he was a professor of physics at the University of Calcutta, he and S. N. Bose published the first English translation of Albert Einstein's and Hermann Minkowski's papers on relativity (figure 4 shows the title page). British astronomer Arthur Eddington had just experimentally verified the theory, and Einstein became a scientific celebrity overnight.

In that same year, Saha began examining the contradictions that emerge when the classical theory of light is used to explain such astrophysical phenomena as solar prominences, the corona, and particularly the constant changes that keep a comet's tail always pointing away from the Sun.[1] He was aware of James Clerk Maxwell's result that the pressure light exerts on

FIGURE 2. EDEN HINDU HOSTEL was Meghnad Saha's home from 1911 to 1913, while he was studying at Presidency College, Calcutta. (Photograph by Biswarup Ganguly.)

material bodies is equal to the intensity divided by the speed of light. But he also recognized that Maxwell's result applied only to obstacles whose dimensions were larger than the wavelength of light. Because atoms were much smaller than light waves, it followed that they experienced no radiation pressure and, therefore, the mystery of the comet's tail pointing away from the Sun remained unanswered.

Saha explained the cometary phenomenon by invoking the energy and momentum of light quanta and noting that pressure is exerted only if the atom is capable of absorbing the radiation. He observed, for example, that in absorbing a pulse of light corresponding to the hydrogen α line, a hydrogen atom would receive an impulsive velocity kick of 60 cm/s. In a subsequent work he remarked,

> Suppose a continuous spectrum from a bright background passes through a layer of gas. Then the gaseous atoms will be acted upon by only those pulses of light in the continuous spectrum, which the gas is itself capable of emitting and absorbing. If, for example, the gas be composed of Sodium atoms; then only radiant energy contained in the spectral regions about the D_1, D_2-lines and sometimes the other lines of the principal series will act upon the Na-atoms. The remaining part of the continuous light will be without action on the Na-atoms. . . . Regarded from this point of view, the theory may properly be styled *as the theory of Selective Radiation-pressure*.[2]

Also in 1919 the *American Astrophysical Journal* published Saha's "On selective radiation pressure and its application," which sketched out the argument for what is now called the Saha equation.[3] The next year his theory of thermal ionization gave new insights about the interior of the Sun and stars, chemical compositions and elemental densities in stars, and surface gravitational forces.[4] During that time Saha used the quantum theory of light and Bohr's atomic theory to show that the repulsive forces experienced by stellar atoms could indeed be associated with radiation pressure. His theory predicted the spectral lines of some elements that would be found only in relatively low-temperature regions of the Sun. He also derived his famous equation for the relative number of atoms N_i with i electrons removed as a function of temperature T:

$$\frac{N_{i+1}}{N_i} = \frac{2Z_{i+1}}{n_e Z_i}\left(\frac{2\pi m_e kT}{h^2}\right)^{3/2} e^{-\chi_i/kT}.$$

Here, n_e is the number density of electrons, Z_i the degeneracy of the ith ionization state, and χ_i the energy required to remove the $(i+1)$st electron. The remaining terms are fundamental constants: the mass of the electron, Planck's constant, and Boltzmann's constant. The Saha equation allows the degree of ionization of any element to be calculated, which enables a more quantitative accounting of astrophysical spectra.

Saha anticipated the Compton effect by several years with his invocation of a light pulse with frequency ν and energy $h\nu$ giving an impulsive kick to an atom that absorbs it. Many physicists in Europe were skeptical about the light quantum before the Compton effect, whose discovery is often seen as a seminal event in physics.[5] Saha, however, effectively used the quantum to explain astrophysical phenomena such as comet tails. His work in ionization theory had a long-lasting impact on astrophysics because it changed astronomical spectroscopy from a qualitative tool for the classification of stars to a precise technique for quantitative measurements.[6] In honor of that work, in 1927 Saha was elected as a fellow of the Royal Society of London. Figure 5 is an image of Saha at about that time.

The nationalist

During his studies at Presidency College, Saha came into contact with the militant nationalists of Bengal, including Subhas Chandra Bose and Sailen Ghosh. Because of the clandestine nature of the militants' activities, historians have yet to thoroughly examine the extent to which Saha was involved with them. Bengali nationalists drew much of their inspiration from a parallel struggle for independence in Ireland and from the Irish revolutionary Sinn Fein party, which became an important model for them. Of all European nations, Ireland was perhaps most keenly interested in India's independence. Irish revolutionaries, with German assistance, had set up several

FIGURE 3. MEGHNAD SAHA'S MENTOR Jagadish Chandra Bose occupies the center seat in this group portrait. Saha is the leftmost seated figure. (Courtesy of the AIP Emilio Segrè Visual Archives.)

underground organizations during World War I. And, as Michael Silvestri has convincingly argued, "the Irish experience provided [for the Bengali nationalists] a heroic model of anticolonial resistance, as well as what seemed to be a blueprint for national liberation."[7]

Sinn Fein was a successful model for the Bengal nationalists mainly because it faced the same enemy—the UK, the country that colonized their nations for years. The Irish Nationalist Party in many ways resembled the Gandhians—supporters of Mahatma Gandhi's philosophy of nonviolence—who sought home rule by means of constitutional reforms. But the United Irishmen group that originated from the Sinn Fein movement had similarities with the radical Indian groups Anushilan Samiti and Jugantar, with whom Saha was associated. Daniel Breen's book *My Fight for Irish Freedom* (Talbot Press, 1924)—also called "the revolutionaries' manual"—was proscribed by the Bengal government because Breen was one of the originators of the Irish Volunteers and later a leader of the Irish Republican Army. Importing the book into India was prohibited by the government under the Sea Customs Act.

As a result of his involvement with revolutionary groups and individuals who advocated armed resistance, notably Jatindra Nath Mukherjee (better known as Bagha Jatin) and Pulin Das, the young Saha had to deal with many difficulties imposed by the colonial government. It was rather unusual in colonial India for a physicist to be so closely involved with the revolutionary movement.

Saha's commitment to the cause is illustrated by the following tragicomic incident that took place in 1915. Anushilan Samiti, it turns out, had close ties with the Ghadar Movement organized by Indian revolutionaries abroad in San Francisco and Canada. A few Berlin-based members of Ghadar informed Bagha Jatin that Germany's Kaiser Wilhelm II was sympathetic toward the Indian nationalists and that Germany was willing to supply arms to them. A joint Indo–German organization known as the Indian Revolutionary Committee was set up in Berlin to coordinate the international effort. Bagha Jatin was informed that the kaiser was sending weapons to Anushilan Samiti on a ship, the *Henry*, that would voyage from Singapore to the Philippines to the coast of Sunderbans in south Bengal.

Saha and Jadu Gopal Mukherjee were assigned the task of picking up the weapons from the vessel. However, on 2 June 1915 the *Henry* arrived in Shanghai, which was under British and French occupation, and all its arms were seized. On 22 June the ship was returned to Germany and never made it to the Sunderbans; Saha came back from his mission empty-handed.

Not only was 1919 a remarkable year in Saha's scientific career, it was also a significant year in the history of Indian nationalism. In 1919, to suppress revolutionary activities in the aftermath of World War I, the controversial Rowlatt Act was passed by the British government and authorized by British judge Sidney Rowlatt. The purview of the act was vast. Anyone could be arrested without a warrant and without the right of appeal, suspected revolutionaries could be detained without arrest, and individuals could be denied open trials and freedom of movement.

The Rowlatt Act sparked protest all over India, particularly in Bengal in the east, which was a hotbed of nationalism, and Punjab in the north, where revolutionary ferment was the most extreme. In the wake of the act, Gandhi launched the Satyagraha—a movement of passive resistance that rapidly gained momentum in several towns. The colonial government dealt strongly with the Indian backlash by imposing martial law wherever possible.

On 13 April 1919, a massacre took place in Jallianwala Bagh, a public garden in Amritsar, Punjab (see the poster on page 38). British Colonel Reginald Dyer ordered his troops to open fire on an unarmed crowd protesting against the deportation of nationalist leaders Satya Pal and Saifuddin Kitchlew. Saha remarked later how he felt about the tragedy:

> Everyone in our great country who has his own interest and that of his fellowmen at heart must have felt extremely grieved, nay shocked at the diabolical outbreak . . . leading to violence and large scale massacre of innocent people, which have disfigured the history of this country at this present momentous epoch. These incidents have degraded us before the whole world and have rendered the prospects of a peaceful betterment of conditions of living for the common man in this country an extremely remote one.[8]

Traumatized by the ongoing violence, Saha took respite in thermodynamics, spectroscopy, and quantum theory. Physics provided him a means to focus away from the depressing situation of colonial India and to contribute to the nation.

Science and Culture

Saha's writings on river management, railway reconstruction, India's need for power development, and more showed a distinct cultural awareness not shared by many of his colleagues. Science for the nation and for national liberation were major motivations for him throughout his life. In 1931 Saha founded the Academy of Sciences of the United Provinces of Agra and Oudh (later India's National Academy of Sciences). At the opening ceremony, he gave an address in which he reflected on the pros and cons of scientific power as seen through the lens of the destruction from World War I. He became president of the academy in 1932.

The humanizing influence of science was another important motivation for Saha. Two years after assuming the presidency of the academy, he helped establish the Indian Science News Association.[3] With the help of the association, he founded the journal *Science and Culture*, which he edited until his death in 1956. The purposes of the new journal, modeled on the prestigious British science journal *Nature*,[9] were to highlight the social function of science and to combat ignorance by disseminating science to a wide public. The journal, Saha hoped, would interpret science in nontechnical language, present new scientific concepts, and advocate the planned application of science to India's problems. That approach would synthesize humanist and cultural elements, cover the interests of people without regard to caste and class hierarchies, and allow for critical evaluations of specific government policies.

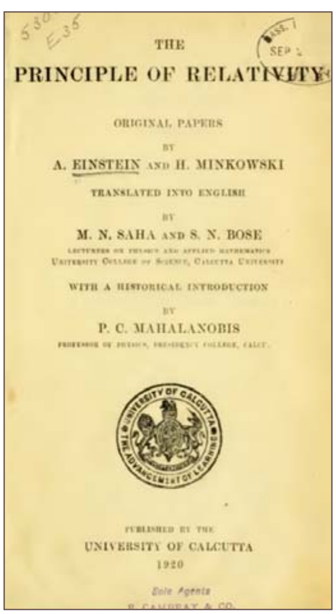

THE
PRINCIPLE OF RELATIVITY
ORIGINAL PAPERS
BY
A. EINSTEIN AND H. MINKOWSKI
TRANSLATED INTO ENGLISH
BY
M. N. SAHA AND S. N. BOSE
LECTURERS ON PHYSICS AND APPLIED MATHEMATICS
UNIVERSITY COLLEGE OF SCIENCE, CALCUTTA UNIVERSITY
WITH A HISTORICAL INTRODUCTION
BY
P. C. MAHALANOBIS
PROFESSOR OF PHYSICS, PRESIDENCY COLLEGE, CALCUTTA
PUBLISHED BY THE
UNIVERSITY OF CALCUTTA
1920
Sole Agents
R. CAMBRAY & CO.

FIGURE 4. ALBERT EINSTEIN'S AND HERMANN MINKOWSKI'S papers on relativity were made available in India in this English translation by Meghnad Saha and Satyendra Nath Bose.

Science and Culture debuted in June 1935. Its first volume, which emphasized new science, included four articles by Saha offered as unsigned editorials. "Ultimate constituents of matter" discussed recent advances in nuclear physics, including Bohr's atomic model and developments in radioactivity. In "The march towards absolute zero" Saha pondered postdoctoral work on thermodynamics and statistical mechanics he had done in Germany in Nernst's lab. "The existence of free magnetic poles" dealt with theoretical speculations of British physicist Paul Dirac about the possibility of an isolated magnetic pole. And "Spectra of comets," on the subject of Saha's own early astrophysics research, described how observations of the spectra of comets could explain the solar spectrum.

Through *Science and Culture*, Saha became an outspoken critic of the Indian government's science policies, especially those espoused by Jawaharlal Nehru, prime minister of India after independence. Saha felt that Nehru was in too much of a hurry to establish a scientific and industrial base and that Nehru's elitist approach did not take into consideration India's prevailing culture. Nehru was a visionary, but he did not have the scientific expertise that Saha possessed. Moreover, Saha's humble background—so unlike Nehru's—afforded him a deeper understanding of the requirements of the common people.

For example, as early as 12 August 1945, Saha wrote to Nehru concerning the Indian National Congress, the political party of Gandhi, Nehru, and other important nationalists,

> If you have not chosen a subject [for an upcoming lecture at the University of Calcutta], I would suggest 'National Planning'.
>
> I believe the time has come when the Congress should formally announce their programme of work in case they get power. Its present programme is too much tied up with old world ideologies—like spinning wheel and homespun, division of power on medieval basis etc. etc. We should give to the country new slogans based on the idea of working up 'a decent living for India's masses' based on the fullest use of science, development of power resources, chemical, mineral and agricultural industries, collective and multipurpose use of land and water, rebuilding of society on the new basis of work.[10]

Saha's pragmatic critique of the Indian National Congress highlighted the jettisoning of "old world ideologies" and emphasized the use of science, technology, and planning for improving the condition of "India's masses"—the non-elites and subaltern sections of society. Through his science, Saha made a transition from a lower-caste and lower-class individual to a member of India's intelligentsia—the *bhadralok*. Nonetheless, he felt for the masses and emphasized their needs whenever he had the chance.

Consequently, Nehru and Saha disagreed frequently, and Saha became unpopular with the prime minister. The friction in their relationship contrasted with the congeniality that existed between Nehru and Indian scientists Homi Bhabha, Shanti Swarup Bhatnagar, and Chandrasekhara Venkata Raman. Years before his letter to Nehru, in 1938 Saha persuaded Subhas Chandra Bose, the president of the Indian National Congress, to create the National Planning Committee to scientifically plan the nation's reconstruction. The bitterness in the relationship between Saha and Nehru culminated when many of the committee's recommendations were later ignored or overturned.

Academic innovations fared better. The Palit Research Laboratory, Saha's lab at the University of Calcutta, conducted many experiments in nuclear physics and instrumentation; his nuclear research program was the first of its kind in an Indian academic institution. By 1940 Saha's efforts had helped make nuclear physics part of the graduate curriculum at the university.

In 1941, as World War II raged, Saha began to establish a nuclear institute that was to be independent of universities. His student Basanti Dulal Nag Chowdhuri had worked with Ernest Lawrence in Berkeley, California, and on his return constructed a cyclotron at the University of Calcutta. Saha's new facility was also to have a cyclotron, to go with its other state-of-the-art scientific equipment. With the patronage of Jehangir Ratanji Dadabhoy Tata, in 1949 Saha founded the Institute of Nuclear Physics in Calcutta. The institute (now the Saha Institute of Nuclear Physics) became fully functional by 11 January 1950—designated as Foundation Day—at which time it was formally inaugurated by Irene Joliot Curie.[11]

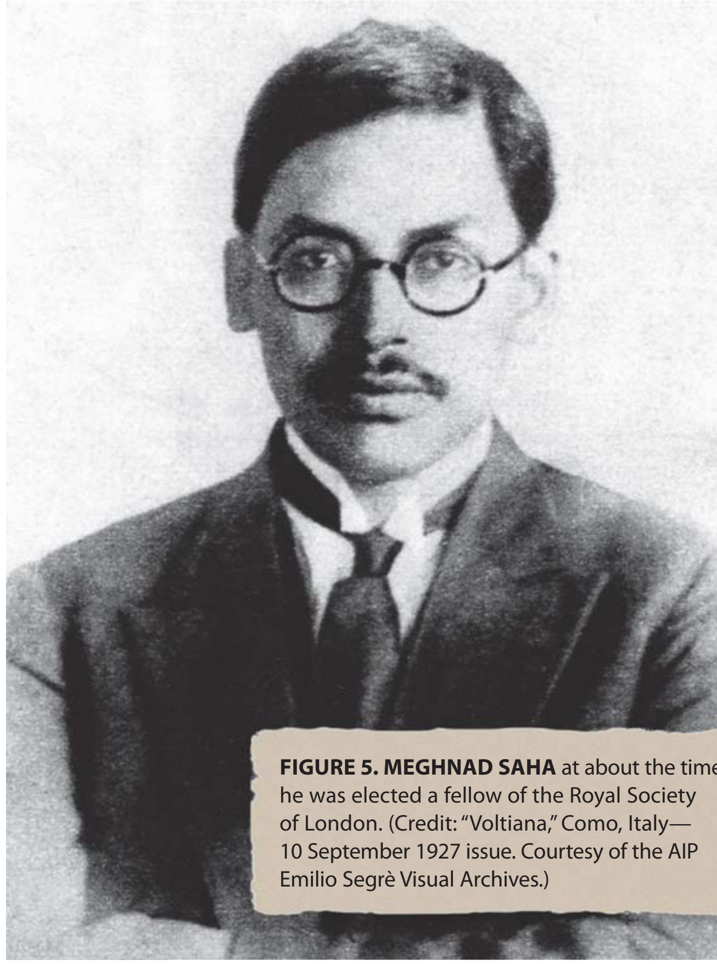


FIGURE 5. MEGHNAD SAHA at about the time he was elected a fellow of the Royal Society of London. (Credit: "Voltiana," Como, Italy—10 September 1927 issue. Courtesy of the AIP Emilio Segrè Visual Archives.)

Coda

Saha's life reflected a dynamic not found in the lives of such distinguished contemporaries as Raman and Bhabha. He came from a poor, lower-caste, uneducated family and was involved in the revolutionary movement. Nonetheless, he established himself as a member of the *bhadralok*: He was a professional physicist who made remarkable contributions to his field and popularized science with the Indian masses in late-colonial and postcolonial India.

Saha's perception of the natural world could not be easily disentangled from his perception of the social world. In his early life, he was singled out and discriminated against due to his caste. Those episodes may have caused him to identify with the tail of the comet: As the tail is an extension of the main body of the comet, Saha considered himself to be set apart from the main body of society. The setbacks in his early life resonated in physical "kicks" of light and "selective" radiation pressure.

Saha's nationalism was manifest by his close association with the Bengal revolutionaries who, unlike the nonviolent Gandhians, argued for armed resistance against the British for national liberation. The social and intellectual milieu in which Saha was raised significantly influenced his career. It is perhaps appropriate, then, that his most significant scientific successes—including the Saha equation—were important milestones in the unfolding of quantum mechanics. And it is surely significant that he used science to promote a spirit of nationalism in colonial India and a distinct national identity that includes modern physics.

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