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Physics in Perspective

Book Reviews

István Hargittai, *The Martians of Science: Five Physicists Who Changed the Twentieth Century*. Oxford: Oxford University Press, 2006, xxiv + 313 pages. $34.50 (cloth).

George Marx, late chair of atomic physics at Eötvös University in Budapest, published a book, *The Voice of the Martians* (1994, third revised edition 2001),[1] in which he described the achievements of twenty Hungarians who made an astonishing number of contributions to science and mathematics between about 1914 and about 1960. The extraordinary number of prizes, including nine Nobel Prizes, these Hungarian scientists and mathematicians received is a puzzling statistic, especially when one considers that the population of Hungary was (and still is) less than ten million.

The Hungarian physical chemist István Hargittai has reduced the number of Martians he discusses in the book under review here to five, arguably the most prominent of Marx's larger group: Theodor von Kármán (1881–1963), Leo Szilard (1898–1954), Eugene Wigner (1902–1995), John von Neumann (1903–1957), and Edward Teller (1908–2003). Von Kármán's contributions to aerodynamics, Szilard's and Wigner's to nuclear physics, quantum mechanics and thermodynamics, von Neumann's to the mathematical foundations of quantum mechanics and computational logic, and Teller's to nuclear physics, including the construction of the hydrogen bomb, are all legendary.

The social status of the parents of Hargitai's five Martians were typical of the educated and well-to-do Jewish middle class. They thought of themselves as Hungarians first and Jews second; they were completely assimilated into Hungarian culture and were economically secure. Their sons all received their primary and secondary educations in Budapest, and all except von Neumann received their doctorates in Germany; von Kármán received his in Budapest but then became a Lecturer (*Privatdozent*) in Berlin. All five emigrated to the United States and after the outbreak of World War II became involved in war-related research, von Kármán at Caltech, the others on the Manhattan Project.

There are several versions of the origin of the myth of the Martians, but the one I like best is found on the first page of Francis Crick's 1982 book, *Life Itself*. Enrico Fermi once wondered, given the enormous number of suns in the universe with planets orbiting around them, why some exceptional and highly intelligent extraterrestrials seem to have overlooked the beautiful Earth to visit. Leo Szilard apparently responded instantly: "They are among us, but they call themselves Hungarians."[2] Indeed, Edward Teller was proud of his initials ET.

When I first looked at Hargittai's book, I wondered why he had decided to write another book on the Martians. He refers to Marx only once (pp. 21–22), albeit quoting him at length in connection with Marx's attempt to explain the Hungarian phenomenon by pointing to their common cultural and educational backgrounds. Marx specifically mentions two influences, the long and ongoing political instability that produced special survival skills, and their Jewish culture, which gave them the advantage of "handling the rapid changes of historical eras." In any case, the story of the Martians, whether Marx's many or Hargittai's few, is a magnificent intellectual tale and tribute to the human spirit that bears retelling.

I found Hargittai's book to be generally well-written, engaging and informative, albeit a little long and often dense and too detailed. While its content overlaps a great deal with Marx's book, Hargittai's is more thorough and wider ranging because it has a well-defined story line, a good treatment of details, and better coverage of the relationships among his five Martians, all of whom had similar educational and cultural backgrounds and exerted an enormous collective impact on science and history while working, often in close collaboration, in the United States. To qualify for inclusion in his group, Hargaittai declares that "one needed to have experienced a turning point in Germany to be among the great pioneers of physics (or to be with Prandtl of aerodynamics, in von Kármán's case). However, this was only necessary, not sufficient. Eventually, they all became deeply involved in the defense of the Free World." (p. 44) While Marx knew most of his Martians personally, as well as Niels Bohr, Werner

Heisenberg, Max Born, and many others, Hargittai, being of a younger generation, met only Wigner and Teller after their prime, although he also interviewed family members of his other Martians.

The first five chapters of Hargittai's book are entitled Arrival and Departure, Turning Points in Germany, Second Transition: To the United States, "To Protect and Defend": World War II, and To Deter: Cold War. In each of the last four, he discusses, in chronological order by year of birth, the life and work of von Kármán, Szilard, Wigner, von Neumann, and Teller. He follows these with a sixth chapter entitled Being Martian and an Epilogue. I will discuss the highlights of the lives and work of Hargattai's five Martians under the headings of Hungary, Germany, United States, Manhattan Project, and Postwar.

Hungary

Theodor von Kármán's father was a reformer of the Hungarian secondary-school system who redirected the control of education from a Church-centered to a secular system, and established the Minta Gymnasium as a model. He exerted a strong influence on his son, trying to discourage his predilection for mathematics, because he was afraid that "his son would turn into a freak with a one-sided development, which could not be used for anything but for entertaining people." (p. 6) Von Kármán nevertheless studied applied mathematics later, and although he could speak several languages well, he could multiply numbers only in Hungarian.

Leo Szilard was a clever and inquisitive child, "a born leader who invented new games and new rules for old ones." (p. 8) His grandfather and mother were his professed role models. His mother inculcated in him an "addiction" to truth; his grandfather impressed upon him that clarity of judgment was not a matter of intelligence but rather "a matter of ability to keep free from emotional involvement." (p. 80)

Eugene Wigner grew up in a successful middle-class family, spoke Hungarian and German, and was taught French by a governess. He was a quiet child who was educated at home before he entered the Lutheran Gymnasium in Budapest at the age of eleven.

John Neumann was born into a well-to-do family and received his early education by private tutoring. He had German and French governesses. His father was raised to the hereditary nobility by Emperor Franz Josef in 1913, becoming von Neumann. His son's maternal grandfather was a wizard at arithmetical manipulations, which the young "Jancsi" evidently inherited. The family had an extensive library; the youth read all forty-four volumes of a German universal history and remembered it for the rest of his life. His father also tried to persuade him to not become a mathematician. As von Kármán recalled: "One day a well-known Budapest banker came to see me with his 17-year old son Johnny. He had an unusual request. He wanted me to dissuade young Johnny from becoming a mathematician."[3]

Edward Teller's grandparents were well-to-do merchants, and his father was a successful lawyer in Budapest. He was happy at home but suffered in school because his fellow students teased him to the extent that he remembered it even in his old age. Soon, however, he earned their respect because he could help them in their studies. When he asked his maternal grandfather about the validity of laws, he replied: "Laws must be obeyed without exception." (p. 11)

Hargittai's five Martians all received outstanding secondary educations and excelled in school, winning major prizes in physics and mathematics. Hargittai reminds us, however, that the rigid requirements and lack of physical education produced students who "were haunted by the fear of being suddenly called on, of being inadequately prepared, and of receiving a consequent poor or failing mark." (p. 12) Von Kármán and Teller attended the famous Minta Gymnasium, Wigner and von Neumann the excellent Lutheran Gymnasium, and Szilard a Real (technical) Gymnasium that had the reputation of having the best experimental equipment in Hungary. Hargittai summarizes: "The Hungarian [gymnasium] education at the beginning of the twentieth century was an elitist kind of education … with a select group of students, and highly educated and cultured teachers who were members of an appreciated and respected profession." (p. 17)

Germany

Von Kármán went to the University of Göttingen on a scholarship in 1906 and two years later received his doctorate under the noted hydrodynamics expert Ludwig Prandtl, after which he became a Lecturer (*Privatdozent*). In Göttingen he met such luminaries as the mathematicians Felix Klein and David Hilbert, the latter of whom apparently convinced him that nature is inherently mathematical. In 1908 he visited Paris, where he met his future wife and witnessed an event that changed his life: the first two-kilometer airplane flight in Europe. In 1913 he accepted an appointment in Aachen, Germany, but after a year returned to Hungary and became head of research in the Austro-Hungarian Army Aviation Corps during the Great War. After the war he worked for a year in the Hungarian Ministry of Education, trying to modernize university education, but was impeded in doing so by anti-Semitism. Leaving again for Aachen, Germany, he established his reputation as an imaginative aerodynamicist. In 1930 he moved permanently to the United States, becoming head of the Guggenheim Aeronautical Laboratory at Caltech in Pasadena, California.

Szilard matriculated at the Technical University in Berlin in January 1920 but that fall transferred to the University of Berlin, where he lived in the Faculty Club, keeping two suitcases always packed, ready to go at any time.[4] He received his doctorate under Max von Laue in 1922 with a thesis on what was later called information theory. He befriended Einstein, and the two wrote joint papers and took out patents together. Einstein enjoyed the free-thinking Szilard with his wild ideas in physics and for bettering the world, coolly assessing Szilard as "a genuinely intelligent man.… [But] he tends to overestimate the role of rational thought in human life." (p. 49) He left Berlin for Vienna in the nick of time on March 30, 1933, just one day before the Germans closed the border, famously remarking later: "You don't have to be clever, you just have to be one day earlier."[5]

Wigner studied chemical engineering in Budapest and then, beginning in 1921, first at the Technical University in Berlin and then at the Kaiser Wilhelm Institute in Berlin-Dahlem, completing his doctorate under Herman Mark with a thesis in an area of crystallography in 1925, but became closer to Michael Polanyi, who greatly encouraged his research. Wigner also met Einstein through Szilard, both of whom influenced his scientific and social views. Between 1925 and 1928, Wigner worked as a chemical engineer in Budapest and was a research assistant first at the University of Berlin and then at the University of Göttingen before returning as a Lecturer (*Privatdozent*) to the Technical University in Berlin where, with the help of von Neumann, he became an expert on the application of group theory to quantum mechanics. In 1930 Wigner sailed for the United States to accept a half-time visiting lectureship at Princeton University.

Von Neumann studied at the Technical University in Berlin from 1921-1923, then at the Swiss Federal Institute of Technology in Zurich from 1923–1925, and completed his doctorate at the University of Budapest under Lipót Fejér in 1926 with a thesis on the axiomatization of set theory. He then became a Lecturer (*Privatdozent*) first at the University of Berlin in 1927, joining Szilard and Wigner there, and then at the University of Hamburg in 1929, having published over thirty major papers in mathematics before the end of that year. He sailed for the United States in 1930 to accept a half-time visiting professorship in mathematics at Princeton University.

Teller entered the Technical University in Karlsruhe in 1926, at the age of 18, to study chemistry but two years later transferred to the University of Munich to work under Arnold Sommerfeld, with whom, however, Teller was disappointed, characterizing him as "very correct, very systematic, and very competent." (p. 60) Teller lost his right foot in a streetcar accident, returned to Budapest to recuperate, and then resumed his studies at the University of Leipzig, where he completed his doctorate under Werner Heisenberg in 1930 with a thesis on the structure of the hydrogen molecular ion. He then became an assistant to the physical chemist Arnold Eucken at the University of Göttingen, remaining there until early 1933 when, knowing that his dismissal was imminent, he emmigrated to London, England.

United States

Von Kármán first visited Caltech in 1926 and four years later accepted a position there as head of the Guggenheim Aeronautical Laboratory. In 1932 his graduate students included U.S. Navy and Air Force officers who later became admirals and generals. He contributed significantly to the modernization of the Air Force by writing two influential reports, "Toward New Horizons" in 1945 and its companion, "Science: The Key to Air Supremacy," and by serving as chairman of the Air Force's Scientific Advisory Board. His interests ranged from the physics of ripple formation on sand in Algiers, to the study of chemical-combustion mechanisms, to the design of supersonic aircraft. He solved problems seemingly beyond his expertise; he concluded, for example, that the Tacoma bridge collapsed in 1940 because vortices developed when the bridge began to oscillate at the same frequency as that of the passing air – an insight that influenced the future construction of bridges in the United States.

Szilard visited Princeton in 1931 (Wigner had arranged his invitation) to work on problems in mathematical physics. In 1933, after leaving Berlin for Vienna, he visited Budapest briefly and then went on to London, England, becoming interested in biology but soon working on theoretical and experimental problems in nuclear physics. When he heard that Ernest Rutherford disparaged the idea of gaining energy from nuclear transformations as "moonshine," he responded to the challenge, saying that "if an authority declared something impossible, this always irritated me." [6] He soon became an expert in neutron physics and in 1934 conceived the idea of a chain reaction but failed to gain financial support to pursue it. He also assisted his fellow refugees in every way possible, continuing to build "his network of influential people." (p. 78). In 1935 he moved to the University of Oxford, continuing to work on problems in nuclear physics, and also attended a meeting of the American Physical Society in Washington, D.C., where he met the émigré Russian theoretical physicist Gregory Breit, then at the University of Wisconsin in Madison. He helped Szilard land a part-time appointment at New York University and thus to continue commuting between England and the United States until he settled permanently in America in January 1938.

Wigner spent half time in Berlin and half time as a visiting professor at Princeton University on von Neumann's recommendation from 1930 to 1933, after which he became full time, supervising such brilliant graduate students as Frederick Seitz and John Bardeen until 1936, when his appointment was suddenly terminated. Gregory Breit was then instrumental in securing an appointment for Wigner as his colleague at the University of Wisconsin. Wigner enjoyed his time and the ordinary people he met there. In 1938 Princeton recalled him and, swallowing his pride, he returned and remained there for the rest of his life, contributing significantly to making its physics department one of the best in the country.

Von Neumann, like Wigner, spent half of the year in Berlin, the other half at Princeton University from 1930 to 1933 and then was appointed to a full professorship in the newly founded Institute for Advanced Study.

After Teller arrived in London, the chemist Frederick G. Donnen at the University of London convinced the Rockefeller Foundation to grant Teller a fellowship to enable him to go to Bohr's institute in Copenhagen from the beginning of 1934 until September of that year. There he met the émigré Russian theoretical physicist George Gamow, and the two became good friends. Hargittai summarizes:

> The stay in Copenhagen signified important changes in Teller's life. He arrived there single, but left married; he arrived feeling solidly versed in quantum mechanics, but was unsure when he left that he would ever become an expert in this field. Niels Bohr had an ambiguous impact on Teller. Bohr loved paradoxes, and while Teller understood his paradoxes, he did not understand Bohr. (p. 83)

In 1935, a few months after Teller returned to London, his new friend Gamow, who himself had recently emmigrated to the United States to accept a professorship at George Washington University in Washington, D.C., invited Teller to join him there as a colleague.

Manhattan Project

Hargittai's five Martians were centrally involved with the physics and design of the atomic bomb from about 1939 until 1945. Von Kármán became a special consultant for shock waves, Teller was involved with theoretical calculations, Wigner was seen as the "first nuclear engineer," and von Neumann showed that the most efficient method of detonating the bomb was by use of lenses to produce an implosion. Szilard, however, was the main driving force from the beginning and continued to contribute significantly, especially when working with Fermi. According to Hargittai, "Fermi was a scientist from beginning to end, whereas for Szilard science was only a means to do something for mankind." (p. 188) Their collaboration was fruitful, but their relationship, between the meticulous and systematic Fermi and the unpredictable, bold, and outspoken Szilard, was often problematic, as Hargittai vividly describes.

The story of Szilard's sudden insight on how to produce a nuclear-chain reaction while stopping at a traffic intersection in London in 1933 is well known, but Hargittai emphasizes that this idea was not new in chemistry. Szilard became obsessed with confirming it experimentally, even attempting unsuccessfully to enlist Lise Meitner in Berlin to do so. Only in 1939, after immigrating to America, did he manage to borrow $2000 privately to set up his own experiments at Columbia University and confirm that extra neutrons are produced in the fissioning of uranium. He then called Teller, cryptically reporting in Hungarian, "I have found the neutrons." (p. 97) Teller and Wigner then joined Szilard in studying fission.

Szilard concluded that water was not suitable as a moderator but that heavy water and graphite were. These three Hungarians seem to have been the only physicists to believe at the time "that the danger of war was imminent and that nuclear weapons might play a role in it." (p. 98). They decided to ask Einstein for help, so in July 1939 Szilard and Wigner drove to Peconic, Long Island, where Einstein was vacationing and explained their findings and concerns to him. Einstein understood instantly, remarking that, "I haven't thought of that at all." (p. 98) Hargittai believes that this encounter persuaded Einstein to abandon his pacifism, and after a second meeting he signed the now-famous letter to President Franklin D. Roosevelt that was drafted by the Hungarians. Wigner was not present at this second meeting, but Teller was, because Szilard could not drive a car but Teller could.

Teller, no longer apolitical as he had been in London and Copenhagen, asked Heisenberg during a visit to America in 1938 why he did not leave Nazi Germany. His answer was a wake-up call for Teller: "Even if my brother steals a silver spoon, he is still my brother." (p. 88) But Roosevelt's speech to the Pan American Congress in 1940 was a turning point for Teller in his attitude toward national defense. Roosevelt said he believed that if necessary all Americans "will act together to protect and defend … our culture, our American freedom and our civilization." Teller "felt as if the president was speaking directly to him." (p. 87)

Financial support for the project, however, was slow in coming. At the initial meeting with representatives from the military, Wigner asked for $6000, which was immediately granted but was not forthcoming until the spring of 1940. Fermi and Szilard designed a uranium-graphite nuclear reactor ("pile") in Chicago, although they were nearly barred from working on it, since army intelligence reports had labeled Fermi as "undoubtedly a Fascist" and Szilard as "very pro-German." (p. 101) When the pile went critical on December 2, 1942, Wigner famously produced his celebratory bottle of Chianti.

General Leslie R. Groves, head of the Manhattan Project, regarded Szilard as arrogant and pushy and accused him of being in the German army during World War I, of never doing any work, not even teaching, just spending all of his time learning, and of trying to prevent the use of the bomb against Japan. Groves told others that in Germany they would shoot scientists like Szilard. Still, Groves insisted that, "I am not prejudiced. I don't like certain Jews, and I don't like certain well-known characteristics of theirs, but I'm not prejudiced." (p. 100)

Groves also was rude to von Kármán, informing the Pentagon that if they wanted information of concern to the Air Force they should send someone to him whose English he understood. Kármán later countered by relating an anecdote: "General Groves and Robert Oppenheimer are in an atomic shelter watching the first A-bomb explosion. 'What did you see,' a reporter asked. 'I saw the end of the world,' Oppenheimer replied. 'And I saw a third star,' said the two-star General." (p. 95)

Teller was always more interested in the possibility of producing a thermonuclear than a fission bomb. He worked under Hans Bethe in the theoretical section at Los Alamos, but only reluctantly, since his and Bethe's styles of doing physics were radically different. "Bethe liked to work on what Fermi called 'little bricks,' and Teller characterized Bethe's work style as 'methodical, meticulous, thorough, and detailed'." (p. 127) Teller characterized his own work this way: "Although I have made a few tiny little bricks, I much prefer… exploring the various structures that can be made from brick, and seeing how the bricks stack up." Teller was hurt when Oppenheimer appointed Bethe instead of him as head of the theoretical section; he characterized Oppenheimer as more of a "bricklayer" than a "brick maker."(p. 128)

Postwar

In the postwar years, financial support for science increased greatly, as did the status of the Martians, who were appointed to influential national advisory boards and committees. As Hargittai notes: "After the war, foreign accents became respectable when scientists had them." (p. 132).

Szilard played a leading role in the postwar scientists' movement that wrested control of atomic energy from the hands of the military and placed it into the hands of the civilian Atomic Energy Commission. Later, in the early 1950s, he was outraged by McCarthy's attacks and the loyalty-security hearings of the House Un-American Activities Committee. In 1946 he had accepted a half-time appointment as professor of biophysics and as half-time advisor on the social aspects of atomic energy at the

University of Chicago. To learn the content and methods of the new field of biophysics, he contacted leading figures in it, such as James D. Watson and Jonas Salk. When a well-known biologist once asked Szilard what knowledge of biology he should assume, Szilard replied: “Assume infinite intelligence and zero prior knowledge.” (p. 141) He helped to found the Salk Institute for Biological Studies and the Pugwash Conferences on Science and World Affairs. As Hargittai remarks, “He just wanted to improve the whole world, and everything in it.” (p. 143) A personal opportunity came when he met Soviet Premier Nikita Khrushchev for two hours in 1960 and persuaded him, as well as President John F. Kennedy, to establish a telephone hotline between Moscow and Washington.

Teller’s role in the conceptualization of the hydrogen bomb, “the Super,” was complex and remains controversial, but the friction that was generated between him and Stanislaw Ulam delayed its construction considerably. Von Neumann contributed significantly to its development by carrying out long and difficult calculations using the new ENIAC and MANIAC computers. He later became President of the American Mathematics Association and held numerous other influential offices and appointments. He received the Fermi Award, the U.S. Medal of Freedom, and the Wolf Prize in Mathematics. As he lay dying in a hospital, his visitors included, at the same time, the Chairman of the Joint Chiefs of Staff and the U.S. Secretary of State.

Hargittai reproduces verbatim excerpts of Teller’s testimony at Oppenheimer’s loyalty-security hearing in 1954 (pp. 208–209), which led to Teller being ostracized by most physicists. Hargittai believes that Teller volunteered to testify against Oppenheimer because of his feeling of duty and out of conscience, but was motivated partly by revenge and partly to please people whom he considered to be his superiors. Further, Hargittai argues that Teller should have been able to anticipate his colleagues’ condemnation. Von Neumann, although no great friend of Oppenheimer, also testified but never questioned Oppenheimer’s integrity and loyalty. Szilard apparently tried but failed to reach Teller on the night before he testified to persuade him not to testify. Isidor I. Rabi refused to shake Teller’s hand after his testimony. Late in life, Teller became a forceful advocate of the Strategic Defense Initiative or “Star Wars,” which Hargittai argues that, “however indirectly, it performed a positive service in that it scared the Soviet Union and forced it into expenditures that it could afford far less than the United States.” (p. 185)

Von Kármán also was investigated by the U.S. House Un-American Activities Committee for his involvement in the short-lived Hungarian Communist regime in 1919. He had a strong interest in the future of nuclear weapons, because the Air Force was charged with delivering them. According to Hargittai, von Kármán “held the view that scientists as a group should not try to persuade governments; they should only analyze a given situation and establish the true picture by scientific methods.” Von Kármán felt that, ”A scientist should be neither a Teller nor an Einstein insofar as public affairs are concerned.” (p. 137) In general, von Kármán was less well-known to the public than Hargittai’s other Martians, perhaps because his field of theoretical aerodynamics is not very accessible to laymen. Nevertheless, his work in this field and in rocket research helped shape both scientific and political history.

Wigner received the Nobel Prize in physics in 1963 “for his contributions to the theory of the atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles.” He lived a long life, but according to Hargittai he stopped being productive in physics by the late 1950s.

Conclusions

One can argue that the Martians, whether Marx’s large group or Hargittai’s much smaller one, did change twentieth-century history. I agree with Hargittai that his five Martians contributed decisively to the Allied victory in World War II, both collectively and individually, as for instance von Kármán did in his work for the U.S. Air Force.

Marx’s book is useful as a reference for physicists and physics teachers; it is written on the level of *Scientific American*, with considerable scientific and mathematical detail. Hargittai’s book is written on a grander scale; it provides much more detail about the personal and scientific interactions among his five Martians and other scientists. His book will appeal to anyone interested in the complex relationship among science, technology, and politics in the 20th century. Hargittai does not shy away from scientific details, but treats them gently. As a physical chemist, however, he emphasizes different aspects of science than the physicist Marx. Still, I found his book to be too long, too dense in places, and some parts unnecessarily detailed. His treatment of his five Martians in chronological order by year of birth in each of his chapters 2 to 5 becomes too predictable and repetitious. Nonetheless, I recommend his book highly to anyone interested in his big picture and its details.

I liked Hargittai's epitaphs for his five Martians. For von Kármán: "reduce everything to an approximate mathematical formulation"; for Szilard: "lighting the torch"; for Wigner: "something must be reasonable"; for von Neumann: "find a quick solution to even the most complex problems"; and for Teller: "protect the free world with whatever means." (p. 228)

Of Hargittai's five Martians, I must single out Leo Szilard as the most forceful, colorful, and flamboyant one, even by Hungarian standards. I can think of only one other scientist who can match Szilard's scientific, political, and social exploits and bravura, namely, Count Rumford, who changed the face of science, politics, and society in England and Germany in the late 18th and early 19th centuries. I have written a play about Rumford that was performed in Germany and Canada.[7] Someone should also write a play about Szilard, even though he already has been the subject of a 45-minute documentary available on videotape, which I have shown with success to future physics teachers.

Finally, full disclosure: I was born and received my early education in Hungary and am proud of my Hungarian roots. Like Wigner and Teller, I have lived in North America for over fifty years, and like von Kármán, I still multiply numbers in Hungarian.

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1 George Marx, *The Voice of the Martians* (Budapest: Roland Eötvös Physical Society, 1994; second edition Akadémiai Kiadó, 1997; third revised edition Akadémiai Kiadó, 2001).
2 Quoted in Marx (2001), p. 116.
3 Quoted in Arthur O. Stinner, "The Hungarian Phenomenon," *The Physics Teacher* **35** (December 1997), 520–524, on 521.
4 Tibor Frank, "Ever Ready to Go: The Multiple Exiles of Leo Szilard," *Physics in Perspective* **7** (2005), 204–252.
5 Quoted in Authur Stinner, "Celebrating a Centennial – Leo Szilárd (1898–1964)." *Phys. Teach*. **36** (April 1998), 234–235, on 234.
6 Quoted in *ibid*., pp. 234–235.
7 See my website <www.ArthurStinner.com>.

Roger G. Newton, *From Clockwork to Crapshoot: A History of Physics*. Cambridge, Mass. and London: The Belknap Press of Harvard University Press, 2007, 340 pages. $29.95 (cloth).

It takes courage and confidence to condense six thousand years of physics into three hundred pages: courage to tackle this immense task, and confidence, born of experience, to select the right material for inclusion. Roger Newton, an emeritus professor at Indiana University, has both. He is well known in the profession for his contributions to theoretical physics as well as his thoughtful commentaries intended for readers with an undergraduate education in physics. Among the latter, my favorite is *Thinking About Physics* (Princeton University Press, 2000).

There are no gimmicks in his new book – no photographs, no didactic boxes, no glossary, no timeline, no technical appendices, not even an epigraph. Just text, a few simple illustrations, and a map of the Hellenistic world. It is, in a way, an old-fashioned history, the sober, factual product of diligent scholarship. References to events outside physics are almost entirely absent, as are discussions of the technological applications of science and their impact on society. The steam engine, for example, merits two sentences. Atomic weapons are dispatched with: "Two such bombs, released over Hiroshima and Nagasaki with devastating effect near the end of the Second World War, imprinted the science of nuclear physics on the public imagination for a long time." Concision is a stern taskmaster.

While experiments receive their proper due, Newton's background as theorist is reflected in a strong emphasis on mathematics. As usual in popularizations of physics, there are very few formulas, but the history of topics such as geometry, calculus, and group theory is seamlessly integrated into the story. The prologue announces the author's perspective: "If Galileo thought that mathematics was the language of nature, some physicists now go even further, believing that the laws of nature should be mathematical theorems. The course of this development will be outlined in this book."

Two themes thread their way through the narrative, lending coherence to the turbulent story. The descent from certainty that gives the book its name culminates in a particularly fine discussion of probability in physics, appropriately tucked between a chapter on thermodynamics and one on quantum mechanics. Objective probability, as understood by most physicists, is defined in terms of frequencies of occurrences – fifty heads in a hundred throws implies a probability of one half. However, a very different conception, called epistemic probability, is defined as the degree of belief in a proposition and is much more subjective in character. Its key advantage is that it can be applied to unique events – as in "the probability of a recession next year is 40%." Newton traces the development of this notion from Leibniz in the seventeenth century to the economist John Maynard Keynes and the mathematician-philosopher Bruno de Finetti in the twentieth. Along the way he pauses to illustrate Bayes's theorem with a one-hundred-word sentence that will befuddle most readers. The theorem itself, however, which formalizes the updating of an epistemic probability by the incorporation of new information, is the cornerstone of promising new approaches to the foundations of quantum mechanics, and thus could turn out to be the most significant of Newton's mathematical excursions.

The book's second guiding thread is the progression from *prediction* to *explanation* as the ultimate purpose of physics. Whereas prediction was central to the classical description of inanimate nature, modern physics is more ambitious. It aims not only to predict what happens when, for example, two electrons collide, but also to show why electrons have just the properties they have, and not others; not only what happens when a crystal is heated, but also why it has its specific molecular structure in the first place; not only how the universe expands, but also why it expands. Newton couches the evolution of the aim of physics in terms of Aristotle's distinction between *efficient cause* of a phenomenon, which "brings about the effect by a physical effort," and the *formal cause*, which identifies the laws that govern the event. From prologue to epilogue this theme reverberates in the background. I think about this evolution as a maturing process, analogous to the development of a child's intellect from concrete to abstract thinking, but Newton's analysis is more profound. He writes: "The goal of physics shifted from explaining *change* to explaining *being*."

Who should buy this book? As I read it, I was reminded of the time I prepared for my Ph.D. qualifying examination almost half a century ago. Though nervous, I remember feeling grateful for the opportunity to review all of physics one last time, and achieving a complete overview of all its parts in their mutual relationships. Reading Newton's book gave me that same opportunity with respect to the history of physics. I was familiar with most of the bits and pieces, but seeing them assembled before my eyes into a coherent whole, from the Stone Age to the Information Age, gave me the same sense of satisfaction I experienced as a student. If I don't have the entire history of physics in my head at the same time, at least I have it in writing. I will keep the book at hand as a reliable reference work, as a corrective for half-remembered anecdotes and circumstances, and as a source for brilliantly crisp formulations of complex contributions to physics. I would urge physicists, teachers, writers, and scientists in other disciplines, as well as "general scientifically interested" readers, as Newton hopes, to follow suit.

However, I think that Newton's style is too spare and dry to appeal to a very broad public. The trouble lies in part in his effort to be inclusive. Too many characters parade across these pages revealing not much more than name, vital dates, country of origin, family background, education, and major accomplishment – dictionary-style. My quick count in the index turned up no fewer than 444 individual persons. If a reader is not already familiar with the majority of them, as most physicists are, their mere mention is insufficient to weave the kind of net that captures the imagination. By Newton's own implication, the history of science is misrepresented when its progress is attributed exclusively to a small handful of stars, such as Nobel Laureates, but I don't think he has found the right balance between inclusiveness and brevity in this book. I look forward to other books from his pen, and hope that he will temper his courage to take on sweeping historical surveys with the courage to trim his cast.

I happened to spot only half a dozen minor errors, an excellent record for a first edition in view of the wealth of material covered. They are available upon request.

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Helge S. Kragh, *Conceptions of Cosmos – From Myths to the Accelerating Universe: History of Cosmology*. Oxford: Oxford University Press, 2007, 276 pages. $70.00 (cloth).

Helge S. Kragh, historian of science and prolific author of books (and a member of the editorial board of this journal), has given us nothing less than a thorough history of cosmology, from biblical myths to the present view of accelerated expansion. It's a noble thing to try, and even if it isn't always perfectly accurate, *Conceptions of Cosmos* makes a real contribution to the literature.

According to Kragh, cosmology became a science only recently. Before that, that is before about 1970, cosmology belonged in the realm of philosophy or even religion. Astronomers or astrophysicists may have dabbled in questions of the cosmos, but they did not take them seriously. Moreover, Kragh insists that the history of cosmology is not a triumphal march to our present-day understanding. Instead, he takes us through the many twists and turns of cosmological theory, but without much guidance about what we believe today.

Take, for example, Olber's paradox. If the universe were infinite and uniformly full of stars, there would be a star at the end of every line of sight and the night sky would be blazing bright. But it manifestly is not; that's Olber's paradox. There are two present-day explanations of this phenomenon. For one thing the universe is not infinite, but rather is finite in both space and time (the farther out you look, the further back in time you're looking, and the universe began with the big bang about 15 billion years ago). And, secondly, the expansion of the universe has red-shifted many stars out of the visible. But Kragh never gives us either of these explanations, since they both depend on the modern view of the universe, and neither one seemed obvious in the days when Olber's paradox was big news (it seems to have been first noticed by Johannes Kepler, who used it to argue for a finite universe). We do eventually learn that the universe is finite, but the second explanation never appears at all.

Kragh draws a sharp distinction between *realism* and *instrumentalism* in cosmology. Realism attempts to tell it like it really is, while instrumentalism is satisfied with a description of the past and an extrapolation to the future. "The zenith of Greek mathematical astronomy," Kragh says, "as represented by Ptolemy's *Almagest*, had a clear instrumentalist orientation…." But he goes on to say, "The model of the *Planetary Hypothesis* was not phenomenological, but a realistic attempt to understand the structure of the universe in terms of Aristotelian physics. Ptolemy seems to have thought of the model as a true representation of the heavens, whereas truth is a quality that is foreign to the mind of the instrumentalist." That, unfortunately, is typical of Kragh's presentation, which is thorough but often a bit confused.

At the end of the book, Kragh waxes philosophical. He quotes the British cosmologist Paul Davies as saying, "It is a striking thought that 10 years of radio astronomy have taught humanity more about the creation and organization of the universe than a thousand years of religion and philosophy." That's true, but up until that point Kragh's book is resolute in ignoring our present understanding, and giving us cosmology as it existed in times long past.

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