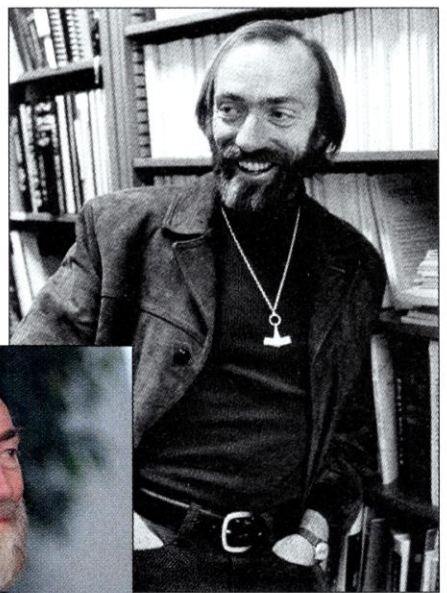
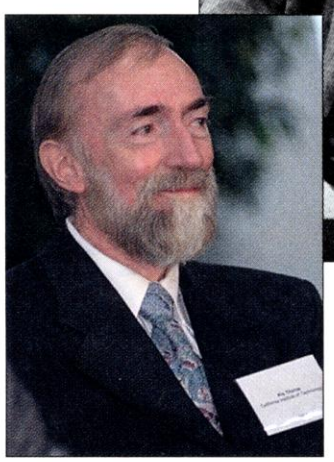
PROFILE
KIP THORNE

The Shaman of Space and Time

A generation of physicists probing the extremes of gravity can trace its scientific heritage to one man: Kip Thorne of Caltech

PASADENA, CALIFORNIA—Kip Thorne was on a roll. Speaking before an overflow crowd at the California Institute of Technology, the visionary physicist enticed his listeners with rapid-fire speculations about gravitational waves, quantum gravity, and wormholes. Suddenly, strains of dramatic music swelled from the front row, streaming from the voice synthesizer of a certain wheelchair-using British physicist. "Thank you, Stephen," said an amused Thorne to his close friend, Stephen Hawking of Cambridge University. "You can tell he's moved by these predictions."





Avant-garde. Thorne has spent 40 years hatching some of the wildest ideas in physics.

Thorne never hesitates to gaze into the future of his field, but this talk was special: It concluded a recent symposium* to mark Thorne's 60th birthday. The meeting brought together nearly 200 experts on gravity at its strongest and strangest: the domains of black holes, colliding neutron stars, and other exotic deep-space objects. Participants came to honor their mentor, who has led the way in converting Albert Einstein's General Theory of Relativity from a purely theoretical science into an astrophysical and observational one.

They also came to salute Thorne's knack for informing and delighting the public. From the outset of his career—at a time when popularizing science was taboo in some circles—Thorne crafted articles about his bizarre brand of physics. His adventurous prose has garnered two science-writing awards from the American Institute of Physics, including one for *Black Holes and Time Warps*, his 1994 book that captivated untold numbers of readers.

The multifaceted guest of honor is a man described by Caltech president David Baltimore as "Caltech's number-one strange scientist, the prince of counterintuitive science." Richard Isaacson, program director for gravitational physics at the National Science Foundation (NSF) in Arlington, Virginia, goes further: "I think he's recognized as a national treasure."

Such words don't rest easily with Thorne, whose modesty is nearly as legendary as his achievements. For instance, he initially refused appointment in 1991 as Feynman Professor of Theoretical Physics at Caltech because he felt unworthy of the intellectual mantle of the late physicist Richard Feynman. "It's obvious in the community that certain people are ever so much more brilliant," Thorne says. "I'm a cut or two below the Feynman level." Moreover, when asked for his career highlights, he unfailingly lists the accomplishments of his former students—including some 40 Ph.D. recipients—rather than his own. "I'm not a poor scientist, but if I have achieved some measure of greatness, it is through my students," he says.

"That's Kip's basic generosity," says symposium co-convener Clifford Will of Washington University in St. Louis, who earned his Ph.D. under Thorne in 1971. "He's just as likely to suggest his ideas to his students and postdocs, then let them carry out the work and get 90% of the credit." Sandor Kovacs, a 1977 Ph.D. who studied how gravitational waves are generated, says that Thorne's students never forget the integrity they observe in his interactions with others. "Even when they are no longer in physics, Kip's imprint and style is evident in what they do today," says Kovacs, now a cardiovascular physiologist at Washington University.

Thorne's path in physics began with his upbringing in Logan, Utah. He and his four siblings were the children of two professors, D. Wynne Thorne, president of the Soil Science Society of America, and economist Alison Thorne, founder of the women's studies program at Utah State University in Logan. Thorne's mother fostered his interest in astronomy; they drew a scale model of the solar system on the sidewalk in front of their house when he was eight. Then, he became enthralled with physics through magazine articles and science books. A catalyst was *One, Two, Three ... Infinity*, by Russian-born physicist George Gamow, which Thorne read four times. (Gamow sent Thorne a Hungarian copy of the book before he died in 1968. The inscription reads: "To Kip Thorne, so that he might not be able to read it a fifth time.")

A glowing article about Caltech in *Time* convinced the teenage Thorne that he should study there, and so he did, receiving his B.S. in physics in 1962. But only upon going to Princeton University did Thorne meet the two men who influenced him most deeply. The first was physicist Robert Dicke, whose group meetings Thorne attended. "From Dicke, I learned the connection of relativity to experiment," Thorne says. By 1970, he observes, "modern technology was finally catching up with the ideas of general relativity. I tried to play a role in helping the experimental field come along."

One of Thorne's recent students, postdoctoral researcher Benjamin Owen of the Max Planck Institute for Gravitational Physics in Potsdam, Germany, says that Thorne's early commitment to relativistic astrophysics was daring. "When Kip started this whole business in the 1960s, nobody in his right mind believed in neutron stars, much less gravitational waves," Owen says. "You had to be truly disturbed to be interested in this stuff, and worse, to corral a bunch of kids into it." Bernard Schutz, director of the Max Planck Institute and a Thorne alumnus from 1971, notes that the late University of Chicago astrophysicist Subrahmanyan Chandrasekhar avoided general relativity in the 1950s "because he thought it would be the death of his career. Kip started just as the fog was lifting."

The second Princeton physicist under whom Thorne blossomed was his adviser: John Archibald Wheeler, a giant in the field

CREDITS: (LEFT TO RIGHT) CALTECH/LIGO; CALIFORNIA INSTITUTE OF TECHNOLOGY

* KipFest, 1 to 3 June: wugrav.wustl.edu/People/CLIFF/KipFest/kipmain.html

and a pioneer of black hole physics. "I learned the power of physical intuition from John," Thorne says. "He saw things that were decades ahead of his time." For example, Thorne credits Wheeler with laying the conceptual foundation for attempts to unify quantum mechanics and general relativity into a quantum theory of gravity. "Only 30 years later did this become a widely accepted and serious thing," he says.

Thorne absorbed something equally valuable from Wheeler: his gentle shepherding of the work and careers of his students. According to Wheeler, who attended Thorne's symposium at age 89, those lessons took deep root. "Kip has an unusual ability to size up, challenge, and guide people," Wheeler says. "His most lasting contribution is the development of people who ask and answer significant questions about nature." Upon hearing the talks by Thorne's protégés at the Caltech meeting, Wheeler simply said, "It makes my own work feel worthwhile."

The tutelage of Wheeler and Dicke served Thorne well when he returned to Caltech in 1966. His early career was a blaze of productivity. Thorne and a clutch of students close to his age performed startling analyses of gravity in the most relativistic settings imaginable: dense star clusters, neutron stars, and black holes. Among his first dozen advisees were Will, perhaps the best known theoretical physicist today working on experimental relativity; Richard Price of the University of Utah, Salt Lake City, who did the first calculations of how a nonspinning black hole settles into a stable state; Saul Teukolsky of Cornell University, who did the same thing for rotating black holes; and William Press, who studied black hole perturbations and is now deputy director of Los Alamos National Laboratory in New Mexico.

This flourishing period led to Thorne's election to the National Academy of Sciences in 1973 at age 33. That youthful honor confirmed Thorne as the central figure in applying relativity to astrophysics, says Caltech colleague Roger Blandford. "Kip translated the seemingly intractable equations of general relativity into practical tools for the astronomer," Blandford says.

The same year saw publication of *Gravitation*, a massive text written by Thorne, Wheeler, and University of Maryland physicist Charles Misner. The book, known simply as "MTW" after its authors, was 5 years in the making. A generation of graduate students came to rely upon it as their bible. The text broke new ground in being a "breezier, populist" book that also contained hard-core physics, Blandford says. "It was a magnificent achievement. It's still surprisingly fresh and useful today."

Thorne's early tenure at Caltech also forged an indelible image that his students recall fondly: the bearded, long-haired professor holding forth on campus or in some wilderness getaway in a New Age tunic, often with a funky pendant around his neck. He dresses more nattily now and is known as a "workaholic, type A–plus, detail-oriented calculator and organizer," says Price. Still, the trademark beard remains. Hawking, with whom Thorne shares a playful relationship, couldn't resist tweaking Thorne's image at the symposium. "You may have noticed that Kip has a slight fuzziness around him," he said. "It corresponds to the slight probability that he's not really there."

Thorne's garb often seemed to match the far-out nature of some of his research. In 1992, the NSF asked Thorne to refrain from using federal funding for research on wormholes—putative links between distant parts of the universe via tunnels through space-time. Thorne wrote one of the first reputable papers on wormhole physics, recalls Eanna Flanagan of Cornell University, a graduate student at the time. However, the subsequent flurry of wormhole papers made NSF nervous about undue public interest in time machines and other H. G. Wellsian notions.

Old friends. Thorne and physicist Stephen Hawking often swap ideas—and playful banter.

Thorne's most enduring NSF-funded work, by contrast, is quite concrete: the $365 million Laser Interferometer Gravitational-Wave Observatory (LIGO) now nearing completion. Physicists hope to use LIGO's instruments to detect the subtle disturbances in space-time set off by violent events in the distant universe (*Science*, 21 April, p. 420). Thorne has led modeling efforts to predict the types of signals LIGO may detect. Seeing the first wave is his dearest dream.

Pay it forward. Like his mentor John Wheeler (right), Thorne is known for nurturing new talent.

It almost became a dream deferred. Throughout the 1980s and early 1990s, NSF needed Thorne's sensible scientific voice to help sway skeptical legislators. Thorne also co-directed the project for several years and smoothed the waters during rough administrative transitions. Hawking believes the inevitable moment of detection will write Thorne's legacy in the annals of physics. "I don't think [LIGO] would have happened if he hadn't pushed it so hard," Hawking says.

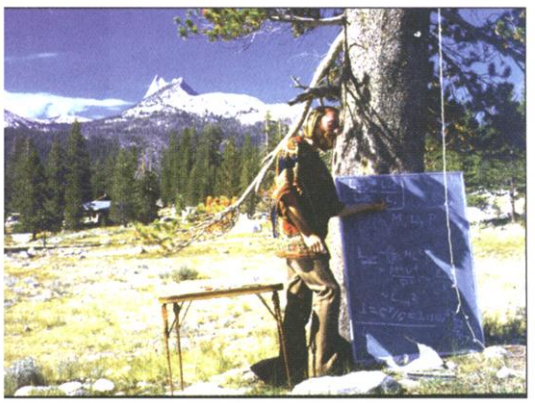
As usual, Thorne's current work on LIGO is ahead of the curve. With his Caltech students, Thorne is examining how to design radical new detectors that LIGO will need after 2010 to see gravitational waves routinely. The research draws heavily on work by Vladimir Braginsky of Moscow State University, one of several Russian physicists with whom Thorne has built close ties during the past 3 decades—even during the latter part of the Cold War. The Russians feel indebted to Thorne for making their work known in the West. "He always emphasized how important the collaborations were for him, at a time when contact was so dangerous," says Igor Novikov, now at Copenhagen University in Denmark.

Novikov adds that he literally owes his life to Thorne, who flew him to California in 1988 and arranged for physicians and a private fund to pay for a critical heart operation. "It was Kip's voice that I heard for the first time in my second life," he says. "He repeated in Russian, 'It's fine, it's fine.' "

Novikov's tale is unique, but common threads weave through other stories told

CREDITS: JAMES M. BARDEEN

whenever Thorne's clan assembles. For example, his alumni note that Thorne took inordinate care to improve their writing. "You would always get back manuscripts that from a distance looked uniformly red," says Price, who convened the symposium with Will and Kovacs. "His usual statement was, 'This was superbly written. I just made a few comments.' "



Al fresco. Thorne's early students enjoyed informal seminars in places such as Yosemite.

Those comments went far beyond revised equations. "He was very concerned about both the correctness of the physics and how well it was written," says physicist and novelist Alan Lightman of the Massachusetts Institute of Technology. Among physicists, only Chandrasekhar spent so much time reading papers critically, Lightman believes.

Thorne is just as careful with his own writing, which has won fans among both his colleagues and the *Star Trek* set. His popular prose bubbles with predictions of the ways in which physicists will peel back the layers of intrigue that shroud their understanding of gravity. Some forecasts have become fodder for wagers in a famous series of bets with Hawking and other physicists. Most recently, Thorne lost a 19-year-old bet with Princeton University astrophysicist Jeremiah Ostriker when LIGO failed to detect gravitational waves by 1 January 2000. "I've been wrong about time scales, but not horrendously wrong," Thorne says with a smile.

Thorne's latest predictions feature some old chestnuts and some new treats. He maintains that by 2010 to 2015, a planned space-based cousin to LIGO, called the Laser Interferometer Space Antenna (LISA), will map "in exquisite detail" the warping of space-time as one black hole spirals into another. After 2020, he speculates, successors to LIGO and LISA will detect every collision of black hole pairs or neutron star pairs in the universe, at a rate of several per day. "We'll build up a huge catalog, like a catalog of stars on the sky," he says.

More broadly, Thorne foresees a 30-year effort to decode the hum of gravitational waves that almost certainly fills the universe, dating from the violence of its birth. This will complement today's analysis of the faint cosmic microwave background radiation, which preserves imprints of the manner in which the universe evolved. "We have good reason to believe that there will be significant gravitational waves from the size of a few meters to the size of the universe, carrying enormous amounts of information about the very early universe," Thorne says.

And to the delight of all, Thorne still thinks about wormholes and time machines. "I expect the laws of quantum gravity will reveal that in contradiction to all directions of recent research, the kind of exotic matter that is essential to the existence of traversable wormholes can exist," he says. But he follows with a letdown: "Constructing traversable wormholes will be unimaginably far beyond the capabilities of any foreseeable human civilization."

Thorne looks ahead benignly confident that he will watch his scientific offspring prove him right or wrong. "I come from a long-lived family," he says. "I expect to live to be 110." Since his wildest speculations extend about 50 years into the future, there's no telling what Kip Thorne may yet see.

–ROBERT IRION

Robert Irion is co-author of *One Universe: At Home in the Cosmos* (Joseph Henry Press, 2000).

PARASITOLOGY

Close Encounters: Good, Bad, and Ugly

Viewed in light of evolution, host-parasite relationships range from deadly to helpful, depending on the communication between them

PARIS—Louis Pasteur was a man of many disciplines. Over the course of a career that spanned half a century, he ranged from chemistry to microbiology and virology. He even dabbled in the origins of life. His many achievements, from discovering handedness in organic molecules to showing that germs cause disease, are testimony to the power of synthesizing ideas from diverse walks of science. A similar synergy was evident last month at a meeting convened here in Pasteur's honor. As an unlikely mix of virologists, bacteriologists, parasitologists, and molecular biologists—each dealing with different microorganisms in distinct ways—discussed their work, they came to better appreciate evolutionary biologist Theodosius Dobzhansky's observation that nothing makes sense except in the light of evolution. Yet, they also lamented, evolution is often considered outside the bailiwick of microbiologists, particularly those studying infectious diseases.

Microbiologists often focus on one organism and its relationship to its host at one point in time. But stepping back to view the whole range of relationships between microbes and their hosts reveals that "there's a spectrum [of microorganisms] from the highly virulent to barely pathogenic," says Stephen Beverley, a molecular parasitologist at Washington University in St. Louis. What's more, the host-parasite relationship changes over time, often shifting from adversarial to friendly, and this relationship "is at

Renaissance researcher. Louis Pasteur.

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