Physicists I have known

Paul P. Ewald

Paul P. Ewald, pioneer solid-state physicist and crystallographer, was born in Berlin in 1888. After obtaining his PhD in Munich in 1912, Ewald taught and did research at Munich, Stuttgart, Cambridge and The Queen's (Belfast) Universities and at the Polytechnic Institute of Brooklyn, where he headed the physics department. Ewald recently gave a talk at the New York State Section of the APS at Rensselaer Polytechnic Institute on which, along with notes he generously supplied to PHYSICS TODAY, this article is based. Ewald and his wife Ella now live in Ithaca, New York, where they are close to their daughter and son-in-law, Rose and Hans Bethe. The picture of Ewald below shows him as a *Feldröntgenmechaniker* (field x-ray technician)—see also the WWI-vintage mobile x-ray unit on the opposite page. A recent photo of Ewald is on page 47.

My first encounter with science came when I was eleven. My mother and I were living in Berlin, but often spent summer vacations with friends in Cambridge, England. In their house we met **Siegfried Ruhemann,** holder of the first chair in organic chemistry in England, at Cambridge's Gonville and Caius College.

Ruhemann, who was then doing delicate research on snake-venom alkaloids, took me to his little laboratory. It was in a one-story shed separated from the other college buildings by a cobblestoned yard. I was amazed to see hundreds of neatly-labelled bottles on the shelves, and benches filled with faucets, glassware and other implements.

The professor took a piece of glass tubing and heated it in the flame of a Bunsen burner, turning it in his hands. I could not understand how he was able to hold the tube while the ends were glowing red. Closing one end with his finger, he brought the other end up to his mouth and, in several stages, blew the midpart to a magnificent bubble five or six inches in diameter. More marvels were to come. After cooling the bulb in the luminous flame, making it (to my dismay) temporarily quite sooty, Ruhemann heated the lower part of the tube in a noisy pointed flame, and quickly severed it. After the now perfectly rounded bulb had cooled thoroughly, Ruhemann poured clear liquids from two different bottles into the bulb and shook it thoroughly. Lo and behold, the inside became the brightest silver! In my enthusiasm I resolved then and there to become a chemist.

I treasured the beautiful silver bulb beyond all my other possessions. But on the midnight journey home, the drowsy boy, carrying his treasure like a priceless relic, hit the railing of the steamer's gangplank. Only a silver star of thin glass was left. Back home in Berlin, however, I started my own laboratory.

Although the boy had just completed high school, Sommerfeld allowed him to enroll in his course. "May I also come to the seminar?" asked Pauli. Reminiscences of the heroic age of physics.

On another visit to Cambridge, our friends introduced me to **J. J. Thomson,** a lively man and splendid conversationalist who seemed to be acquainted with every novel that was mentioned. I think he said that he read a novel a night. He was very proud of his son, now **Sir George Thomson** of electron diffraction fame. George, with the help of his father, constructed scale models of warships—one of every type in the British navy.

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When I returned to Cambridge in 1905 as an undergraduate at Gonville and Caius, I attended a very impressive evening lecture by J. J. Thomson. It was entitled "The Structure of Atoms." In his model of the atom, negative electrons swam freely in a uniformly filled sphere of positive electricity. They were thus attracted to the center and repelled by one another—all by coulomb forces. The idea was illustrated by J. J.'s famous assistant-mechanic in a demonstration of intriguing simplicity. Little cork boats, each carrying a compass needle, floated in a round dish of water. One pole of a bar magnet suspended above the center of the dish provided the central force. Watching the image projected by an overhead mirror, I saw a single boat (for hydrogen) place itself at the center. Two boats, representing the helium atom, came to rest on opposite sides of the center. Three formed an equilateral triangle and four a square. With the addition of a few more boats, however, these symmetrical arrangements clearly became unstable; in addition to the symmetrical inner array, an incomplete outer circle began to form. To Thomson, the relevance of this phenomenon to the periodic system was obvious. What a pity the model was a wrong guess!

J. J. THOMSON

The next day I repeated Thomson's demonstration in my "digs"—I am sure I was not the only one. I was very proud when the experiment in my wash

SOMMERFELD . . .

. . . AND FELLOW HIGH-SCHOOL GRADUATES

basin, using magnetized sewing needles, succeeded.

In the spring of 1901, when I was 13, my mother took me to the village of Glion on Lake Geneva to recover from bronchitis. The mountain meadows were full of crocuses and narcissi and the air was balmy. As my mother sketched the scenery, a rather haggard young lady walked up to chat about the painting with her. She was in her twenties, with a beautiful pale face dominated by startling blue-grey eyes. **Edith Stoney** was a lecturer in physics at a women's college in London, and was staying in a big hotel higher up the road to recover from overwork and a tuberculosis attack. I instantly fell in love with her and could hardly wait to meet her again. Our stay came to an end too soon, but she invited us to visit her on our next trip to England.

Next year we went to London and were invited to tea with Miss Stoney and her parents. I was deeply disappointed when Miss Stoney opened the door—the angelic invalid with the translucent features had turned into a red-cheeked, somewhat buxom young woman. She introduced us to her lively mother and her retired-physicist father, **Johnstone Stoney.** Little did I know at the time that this was the man to whom we owe the name electron for J. J. Thomson's "corpuscles." The bearded old gentleman took me to his attic room as the sun set over a sea of roofs and chimneypots, and showed me the large spectrograph with which he studied light absorption in the atmosphere.

In 1906 I enrolled in the chemistry course at Göttingen. In the interests of the medical students, the course was given at seven in the morning. Chemistry was taught as a jumble of facts with as little theoretical connection as the recipes in a cookbook. When I found myself dozing off for the third time, I gave up attendance.

My interest changed to mathematics, for which Göttingen was the Eldorado. **David Hilbert** gave me my first paid appointment—to write out, for 100 marks per semester (about $24 at that time), his lecture course on differential and integral calculus. Going over these notes carefully with Hilbert's assistant **Hellinger,** a devoted teacher, taught me practically all the analysis I ever needed. Through Hellinger I met a group of advanced students, including **Herman Weyl** and his classmate **Wink,** who had composed a rhymed play for the mathematician's excursion.

On this yearly occasion, some 100 mathematics students and their teachers, from the great **Felix Klein** down to the lowliest assistant, wound through fields and meadows to Mariaspring, a

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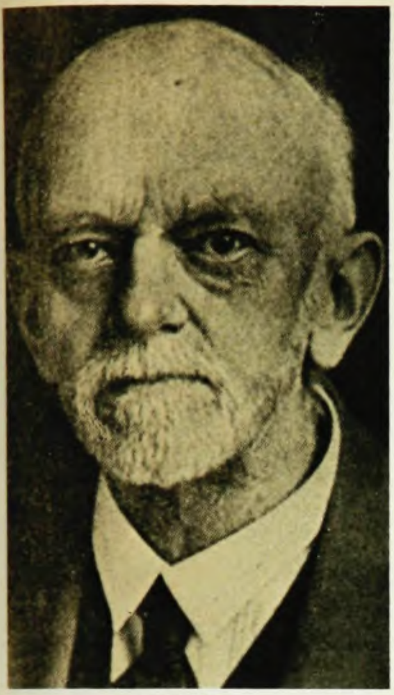
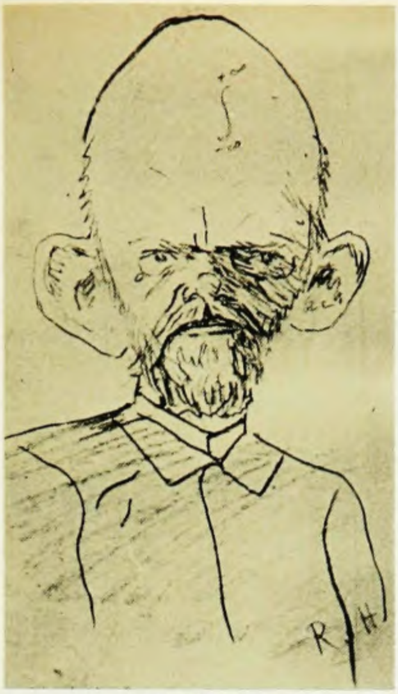


HILBERT . . .



. . . AS DRAWN BY HOLM

DEBYE

linden-shaded rural inn about four miles from Göttingen. There we had supper, easy approach to our teachers and entertainment. The play showed a timid young student seeking advice on the various branches of mathematics from a professor. In the role of the professor I unwittingly presented a caricature of the formidable Felix, but no harm came of it.

Hilbert was not a smooth lecturer; he made mistakes. He would walk about the dais and think until you became so nervous that you wanted to shake him to find out what was going to happen. What finally emerged, however, was so impressive you did not easily forget it.

In a student's mess where I took my middle meal (the main meal of the day) I met **Ragnar Holm,** who was later to become the chief authority on electrical contacts and the father of plasma physics. Holm, who had a keen sense of humor, once gave a talk at the Göttingen Physical Society, a rather dignified, formal group. He spoke in a German strongly laced with a musical Swedish accent; so he ended by saying, "I have heard many a bad talk in this society, but today I have taken my vengeance." It was Holm who, during a lecture, drew the caricature of Hilbert shown on this page—he even put an integral sign on the enormous forehead!

After two years at Göttingen I transferred to Munich to study the new rigorous approach to mathematics originated by **Karl Weierstrass.** My professor was **Alfred Pringsheim,** a dapper little man with a bald crown flanked by bristling rows of gray hair and the convivial red face of a *bon vivant.* His lectures were works of perfection. It was a pleasure to see Pringsheim's neat writing extending over the blackboard, and to listen to his occasional sarcastic remarks on other trends of mathematics. Yet, much as I enjoyed these lectures, I later found that they had really not penetrated under my skin—as Hilbert's certainly had.

When a friend dragged me into a lecture course by **Arnold Sommerfeld** I was quite unwilling to be distracted from pure mathematics into the field of hydrodynamics. Besides, I had not taken the course in mechanics which generally precedes it. In a few lectures, however, Sommerfeld introduced the notions of vector algebra and vector analysis, illustrating them with the behavior of liquids. The immediacy of the correspondence between concept and phenomenon was a delight. My resistance gone, I joined the Sommerfeld school, renouncing the pale shade of pure mathematics.

Sommerfeld's school of theoretical physics was unique until about 1924,

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BORN . . .

. . . 60 YEARS LATER

KARMAN

when **Max Born** in Göttingen and **Niels Bohr** in Copenhagen formed comparable schools. Aside from the obvious requirement of a scientific leader of great experience, fertility and integrity, environment and the snowball effect also played a role in the formation of such schools, which attracted so many devoted, highly qualified students.

Before his world-wide lecture tours acquainted him with life in other countries (particularly the US), Sommerfeld's understanding of the world was rather restricted. This cannot be said of his relations with his students, the development of whose faculties he loved to watch. He stimulated beginners by giving them small tasks, such as drawing diagrams, calculating tables or discussing special cases for his own research papers, or giving seminar talks. He gave his students the freedom to find their own way. There were no formal examinations except the final ones: the doctorate or the qualifying exam for high school teachers.

Sommerfeld made what he called his greatest discovery among the engineering students at the Polytechnic School in Aachen, where he was professor of technical mechanics after leaving Göttingen. This was **Peter Debye,** a keen, bright-eyed young man who commuted from the nearby Dutch town of Maastricht. Sommerfeld made him his assistant and, when he was offered the chair of theoretical physics in Munich, accepted it on the condition that he could bring Debye with him.

When I joined Sommerfeld's group in 1909, Debye was still working on his voluminous thesis on the theory of the rainbow. In it he replaced the old Cartesian theory of refraction and dispersion of the sun's rays in raindrops with a theory based on the diffraction of light by small drops of water. He promised the manuscript to Teubner for publication as a book, but more urgent problems intervened and the book never appeared.

Max Planck's quantum theory of blackbody radiation had introduced the enigmatic new universal constant h. Was h a property of the atom or of the radiation? Were energy quanta produced in emission, absorption or both? **Albert Einstein** had already applied the quantum theory to the vibrations of atoms in a solid, thereby obtaining a relation for the temperature dependence of the specific heat. Unfortunately, Einstein's model, in which all vibrations were assumed to be of the same frequency, was unsuccessful in rendering the accurate measurements of **Walther Nernst** and his school. Debye, applying Planck's distribution of energy quanta to the entire spectrum of frequencies in a solid, obtained a different formula for specific heat. This turned out to be well in accord with the measurements. It was a daring innova-

CERN

PAULI

LORENTZ

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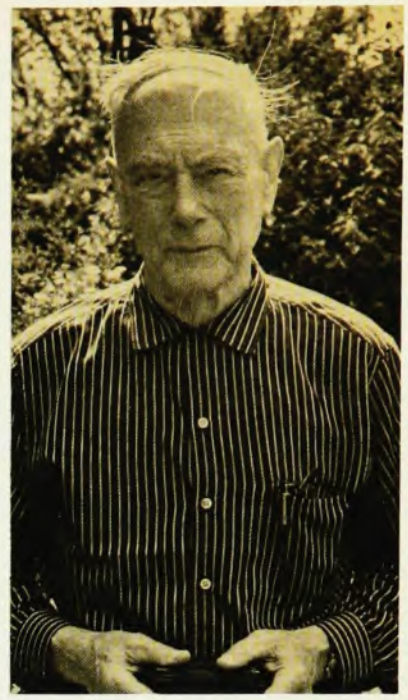

EWALD

tion to consider quantum effects to be spread throughout the solid body, instead of being localized at a single atom.

Born and **Theodore von Kármán** used a similar approach in Göttingen at about the same time. Using a crystal lattice as a model of a solid, they determined its vibrational spectrum. This was the beginning of crystal dynamics as we know it today.

In 1919, with the development of atomic and quantum physics in full swing, a slim, young-looking boy appeared in Munich. The boy, **Wolfgang Pauli**, had a letter from his father, a chemistry professor at the University of Vienna, asking Sommerfeld to place his son where he saw fit. Pauli has just completed high school, but had also studied physics on his own. Sommerfeld told the young man that he could enroll in his current lecture course, but doubted whether he could understand it. "Certainly," replied Pauli, and added, "May I also come to the seminar?" Sommerfeld could see no sense in his coming to the seminar, which was for advanced graduate students, but nevertheless gave Pauli permission to sit in. It soon turned out that Pauli had the quickest grasp, the most profound understanding and the greatest ability of the participants.

My wife and I had Pauli, who could not go home to Vienna, with us for Christmas 1919. He told us how he used to wear himself out during his high school vacations by reading mathematics until two in the morning. He needed the school term, when his father insisted on his going to bed at eleven, for recovery.

I was deeply impressed by the great Dutch physicist **H. A. Lorentz**, the originator of the electron theory of metals, which formed the foundation of my thesis and later work. It was many years after the first World War before German physicists were welcome in the Allied countries. Through **A. D. Fokker** I was invited to lecture in Holland in 1923, and on that occasion I was received by Lorentz in the Teyler Stichting in Haarlem. To my surprise, Lorentz the physicist was most proud of his engineering achievements as the head of the state commission for the reclamation of land from the Zuider Zee. Goethe's Faust, who obtained the greatest satisfaction from the fact that he had reclaimed land from the sea, came to my mind.

When I attended a lecture of his Amsterdam University course, I was struck by the personal, rather fatherly way Lorentz spoke to his class, a contrast to the more aloof lecture style of most German university courses.

The discovery of x-ray diffraction and the development of the "new crystallography" brought friendship with many more memorable personalities than I can include here. □