



Professor Herbert Bishop Keller (1925-2008)

See:

https://en.wikipedia.org/wiki/Herbert_Keller

<http://www.worldcat.org/title/interview-with-herbert-b-keller/oclc/41449624>

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Applied Mathematics/Applied Science
California Institute of Technology, Pasadena, California

Biography (from : <http://www.worldcat.org/title/interview-with-herbert-b-keller/oclc/41449624>):

Dr. Keller received his BEE at Georgia Tech in 1945 and his PhD from New York University (Institute for Mathematics and Mechanics, later the Courant Institute) in 1954. At Caltech as a visiting professor in 1965; joined the faculty as full professor in 1967. Executive officer for applied mathematics, 1980-1985.

He discusses growing up in Paterson, N.J., with his older brother, mathematician Joseph Keller, and education in mathematics at Eastside High School. Matriculates at Georgia Tech and joins NROTC; in World War II, serves as a fire-control officer on the USS Mississippi.

After the war, he takes graduate courses in electrical engineering at Georgia Tech; soon follows his brother to NYU and the institute established there by Richard Courant. Recollections of Courant and Charles De Prima; fellow students: Peter Lax, Louis Nirenberg, Cathleen Morawetz, and Harold Grad. Bicycling trip in Europe, 1948, with his brother; meeting up with Courant in Switzerland. Thesis work with Bernard Friedman. From

1951-1953, he taught mathematics at Sarah Lawrence.

Recalls working with Robert Richtmyer at Courant on the Atomic Energy Commission's UNIVAC computer; becomes associate director of the AEC Computation and Applied Mathematics Center; Edward Teller and Hans Bethe as consultants; visits Los Alamos and Livermore. Initial invitation to Caltech in 1960 from Gilbert McCann, head of what was then called information science (now computer science). Happy at Courant and unimpressed with Caltech's offer, he declines, but visits Caltech in 1965 at invitation of Gerald Whitham, joining new applied mathematics program. Returns to NYU for a year, then back to Caltech to stay. Recalls applied math group—Donald Cohen, Philip Saffman, Julian Cole, later Joel Franklin. Recalls Jack Todd. Helps establish and for many years teaches one of Caltech's most popular courses: Applied Mathematics 95 (AMA 95).

Discusses early development of computer science at Caltech: Donald Knuth, Carver Mead, Charles L. Seitz., Ivan Sutherland, Mani Chandy. Discusses his relations with Caltech's pure mathematicians and aerodynamicists. Recalls sabbatical at INRIA [Institut National de Recherche en d'Informatique et en Automatique] and visiting professorship at Paris-Orsay. Visiting fellow at Christ College, Cambridge, and DAMTP (Department of Applied Mathematics and Theoretical Physics) in 1993. Concludes by recalling his impressions of K.O. Friedrichs and Fritz John at Courant and his work with his brother.

Obituary by Michael Holst (University of California, San Diego) and Thomas Y. Hou (California Institute of Technology), et al in SIAM News, July 10, 2008 (SIAM = Society for Industrial and Applied Mathematics)

The applied mathematics community lost one of its intellectual and spiritual leaders when Herbert B. Keller, a long-time professor of applied mathematics at the California Institute of Technology, died unexpectedly on January 26, 2008, at his home in Pasadena. He had just returned from his regular 40-mile Saturday morning bike ride with friends. He was 82.

Herb was a central figure in the numerical analysis community, although his work branched out into a number of other areas in applied mathematics, including bifurcation theory, computational fluid dynamics, homotopy and path-following methods, and parallel computing algorithms. He is the co-author (with Eugene Isaacson) of the classic 1966 textbook *Analysis of Numerical Methods*, which is still in use in leading graduate programs in computational and applied mathematics.

Herb was an active member of SIAM, serving as vice president (1973–74) and president (1975–76); he was a member of the SIAM publications committee (1964–71), the SIAM Council (1965–68), and the SIAM Committee on Science Policy (1985–90). In 1994 he received SIAM's Theodore von Kármán Prize. He was also a Guggenheim Fellow (1979–80), and he was a Fellow of both the American Academy of Arts and Sciences and the American Association for Arts and Sciences. Beyond these and numerous other professional achievements, Herb was simply adored by his many friends, colleagues, and students, and his passing is a tremendous loss to a very large personal and professional network. Herb is survived by his son, Steve, daughter, Debbie, former wife, Loretta, and four grandchildren.

Herb was born in Paterson, New Jersey, on June 19, 1925. He and his well-known brother, Joseph B. Keller, who is older by two years, were the only children of Sarah Bishop Keller and Isaac Keller.

On graduating from Eastside High School in Paterson, Herb went to the Georgia Institute of Technology, where he majored in engineering physics and joined the Naval ROTC. On his graduation he entered the Navy as an officer. He became a gunnery officer on a ship that patrolled the Atlantic during World War II. When it was time for his release from the Navy, Joe Keller recalls, Herb was told that the release could not be granted—there was no other gunnery officer on board. Herb was advised to teach a gunnery course to incoming officers, which he did, to a class in which one of the students was Jimmy Carter! Herb was then released from duty.

He returned to Georgia Tech as a graduate student but after a year moved to New York University to study mathematics. At that time, Joe, having received his PhD in 1948, invited Herb to join him on a two-month trip

to Europe. As Joe recalls, they bought bikes there and did a great deal of cycling. One day, near Marseilles, they found the road lined with thousands of people, who cheered and applauded them wildly. It turns out that they had entered the route of the Tour de France, ahead of the pack. Many years later Herb took his son Steve to Europe for a similar cycling trip. Herb's love affair with bicycling really took off in 1985, when, after several weeks of trekking in the Himalayas, he gave up smoking, became a biking fanatic, and devoted much of his time to cycling with friends from cycling clubs in Pasadena and San Diego.

Joe became Herb's adviser at NYU, and they wrote several papers together, on wave propagation and reflection. Thinking that it would not look right for him to be listed as his brother's adviser, Joe asked his colleague Wilhelm Magnus to sign Herb's thesis. Joe comments that this was a big mistake---Herb turned out to be one of his best students! Herb remained at NYU as a faculty member, and decided to work in numerical analysis and computing. (He would tell colleagues over the years that the decision was motivated by his desire to make a mark in mathematics distinct from that of his brother.) He became the associate director of the Atomic Energy Commission's Computing and Applied Mathematics Center at the Courant Institute. Herb met and married Loretta at this time, and from 1951 to 1953 he also ran the mathematics department at nearby Sarah Lawrence College. He often spoke of his experience at Sarah Lawrence, which influenced his approach to teaching at Caltech and, later, the summer teaching programs he developed for the National Science Foundation Center for Research on Parallel Computation, which he directed at Caltech from 1989 until his retirement in 2000. In 1965, at the invitation of Gerald Whitham, Herb visited the Applied Mathematics Group at Caltech for a year. He returned to NYU for the academic year 1966–67 but found that he missed California; in 1967 he accepted a position at Caltech as a professor of applied mathematics, with a joint appointment in mathematics. He remained at Caltech until his retirement. Caltech allowed Herb's career in applied mathematics to blossom fully, and he in turn was a lifelong believer in Caltech as an institution, even donating his Pasadena home to Caltech to endow a lectureship.

It was during his years as a professor of applied mathematics at Caltech that Herb became a central figure in the numerical analysis and applied mathematics community. He is particularly well known for his work on numerical methods for two-point boundary-value problems, and for his careful numerical analysis of nonlinear problems exhibiting folds and bifurcation phenomena. He is considered one of the pioneers of pseudo-arc-length continuation and other numerical homotopy techniques for difficult parameter-dependent nonlinear problems. His work in numerical homotopy methods is a beautiful blend of ideas from numerical analysis, linear algebra, nonlinear analysis, differential geometry, and topology. (His elegant work in this area heavily influenced the first author of this obituary to choose numerical analysis as a field.) Later in his career, Herb and G.M. Shroff developed the recursive projection method for stabilizing fixed-point iterative procedures in the solution of nonlinear parameter-dependent problems; the method has generated a great deal of interest in the scientific community and has found interesting applications in different scientific disciplines.

Beyond SIAM, Herb made extensive contributions to the scientific community as a member of panels and committees of the National Academy of Sciences, the Conference Board of the Mathematical Sciences, the American Mathematical Society, and other national organizations too numerous to name here; the list of corporations and laboratories to which he lent his expertise as a consultant is almost equally long.

He was a member of the editorial boards of a number of the central journals in applied and computational mathematics, including SIAM Journal on Applied Mathematics and SIAM Journal on Numerical Analysis, Numerische Mathematik, and the Journal of Computer and System Sciences. He was also an editor for the ACM Monograph Series, Acta Numerica, the Springer Series in Computational Physics, and the North-Holland series on Studies in Mathematics and its Applications.

In addition to the classic Isaacson/Keller textbook, Herb was the author of several seminal books and monographs. His early work on two-point boundary-value problems appears in both a Dover monograph and a shorter SIAM monograph. His later work on bifurcation and path-following appears in a well-known

monograph published by the Tata Institute. (As to Isaacson/Keller, the authors of this obituary use it regularly for its careful treatment of a number of topics not covered in more modern surveys in the area.)

Even those who know Isaacson/Keller well might not have heard the following story (related by Tony Chan): Apparently, Herb and Eugene were having a lot of trouble agreeing on the preface to their book; one would rewrite it and pass it to the other, who would then completely rewrite it yet again. Finally, Herb decided to use an acrostic to embed a hidden message in the preface; if Eugene made further modifications, he would destroy the message. At that, Eugene gave in and told Herb that he agreed to that version, which is the one that eventually appeared in the book. (We challenge readers to find the hidden message.)

In 2000, after retiring from Caltech, Herb joined the Center for Computational Mathematics in the Mathematics Department at UC San Diego as a senior research scientist. From that time on, he split his time between his home in Pasadena and a condo in Leucadia, about 17 miles north of UCSD. Herb regularly attended the Tuesday CCM seminars, including the one held the week before his death. He usually made the round trip between Leucadia and UCSD by bicycle.

On February 24, a number of Herb's close colleagues and friends gathered with his family at the Athenaeum at Caltech to celebrate Herb's life with a memorial service. Many took advantage of the opportunity to say a few words about Herb. His wonderful appetite for life, generosity, and sense of humor were remembered. Several people mentioned the "Keller principle," a general approach to problem solving they had learned from Herb, which involves "asking for forgiveness later" rather than "asking for permission first."

A number of Herb's colleagues and friends have come forward with insightful stories and comments about Herb. A sample of their slightly edited contributions follows.

An incident about 30 years ago boosted my esteem for Herb sky high. It concerned referees' reports for an Habilitation. This is much more critical than reports for a paper, more like a tenure decision in that it determines whether a career can proceed. To make a long story short, one report was unfairly negative and had thrown the Habilitation committee into uncertainty. Two additional expert referees were called upon to give their opinions. One of them was Herb, who indicated in no uncertain terms that the Habilitation paper was an excellent piece of work and he didn't understand why there could be any dithering over the matter. That settled that! In that regard, I always found Herb to be totally direct and fair as a referee or as a reference giver.

Contributions to the Obituary by Others:

I well remember a personal incident too. About 10 years ago, I attended a conference at IMA on crutches, due to a broken hip. When Herb and his partner solicitously asked how I had broken my hip, I told them that it resulted from a bicycling accident. They replied that a real bicyclist would have broken his collarbone!--- Eugene Allgower

I was Herb's postdoc from January 1978 to August 1979. But even before that Herb indirectly influenced my academic life. First, I used the Isaacson/Keller book in my undergraduate course on numerical analysis at Caltech. Near completion of my PhD at Stanford, Joe Keller referred me to the postdoc with Herb. Given my background in computational linear algebra, it was natural that the first problem Herb asked me to work on was on the iterative solution of singular linear systems, which quickly brought me to the source of these problems---namely, bifurcation problems where the Jacobian matrices are singular at critical points. This opened up a whole area of math that I had not been exposed to previously, and for this I will always be indebted to Herb. Shortly afterward, while Achi Brandt was visiting Caltech, we started working on multigrid methods for singular and indefinite elliptic systems. My interest in multigrid methods continued for many more years. It all began with Herb, who was a very intense, some may say competitive, person, whether at work or play (tennis was his main game back then, and we often played at the Athenaeum). He was confident, set high standards for himself and people he worked with, and wanted to be the world leader in whatever he was

working on. That certainly had a lasting effect on my own career. Yet he always had a sense of humor. The best example is the "hidden" message in the preface of Isaacson/Keller. That mischievous and rebellious sense of humor is quintessential Herb. For a young person starting out, just knowing that even a revered senior role model can be a bit of fun in work was a revelation. I'll remember him dearly.---Tony Chan

Herb was an informal adviser when the mathematics clinics were inaugurated at Claremont Graduate University and Harvey Mudd College in the 1970s. Subsequently, he was a frequent visitor when students presented their project results at the end of the academic year. He was interested in the problems that industry had set and in the approaches the teams adopted, but he was also on the lookout for talent to attract to the Caltech program. He was a valued member of the CGU Math Board of Visitors from the mid-90s, giving generously of his time and experience. He came to a BOV dinner in Claremont in December 2007, bringing a bike in his Prius and pedaling 28 miles before the wine session. Claremont is an attractive destination for Caltech faculty cyclists; it has a pleasant downtown boasting a high-end bike shop and a first-class bakery---a frequent Sunday morning venue for Herb and his bike group.---Ellis Cumberbatch

Jim Varah introduced me to Herb, who offered me a postdoc in applied math at Caltech (1975–77). It was during this time that I learned about bifurcations and their numerical analysis in a graduate course that Herb gave and in many discussions with him. During this period I also implemented Herb's ideas in a program for computing bifurcating solution families in nonlinear ODE boundary-value problems. This period was extraordinarily exciting for me: I felt that I was being introduced to something very important and very useful. In 1979, when I got a job at Concordia University in Montreal, I started working on the continuation of periodic solutions, their bifurcations, and related topics. This work, which led to the software package AUTO, was greatly influenced by Herb's fundamental work. When Herb found out about AUTO, he invited me to Caltech for return visits, not just for a few days, but in fact for several years total time! These visits led to work on applications of continuation methods, which in turn resulted in improved algorithms in AUTO. I have fond memories of Herb: Not only did he provide me with key ideas, but he was also always extremely supportive of my work in many ways. I greatly admired his originality, his incredible energy, and his courage to try out totally new ideas. Moreover, I deeply valued the personal friendship, the many bike rides with him, his company during visits to France, the Netherlands, and many other places.---Sebius Doedel

Herb Keller had an enormous impact on my life, both personal and professional. Much of my personal interaction with him revolved around cycling. Indeed, Herb and a mutual friend, playing matchmakers, introduced me to my future wife on a ride to Claremont. Eighteen years and three children later, we still enjoy riding together, thanks to Herb. Many of my best memories of Herb, and still the subject of stories when we get together with mutual friends, are the times we spent together on our bicycling trips around the U.S. and Europe. Professionally, it is hard to describe the impact that Herb had on my career. When, as an assistant professor, I was languishing in a poisonous "pure versus applied" climate in my own department, Herb gave me two precious years at Caltech in which I could find my own direction. By providing me with the example of his own scientific courage, he taught me to pursue new ideas without fear of failure and that the key to a successful, and fun, career in a university is to keep scientific issues paramount. But I was just one of many young people helped by Herb in this way. My last memory is listening to Herb answer the endless questions of my son about the motion of waves while we sat on the beach outside his San Diego condominium. Seeing Herb instill the joy of science and mathematics in yet another young person is a fitting way to keep him in mind.---Donald Estep

I met Herb several times in the seventies and had a friendly relationship with him but no real scientific cooperation. Things changed when he came to INRIA, in France, in the early eighties, to spend a sabbatical year

in the research group (called MENUSIN) I was directing at the time. We started working together, merging his knowledge of the mathematical and numerical aspects of bifurcation theory with our own knowledge of finite element and variational methods. This led to the doctoral thesis of Laure Reinhart on the computation of the post-buckled solutions of the von Kármán (another Caltech hero) equation for plates and to a joint paper by Herb, Reinhart, and me, published in SISSC in 1985. Thanks to Herb, we demystified bifurcation, continuation methods, non-monotonic nonlinearities. Indeed, he got us interested in the Gelfand–Bratu problem, and in the late nineties, my colleague J. He and I dedicated an article (published in JOTA) on the chattering boundary control of the time-dependent Bratu equation to Herb. Working with him was a real pleasure, because of his knowledge, his enthusiasm, his predilection for difficult problems, and the creative way he had of looking at things. He was instrumental in arranging my visit to Caltech for a semester in 1988–89 as a Fairchild scholar. In 2006, I asked him to be part of the thesis committee of my PhD student F. Foss; because the thesis was about nonlinear eigenvalues and arc-length continuation for some elliptic operators, he accepted with enthusiasm, making the defense of the thesis a most memorable event. We will miss him.---Roland Glowinski

My close interaction with Herb was at the stage of my own mathematical journey when, in the late 1980s, I "discovered" computational dynamics and attempted to use ideas from dynamical systems to understand the behavior of numerical methods. Herb was then already the central person in computational dynamics. It is indeed no exaggeration to say that his work defined the subject: from bifurcation theory to continuation methods, the AUTO package, etc. It was natural to talk with him, and so our contact started in earnest; I valued his feedback and encouragement. In 1989 I organized a conference in Bristol with the memorable title "Dynamics of Numerics and Numerics of Dynamics"; Herb was one of the main speakers. In a flash of true genius, I persuaded him and Steve Smale to spend the preceding summer with me in Cambridge; it was a memorable time indeed and an opportunity to learn a great deal, witness some great mathematical discussions, and hear some great stories. Of course, Herb arrived from the airport on a bike and left for Bristol on a bike. A few years later Herb came to Cambridge for a year. We have many visitors in Cambridge, but Herb was unique. Firstly, he was fun and a true character. It was in 1995, the year the big event commemorating the 50th anniversary of the end of World War II was held at the American Cemetery at Madingley, outside Cambridge. Herb, needless to say, attended with his bike, in a stars-and-stripes biking outfit. The next day, Cambridge Evening News carried two huge photographs on its front page: one of President Clinton and Prime Minister Major, the other of an "American visitor" with white beard and a cycling helmet. Besides being fantastic company and a phenomenal storyteller, Herb weaved among us his mathematical magic. He gave a graduate course from which we learned degree theory, differential geometry, and homotopy methods, something that was just in time for my own evolving research concerns and also influenced some of my colleagues. He was a Distinguished Visiting Fellow of Christ College and immensely enjoyed the college life and fellowship privileges. Within a year he became a real Cantabrigian, and we were immensely sad when he, his bicycle, and his stories returned to southern California.---Arieh Iserles

Herb was very generous and supportive of young people. In 2003, when I was trying to figure out the logistics of participating in the numerical relativity visitor program at Caltech while my wife, Mai, was pregnant with our first child, Herb simply gave me the keys to his house in Pasadena, so that Mai could stay in San Diego and I could go up to Caltech whenever it worked out. In recent years, Herb became close to Mai and both of our children, Mason and Makenna.

Herb had a large impact on my life, both professionally and personally. I admired him tremendously; he was fearless, both with regard to activities like biking (those who kept track of his numerous accidents have some insight into this), and with regard to mathematics and science. Our interactions during the years I spent with him at Caltech, as a postdoc (1993–97) and later on sabbatical (2003–05), changed the way I thought not only about

mathematics and science, but also about myself. With tremendous confidence in his own abilities, Herb refused to be limited by anyone's opinion of where exactly he fit in science; he would work on any problem he considered particularly interesting. On his desk at UCSD when he passed away was one of Perelman's papers on Ricci flow. Herb was extremely interested in this work; confident that he could learn the area, he was methodically working through the paper. He and I had a number of discussions about this in recent months. His influence and example had led directly to my own work in mathematical physics, quite far from my dissertation work in numerical analysis. It fills me with great sadness that we are no longer going to have the honor and pleasure of his company. He will be missed.---Michael Holst

When I was little my dad used to take me to the driving range. I loved the wire bucket the balls came in. I loved handing Dad balls from the bucket and watching him practice his swing with a passion that consumed him. If you were to ask me to describe my dad in a single word, that's the word I'd use: passionate. Whatever it was that interested him, passion drove Dad to both excel in and relish it. Numerical analysis, cycling, reading the blurbs next to the paintings in the Norton Simon Museum. One of the things Dad relished was athletics. He was proud of himself and readily shared his accomplishments---he rode X miles on his bike that day, swam X laps, did X sit-ups, weighed X pounds and therefore had to lose Y pounds. I thought this constant stream of numbers was Dad boasting of his prowess, but I was wrong. I discovered the truth last summer. Dad was visiting us in Sacramento and we'd gone out to dinner. The streets were crowded, and we had to park blocks away from the restaurant. We knew Dad wouldn't mind the walk. He clasped his hands behind his back, leaned forward, and set forth, mumbling numbers as he went. My son asked if he was working on a problem. Dad stopped and looked up. "No. No problem," he said, smiling. "Just counting the number of steps to the restaurant so we can compare them to the number of steps back." Dad was a numbers man. Numbers were his passion in every facet of his life: the X miles he rode, the scores of his arrows, the lengths of his golf drives, and he probably counted the number of balls in the wire bucket, too. I love that about my dad.---Debbie Keller

Selected Publications:

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