History of Physics
NEWSLETTER

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Report from the Chair

By Gloria B. Lubkin, Forum Chair

I have served the Forum on History of Physics (and its predecessor, the Division of History of Physics) in many capacities over its lifetime. However, when I was elected Vice Chair, I discovered that I still had a lot of learning to do.

Our most visible activity is organizing sessions for the APS March and April meetings. FHP sessions sometimes draw very large audiences, and those sessions appear to be widely appreciated by meeting attendees. We are typically allocated three invited sessions at each of those meetings; by cosponsoring sessions with other APS units we've generally been able to offer a larger number of them. In addition, in recent years we've been holding contributed sessions at both meetings. It doesn't appear to be widely known that the Forum offers the possibility of $600 awards for partial support to students who have submitted an abstract for contributed FHP sessions. (For further information, see the FHP website, *http://www.aps.org/units/fhp/*.)

Forum Chair, Gloria Lubkin

Next year is the 50th anniversary of the first laser. To commemorate that anniversary, Dan Kleppner, Chair of the program committee, and Marty Blume, Vice Chair of the program committee, have organized sessions on the laser at both the March and "April" 2010 APS meetings. I put April in quotes because the meeting will actually be held 13-16 February (in Washington D.C.) so that it can be held jointly with the Winter meeting of the American Association of Physics Teachers. (See the article by Kleppner on p. 11.)

Because the regular meeting of the FHP will be held February 2010, the election of new officers must be held about two months earlier than has been customary. The Nominating Committee, headed by Past Chair David Cassidy, has chosen a slate of candidates. (See the announcement of candidates on page 2.) I hope you will all exercise your privilege of voting.

The Abraham Pais Prize for the History of Physics, jointly sponsored by APS and AIP, was first awarded in 2005. The first winner of the Pais Prize, Martin Klein, died in March. His death was a great loss to all who knew him and to all who knew his research. The 2010 Pais Prize Selection Committee, chaired by Laurie Brown, has selected another outstanding winner, Russell McCormmach (see the story on page 2 in this issue), who will give an invited talk in March at the meeting in Portland, Oregon. The 2009 Prizewinner, Stephen Brush, will give an invited talk at the Washington meeting in February.

The FHP website has become a valuable resource, thanks to George Zimmerman's efforts. Last

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year he posted the invited talks given at the March and April 2008 meetings on our website, where you can find both the audio recordings and PowerPoint presentations. This year's invited talks have not yet been posted because of APS concerns about intellectual property rights, particularly for the PowerPoint presentations. However, George has posted a slide show of photos he took at the sessions. (See session reports for web addresses.)

Of the 3775 FHP members, 1017 are student members of APS. With that in mind, FHP bylaws were changed and in the 2008 election a student member was elected to the FHP executive committee. He is Paul Cadden-Zimansky from Columbia University. ■

History of Physics NEWSLETTER

The Forum on History of Physics of the American Physical Society publishes this Newsletter semiannually. Nonmembers who wish to receive the Newsletter should make a donation to the Forum of $5 per year (+ $3 additional for airmail). Each 3-year volume consists of six issues.

The articles in this issue represent the views of their authors and are not necessarily those of the Forum or APS.

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McCormmach is the 2010 Winner of the Pais Prize

Russell McCormmach has been chosen as the winner of the 2010 Abraham Pais Prize for the History of Physics "for the study of German science in the 19th and 20th centuries and a major biography of Henry Cavendish (with Christa Jungnickel, his late wife), and for founding the journal *Historical Studies in the Physical Sciences*."

The Spring 2010 Newsletter will carry a more complete account of McCormmach's work. ■

Congratulations and Thanks...

Congratulations to Michael Riordan of the University of California, Santa Cruz, who was elected to represent the Forum on History of Physics on the APS Council. Riordan will serve a 4-year term as Forum Councilor beginning 1 January 2010.

Thanks to Roger Stuewer, who served as the Forum Councilor for the past four years. ■

History of Physics Newsletter Back Issues Now Available

Thomas Miller has scanned all the past History of Physics Newsletters, beginning with the August 1982 issue. They are now available on the FHP website at *http://www.aps.org/units/fhp/newsletters/index.cfm*. Tom writes, "The first one gives a summary of the origin of the FHP (originally installed as a "division" of APS), and notes that the first editor was [the 2009] Pais Prize winner, Stephen Brush." ■

Forum Elections

The Nominating Committee of the Forum on History of Physics has chosen a slate of candidates for the 2010 elections, which are being held at the end of 2009 because the Forum's 2010 Regular Meeting comes so early – the APS "April" meeting is being held two months earlier in 2010, in February. The election will begin on November 15 and end on December 13.

You will be asked to vote for Forum Vice Chair and two at-large members of the Executive Committee. The person elected to be Vice Chair normally becomes the new Chair-Elect in 2011 and Chair of the Forum in 2012. The primary responsibilities of the Vice Chair and Chair-Elect are to decide upon timely topics for invited and contributed sessions at APS and divisional meetings, often in collaboration with other APS units, and to arrange these along with sessions of contributed papers. The incumbent Secretary-Treasurer was renominated to run unopposed.

In alphabetical order the candidates are:

Vice Chair: Peter Pesic, George Zimmerman.

Members at Large: Elizabeth Garber, Clayton Gearhart, Danian Hu, Daniel Kennefick.

Secretary-Treasurer: Thomas Miller.

The candidate's statements and resumes are available at *http://www.aps.org/units/fhp/governance/elections/index.cfm*. Those elected will take office in February 2010.

If you have an email address registered with APS, you will receive a message inviting you to vote electronically. If you do not have such an address, you should receive a paper ballot by mail. If you want a paper ballot but have not yet received one, please either email your request to the Secretary-Treasurer, Tom Miller (*millertf@bc.edu*) or contact him postally

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or by telephone (781-377-5031). The closing date of the election is 13 December 2009. An additional week will be allowed for receipt of paper ballots. ■

The (New) Editor's Corner

As your new editor of the FHP Newsletter, I find myself surrounded by people who have a passion for the history of physics and are authentic experts. My own attempts at physics historical scholarship are modest by comparison, but those experiences have taught me how difficult it can be to get it right—and how rewarding it is to try. Therefore I appreciate the difficulties, depth, and value of the work done by historians of physics. It is an honor to be associated with the Forum on History of Physics.

Your previous editor Michael Riordan, and his predecessors Benjamin Bederson, William Evenson, William A. Blanpied, Albert Wattenberg, and Stephen G. Brush have set high standards indeed. I therefore am glad Michael Riordan saw fit to remain through this issue as Associate Editor, to help me learn my way around.

When I decided to major in physics, I knew the ride would be interesting. But I had little idea how wide the perspective would be. Physics is not just about black holes and Lagrangians—it's a community that cuts across cultures and centuries. Having for our intellectual companions the likes of Albert Einstein and Emmy Noether—and our colleagues down the hall and those we see at meetings—offers one the joy of being engaged in a work larger than one's self. Like you, I have held in my hands the original letters exchanged between individuals I knew only as names in textbooks—and they came to life. Like you, I have stood with my students at the Trinity site monument and at Fermilab—and remote events became real. Like you, my students and I have engaged Isaac Newton and James Clerk Maxwell and Marie Curie in conversation—and have learned more than physics. As a teacher, very quickly I found, as you have, that the history of a physics topic is essential to its pedagogy. Thank you for this opportunity to share a role in the community of physics history practitioners and appreciators.

—Dwight E. Neuenschwander, Editor

Meeting Reports from Forum-Sponsored Sessions: 2009 March Meeting*

The Origins of Silicon Valley

By Gloria B. Lubkin, Forum Chair

On Monday afternoon, March 16, the Forum sponsored an invited session on "The Origins of Silicon Valley." The three speakers traced its origins back to 1910, covering the major scientific, technological, educational, military, and business developments that culminated half a century later in the production of the first commercial silicon integrated circuits. At the session's end they participated in a panel discussion chaired by Gloria Lubkin, fielding questions from an audience of nearly 200.

Stewart Gillmor of Wesleyan University covered the prehistory of the valley, from 1910 to 1965. By the time the term "Silicon Valley" was coined in 1971, he said, the San Francisco Bay Area had already become a thriving center of instrumentation, electronics, avionics, and particle physics. He attributed this rise to its location with respect to continental and Pacific transportation and communication needs; the growth of West Coast population, markets and universities; the recruitment of talented people from the East; and innovative industrial and business methods.

Gillmor cited many examples of scientists and engineers who contributed new ideas over that period, especially at Stanford. He discussed life in Frederick Terman's electrical engineering lab there during the 1930s and its relationship with the physics department. It was Terman who encouraged his students William Hewlett and David Packard to build the lab in a local garage that grew into a great corporation. Gillmor also discussed Sigurd and Russell Varian's invention of the klystron in 1937-38, followed by William Hansen and Edward Ginzton's improvement of its performance, which enabled construction of the Stanford Linear Accelerator Center.

David Leeson (Stanford University) talked about "W. W. Hansen, Microwave Physics, and Silicon Valley." Known as the father of microwave electronics, Hansen and his collaborators laid the foundations of Silicon Valley's postwar microwave phase, when numerous companies flourished around Stanford, Leeson said. These firms furthered the regional entrepreneurial culture and prepared the ground for the semiconductor and computer developments that followed. After getting his Ph.D. from Stanford in 1932, Hansen spent two years as an MIT postdoc and then returned to Stanford "as a whiz in electromagnetism." He invented and patented the cavity resonator. From 1935 to 1937, he applied the cavity resonator to his concept of the radiofrequency linear accelerator and, with the Varian brothers, to the klystron invention. The Varians first set up a lab in their house; then in May 1937 they came to Stanford and asked Hansen to help them. After the invention was demonstrated in August 1937, Sperry Gyroscope licensed the rights to use the klystron for radar. It made airborne radar possible, according to Leeson, and contributed to the Allied victory in World War II.

During the War, Hansen's group relocated to Sperry's Long Island plant. He also gave a series of lectures to the scientists and engineers recruited to work on radar at the MIT Radiation Lab. In Leeson's opinion, the notes were never published because of rivalry between MIT and Stanford, Hansen's failing health, and his postwar work. But they had a major impact on subsequent works, including the Rad Lab series on radar.

After the War, Hansen founded Stanford's Microwave Lab to develop high-power klystrons and linear accelerators. He collaborated with Felix Bloch in the discovery of nuclear

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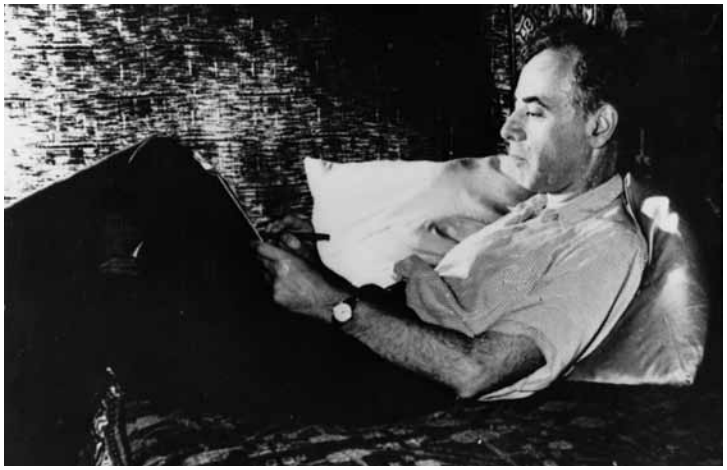
**Note:* 2009 March Meeting FHP session pictures taken by George Zimmerman are available at http://www.aps.org/units/fhp/gallery/march09.cfm.*

Centenary of Lev Landau

By Gloria B. Lubkin, Forum Chair

The Forum commemorated the "Centenary of Lev Landau" in an invited session on Wednesday morning, March 19. Four of the five speakers had worked with him. They discussed his achievements and their personal interactions with him. All five emphasized Landau's impact on theoretical physics over much of the 20th century. An enthusiastic audience overflowed a lecture hall with 300 seats. Many listeners stood in the back of the room for three hours, while others waited outside the doors until they could slip in.



Lev Davidovich Landau. Credit: AIP Emilio Segré Visual Archives, Physics Today Collection.

The first speaker, Pierre Hohenberg (NYU), was the only one who had not worked with Landau. His talk, "Lev Landau: A View from the West," gave an overview of Landau's main scientific achievements. For Landau's 50th birthday, he was presented tablets with the "Ten Commandments" to represent his ten greatest papers: These were: density matrix (1927); Landau diamagnetism (1930); dynamics of ferromagnets (1935, written with Evgenii Lifshitz); theory of phase transitions (1937); intermediate state of superconductors (1937); statistical theory of nuclei (1937); theory of superfluidity (1941); renormalization of electron charge in quantum electrodynamics (1954, with Alexei Abrikosov and Isaac Khalatnikov); theory of Fermi Liquid (1956); and two-component neutrino theory (1957). Members of the famed "Landau school" of physics extended his influence. He also had a great impact on 20th century physics through the ten volumes of *The Course of Theoretical Physics*, by Landau and Lifshitz (after 1962, with Lev Pitaevskii and V. B. Berestetsky).

Even more significant, Hohenberg said, is Landau's pervasive influence on many major theoretical advances in condensed matter and statistical physics during the second half of the 20th century. Some of these developments can be viewed as "elaborations, advances and, yes, corrections to the foundational theories and points of view" that Landau had initiated. One example is the theory of superfluidity in Bose liquids, in which he resisted the explanation in terms of Bose condensation that had been introduced by Fritz London and László Tisza. Another example is the theory of second-order phase transitions, which laid the foundation of the study of critical phenomena using the renormalization group.

Lev Pitaevskii (University of Trento and Kapitsa Institute for Physical Problems) spoke on "Landau and Theory of Quantum Liquids." He concentrated on Landau's most famous contributions—the theory of superfluidity and the theory of quantum liquids. "Superfluidity literally saved his life," Pitaevskii said. After Landau's arrest in 1938, Peter Kapitsa wrote to Stalin asking for his release, but to no avail. A year later he wrote to Vyacheslav Molotov, then the nominal head of the government, telling him that "during work on liquid helium, at temperatures near absolute zero, I have been able to discover a number of new phenomena which can clear up one of the most puzzling areas in modern physics." To understand the phenomena he would need Landau's help, "but he has been under arrest a year now." The second plea led to his release. Landau later told Pitaevskii that just before he was released, he had felt that he would die in another week or two.

In his theory of superfluidity, Landau assumed that the observable properties of a macroscopic body at low temperature can be described in terms of elementary excitations, and that liquid helium is a "mixture" of a superfluid liquid with no viscosity and a normal liquid. An elementary excitation would not exist at absolute zero. He knew the spectrum of excitations was phonon-like at low momentum. Experiments pointed to the existence of excitations at energies of 8-9 K, so Landau assumed that the spectrum had a second branch with a gap, known as "rotons." From the theory, Landau predicted the existence of the "second-sound" mode of wave propagation in liquid helium II. When Landau received a preprint from Harry Palevsky of the latter's 1955 paper reporting the direct observation of the phonon-roton spectrum, Pitaevskii was in Landau's office. "Landau was very excited," he recalled. "I believe it was one of the happiest days of his life."

Valery Pokrovsky (Texas A&M University and Landau Institute) spoke about "Landau and the Theory of Phase Transitions." When Pokrovsky first met Landau, he observed that he "was very tall, almost one-dimensional, with a very bright and penetrating gaze. He was extremely fast with a deep understanding." Landau was very influential but not a revolutionary like Niels Bohr or Albert Einstein. To evaluate his influence, Pokrovsky used the Scirus 2008 database of scientific citations. His work on Fermi liquids had 45,000 citations, phase transitions 30,000, Landau levels 75,500, and the Landau-Lifshitz equation 23,000. Five Nobel prizes derived from

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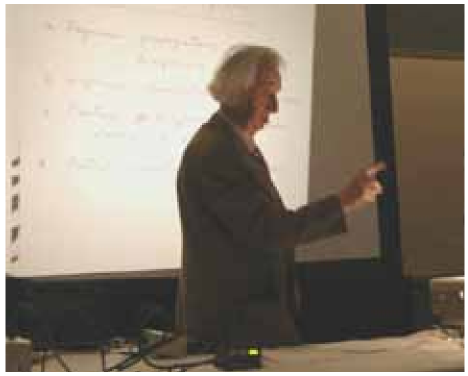
Landau's work, awarded to Kenneth Wilson; Klaus von Klitzing; Pierre-Gilles de Gennes; Daniel Tsui, Horst Störmer, and Robert Laughlin; and Alexei Abrikosov, Vitaly Ginzburg, and Anthony Leggett. And the Landau-Lifshitz *Course* has had unprecedented longevity, from 1940 until today.

According to Pokrovsky, Landau's approach to theory was characterized by three features: (1) extremely general, simple notions, such as the density matrix, spontaneous symmetry breaking, Fermi liquids, and quasiparticles; (2) a simple, effective formalism, e.g., in phase transitions, Landau levels, and neutron stars; and (3) a comprehensive view of all of physics. Landau formulated his theory of phase transitions in three 1937 articles. They introduced the order parameter as a measure of symmetry violation and showed how it appears spontaneously within the framework of the mean-field approximation. In the early 1940s, Lars Onsager published his solution of the two-dimensional Ising model, disagreeing with Landau, who then doubted his own theory was applicable at all until A. P. Levanyuk and Ginzburg showed the mean-field approximation to be invalid near phase transitions.

Igor Dzyaloshinskii (University of California, Irvine) discussed "Landau and Feynman Diagrams." In the latter part of the 20th century, these diagrams dominated theoretical physics. "Feynman introduced an alternative to symbols and used a visual presentation instead," said Dzyaloshinskii. Landau regarded Feynman diagrams and Freeman Dyson's concept of their visual summation as breakthroughs in the physics of particles. In his intuitive way, Landau introduced the concept of partial-summation, which led to major results in particle physics and condensed-matter theory.

Dzyaloshinskii traced some major developments in condensed-matter theory by members of the Landau school, growing out of Landau's partial summation ideas. These included: the discovery by Landau, Abrikosov, and Khalatnikov of the connections between bare charge and renormalized charge and between bare mass and renormalized electron mass; the application by Arkady Migdal and others of Feynman diagrams to Fermi and Bose gases; Landau's development of the theory of Fermi liquids; and a Feynman diagram approach to the BCS theory of superconductivity developed by Led P. Gorkov.



Igor Dzyaloshinskii at the Landau Centenary session. Photo by George Zimmerman.

The last speaker was Roald Sagdeev (University of Maryland), who spoke on "Landau's Contributions to Applied Physics." He quoted from Lifshitz's preface to their volume on hydrodynamics: "Here Landau has brought part of his soul. He was fascinated by this area of theoretical physics. He started to derive and rethink all of its key results." During World War II, Landau worked on a strong shock wave spherically imploding and converging to the center. In the paper, Landau noted that he wasn't considering what caused the shock wave, just what happens next. Later he introduced the concept of evolutionary behavior and what behaviors need to be excluded as unphysical. He gave credit to others who had contributed to the field, including Leonid Sedov, who had organized a campaign against one of Landau's adopted pupils, Yakov Zel'dovich. When the Soviet Union launched the first artificial satellite in 1957, the program was highly classified, so nobody knew who was responsible for the satellite's success. In public statements, the government gave credit to Sedov. Years later Zel'dovich was asked why he hadn't worked on *Sputnik*. In his reply Zel'dovich finally retaliated, saying, "When you eat a nice dinner in a restaurant, you thank the waiter, not the cook."

Sagdeev remarked that the hydrodynamics volume of Landau and Lifshitz introduced the special language of theoretical physics. In areas such as turbulence you can't get much from first principles, so Landau used a semi-empirical approach for concepts such as mixing length, viscosity, and heat conductivity (especially in boundary layers). Landau's first major contribution to plasma physics came before the war. He simplified the collision integral in the Boltzmann equation as applied to plasmas. And in 1956 he introduced the idea of Landau damping in collisionless plasma.

When Sagdeev was still a student at Moscow State University, Landau wanted to see the recently built skyscraper that was the university's new home. During the visit, Sagdeev met Landau and asked if he could become his student. "If you pass my exams, you can be my student, even if you're a criminal," Landau replied. After he passed the theoretical minimum, he was faced with a Soviet government decree that all theoretical physics graduates of Moscow University were to be sent to a new nuclear weapons lab in the Urals. But Landau persuaded Igor Kurchatov to bring Sagdeev to his own atomic energy institute in Moscow. In that way, Sagdeev worked at Kurchatov's institute 80 percent of the time and could attend Landau's seminar the rest of the time. ■

An article on Anderson Localization, the topic of the third FHP invited session of the 2009 March Meeting, will appear in the Spring 2010 Newsletter.

APS Meeting Reports on Forum-Sponsored Sessions: 2009 April Meeting*

Science Policy: Yesterday, Today and Tomorrow

By Michael Riordan

On Sunday morning, May 3, the Forum co-sponsored with the Forum on Physics and Society an invited session bearing the title "Science Policy: Yesterday, Today, and Tomorrow." Chaired by Daniel Kleppner, it featured the two President's Science Advisors from the Clinton Administration, Jack Gibbons and Neal Lane; and former Director of the National Bureau of Standards, Lewis Branscomb. An overflow crowd of more than 100 filled the small room to take part in the lively session.

Gibbons, now retired to his home state of Tennessee, led off with his talk on "Lessons from Skating on Thin Ice: the Office of Energy Conservation, OTA, and OSTP." He recalled how he made the move to Washington from doing astrophysics research at Oak Ridge after witnessing the nearby mountaintops coming down and rivers silting up from the mining of coal—and seeing the snows being blackened by soot emitted by the TVA power plants burning it. At the OEC, Gibbons was one of the earliest to recognize the potential of energy efficiency, but recognized that there were "enormous impediments" to its adoption in the marketplace. He found a piddling $50,000 to fund the landmark 1974 APS Summer Study on Energy Efficiency, whose roster included Arthur Rosenfeld of Lawrence Berkeley Lab and Robert Socolow of Princeton among its far-sighted participants. From there Gibbons became the second Director of the Office of Technology Assessement (OTA), set up by Congress to provide brief but knowledgeable assessments of almost anything technological—from solar energy to the effects of nuclear war. It was at OTA that he learned a crucial political lesson, that "appearance counts for a lot in Washington." After Clinton was elected, Gibbons was named Science Advisor and Director of the Office of Science and Technology Policy (OSTP), largely through the influence of his fellow-Tennesseean Al Gore. Originally focused on scientific issues related to national defense, OSTP became increasingly involved in health, the environment, and industrial competitiveness during the 1980s. With the Cold War's end, such issues became the primary focus during Gibbons's tenure.

Lane, currently a University Professor at Rice and Senior Fellow at its James A. Baker III Institute for Public Policy, spoke next about "The Civic Scientist Era," sounding a theme he has spoken and written about frequently since serving as Clinton's second Science Advisor. Physics has provided a great number of civic scientists, he said, following in the tradition of Benjamin Franklin, the first scientist to serve the nation in such a role. A civic scientist, Lane said, engages the public in forums from schools to political circles. Among other things, it involves using one's scientific expertise for the greater benefit of the country, whether in defense, the environment, health, or other national concerns. He noted that we have lived through a "golden age of science," lasting from roughly 1950 to 2000, which witnessed Cold-War-driven initiatives in basic research as well as unprecedented—and probably never-to-be-repeated—success in industrial research. Following the abrupt decline in scientists' influence during the Bush years, said Lane, he looked forward to its revival under President Obama. But he cautioned his audience not to take this resurgence for granted, saying current Science Advisor John Holdren needs "all the help he can get" from other scientists. Here physicists can take the lead, but they will be most effective if they recognize the interdisciplinary nature of science and collaborate with colleagues in other fields. "We must hang together, or we will hang separately," quipped Lane, a quote he thought had originated with Franklin.

Rounding out the thought-provoking session, Branscomb, formerly Chair of the National Science Board and now at Harvard's Kennedy School of Government, spoke about "Science as a Model for Rational, Legitimate Government Capable of Meeting Society's Grand Challenges" (Branscomb's talk appears in the October 2009 issue of the Forum on Physics and Society Newsletter, *http://www.aps.org/units/fps/newsletters/index.cfm*). He began by noting that both democracy and modern science are products of the 18th-century Enlightenment, with a common emphasis "on reason and openness rather than religious and political authority." In a democracy, he observed, the government must be responsive to a well-informed public. The only way our elected leaders can be seen as legitimate is by the public becoming aware of and endorsing their opinions and activities. But how well informed can the public be regarding the challenges that involve modern science and technology? Branscomb cited recent polls indicating how poorly informed people actually are about science and technology. For example, according to a 2008 poll by *The Public Agenda*, people recognize the energy challenge is here to stay, but are largely unwilling to make any major changes or sacrifices in their personal lives to deal with it. They support efforts to reduce global warming—but only if these measures don't increase their costs of driving. Over half of all the Americans polled could not identify a specific renewable energy source, and about a third could not come up with a fossil fuel. In closing, Branscomb argued, somewhat idealistically, for a return to "Jeffersonian science" (a phrase he attributed to Gerald Holton)—creative, long-term research relevant to society's most difficult challenges, such as climate change and energy consumption. ■

****Note:*** *2009 April Meeting FHP session pictures taken by George Zimmerman are available at http://www.aps.org/units/fhp/gallery/april09.cfm.*

History of MURA, Fermilab, and the SSC

By Michael Riordan

On Sunday afternoon, May 4, the Forum co-sponsored with the Division of Physics of Beams a session on the "History of MURA, Fermilab and the SSC." Ably chaired by Gloria Lubkin, it emphasized proton accelerators and colliders in the central portions of the United States. Over 100 people attended, participating in the question-and-answer sessions after each talk.

Larry Jones of the University of Michigan led off with "Innovation Was Not Enough," a history of the fixed-field alternating-gradient (FFAG) proton accelerator proposed by the Midwestern Universities Research Association (MURA) in the mid-1950s. This project originated in reaction to the AEC's lavish funding of particle accelerators on both US coasts, which overlooked the Midwest. MURA even began to consider proton-proton colliding beams in 1956. But the project never got beyond the planning and prototyping stages, largely because of political pressures. The decision to build the Zero-Gradient Synchrotron at Argonne "really took the wind out of MURA's sails," recalled Jones. Nevertheless, MURA physicists made significant contributions to the understanding of particle dynamics in high-intensity proton beams, which have influenced accelerator physics ever since.

Fermilab Archivist Adrienne Kolb spoke next on "Fermilab: The Ring of the Frontier, 1965-1978." A co-author of the recent book *Fermilab* (see review in the Spring 2009 issue of the Newsletter, p. 10), she confined her remarks to the laboratory's first decade—including its construction—under Robert R. Wilson. A visionary physicist from Frontier, WY, by way of Berkeley and Cornell, he viewed accelerators as the "cathedrals of the modern age," Kolb said, "bringing people together to worship at the altar of Nature." She laced her lecture with a discussion of how "the frontier" became part of the rhetoric of high-energy physics during the 1960s and 1970s. In response to a question before the Joint Committee on Atomic Energy, about what the proposed National Accelerator Laboratory had to do with national defense, Wilson made his famous remark that it had "only to do with the respect with which we regard one another, the dignity of men, our love of culture . . . . It has nothing to do directly with defending our country, except to make it worth defending." Wilson succeeded in building NAL's Main Ring in 1972, under budget and ahead of schedule, but serious problems with its dipole magnets, many of which shorted out and had to be replaced, delayed the startup of its physics program for over a year. Kolb described those trying times in graphic detail, as "bundled-up teams worked in the cold and rain, sharing space with raccoons, spiders and snakes." Fermilab began to hit stride in the mid-1970s after the proton energy reached 400 GeV and an experimental team led by Leon Lederman of Columbia University discovered the upsilon particles in 1977—the earliest evidence for a predicted fifth quark known as the bottom quark. Wilson resigned as Director in 1978, in part to protest the restrictive Department of Energy funding of Fermilab. Lederman replaced him, ushering the laboratory into its second era, when the Main Ring was upgraded with superconducting magnets and converted into the highly productive Tevatron proton collider.

Stan Wojcicki of Stanford University wrapped up the session with a riveting account on the "History of the Supercollider: A Personal Recollection." He had played central roles in this abortive project, serving as Chair of a 1983 subpanel of the High-Energy Physics Advisory Panel (HEPAP) that recommended pursuing it, next as Associate Director of the SSC Central Design Group (CDG) at Lawrence Berkeley Lab, and finally as the Chair of HEPAP during the SSC construction phase. Few, if any, can speak with such authority on the subject (see his article "The Supercollider: The Pre-Texas Days—A Personal Recolletion of Its Birth and Berkeley Years, " *Reviews of Accelerator Science and Technology* **1**, 259 (2008)). Wojcicki emphasized the "remarkable speed of the conceptual design process" at CDG, which took less than three years, and the highly effective management of that effort by Maury Tigner. But the selection of the SSC Director was rushed and poorly executed. As Wojcicki noted, "It is curious that no member of CDG was ever consulted during the Director choice process." The new SSC management under SSCL Director Roy Schwitters had a more conservative design philosophy that led to major cost increases when the site-specific design for Texas was developed. At that juncture, a key question arose about whether to descope the project to hold costs down; but the decision was made not to do so, and the total project cost ballooned nearly 40 percent to $8.25 billion. As the session ended, the audience joined a spirited discussion of reasons for the SSC's 1993 termination—among them the continuing cost increases and lack of any major foreign participation. This debate will doubtless continue for years to come. ■

The Scientific Legacy of John Wheeler

On Saturday morning, 2 May 2009, about 200 rapt listeners attended a Forum session, chaired by James Hartle of UC Santa Barbara, devoted to the legacy of John Wheeler. All three speakers—Kenneth W. Ford (former chief executive officer of the American Institute of Physics), Kip S. Thorne of Caltech, and Wojciech H. Zurek of Los Alamos—worked with Wheeler as graduate students and/or postdocs during three major phases of his career: nuclear and particle physics; black holes and gravitation; and information theory. (See the special issue of *Physics Today* on Wheeler, April 2009, featuring extensive articles by these authors.)

Albert Einstein, Hideki Yukawa, and John Wheeler outdoors in Marquand Park, Princeton (1954). Photo by Wallace Litwin and Josef Kringold, courtesy AIP Emilio Segré Visual Archives, Wheeler Collection.

Ford launched the session with a talk titled "John Wheeler, 1933-1959: Particles and Weapons." Ford mentioned Wheeler's postdoctoral work, under Bohr at Copenhagen, on the liquid-drop model of the nucleus. That work was followed by their famous 1939 paper on nuclear fission, which was written during Bohr's visit to Princeton that year ("The Mechanism of Nuclear Fission," *Phys. Rev.* **56**, 426). During the 1940s, Wheeler worked on the theory of positronium and served as Feynman's thesis adviser. Later that decade Wheeler originated the idea of a universal Fermi interaction, with a single weak-interaction coupling constant, and foreshadowed the possibility of a distinctive muon-type neutrino. In the last part of his talk, Ford noted Wheeler's defense work, first at the Hanford Lab during the Manhattan Project, where he helped to diagnose and solve the problem of Xe-135 poisoning of the nuclear pile. Following the War, at Edward Teller's urging Wheeler joined the hydrogen bomb effort in 1950, and in the mid-1950s co-founded (with Lyman Spitzer) Project Matterhorn at Princeton to perform computer simulations of nuclear fusion, on which Ford worked as his graduate student (the other branch of Matterhorn grew into the Princeton Plasma Physics Laboratory; see Ford's article "Working (and Not Working) on Weapons," *Radiations* Spring 2005, *http://www.sigmapisigma.org/radiations/2005/spring_05.htm*).

Kip Thorne spoke next on "John Archibald Wheeler, 1952-1976: Black Holes and Geometrodynamics." In 1952, Wheeler decided to strike out in a completely new direction and took up the study of general relativity, teaching a course on the subject at Princeton as one way to learn about it. Strange new concepts such at the "geon," a gravitationally bound electromagnetically interacting particle, the "black hole," and the "wormhole" convinced him of the richness that nonlinearities can produce in curved spacetime. According to Thorne, Wheeler also was the first to recognize the Planck length of 10^{-33} cm as the scale where quantum effects would become important in general relativity. In 1957 he coauthored a paper with Joseph Weber titled, "Reality of the Cylindrical Gravitational Waves of Einstein and Rosen" (*Rev. Mod. Phys*. **29**, 509). And of course there is the famous textbook *Gravitation,* first published in 1973, that Wheeler co-authored with Thorne and Charles Misner. This book and other works by Wheeler pioneered the study of what he dubbed "geometrodynamics"—the dynamics of curved space-time.

Zurek, who was Wheeler's graduate student and postdoc during the late 1970s and early 1980s at the University of Texas, closed the session with his presentation "John Wheeler, 1976-1996: Law Without Law and Quantum Information." During his Texas period, Wheeler turned his attention to the quantum measurement problem—the role of the observer in defining what "is." In this research, said Zurek, Wheeler followed what he called the principle of "radical conservatism," adhering to well-established physical principles while pushing them into extreme situations—an intellectual tendency Wheeler attributed to Bohr. As described in *Quantum Theory and Measurement* (edited by Wheeler and Zurek, Princeton Univ. Press,1983), Zurek said that the observer confers "reality" on the past by observing it, and offered the Big Bang as an example. "What do we mean by 'reality' except the results of observations?" he asked.

The session ended with a segment of a videotaped interview with Wheeler, in which he stated, "Philosophy is too important to be left to the philosophers." It was obvious to all attendees that the three speakers were sharing not only the work of a great physicist. They were also paying homage to their friend. Even those who did not know John Archibald Wheeler personally came away uplifted. ■

History of Telescopes

By Daniel Kleppner

In honor of the 400th anniversary of the telescope, FHP sponsored an invited session on the history of the telescope on Saturday, May 2nd, 2009. The session opened with a presentation by Neville Woolf of the Steward Observatory on "The Bionic Telescope." He noted that the essential elements of Galileo's telescope live on, but that they have been totally transformed. The lens was long ago replaced by a mirror, and the observer's eye replaced by the photographic plate, which was itself replaced by CCD arrays of fantastic sensitivity. The housing—a simple tube—has been transformed into dynamical structures that hold massive mirrors in alignment to sub-wavelength precision. He described the modern era of telescopes as beginning in 1979 with the advent of mirrors cast in rotating ovens and the creation of multiple-mirror telescopes. A major advance in resolution followed the discovery that the limiting factor was often thermal accommodation. Thermal problems are ameliorated by using lightweight mirrors that allow tight thermal coupling to the atmosphere, and by carefully controlling the thermal environment so that the temperature does not change when the mirrors are exposed to the night sky. A second advance in resolution was enabled by the development of ground-layer adaptive optics. Towards this end, up to five laser beams are employed. These advances have made the diffraction limit achievable for large mirrors. Such adaptive optics enabled the first imaging of exoplanets. Woolf concluded with a description of the Giant Magellan telescope in which seven 8.4-m mirrors, their size limited only by the problem of transporting them to the observatory, will be joined to form a parent surface with a diameter of 25 m. In Europe, plans are being developed for such a telescope with 40 mirrors.

Christine Jones of the Harvard/Smithsonian Center for Astrophysics followed up with a talk on "Black Holes, Dark Matter, and Dark Energy: Measuring the Invisible through X-rays." The first observations of X-rays from the Sun were made in 1949 by Herbert Friedman of the Naval Research Lab, but it was Riccardo Giacconi, then at American Science and Engineering, who really pioneered X-ray astronomy during the 1960s. In 1962 he noticed X-rays reflected from the surface of the moon, and three years later, using an X-ray telescope fixed to a rocket, observed hot spots in the Sun. The first observations of non-solar X-rays came in 1978-81, by the Einstein Observatory and the Roentgen Satellite, or ROSAT. But it was the Chandra X-ray Observatory launched in 1999 that really broke the field open, said Jones. Using the glancing reflections of X-rays from hyperbolic cylindrical mirrors, Chandra has achieved a resolution of 1 arc-sec and has been able to resolve the heretofore "diffuse" X-ray background into a profusion of point sources. Perhaps its most telling discovery is the Bullet Cluster, a bullet-shaped region of hot gas due to a collision of galaxies. By comparing X-ray images (which trace only baryonic matter) with maps of the same region made using gravitational lensing (which traces all matter, baryonic or not), researchers have produced a stunning visual image that demonstrates the existence of dark matter beyond reasonable doubt.

Paul Vanden Bout of the National Radio Astronomy Observatory (NRAO) ended the session with an excellent talk on the history of radio astronomy. It began with Karl Jansky of Bell Labs, who, while searching for sources of static in 1933, discovered 14.6-m radiation moving across the sky at the sidereal rate—coming largely from the Milky Way. In 1937, Grote Reber began observations using a 31-foot reflector built in his back yard; he eventually worked his way down to 160 MHz and published maps of the radio sky in 1944. After the War, with surplus radar reflectors becoming available from military sources, the field of radio astronomy exploded. Van den Bout briefly noted the structural details and major contributions of the Areceibo radio telescope in Puerto Rico, the Mark I at Jodrell Bank in Britain, and the 300-ft NRAO telescope—all tracing back to the 1950s. But it was a small horn receiver at Holmdel, NJ, originally built by Bell Labs for satellite communications, that allowed Arno Penzias and Robert Wilson to make what he called "the biggest discovery in radio astronomy"—of the cosmic background radiation. A few years later another astounding discovery was made with a low technology receiver. This was the discovery of pulsars by Jocelyn Bell and Anthony Hewish, who worked with a large wire-array receiver. More recently, highly sophisticated radio receivers in the COBE and WMAP satellites have revolutionized our understanding of the early universe by discerning ever-so-subtle ripples in the otherwise uniform cosmic background radiation. ■

Silicon Valley

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magnetic resonance, but died in 1949, at age 39, of berylliosis. To celebrate the centenary of Hansen's birth, Leeson will publish Hansen's lecture notes with a biography of him. Leeson was a founder of a Silicon Valley company, California Microwaves; after 25 years as its CEO, he retired to become a Stanford professor.

"From Bell Labs to Silicon Valley: A Saga of Technology Transfer, 1954-1961" was the title of the talk by Michael Riordan (Stanford and UC Santa Cruz), the John Bardeen Lecturer. "Although Bell Labs invented the transistor and developed most of the underlying semiconductor technology," Riordan said, the integrated circuit emerged elsewhere—at Texas Instruments and Fairchild Semiconductor. In 1947 the point-contact transistor was invented by Bardeen and Walter Brattain. A month later William Shockley conceived the junction transistor, which used three layers of either silicon or germanium. The first silicon transistors were fabricated in 1954, by Morris Tanenbaum at Bell Labs and by Gordon Teal, who had left Bell Labs

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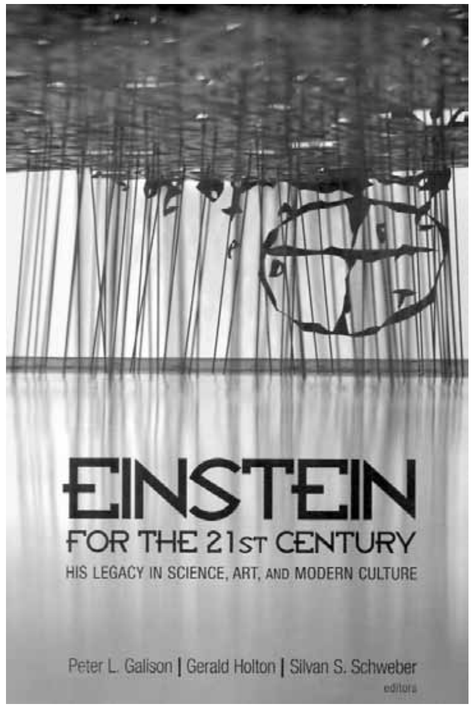
Einstein for the 21st Century
His Legacy in Science, Art, and Modern Culture

by Peter L. Galison, Gerald Holton, Silvan S. Schweber, Editors
Princeton University Press, 2008, 400 pp., illustrated, $35.00

Reviewed by Michael Riordan



We all recognize Albert Einstein for his unparalleled contributions to 20th-century physics, in which he established a radically new style of scientific thought founded in the simplicity, rationality and symmetry of Nature. But few of us know much about his broader impact on philosophy, art, and modern culture. This book, based on contributions to the Berlin Einstein Symposium of 2005, helps fill this gap in our appreciation of the man and his works. Edited by three physicists with distinguished careers in the history of our field, it gathers in one volume the observations of twenty scholars about the many dimensions of Einstein and his impacts on science and culture. In addition to the editors themselves, the authors include leading historians and philosophers of science such as Lorraine Daston and Michael Friedman, art historians Linda Dalrymple Henderson and Caroline A. Jones, novelist E. L. Doctorow, and Nobel laureates David Gross and Dudley Herschbach.

As Holton remarks in his introductory article, "Not since Isaac Newton's *Principia* can one imagine an analogous symposium to mark a physical scientist's legacy in such a wide spectrum of fields" (p. 3). He identifies Einstein as a German *Kulturträger,* or culture carrier, one who "not only imbues and represents the culture of his time and place, but also stimulates others, widens their horizon, imagination, and vocabulary" (p. 13). Kant and Goethe, for example, prodded European culture into completely new realms of thought. The other contributors then help to flesh out Holton's vision of Einstein's "meaning" for the 20th century and beyond.

Daston writes eloquently about Einstein's search for a paradise beyond the merely personal, a longing shared with such turn-of-the-century physicists as Max Planck and Henri Poincaré. The transcendence they sought was more than just a replacement for Judaism or Christianity; it was "a genuinely new ideal of how to be and know in the world" (p. 16). These theorists helped redefine what it meant to be a scientist, or more exactly a theoretical physicist — just then beginning to emerge as a distinct avocation. Their community of like-minded thinkers is recognized more broadly today as a "scientific community," a term first coined by Charles Saunders Peirce in the late 19th century.

Despite his vast contributions to physics, Einstein was largely unknown to the public until 1919, when observations of the bending of light rays by the Sun gave stunning confirmation of his theory of general relativity. He subsequently became a cultural hero in part because of his wartime pacifism and opposition to German militarism. But this fame earned him the undying enmity of the nascent Nazism in Weimar Germany. Relativity began to be reviled as "Jewish physics" by the Nazis, including two Nobel laureates, and Einstein eventually emigrated to America and Princeton in 1933, just steps ahead of Hitler. Curiously, his 1920s emergence as a cultural figure also marked the end of his major contributions to theoretical physics.

Art historian Henderson remarks that Einstein's impact on modern art began in that decade. She debunks the "myth" that his ideas of special relativity spawned the cubism of Braque and Picasso, which had deeper roots in the multi-dimensional, non-Euclidean geometries of 19th century mathematicians. But Einstein's theories of relativity *did* influence Dadaism, German Expressionism and the Bauhaus, Russian Constructivism, and the Surrealism of Salvador Dali. To these *avante-garde* artists, the fourth dimension was not one of space but of time, which they tried to invoke or evoke in their work. For Caroline Jones, "Einstein is the unspoken fulcrum" (p. 131) of an important shift in spatio-temporal visualization by artists of the late 19th and early 20th centuries. She discusses how distinctly differently the French Impressionist Claude Monet and today's "explicit Einsteinian" Matthew Ritchie—whose artwork graces the book's dust jacket—have rendered the ideas of time and motion.

Although interesting, the contributions of Galison and Schweber did little to expand my understanding of Einstein. In "The Assassin of Relativity," Galison writes principally about Friedrich Adler, a theorist and contemporary of Einstein's at Zurich, whose leftist leanings led him to murder the Austrian Prime Minister in 1916. We glimpse their correspondence while Adler languished in jail awaiting trial, and watch as a dispute about relativity

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erupts between them. All I learned here about Einstein was his compassion for and loyalty to an old friend, however guilty of a heinous crime. Schweber writes about "Einstein and Nuclear Weapons," retelling the well-worn story of his famous August 1939 letter to President Roosevelt warning of the possibility of a uranium bomb. But later in the piece, he offers numerous details I'd previously been unaware of about Einstein's reactions to Hiroshima and Nagasaki and his postwar efforts to promote international control of nuclear weapons.

This volume ends with an article by Harvard string theorist and author Lisa Randall on "Energy in Einstein's Universe" focusing naturally enough on $E=mc^2$ and dark energy. That space itself, even without any particles or radiation present, contains energy is the most astonishing scientific revelation of recent decades. And the fact that this dark energy dominates the mass-energy density of the Universe, accelerating its rate of expansion, is equally amazing. But as measurements of dark energy improve, it increasingly appears that Uncle Albert got there first—and got it correct, although for the wrong reason—by postulating the cosmological constant. What has been called his "biggest blunder" is doing an awfully good job recently of fitting the growing data on dark energy. As Randall observes, Einstein's blunder was not in adding the cosmological constant to his equations of general relativity, but in assuming that the Universe was static as his reason for doing so.

In summary, *Einstein for the 21st Century* is an excellent account, written from diverse perspectives, of the many and varied influences that Einstein has had upon modernity and the way we have come to grasp our world. I heartily recommend it for readers who want to understand his impact in this broader sense.

Associate Editor Michael Riordan teaches the history of physics and technology at Stanford University and the University of California, Santa Cruz. ■

"April 2010" Forum Sessions

By Daniel Kleppner

The Forum on History of Physics has planned four invited sessions and a contributed session for the 2010 "April" meeting in Washington D.C. The meeting is being held in conjunction with the of the American Association of Physics Teachers annual meeting.

James W. Cronin has organized a session "Remembering Enrico Fermi," to take place on Sunday, Feb. 14. The speakers, all former students of Fermi, and their presentation titles are: T. D. Lee, Columbia University, "Fermi at Columbia and Reminiscences of Chicago Days"; Richard L. Garwin, IBM T. J. Watson Research Center, "Working with Fermi at Chicago and Los Alamos"; and Jerome I. Friedman, M.I.T., "A Student's View of Fermi". The session is co-sponsored by the AAPT.

Another session co-sponsored by AAPT has been organized by Ronald E. Mickens. Entitled "Origins of Research and Teaching at Selected Physics Departments," the speakers and titles are: Hans C. von Baeyer, College of William and Mary, "History of the William and Mary Physics Department from 1757 to 2009"; Warren Eugene Collins; Fisk University, "Physics Research and Education at Fisk University"; and Jerry P. Gollub, Haverford College, "Research and Education in Physics and Astronomy at Haverford College." The session is scheduled for Monday, Feb. 16.

In support of the Laserfest celebration to mark the 50th anniversary of the laser, Joseph A. Giordmaine has organized a session "The Laser: its History and Impact on Precision Measurements," which is co-sponsored by the Topical Group on Precision Measurements and Fundamental Constants. The session will take place on Tuesday, Feb. 16. Giordmaine will present the opening talk, "The Kickoff Years: from Ruby Laser to Nonlinear Optics," to be followed by Federico Capasso, Harvard University, "Freedom from Bandgap Slavery: from Diode Lasers to Quantum Cascade Lasers," and John L. Hall, JILA, "The Whirlwind from the Speed of Light and the Meter on to the Optical Comb."

Finally, a session entitled "Secrecy and Physics" has been organized by Peter Galison and Charles Holbrow. This session is co-sponsored by AAPT and the Forum on Physics and Society. It will be held on Saturday, Feb. 13. Speakers and titles are Steven Aftergood, Federation of American Scientists, "Secrecy and Physicists: Intersections of Science and National Security"; William Happer, Princeton University, "How Much Secrecy?" and Peter Galison, Harvard University, "Physics and Modern Secrecy." In conjunction with this session, screenings of a new documentary, "Secrecy", will be shown at both the APS and AAPT meetings. ■

Silicon Valley

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for Texas Instruments. The following year Tanenbaum and his technician made the first diffused-base transistor in silicon.

When Shockley learned about the diffused-base silicon transistor, he almost immediately recognized its commercial potential. In 1955, with the backing of Arnold Beckman (founder of Beckman Instruments), Shockley Semiconductor Laboratory opened for business in Mountain View, California. Shockley hired a promising team of engineers and scientists to develop and manufacture transistors and related semiconductor devices. Because Shockley had licensed rights to the transistor patents from AT&T, he wound up getting a lot of handholding through his personal contacts at Bell Labs. But two years later eight of the original hires, including Gordon Moore and Robert Noyce, resigned together to start Fairchild Semiconductor in 1957. That event, observed Riordan, "marked the birth of Silicon Valley, both technologically and culturally." In 1961 the company marketed the first commercial silicon integrated circuits, the Micrologic series. "Seven years later Noyce and Moore left to form Intel," he said, "and the rest is history." ■

History of Physics
NEWSLETTER

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