



Institute for Advanced Study

Summer 2014

Sabine Schmidtke Appointed to Faculty

Researching the Intellectual History of the Islamic World



Sabine Schmidtke

Sabine Schmidtke, a leading scholar of Islamic intellectual history whose innovative and insightful work has shaped new understanding of the classical and postclassical Islamic world, has joined the Faculty in the School of Historical Studies.

Schmidtke, who is a former Member (2008–09, 2013–14) in the School, was Professor of Islamic Studies at the Freie Universität Berlin and founding Director of the University's Research Unit on the Intellectual History of the Islamicate World, as well as an Associate Member of the Laboratoire

d'Études sur les Monothéismes, Centre National de la Recherche Scientifique (CNRS) in Paris. Schmidtke succeeds Patricia Crone, Andrew W. Mellon Professor since 1997, who has become Professor Emerita. Schmidtke will continue the important work begun with the 1990 appointment of the late Oleg Grabar (1929–2011),

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Environmental Turn in the Human Sciences

Will It Become Decisive Enough?

BY SVERKER SÖRLIN

What do the humanities have to do with the environment? As they are commonly understood, environmental problems are issues that manifest themselves primarily in the environment itself. Natural scientists research these problems and suggest solutions, aided by technology, economics, and policy. It was scientists who defined the modern usage of the concept of “the environment” after World War II. Ecologist William Vogt famously used it in his 1948 volume *The Road to Survival*: “We live in one world in an ecological—an environmental—sense.” He and others at the time thought of “the environment” as a composite of issues that had been in the making for some time—most prominently, population growth, which had been much discussed since the World Population Conference in Geneva in 1927, but also soil erosion, desertification (observed by Paul Sears in his famous 1935 book *Deserts on the March*), pollution, food, poverty, and starvation.

In the public's mind, environmentalism is still connected with the 1960s, from Rachel Carson's *Silent Spring* (1962) to the foundation of the U.S. Environmental Protection Agency and Earth Day in 1970, but in reality, its start was earlier, and humanist thinkers were deeply part of the first phase of the environmental revolution. In France, a cohort of eminent historians started the journal *Annales d'histoire économique et sociale* in 1929, which became an outlet for a take on history as an interaction of humans with physical geographies. Aldo Leopold was as much a philosopher as an ecologist when he developed his concept of a “land ethic” in *A Sand County Almanac* (1949). When the important Princeton conference on “The Earth as Transformed by Human Action” took place in 1955, Lewis Mumford, the planning philosopher and urban historian, was a notable speaker.

However, the humanist presence faded quickly, and for half a century there were few humanists at the top levels of environmental science planning and as policy advisers. Humanists themselves commonly accepted the outsider role.

The widening domain of environmentally relevant knowledge

Now we seem to be in for a change. The background is the current inadequacy of the established scientific, policymaking, and economic approaches. In fact, despite all our efforts, most indicators of our future point in the wrong direction. As some of us, members of a team led by ecologist Johan Rockström, discussed in “A Safe Operating Space for Humanity,” a since much-cited 2009 article in *Nature*, human societies are rapidly transgressing a set of planetary boundaries, including rising levels of atmospheric carbon dioxide, biodiversity loss, and ocean acidity. We face both local and global coupled multiscalar crises of geopolitical instability, resource scarcity, and economic collapse.

Our belief that science alone could deliver us from the planetary quagmire is long dead. While science remains essential for “the power of betterment—that riddled word”—just as J. Robert Oppenheimer reminded us in his 1953 Reith lectures,

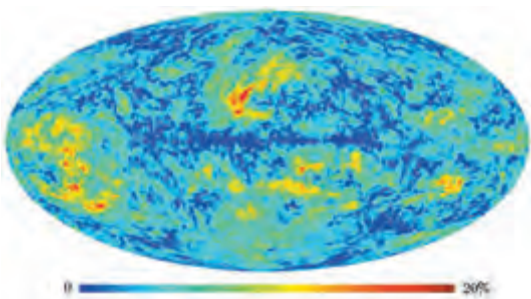
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ERIC LEWIS, THE NEW YORKER COLLECTION/THE CARTOON BANK

BICEP: Spacetime Ripples or Galaxy Dust?

Doubts Arise Over Claims of Evidence for Cosmic Inflation



In September, Planck researchers confirmed Member Raphael Flauger's assertion that the level of galaxy dust in this Planck slide was underestimated by the BICEP team.

a theory about the very beginnings of the universe first proposed in 1979.

The BICEP announcement claimed that the first images of gravitational waves, or ripples in spacetime, had been detected, a tantalizing and long hoped-for connection between quantum mechanics and general relativity. The landmark claim ignited the field and led to talk of a new era of cosmology.

At the Institute for Advanced Study, Raphael Flauger, Member (2013–14) in the School of Natural Sciences, began looking closely at the data. The year prior, Flauger had analyzed the first round of cosmic microwave background data released by the

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News of the Institute Community

DANIELLE ALLEN, UPS Foundation Professor in the School of Social Science, has been elected Chair of the Pulitzer Prize Board. Her book *Our Declaration: A Reading of the Declaration of Independence in Defense of Equality* was recently published by Liveright Publishing Corporation.

DANI RODRIK, Albert O. Hirschman Professor in the School of Social Science, has been awarded an honorary doctorate from the University of Groningen in the Netherlands. Rodrik has also been appointed visiting Centennial Professor at the London School of Economics for the three-year period 2013–16.

RICHARD TAYLOR, Robert and Luisa Fernholz Professor in the School of Mathematics, and three former Members in the School, have been awarded the inaugural Breakthrough Prizes in Mathematics from the Breakthrough Prize Foundation. Taylor is honored for his numerous results in the theory of automorphic forms, including the Taniyama-Weil conjecture, the local Langlands conjecture for general linear groups, and the Sato-Tate conjecture.

EDWARD WITTEN, Charles Simonyi Professor in the School of Natural Sciences, has been awarded the 2014 Kyoto Prize in Basic Sciences by the Inamori Foundation for his outstanding contributions to mathematical science through his exploration of superstring theory.

PATRICIA CRONE, Andrew W. Mellon Professor in the School of Historical Studies since 1997, has become Professor Emerita as of July 1. JONATHAN ISRAEL, Professor in the School since 2001, succeeds Crone as Andrew W. Mellon Professor. In addition, Crone has been awarded an honorary doctorate from the Hebrew University of Jerusalem.

PHILLIP A. GRIFFITHS, Professor Emeritus in the School of Mathematics and former Institute Director, has been awarded the Chern Medal from the International Mathematical Union for his groundbreaking and transformative development of transcen-

dental methods in complex geometry. Griffiths, with Mark Green and Matt Kerr, has also coauthored *Special Values of Automorphic Cohomology Classes* (American Mathematical Society, 2014) and served as editor, with Eduardo Cattani, Fouad El Zein, and Lê Dũng Tráng, of *Hodge Theory* (Princeton University Press, 2014).

JOAN WALLACH SCOTT, Professor in the School of Social Science since 1985 and Harold F. Linder Professor since 2000, has become Professor Emerita, with effect from July 1.

Institute Trustees JEFFREY A. HARVEY and JAMES H. SIMONS, Vice Chairman of the Board, along with six former Members, have been elected to the National Academy of Sciences.

Institute Trustee SHIRLEY TILGHMAN, President Emerita of Princeton University and Professor of Molecular Biology and Public Affairs, has been named an Officer of the Order of Canada for outstanding level of talent and service to Canadians.

MARTIN HAIRER, Member (2014) in the School of Mathematics, and MANJUL BHARGAVA, former Member (2001–02) in the School, have been awarded the 2014 Fields Medal. Bhargava, Professor of Mathematics at Princeton University, received the award for developing powerful new methods in the geometry of numbers. Hairer was cited for his outstanding contributions to the theory of stochastic partial differential equations, and in particular for the creation of a theory of regularity structures for such equations.

JOSEPH P. MASCO, Ralph E. and Doris M. Hansmann Member (2013–14) in the School of Social Science, has won the 2014 J. I. Staley Prize from the School for Advanced Research for his book *The Nuclear Borderlands: The Manhattan Project in Post-Cold War New Mexico* (Princeton University Press, 2006).

YITANG ZHANG, Member (2014) in the School of Mathematics, has been selected as one of the twenty-one 2014 MacArthur Fellows awarded by the John D. and Catherine T. MacArthur Foundation. Zhang was cited for his landmark theorem in the distribution of prime numbers.

GEORGIA BENKART, former Member (1996) in the School of Mathematics, has been honored as the 2014 ICM Emmy Noether Lecturer by the Association for Women in Mathematics for her fundamental contributions to several branches of Lie Theory. Benkart is E. B. Van Vleck Professor Emerita at the University of Wisconsin–Madison.

MICHAEL CURTIS, former Visitor (1981) in the School of Social Science, has been appointed to the rank of Chevalier of the French Legion of Honor for his contributions to the history of the politics of France in the nineteenth to twenty-first centuries. Curtis is Distinguished Professor Emeritus of Political Science at Rutgers, The State University of New Jersey.

DANIEL EISENSTEIN, former Member (1996–99) in the School of Natural Sciences, has received the 2014 Shaw Prize in Astronomy, which recognizes significant breakthroughs in academic and scientific research resulting in a positive and profound impact on

Of Historical Note

The following excerpt is from the article “Can We Survive Technology?” by John von Neumann, published by *Fortune* magazine in 1955. Von Neumann was among the Institute’s first Professors and its youngest. Having pioneered the modern computer, game theory, nuclear deterrence, and more, von Neumann illuminated the fields of pure and applied mathematics, computer science, physics, and economics. He remained a Professor at IAS until his death in 1957.

“All experience shows that even smaller technological changes than those now in the cards profoundly transform political and social relationships. Experience also shows that these transformations are not a priori predictable and that most contemporary “first guesses” concerning them are wrong. For all these reasons, one should take neither present difficulties nor presently proposed reforms too seriously.

The one solid fact is that the difficulties are due to an evolution that, while useful and constructive, is also dangerous. Can we produce the required adjustments with the necessary speed? The most hopeful answer is that the human species has been subjected to similar tests before and seems to have a congenital ability to come through, after varying amounts of trouble. To ask in advance for a complete recipe would be unreasonable. We can specify only the human qualities required: patience, flexibility, intelligence.” ■

mankind. Eisenstein, Professor at Harvard University, shares this award with Shaun Cole, Professor at Durham University, and John A. Peacock, Professor at the Institute for Astronomy at the University of Edinburgh.

IGOR KLEBANOV, former Member (2003, 2011–12) and Visitor (2003–06) in the School of Natural Sciences, has been awarded the Caterina Tomassoni and Felice Pietro Chisesi Prize from Università degli Studi di Roma, La Sapienza, for outstanding achievements in physics. Klebanov is Associate Director of the Princeton Center for Theoretical Science at Princeton University.

Former Members in the School of Natural Sciences ASHOKE SEN (1997–98), Professor at the Harish-Chandra Research Institute, ANDREW STROMINGER (1982–87), Professor of Physics at Harvard University and former Institute Trustee, and GABRIELE VENEZIANO (1970, 1998) of CERN have received the 2014 Dirac Medal from the International Centre for Theoretical Physics for their crucial contributions to the origin, development, and further understanding of string theory.

ANNA SUN, former Member (2010–11) in the School of Social Science, has received the 2014 Best Book Award from the American Sociological Association for her book *Confucianism as a World Religion: Contested Histories and Contemporary Realities* (Princeton University Press, 2013). Sun is Associate Professor of Sociology and Asian Studies at Kenyon College.

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Questions and comments regarding the *Institute Letter* should be directed to Kelly Devine Thomas, Senior Publications Officer, via email at kdthomas@ias.edu or by telephone at (609) 734-8091.

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A Room, an Office, a Library, a World

A Year (Well, Nine Months) in the Life of an IAS Member

BY MONICA H. GREEN

The Institute is a remarkably modest place. Like all Members of the School of Historical Studies, I was provided a lovely apartment, a simple office (with computer), access to both the Institute's libraries and those of Princeton University, lunch in the dining hall, tea in the afternoon. So how does new knowledge come out of such a simple mix? Juxtaposition! So much of the wealth of insight I've had this year (and there's been a lot of it) has come from the chance conversations, the oblique reference in a lecture, the reference exchanged in the hallway.

The world of scholarship is a very different place than when I was a Member here for the first time in 1990–92. There was an Internet then, I suppose, but I was not yet a user. I was not yet using email, there was no Google, no online digital reproductions of unique medieval manuscripts that I could call up for viewing within seconds, rather than having to travel thousands of miles to get to distant libraries during their rare opening hours or buying expensive films that had to be strung up on a microfilm viewer (ugh!) for long, eyeball-shrinking, mind-numbing sessions. So much of the world of knowledge is now at my fingertips; I can go for hours without ever leaving my desk. So what is the value of the IAS in such a hyper-connected world? Even more than twenty years ago, I found that the richness of this place lies in the human interactions, the analogue-ness (if you will) of life at this community in the woods.

Much of my work this year has been in collaboration with scholars elsewhere, building on projects already many years in the making. But my work and theirs has been infinitely enriched by the daily stimuli I've had from my colleagues here at IAS. Here are a few vignettes.

Even before I arrived last fall, I went through the list of scholars who would be here both in Historical Studies and Social Science. Lady Mungo jumped out at me. Lady Mungo is the name given to an Australian Aborigine who likely lived between 40,000 and 50,000 years ago. I've been moving my work on the history of human disease into "deep time" and the early peopling of the Earth has been on my radar. Ann McGrath, from the Australian National University, was coming into the School of Social Science to do a study on Lady Mungo. So I made contact via email last summer, and we were all ready to talk once we arrived in September.

The last lecture I went to this year was also in Social Science and also looking at a very *big picture*. This was a lecture on "Six Ways of Looking at the Anthropocene" by Joseph Masco in the School of Social Science, a look at a very recent art installation that tried to capture the impacts humans have had on Earth, to the point of becoming a geological epoch in our own right (see articles, pages 1 and 13). Between the Pleistocene and the Anthropocene, there was every other element of human history on hand this year. I only went to a fraction of the talks and seminars I would have liked to, but even those boggle my mind as I look back on my packed calendar of the last few months.

Nor were my stimuli limited to my most closely allied fields in history and anthropology. A recent innovation here at IAS is "After Hours Conversations." The format is fixed: ten minutes of talk (no notes, no slides), followed by twenty minutes of open discussion. (Oh, and drinks. The sessions are held at Harry's Bar.) Talks ranged from "Origins of Life" (Piet Hut) and "Terrorism and the World-Wide Web of Interdiction" (Kim Scheppele) to "Why Petroleum Did Not

Save the Whales" (Richard York) and "Category Theory" (David Spivak). I even gave my own talk, "Scales of Time and Space in Global Health: Getting Historians and Geneticists on the Same Page," which was a welcome opportunity for me to riff on why the notions of "working at scale" that have been pioneered by global historians can be so fruitful in finding common ground between different disciplines.

But perhaps even more valuable to me, beyond the formal lectures or even informal talks, were the chance encounters—the tips about a new article, a new method, a different insight that came over lunch, at tea, or in the hallway. The best (because so unexpected) were those that came from people working on topics far distant in time or place or method from my own. I had been to David Pankenier's talk, for example, on his work on ancient Chinese astronomy in the fall. "Fascinating work," I thought. "Who knew that dragons could have such significance?" But it had no connection to my own work on medieval medicine.

But then, in January, when all of us in Historical Studies were reintroducing ourselves to the new crop of scholars who had just arrived, David said that now he was working on the dust-veil event of the early sixth century, which might, he suggested, have been an asteroid rather than (as has commonly been believed) a volcanic eruption.

"Well, that's no closer to medieval medicine than ancient astronomical dragons," you may be thinking. But in fact, bells were ringing and lightbulbs flashing in my head when David said those words. For

by January, my interests had finally turned to a volume of collected essays I was editing "on the side" of all my other projects. My topic? The Black Death—a rethinking, in fact, of nearly everything we thought we knew about the great medieval pandemics of plague. This rethinking had been prompted by new work in the genetics of *Yersinia pestis* (the plague pathogen) in the past decade and a half. And genetics connects to astronomy because there may be reason to think that what pushed *Y. pestis* into new ecosystems in the sixth and fourteenth centuries

(the explosive beginnings of the two medieval pandemics) were climatic events. David kindly joined me when I presented on the plague at the medieval seminar later that month, which in turn gave me the nudge I needed to finish my own contribution to the volume. The sixth-century asteroid doesn't figure there because I was focusing on the fourteenth century only. But China does, because of yet another IAS connection.

Stephen West, also in the East Asia group but a regular guest among the "Western" medievalists, cyber-introduced me to a colleague at Columbia, who joined the contributors to my volume of essays on the Black Death. Those essays will be appearing in a journal called, fittingly enough, *The Medieval Globe*. And that, really, sums up the beauty of this place: the whole world truly is brought together here, making that plain little office of mine a window out onto a universe of learning. ■

PERHAPS EVEN MORE VALUABLE TO ME, BEYOND THE FORMAL LECTURES OR EVEN INFORMAL TALKS, WERE THE CHANCE ENCOUNTERS—THE TIPS ABOUT A NEW ARTICLE, A NEW METHOD, A DIFFERENT INSIGHT THAT CAME OVER LUNCH, AT TEA, OR IN THE HALLWAY.



Monica Green (left) joins a conversation hosted by Alan Alda (right) on engaging a general audience through the craft of storytelling.

Monica H. Green, Willis F. Doney Member (2013–14) and Member (1990–91) in the School of Historical Studies, is Professor of History at Arizona State University. She specializes in the global history of health and medieval European history, particularly the history of medicine and the history of gender.

Yitang Zhang's Spectacular Mathematical Journey

Curiosity and Persistence by Unknown Mathematician Leads to Fundamental Breakthrough

A year ago April, the editors of the *Annals of Mathematics*, a journal published by the Institute and Princeton University, received an email with a submission by an unknown mathematician. "Bounded Gaps Between Primes" by Yitang Zhang, an adjunct professor at the University of New Hampshire, immediately caught the attention of the editors as well as Professors in the School of Mathematics. It was refereed by mathematicians who were visiting the Institute at the time and was accepted three weeks later, an unusually expedited pace.

"He is not a fellow who had done much before," says Peter Sarnak, Professor in the School of Mathematics. "Nobody knew him. Thanks to the refereeing process, there were a lot of vibes here at the Institute long before the newspapers heard of it. His result was spectacular."

A month after he submitted his paper, Zhang's result was reported in the *New York Times*, "Solving a Riddle of Primes," and in subsequent publications. Zhang's theorem relates to the twin primes conjecture, which asserts that there are an infinite number of prime numbers that are only two numbers apart. Such pairs are more frequent at the beginning of the number line and less so among large numbers.

Zhang's result does not prove that there are an infinite number of twin primes; rather, it gives a finite upper bound—70 million—for which the gaps between pairs of primes persist infinitely often. His work is dependent on findings by Institute Faculty and Members, in particular the Bombieri-Vinogradov theorem named in part for Enrico Bombieri, Professor Emeritus in the School. Zhang was immediately invited to give a lecture, "Distribution of Primes in Arithmetic Progressions with Applications," last fall, and he accepted an invitation to come as a Member for the spring term.

A deep extension of the Bombieri-Vinogradov theorem had been developed through the efforts of Bombieri and former Institute Members—Henryk Iwaniec and John Friedlander—along with Étienne Fouvry. "But the extension was not flexible enough to be used spectacularly," says Sarnak. "Zhang made it technically flexible, allowing for its application to bounded gaps in a striking way."

With ingenious and sustained effort, Zhang combined the ideas of Pierre Deligne, Professor Emeritus in the School, with this deep extension of the Bombieri-Vinogradov theorem and work by former Members Daniel Goldston, János Pintz, and Cem Yildirim on bounded gaps.

"I knew this [twin prime] problem very early, when I was an elementary school student in Shanghai," says Zhang. "I was very interested in many math problems, not only this one, but many number theory problems and, of course, primes."

During Mao's Cultural Revolution, Zhang was raised by his grandmother, an illiterate factory worker. "During that time, it was difficult to find a person who had a college education," says Zhang. "It was difficult to find a book." He did not attend middle school or high school, and instead taught himself mathematics from books that he had collected from a local high school prior to the revolution.

He went on to attend Peking University where he was a star student, earning bachelor's and master's degrees. "I met his adviser in China, who is very proud of him, and he said that Zhang was the most promising student in the year that he finished," says Sarnak. "He was always, I think, considered very talented, but what is unusual about him is that he is not doing incremental stuff. He is very fixated on mathematics, and he is not distracted by other things. He is extremely focused."

Zhang earned his doctorate from Purdue University, and, in 1999, he moved to New Hampshire where a few of his classmates from Peking University were on the

Faculty and helped him get a job. He had spent periods working as an accountant and at a Subway sandwich shop.

"I was born for math," says Zhang. "For many years, the situation was not easy, but I didn't give up. I just kept going, kept pushing. Curiosity was of first-rank importance—it is what makes mathematics an indispensable part of my life."

Zhang spent three years working on the bounded gap problem. On July 3, 2012, while visiting a friend's house in Colorado, he made his crucial breakthrough. "I tried to really make it a vacation. I didn't bring any book, notes, sheets, or my computer. I didn't use a pen," says Zhang. "But still I couldn't get rid of this completely. Sometimes I still tried to think about this point, this one small gap. How can we cross it?" As he was waiting to leave for a symphony concert that his friend was conducting, Zhang went into the backyard and started looking for some deer. "There are many deer sometimes," says Zhang. "I didn't see any deer, but I got the idea."

It took him a little over eight months before he submitted it to the *Annals*. He says he didn't feel very excited; he felt peaceful. "I spent a lot of time checking all of the details and simplifying

many, many points," says Zhang. "I was asked by somebody, 'Could you sleep during that time?' And I said, 'Yes, I slept very well.'"

No one he knew understood this work, so there was no one aside from himself who could check it for him. He waited two months after finishing it to submit it. "I told myself I should be very careful and double check all things," says Zhang. "That took a long time."

He had not expected that his paper would be accepted so quickly. The day after its acceptance, he received many emails, followed by invitations. "I accepted some invitations," says Zhang, "but what I want to do is try to just keep quiet and live a very quiet, very peaceful life."

At the Institute, Zhang has been working on a very difficult problem related to the spacing of the zeros of the Riemann zeta function, which would have spectacular applications, if solved. "Many people have worked on it and have thought they have solved it, but it is very elusive," says Sarnak. "Zhang has worked on it for many years. He has proved that he is able to stick with something in a very stubborn way, and that is what it takes to do something like this. He never gives up. He likes being left alone to work, and the Institute is the ideal environment for him to do that."

In the meantime, Zhang's bounded gap theorem has been proven in a much more elementary way by James Maynard, a postdoc at the University of Montreal. His proof is based primarily on the Selberg sieve of the late Atle Selberg, Professor in the School. Maynard visited IAS in the spring to give a seminar, "Small Gaps between Primes," on his result. "So this was another shock," says Sarnak. "As far as gaps between primes, Maynard's work is just as dramatic at a different level, although Zhang's was spectacular. The first is always the most important. Zhang's breakthrough, which was first used in this bounded gap context, will be used in many other ways. It is a very fundamental theorem." ■

—Kelly Devine Thomas, Senior Publications Officer, kdthomas@ias.edu



Member Yitang Zhang looking out at the Institute pond

I WAS BORN FOR MATH. . . . FOR MANY YEARS,
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Yitang Zhang, Member (2014) in the School of Mathematics and Professor in the Department of Mathematics and Statistics at the University of New Hampshire, has been named a 2014 MacArthur Fellow. To hear Zhang tell the story in his own words, see the short video: www.macfound.org/fellows/927/.

Neurophilosophy and Its Discontents

How Do We Understand Consciousness Without Becoming Complicit in That Understanding?

BY GABRIELLE BENETTE JACKSON

What is consciousness? “It is being awake,” “being responsive,” “acting,” “being aware,” “being self-aware,” “paying attention,” “perceiving,” “feeling emotions,” “feeling feelings,” “having thoughts,” “thinking about thoughts,” “it is like this!”

Who is conscious? “We humans, surely!” Well, maybe not all the time. “Animals!” Debatable. “Computers?” No—at least, not yet. “Other machines?” Only in fiction. “Plants?” Absolutely not, right?

Nearly twenty-five years ago, we lived through “the project of the decade of the brain,” a governmental initiative set forth by President George H. W. Bush.¹ Presidential Proclamation 6158 begins, “The human brain, a three-pound mass of interwoven nerve cells that controls our activity, is one of the most magnificent—and mysterious—wonders of creation. The seat of human intelligence, interpreter of senses, and controller of movement, this incredible organ continues to intrigue scientists and laymen alike. Over the years, our understanding of the brain—how it works, what goes wrong when it is injured or diseased—has increased dramatically. However, we still have much more to learn.” And it concludes, “Now, Therefore, I, George Bush, President of the United States of America, do hereby proclaim the decade beginning January 1, 1990, as the Decade of the Brain. I call upon all public officials and the people of the United States to observe that decade with appropriate programs, ceremonies, and activities.”

What the former President did not say—what is perhaps understood by his readers—is that the brain is quite different from other body parts that have come under scientific investigation. We might be grateful to receive a donated kidney, or to have an artificial heart. But unlike every other body part, without *my* brain, there may be no I. Our sense of self, of awareness, of life—are profoundly connected to a working brain. A philosopher once said, “in a brain transplant, one wants to be the donor not the recipient.” Indeed, saying that the brain is the seat of mentality is like saying that the sun is a source of light.

The decade of the brain is now over. No longer are the questions on the order of “What region of the brain is associated with facial recognition?” But rather, “Which particular neuron fires before a picture of Halle Berry’s face?” We have learned that the different frequency and synchronization with which neurons fire is associated with different states of conscious awareness. There is optimism that diseases such as Alzheimer’s could be treatable with therapies implemented at the neural level. We have entered the era of the neuron.

But for all that this trajectory has and will accomplish, we seem no closer to answering basic (actually, quite old) questions about the relationship between the mind and the body—between consciousness and the physical substrates that realize it.

These questions come in two general forms. First, a metaphysical point: why should this particular physical matter (the neurochemical, the nerve cell, the neural network) give rise to consciousness? It seems we can imagine creatures who have brains just like ours, but who don’t feel pain. So why do we feel it? Why does activation of group C nerve fibers in my brain give rise to pain, rather than some other feeling, or nothing at all? Second, an epistemological point: even if we were to know everything about this particular physical matter (the neurochemical, the nerve cell, the neural network), what does this tell us about consciousness? Tell me all there is to know about the chemistry of H₂O, and I might know what water is. Tell me all there is to know about the neural biological basis of pain, and I still surely won’t know what pain is. Unless I have experienced it myself, a truly essential aspect—*how pain feels*—has been left out.

These metaphysical and epistemological questions together form what philosophers call, respectively, “the hard problem” and “the knowledge argument.” We can combine them, limit the jargon, and talk about “the problem of consciousness.”

In what is perhaps the best known articulation of the problem of consciousness, in Thomas Nagel’s essay “What Is It Like to Be a Bat?” (1974), he stipulates that no matter what form consciousness might take, “there is something it like to be” conscious, there is “something it is like for” a conscious being, and no objective fact will ever explain this subjective fact.² The best we can hope is to establish correlations between the two. Posit a connection stronger than correlation, and we overstep.

If this were all there was to say, we would have to learn to live with the problem of consciousness. But in the final paragraphs of the selfsame article, Nagel offered an alternative. The problem of consciousness “should be regarded as a challenge to form new concepts and devise a new method—an objective phenomenology not depend-

ent on empathy or imagination. Though presumably it would not capture everything, its goal would be to describe, at least in part, the subjective character of experience in a form comprehensible to beings incapable of having those experiences. [...] It should be possible to devise a method of expressing in objective terms much more than we can at present, and with much greater precision.” The proposal, simply put, was to develop a language to describe subjectivity in non-subjective terms. And although it is definitely not the case that all theorists pushing past the problem of consciousness consider themselves to be implementing Nagel’s plan, it does help to understand a particular set of accumulated answers. Two fundamental approaches have been *neurophilosophy* and *neurophenomenology*, each emphasizing one aspect of

Nagel’s suggestion—either the objective part (*viz.* neurophilosophy) or the phenomenology part (*viz.* neurophenomenology).

Despite the similarity of nomenclature, neurophilosophy and neurophenomenology are very different approaches emerging from different traditions.

Suppose we start, though, with what the neurophilosopher and the neurophenomenologist share. Both hold in common the belief that the problem of consciousness is a pseudoproblem created by our inability to move beyond the conceptual binarism of mind versus body—an error Gilbert Ryle identified in his famous critique of “the dogma of the ghost in the machine.” Both the neurophilosopher and the neurophenomenologist agree that the problem of consciousness is generated by some combination of false dichotomies and faulty concepts. However, they each have different ways of solving it.

Neurophilosophy develops in the “analytic” philosophical tradition in the late twentieth century. Its early formulation can be found in Patricia Churchland’s 1986 book *Neurophilosophy: Toward a Unified Science of the Mind-Brain*. But it is also manifest in the work of many other theorists (e.g., Paul Churchland, Antonio Damasio, Christof Koch). Neurophilosophy is a reductionist theory of consciousness, one that aspires to the Quinean goal of eliminating all things that cannot be reduced to physical (or functional) processes, within which a general method emerges. First, it identifies ideas about consciousness derived from common sense, folk psychology, or introspection. Second, it reduces these “soft” concepts to “hard” neuroscientific data. Third, if they no longer are practically useful, it eliminates the original ideas about consciousness in favor of their neurobiological counterparts. To give an

embarrassingly oversimplified example, take the conventional idea of the love one feels for one’s child. The neurophilosopher takes this subjective idea and, informed by the best neuroscience available, translates it into an objective account—imagine the neurophilosopher saying, “Love is nothing more than oxytocin release.” In the future, the neurophilosopher will replace the word “love” with the more perspicuous word

“oxytocin” in everyday conversation. About the possibility that the feeling of parental love is just neural chemistry, Patricia Churchland herself said, “well, actually, yes, it is. But that doesn’t bother me.”³

Thus, the neurophilosopher strives to convert mind into matter, parsing a singular subjective phenomenon in a shared objective language. But eliminating consciousness in our favor of the neuron may give away more than is necessary or useful. The price of characterizing consciousness in a more scientific language need not be the abandonment of consciousness itself.

If neuroscience hopes to do more than describe arbitrary processes at the neural level, it will always need conscious experience to direct where to look in the brain. We are not mere bystanders in the investigation of consciousness. Our own consciousness is both essential and unavoidable in this endeavor. Neuroscience sometimes forgets that it begins with what interests us about our own conscious experience. And while this certainly involves the fascination with our own subjectivity, it also involves our personal histories, our embodied and embedded situations, and our social values. Strictly speaking, the feeling of love for one’s child is not oxytocin release. More precisely, parental love is *disclosed to us* through oxytocin release, as a situated normative phenomenon. An (imagined) culture that doesn’t value parental love will not care one lick to discover what its neural correlate happens to be. Oxytocin release is important to us here and now because it is tied to the feeling of love for one’s child, a subjective phenomenon that we already recognize and value. For this reason alone, neuroscience needs the first-person point of view.

There is a deeper problem to consider, however, one that insinuates itself into all investigations of consciousness. Technically, we never establish identity statements linking neurochemical processes directly to consciousness. What we do get are equivalences linking our conception of neurochemical processes to our conception

(Continued on page 6)



SAYING THAT THE BRAIN IS
THE SEAT OF MENTALITY IS
LIKE SAYING THAT THE SUN
IS A SOURCE OF LIGHT.

of consciousness. We then have to wonder how accurate and stable our concepts are. To what extent do the concepts we use *transform* the explananda? This is particularly relevant when what we are trying to explain is consciousness itself.

How do we understand consciousness without becoming complicit in that understanding, wrongly attaching the properties of our (conscious) inquiry to the properties of the inquired into (consciousness)? We can never completely avoid our own contribution, however accidental, to the discovery process. This is true for the philosopher in her armchair *as well as* the scientist in her lab. When investigating consciousness, there emerges, for lack of a better phrase, a kind of “observer effect.” The fact that consciousness is both the tool for investigation and the thing to be investigated leads to a lot of mischief. To take a classic example: when we talk about the visual experiences of a red apple, a red stop sign, and a red sweater, we can isolate their red quality, their *redness*. But is this abstracted quality—the color distinct from its object—a property of our *visual experience* of the object, as is generally assumed, or is it rather a property of our *reflection* on the visual experience of the object? What if “a color is never simply a color, but rather the color of a certain object, and the blue of a rug would not be the same blue if it were not a woolly blue?” (Maurice Merleau-Ponty⁴). Simply put, in visual experience, prior to reflection, what if there is no such thing as uninstigated redness?

The neurophilosopher in search of the neural correlate of redness has already assumed an answer to these questions. But this assumption may be, at best, unwarranted and, at worst, wrong. The neurophenomenologist, on the other hand, takes such concerns effectively as her starting point.

Neurophenomenology emerges out of continental philosophy in the late twentieth century. At its inception, we find Francisco Varela, who articulated the approach in his 1996 article “Neurophenomenology: A Methodological Remedy for the Hard Problem.” Since then there have been many collaborators in the development of this movement (e.g., Evan Thompson, Shaun Gallagher, Vittorio Gallese, Giacomo Rizzolatti). Growing out of the phenomenological tradition initiated by Edmund Husserl, neurophenomenology is primarily a method that attempts to naturalize consciousness. First, it identifies a multiplicity of cases, both observed (scientific, empirical) and introspected (described, imagined), in which consciousness is operative. Second, setting aside questions of the physical (functional) reality of consciousness, it identifies the invariant structures that all these cases have in common. Third, it uses these invariant structures to furnish an idea of consciousness that is consonant with the natural sciences.

To give an example of how this works, consider two accounts—the phenomenological and the neuroscientific—of how we come to understand the actions of others. That is, why do we experience the observed bodily movements of other people as genuine actions rather than as mere automation? I do not see a sequence of movements, take a moment to assess the situation, and then make an inference to the best explanation of what a person is doing. As is often the case with my own movements, I know immediately, directly, and implicitly what action is underway. But those are my actions to which I have privileged access. How is it, then, that I seem to have the same kind of access to the actions of others?

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WHEN INVESTIGATING CONSCIOUSNESS, THERE EMERGES, FOR LACK OF A BETTER PHRASE, A KIND OF “OBSERVER EFFECT.”

Phenomenologists have long argued that our access to the intentional goal-directed actions of others is actually the reverse side of our access to our own intentional actions (e.g., Edmund Husserl, Maurice Merleau-Ponty, Dan Zahavi, Natalie Depraz). For instance, when my partner lifts a heavy box, I understand what is happening instantaneously, without any inference or intervening judgment. I might even, also without thinking, reach out and offer my assistance. We live in a shared world that we experience together, the phenomenologists claim, through a kind of “bodily reciprocity”—when we see another person acting intentionally, we experience the same intention in our own bodies, and we transpose our motor intentions into that person.

Neuroscientists discovered that activity in the premotor cortex of the brain was correlated with the preparation of certain physical movements in response to sensory stimulus (e.g., Giacomo Rizzolatti, Vittorio Gallese). These physical movements were not reflexive responses, but rather intentional goal-directed actions—such as reaching, tearing, grasping. These same neuroscientists also discovered that a subset of neurons in the premotor cortex not only activate during the execution of intentional actions, but also discharge when observing similar intentional actions performed by another individual. These neurons do not activate, however, when one’s body moves or is moved unintentionally in a physically analogous manner. For an example from the original experi-

ments, whether a monkey reaches for a raisin or watches another monkey reach for a raisin, the same sets of neurons are activated. But if the monkey’s arm is moved passively toward a raisin, those neurons do not discharge. These neurons appear to mirror the active movements of others, particularly, conspecifics—hence the nomenclature, “mirror neurons.”

The task of the neurophenomenologist now becomes to integrate all this data, finding the invariant structures they share. A first striking commonality is that, on both accounts, to observe an action is also to simulate it through transpositional (*viz.* bodily reciprocity) or mirroring (*viz.* mirror neurons) processes. Another point of convergence is that these processes are not reflective, linguistic, or intellectual. Instead, they appear to be prereflective, nonverbal, and practical. A third parallel is that these interactions occur specifically among conspecifics. This suggests some kind of intersubjectivity at work—in order to simulate the other, we have first to identify with it. There may be other homologies, too, but even with just these three, a single unified explanation is already taking shape. Our understanding of the movements of others as genuine actions is fundamentally a bodily understanding, one that is experienced through shared empathetic connections with other like beings, whereby we simulate in ourselves their intentional goal-directed actions, transposing into them our motor intentions, a capacity realized by dedicated neural processes in the brain.

Neurophenomenology, as an approach to understanding consciousness, is not in competition with phenomenological description or scientific data. It is an intriguing place where we are allowed to surpass the alternative of subjectivity and objectivity, interpolating a conceptual space between them, in which a deeper understanding of both can emerge, a place that we already knew could be inhabited, in a way, because our very existence proves mind and matter compatible. ■

- 1 George H. W. Bush, Presidential Proclamation 6158, July 17, 1990. www.loc.gov/loc/brain/proclaim.html
- 2 Thomas Nagel, “What Is It Like to Be a Bat,” *Mortal Questions* (Cambridge University Press, 1979).
- 3 “The Benefits to Realizing You Are Just Your Brain,” Graham Lawton interviews Patricia Churchland for *New Scientist* 2945 (November 29, 2013).
- 4 Maurice Merleau-Ponty (1945), *Phenomenology of Perception*, trans. Donald A. Landes (Routledge, 2012).

From B-Mode Cosmology to the Fate of Spacetime

The Institute’s thirteenth annual Prospects in Theoretical Physics (PiTP) summer program for graduate students and postdoctoral scholars, which focused on string theory, was truly extraordinary in that it overlapped with Strings 2014. This is one of the field’s most important gatherings, which the Institute hosted with Princeton University, convening international experts and researchers to discuss string theory and its most recent developments. Six hundred attendees gathered for Strings 2014, which made it one of the largest Strings conferences since their inception in 1995.

Strings 2014 talks, which covered topics from B-mode cosmology and the theory of inflation to quantum entanglement, the amplituhedron, and the fate of spacetime, may be viewed at https://physics.princeton.edu/strings2014/Talk_titles.shtml. The program for PiTP and videos of its string theory talks may be viewed at <https://pitp2014.ias.edu/schedule.html>.

As part of the PiTP program, the Institute showed a screening of *Particle Fever*, a new film that follows six scientists, including the Institute’s Nima Arkani-Hamed, during the launch of the Large Hadron Collider and fortuitously captures the discovery of the Higgs particle. Peter Higgs, who predicted the existence of the particle fifty years ago, gave one of his first seminars on the topic at the Institute in 1966.



Planck satellite, a mission of the European Space Agency, which the BICEP team had used in its findings.

“Initially, the announcement was very exciting,” says Flauger. “Like everyone, I thought it would be great if they had detected quantum fluctuations in the space-time metric that were generated when the universe was 10^{-30} seconds old. That’s a big, big thing to look at. It was a unique opportunity.”

But as Flauger delved deeper into the evidence, he grew to doubt whether the BICEP team had detected evidence of primordial gravitational waves. The issue hinged on the nature of the detected B-modes, a polarization pattern identified as a means for detecting such waves by Matias Zaldarriaga, Professor in the School of Natural Sciences, and Uros Seljak in 1997. Foreground contamination from dust in the Milky Way can lead to a similar B-mode signature. Flauger began to believe that the BICEP team had underestimated the level of dust in a Planck slide that the team had lifted from a 2013 presentation and used in their study. The slide was based on unpublished polarization data; Planck plans to release the actual polarization data later this year, which should clarify the cause of the B-modes.

Flauger presented his own analysis at Princeton University in May, and his doubts and those of others about BICEP’s claims were widely reported in the media. “BICEP definitely detected B-modes, but it is unclear if they are caused by primordial gravitational waves or if they are caused by dust in our galaxy,” says Flauger, who recently coauthored the paper “Toward an Understanding of Foreground Emission in the BICEP2 Region” with astrophysicists James Colin Hill and David Spergel, current Visitor (2014) in the School of Natural Sciences. On September 19, Planck researchers published a paper confirming that the amount of galaxy dust had been underestimated by the BICEP team.

According to the standard cosmology model, in the current phase in the history of the Big Bang, the universe began about fourteen billion years ago. Initially the universe was hot and dense with interacting particles. It has been conjectured that prior to this phase, the universe underwent a brief period of accelerated expansion known as inflation when quantum fluctuations, stretched to cosmologically large scales, became the seeds of the universe’s stars and galaxies.

A map released by Planck in 2013—a composite made from nine maps of the sky in nine different frequencies by the Planck satellite—captures the early light from the cosmic microwave background radiation that is remnant from the Big Bang. The cosmic microwave background was first detected in 1964, and since then space, ground, and balloon-based experiments have mapped temperature variations of this light left over from the very early universe, allowing cosmologists to see if theoretical models can reproduce the formation of objects that can be seen through cosmic history.

In the 1980s, cosmologists developed inflation models of the very early universe that incorporated our current understanding of the laws of physics—the laws of general relativity to understand how gravity works, and quantum mechanics to understand how matter behaves. To explain the universe’s longevity and homogeneity, theorists introduced a period of inflation before the Big Bang. Without it, a universe, behaving according to the laws of general relativity, would collapse into a black hole or become completely empty within a period of a few fractions of a second. Inflation had a surprise bonus: due to the uncertainty principles of quantum mechanics, inflation had to last longer in different regions. These tiny differences could then act as the seeds for structure.

A theoretical physicist, Flauger first became interested in cosmic microwave background data as a doctoral student of Steven Weinberg’s at the University of

Recommended Viewing: “The Dawn of B-Mode Cosmology” by Professor Matias Zaldarriaga from Strings 2014: <http://ow.ly/BC5hj/>. To read the Planck Collaboration’s paper, see <http://arxiv.org/pdf/1409.5738.pdf>

Texas at Austin. In 2007, Flauger and Weinberg wrote a paper related to tensor fluctuations in the microwave background, which predict B-modes that show up as gravitational waves in spacetime. Since then, Flauger and others have worked to

develop models in the context of string theory that incorporate observably large B-modes. Prior to these models, it was speculated that the discovery of B-modes could disprove string theory.

“The nice thing about B-modes is that if you measure them, they tell you something about the energy scale during the earliest moments in the universe,” says Flauger, now Assistant Professor at Carnegie Mellon University. “If you see such a B-mode signal, you can show that it means that the energy scale is quite high, about 10^{16} GeV, which is typically what people associate with the grand unified theory scale, and it is not so far from the string scale. With this data set, we have hopes of learning more about string theory.”

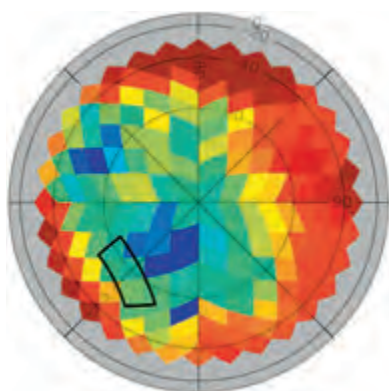
Like CERN’s Large Hadron Collider experiment, which detected the Higgs particle nearly fifty years after it had been predicted in theory, theoretical models are allowing the Planck team to determine the composition of the universe, map the seeds for the formation of structure, and confirm our broad understanding of the beginnings and evolution of the universe. Flauger, for one, has been looking at other features in the microwave background predicted by B-mode

string theory models. Unrelated to B-modes, Flauger and his collaborators Eva Silverstein and Liam McAllister have been looking for axion scalar field signatures in Planck’s temperature data, which support a subset of stringy models. Planck is expected to use this theoretical work in their analysis of the polarization data later this year.

According to inflation theory, as the universe expands exponentially fast, its geometry becomes flat—this geometry was confirmed experimentally around 2000. Theorists then had to use the laws of physics to solve the problem of how to make the inflation stop so that the universe cools and structure starts to form. “The axion scalar field works like a clock,” says Flauger. “This clock, it is slowly rolling, but then it has small ripples, marking time. We are looking for features imprinted in the primordial power spectrum from these small periodic features. To me, identifying these would be interesting because people hadn’t looked for them before the stringy models were proposed. It would not necessarily mean that string theory is true because they could have been proposed earlier, but they weren’t.”

Beyond questioning the actual results of BICEP, there are a number of outstanding questions about inflation. Among them, asks Zaldarriaga, “Is it true that the only way to produce gravitational waves is through inflation?” In the meantime, astrophysicists and theorists continue to debate the nature of BICEP’s findings, awaiting the release of the remaining Planck data.

“If the B-modes are as strong as BICEP says, Planck should also be able to see them,” says Flauger. “That would be really exciting because then we would just know for sure. But we will have to wait and see. My suspicion is that there may still be primordial B-modes in the signal, but that there is also significant dust contribution and that would make it very hard for Planck to see them.... Sometimes it gets phrased that BICEP is just wrong, but I think these maps, no matter what, will be important. They will be used in combination with other datasets to understand if there are primordial B-modes there or not. They are very, very valuable.”—Kelly Devine Thomas



Planck data indicating levels of dust contamination in the southern galactic sky, with red regions the most contaminated and blue regions the least. The black outline in the lower left quadrant shows the approximate region studied by BICEP.

PLANCK COLLABORATION



FROM LEFT: ALEXANDRA ALTMAN, AMY RAMSEY, DAN KOMODA

The Origins and Motivations of Univalent Foundations

Professor Voevodsky's Personal Mission to Develop Computer Proof Verification to Avoid Mathematical Mistakes

BY VLADIMIR VOEVODSKY

In January 1984, Alexander Grothendieck submitted to the French National Centre for Scientific Research his proposal “Esquisse d’un Programme.” Soon copies of this text started circulating among mathematicians. A few months later, as a first-year undergraduate at Moscow University, I was given a copy of it by George Shabat, my first scientific adviser. After learning some French with the sole purpose of being able to read this text, I started to work on some of the ideas outlined there.

In 1988 or 1989, I met Michael Kapranov who was equally fascinated by the perspectives of developing mathematics of new “higher-dimensional” objects inspired by the theory of categories and 2-categories.

The first paper that we published together was called “ ∞ -Groupoids as a Model for a Homotopy Category.” In it, we claimed to provide a rigorous mathematical formulation and a proof of Grothendieck’s idea connecting two classes of mathematical objects: ∞ -groupoids and homotopy types.

Later we decided that we could apply similar ideas to another top mathematical problem of that time: to construct motivic cohomology, conjectured to exist in a 1987 paper by Alexander Beilinson, Robert MacPherson (now Professor in the School of Mathematics), and Vadim Schechtman.

In the summer of 1990, Kapranov arranged for me to be accepted to graduate school at Harvard without applying. After a few months, while he was at Cornell and I was at Harvard, our mathematical paths diverged. I concentrated my efforts on motivic cohomology and later on motivic homotopy theory. My notes dated March 29, 1991, start with the question “What is a homotopy theory for algebraic varieties or schemes?”

The field of motivic cohomology was considered at that time to be highly speculative and lacking firm foundation. The groundbreaking 1986 paper “Algebraic Cycles and Higher K-theory” by Spencer Bloch was soon after publication found by Andrei Suslin to contain a mistake in the proof of Lemma 1.1. The proof could not be fixed, and almost all of the claims of the paper were left unsubstantiated.

A new proof, which replaced one paragraph from the original paper by thirty pages of complex arguments, was not made public until 1993, and it took many more years for it to be accepted as correct. Interestingly, this new proof was based on an older result of Mark Spivakovsky, who, at about the same time, announced a proof of the resolution of singularities conjecture. Spivakovsky’s proof of resolution of singularities was believed to be correct for several years before being found to contain a mistake. The conjecture remains open.

The approach to motivic cohomology that I developed with Andrei Suslin and Eric Friedlander circumvented Bloch’s lemma by relying instead on my paper “Cohomological Theory of Presheaves with Transfers,” which was written when I was a Member at the Institute in 1992–93. In 1999–2000, again at the IAS, I was giving a series of lectures, and Pierre Deligne (Professor in the School of Mathematics) was taking notes and checking every step of my arguments. Only then did I discover that the proof of a key lemma in my paper contained a mistake and that the lemma, as stated, could not be salvaged. Fortunately, I was able to prove a weaker and more complicated lemma, which turned out to be sufficient for all applications. A corrected sequence of arguments was published in 2006.

This story got me scared. Starting from 1993, multiple groups of mathematicians studied my paper at seminars and used it in their work and none of them noticed the mistake. And it clearly was not an accident. A technical argument by a trusted author, which is hard to check and looks similar to arguments known to be correct,

is hardly ever checked in detail.

But this is not the only problem that allows mistakes in mathematical texts to persist. In October 1998, Carlos Simpson submitted to the arXiv preprint server a paper called “Homotopy Types of Strict 3-groupoids.” It claimed to provide an argument that implied that the main result of the “ ∞ -groupoids” paper, which Kapranov and I had published in 1989, cannot be true. However, Kapranov and I had considered a similar critique ourselves and had convinced each other that it did not apply.

I was sure that we were right until the fall of 2013 (!!).

I can see two factors that contributed to this outrageous situation: Simpson claimed to have constructed a counterexample, but he was not able to show where the mistake was in our paper. Because of this, it was not clear whether we made a mistake somewhere in our paper or he made a mistake somewhere in his counterexample. Mathematical research currently relies on a complex system of mutual trust based on reputations. By the time Simpson’s paper appeared, both Kapranov and I had strong reputations. Simpson’s paper created doubts in our result, which led to it being unused by other researchers, but no one came forward and challenged us on it.

Around the time that I discovered the mistake in my motivic paper, I was working on a new development, which I called 2-theories. As I was working on these ideas, I was getting more and more uncertain about how to proceed. The mathematics of 2-theories is an example of precisely that kind of higher-dimensional mathematics that Kapranov and I had dreamed about in 1989. And I really enjoyed discovering new structures that were not direct extensions of structures in lower dimensions.

But to do the work at the level of rigor and precision I felt was necessary would take an enormous amount of effort and would produce a text that would be very hard to read. And who would ensure that I did not forget something and did not make a mistake, if even the mistakes in much more simple arguments take years to uncover? I think it was at this moment that I largely stopped doing what is called “curiosity-driven research” and started to think seriously about the future. I didn’t have the tools to explore the areas where curiosity was leading me and the areas that I considered to be of value and of interest and of beauty.

So I started to look into what I could do to create such tools. And it soon became clear that the only long-term solution was somehow to make it possible for

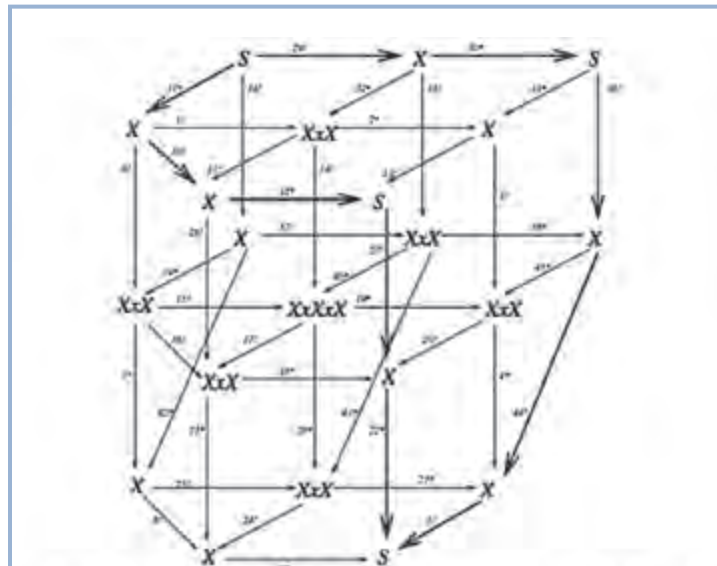
me to use computers to verify my abstract, logical, and mathematical constructions. The software for doing this has been in development since the sixties. At the time, when I started to look for a practical proof assistant around 2000, I could not find any. There were several groups developing such systems, but none of them was in any way appropriate for the kind of mathematics for which I needed a system.

When I first started to explore the possibility, computer proof verification was almost a forbidden subject among mathematicians. A conversation about the need for computer proof assistants would invariably drift to Gödel’s incompleteness theorem (which has nothing to do with the actual problem) or to one or two cases of verification of already existing proofs, which were used only to demonstrate how impractical the whole idea was.

Among the very few mathematicians who persisted in trying to advance the field of computer verification in mathematics during this time were Tom Hales and Carlos Simpson. Today, only a few years later, computer verification of proofs and of mathematical reasoning in general looks completely practical to many people who work on univalent foundations and homotopy type theory.

The primary challenge that needed to be addressed was that the foundations of mathematics were unprepared for the requirements of the task. Formulating mathematical reasoning in a language precise enough for a computer to follow meant using a foundational system of mathematics not as a standard of consistency to establish a few fundamental theorems, but as a tool that can be employed in everyday mathematical work. There were two main problems with the existing foundational systems, which made them inadequate. Firstly, existing foundations of mathematics were based on the languages of predicate logic and languages of

(Continued on page 9)



For the convenience of further reference we numbered all the arrows. The right vertical face of the diagram is the diagram (2) defining the 2-morphism $Id \rightarrow \Omega\Sigma$ and the upper horizontal face is the diagram (1) defining the 2-morphism $\Sigma\Omega \rightarrow Id$. The whole diagram is the union of the front part which

This three-dimensional diagram is an example of the kind of “formulas” that Voevodsky would have to use to support his arguments about 2-theories.

I DIDN'T HAVE THE TOOLS TO EXPLORE THE AREAS WHERE CURIOSITY WAS LEADING ME AND THE AREAS THAT I CONSIDERED TO BE OF VALUE AND OF INTEREST AND OF BEAUTY.

Vladimir Voevodsky, who joined the School of Mathematics as Professor in 2002, is known for his work in the homotopy theory of schemes, algebraic K-theory, and interrelations between algebraic geometry and algebraic topology. He made one of the most outstanding advances in algebraic geometry in the past few decades by developing new cohomology theories for algebraic varieties. Among the consequences of his work are the solutions of the Milnor and Bloch-Kato conjectures.

this class are too limited. *Secondly*, existing foundations could not be used to directly express statements about such objects as, for example, the ones in my work on 2-theories.

Still, it is extremely difficult to accept that mathematics is in need of a completely new foundation. Even many of the people who are directly connected with the advances in homotopy type theory are struggling with this idea. There is a good reason: the existing foundations of mathematics—ZFC and category theory—have been very successful. Overcoming the appeal of category theory as a candidate for new foundations of mathematics was for me personally the most challenging.

The story starts with ZFC: the Zermelo-Fraenkel theory with the axiom of choice. Since the first half of the twentieth century, mathematics has been pre-

applying this mechanism to a set of operations and axioms. The second component in ZFC is based on the human ability to intuitively comprehend hierarchies. In fact, the axioms of ZFC can be seen as a collection of properties that all hierarchies satisfy, together with the axiom of infinity, which postulates the existence of an infinite hierarchy. The third component is a way to encode mathematical notions in terms of hierarchies that starts with rules for encoding mathematical properties of sets. That is why ZFC is often called a set theory.

The original formal deduction system of univalent foundations is called the calculus of inductive constructions, or CIC. It was developed by Thierry Coquand and Christine Pauline around 1988 and was based on a combination of ideas from the theory and practice of computer languages with ideas in constructive mathe-



From left to right: Voevodsky at a lunch seminar, pictured here with Jonathan Israel, Andrew W. Mellon Professor in the School of Historical Studies; delivering the lecture “What if Current Foundations of Mathematics are Inconsistent?” at the 80th anniversary celebration of the Schools of Mathematics and Natural Sciences in 2010; a lunchtime conversation this spring

sented as a science based on ZFC, and ZFC was introduced as a particular theory in predicate logic. Therefore, someone who wanted to get to the bottom of things in mathematics had a simple road to follow—learn what predicate logic is, then learn a particular theory called ZFC, then learn how to translate propositions about a few basic mathematical concepts into formulas of ZFC, and then learn to believe, through examples, that the rest of mathematics can be reduced to these few basic concepts.

This state of affairs was extremely beneficial for mathematics, and it is rightly credited for the great successes of abstract mathematics in the twentieth century. Historically, the first problems with ZFC could be seen in the decline of the great enterprise of early Bourbaki, which occurred because the main organizational ideas of mathematics of the second half of the twentieth century were based on category theory, and category theory could not be well presented in terms of ZFC. The successes of category theory inspired the idea that categories are “sets in the next dimension” and that the foundation of mathematics should be based on category theory or on its higher-dimensional analogues.

The greatest roadblock for me was the idea that categories are “sets in the next dimension.” I clearly recall the feeling of a breakthrough that I experienced when I understood that this idea is wrong. Categories are not “sets in the next dimension.” They are “partially ordered sets in the next dimension” and “sets in the next dimension” are groupoids.

This new perspective on “groupoids” and “categories” took some adjustment for me because I remember it being emphasized by people I learned mathematics from that one of the things that made Grothendieck’s approach to algebraic geometry so successful was that he broke with the old-schoolers and insisted on the importance of considering all morphisms and not only isomorphisms. (Groupoids are often made of set-level objects and their isomorphisms, while categories are often made of set-level objects and *all* morphisms.)

Univalent foundations, like ZFC-based foundations and unlike category theory, is a complete foundational system, but it is very different from ZFC. To provide a format for comparison, let me suppose that any foundation for mathematics adequate both for human reasoning and for computer verification should have the following three components.

The *first component* is a formal deduction system: a language and rules of manipulating sentences in this language that are purely formal, such that a record of such manipulations can be verified by a computer program. The *second component* is a structure that provides a meaning to the sentences of this language in terms of mental objects intuitively comprehensible to humans. The *third component* is a structure that enables humans to encode mathematical ideas in terms of the objects directly associated with the language.

In ZFC-based foundations, the first component has two “layers.” The first layer is a general mechanism for building deduction systems, which is called predicate logic; the second layer is a particular deduction system called ZFC obtained by

mathematics. The key names associated with these ideas are Nicolaas Govert de Bruijn, Per Martin-Löf and Jean-Yves Girard. The formal deduction system of the proof assistant Coq is a direct descendant of CIC.

The second component of univalent foundations, the structure that provides a direct meaning to the sentences of CIC, is based on univalent models. The objects directly associated with sentences of CIC by these models are called homotopy types. The world of homotopy types is stratified by what we call h-levels, with types of h-level 1 corresponding to logical propositions and types of h-level 2 correspond-

ing to sets. Our intuition about types of higher levels comes mostly from their connection with multidimensional shapes, which was studied by ZFC-based mathematics for several decades.

The third component of univalent foundations, a way to encode general mathematical notions in terms of homotopy types, is based on the reversal of Grothendieck’s idea from the late seventies considered in our “ ∞ -groupoids” paper. Both mathematically and philosophically, this is the deepest and least understood part of the story.

I have been working on the ideas that led to the discovery of univalent models since 2005 and gave the first public presentation on this subject at Ludwig-Maximilians-Universität München in November 2009. While I have constructed my models independently, advances in this direction started to appear as early as 1995 and are associated with Martin Hofmann, Thomas Streicher, Steve Awodey, and Michael Warren.

In the spring of 2010, I suggested to the School of Mathematics that I would organize a special program on new foundations of mathematics in 2012–13, despite the fact that at the time it was not clear that the field would be ready for such a program.

And I now do my mathematics with a proof assistant. I have a lot of wishes in terms of getting this proof assistant to work better, but at least I don’t have to go home and worry about having made a mistake in my work. I know that if I did something, I did it, and I don’t have to come back to it nor do I have to worry about my arguments being too complicated or about how to convince others that my arguments are correct. I can just trust the computer. There are many people in computer science who are contributing to our program, but most mathematicians still don’t believe that it is a good idea. And I think that is very wrong.

I would like to thank all of those who are trying to understand the ideas of univalent foundations, who are developing these ideas, and who are trying to communicate these ideas to others. ■

FORMULATING MATHEMATICAL REASONING IN A LANGUAGE PRECISE ENOUGH FOR A COMPUTER TO FOLLOW MEANT USING A FOUNDATIONAL SYSTEM OF MATHEMATICS AS A TOOL THAT CAN BE EMPLOYED IN EVERYDAY MATHEMATICAL WORK.

The special program on univalent foundations that Vladimir Voevodsky organized at the Institute in 2012–13 resulted in a group of two-dozen mathematicians writing a six-hundred-page book in less than six months. The book is available freely at <http://homotopytypetheory.org/book/>. This article was adapted from a lecture given by Voevodsky in March; the video may be viewed at <https://video.ias.edu/voevodsky14/>.

Conspiring with the Enemy and Cooperating in Warfare

'Live and Let Live' as a Representative Element of War

BY YVONNE CHIU

Images that convey the essence of war are more likely to resemble the frenzied, merciless, mutual slaughter between the Aegeans and the Trojans as told in *The Iliad*, the rapes depicted in Goya's *The Disasters of War*, the torture portrayed in *The Battle of Algiers*, or the indiscriminate napalm bombing in Vietnam dramatized in *Apocalypse Now*. It is commonly believed—and for good reason—that morality and civilization are inevitably forgotten in war, as participants become desperate to survive, get caught up in the bloodlust, or lose touch with their humanity. There is truth to that, so it might be surprising to think of banning hollow point bullets (Hague Convention, 1899) or regulating prisoner-of-war treatment (from the 1648 Peace of Westphalia through the 1949 Geneva Conventions) as simultaneously capturing an essential element of warfare, but in fact they represent a significant component of war, which is cooperation between enemies.

Some of the more amazing stories of cooperation in warfare come from the trenches of World War I. During the Christmas truces in 1914, and to a lesser extent in 1915, not only did 100,000 British and German soldiers in WWI unofficially stop fighting, but in some places in Belgium, German soldiers who decorated their trenches with candles and trees and sang carols were met with British soldiers singing in kind; eventually, the two sides mingled in No Man's Land, exchanging gifts, food, and souvenirs, and even engaging in short, casual football games.

In addition to *ad hoc* cooperation on a shared holy day, opposing trenches spontaneously developed a longer-lived system of timed shellings to allow the other side to anticipate and avoid their impact. While trench warfare was a large part of the WWI experience, it is not particularly interesting militarily. Rather, it is noteworthy for what fighting did not happen. This "live and let live" system has been recounted in marvelous detail by Tony Ashworth (*Trench Warfare 1914–1918*). That reciprocal exchange—of minimization of injury and death—took different forms during the war: truces lasted anywhere from a few minutes to several months; some were explicit agreements between fraternizing soldiers in close quarters, while others were indirect (due to legal sanctions), over long distances, and involving large numbers of people. There were numerous reports of people walking openly above trenches; unrestricted movement in and out of the trenches; Germans frying sausages and photos of Brits frying bacon in the trenches, despite the fact that smoke from the fires would have attracted gunfire on active fronts; and descriptions of "quiet" fronts, where there were no ammunition shortages. In some trenches, people hunted and retrieved small game, harvested vegetables, kept milking cows for fresh milk, and had pianos and books.

What kept these tacit truces alive? Inertial truces arose where there was general reluctance to fight, usually out of a combination of self-interest and empathy. If fired upon, parties would return fire, but both sides preferred to "let sleeping dogs lie." High command did not look favorably on this inactivity, so in the latter half of the war, they exerted more direct control over the trenches, e.g., by ordering specific raids. Soldiers adapted by ritualizing their aggression and conforming with the letter, but not the spirit, of the commands. They deliberately aimed their rounds high, patrols pretended not to see each other or followed routes such that they would not encounter each other, they fired into no-man's land instead of into the trenches, and they shelled the same place or at the same time every day so that the other side could avoid that area or schedule to suit. Such ritualized aggression still looked like a battle from the outside, and reports could be sent to high command about the times and duration of the battles and how much ammunition was spent. The complexity of this uncoordinated cooperation between warring parties—usually without direct communication between the two sides, with individuals constantly rotating in and out, and sanctions imposed both within each side and between enemies—is impressive, to say the least.

Truces were not all fun and games or cuddly cooperation, however. Underlying and holding the truce together was always the threat of damage should someone defect or secede from the agreement. For example, ritualized exchange of fire some-

times took the form of repeatedly "just missing" the target. This maintained the peace while simultaneously showing the enemy that one had the range and accuracy to harm him should the truce break down.

"Live and let live" is admittedly quite unique, partly because of the structure of trench warfare—such truces did not develop under other circumstances. It does not mean that fellow feeling or the desire to cooperate does not exist elsewhere; it is simply more diffuse or on a different scale, e.g., not sniping a man taking a cigarette break or trying not to kill women and children. The strategy of trench warfare just happens to have a structure that makes for clean iterative, cooperative games, and the "live and let live" that evolved shows cooperation in its distilled form.

As amazing as this sustained cooperation was, however, in some ways, it should not be surprising. Although the major warring parties stoked their populations' nationalistic passions with stirring propaganda and dehumanization of the enemy, most of the soldiers in the trenches were conscripts with little at stake in the war. Once they experienced its horrors, many of them found they preferred to save themselves; and once they recognized the humanity of their enemies across the way, they were willing to collude to save others if that was necessary for their own survival.

Perhaps what is truly surprising is how cooperation between enemies can take much more systematic forms, in ways taken for granted such that we hardly notice them anymore. In addition to weapons bans and prisoner-of-war regulations, other notable examples include the Geneva Conventions regulations for wearing uniforms into combat and protections for clergy and medics who are national military personnel. The latter are especially notable because they developed in some form before any widespread discussion of human rights. They are conventional, a practice that has been agreed upon.

But why should medics be treated as neutral (so long as they do not pick up arms) even when they are part of a national military? Their jobs are essential to the war effort, and the very soldiers they heal may return to the battlefield in the future and continue to fight.

These conventions were motivated by many different things, but one major goal was to minimize overall damage—although where the line is drawn is often arbitrary, as the medic case shows. For example, the distinction between soldiers and civilians is a matter of convention. Historically, no such differentiation was made, even if women and children were spared more often than men; and when members of the civilian population contribute in varying ways to the war effort, as they inevitably do, then where the line is drawn (e.g. munition factory workers can be targeted but medics cannot) is subjective and a matter of agreement.

At this point, some context is required: (1) Cooperation in warfare is certainly not the norm: historically, and even in contemporary times, it is an anomaly in human history. Guerrilla, or "irregular," warfare—which takes an indirect approach and utilizes raids, ambushes, sabotage, and short skirmishes—has been and continues to be the norm over the 150,000 years of *Homo sapiens*. (2) Cooperation in warfare is not a uniquely modern phenomenon. It has happened all throughout human history, on a variety of levels, and in many different forms, although the contemporary systematization of this cooperation through international law and institutions is different. And (3) although the rules are not always obeyed—in fact, they are more often deliberately violated—and even if international law looks much less dramatic and interesting than tensely negotiated truces in muddy trenches, the systematization of cooperation at the interstate and international levels and the extent to which individuals do obey those rules in the field is significant. It shows that moral considerations are possible even in the most horrifying of human activities and even between people who have much to gain from not cooperating with each other.

Why would states and soldiers make it harder for themselves to win and end wars? While these rules could be a form of hegemony imposed by stronger states on weaker ones, they also make it harder to win, which is why countries and individuals are constantly trying to break the rules and get away with it. They were also created and sustained at least in part by sincere beliefs that there are right and wrong ways to

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A wounded German soldier lighting a cigarette for a wounded British soldier at a British field hospital during the Battle of Épehy, near the end of the First World War (1918)

LT THOMAS K. AITKEN, BRITISH ARMY PHOTOGRAPHER, IMPERIAL WAR MUSEUMS



A simple wooden memorial cross marks the field outside Ploegsteert Wood, Flanders, where British and German soldiers played soccer during the World War One Christmas Day truce in 1914. August 4, 2014 marked the 100th anniversary of Great Britain declaring war on Germany.

GAUTIER DEMOULÉ/UNIBRAUTIN/CORBIS

A Declaration of Freedom and Equality

Exploring the Arguments of Independence

The following text is excerpted from *Our Declaration: A Reading of the Declaration of Independence in Defense of Equality* (Liveright Publishing Corporation, 2014) by Danielle Allen, UPS Foundation Professor in the School of Social Science.

The Declaration of Independence matters because it helps us see that we cannot have freedom without equality. It is out of an egalitarian commitment that a people grows—a people that is capable of protecting us all collectively, and each of us individually, from domination. If the Declaration can stake a claim to freedom, it is only because it is so clear-eyed about the fact that the people's strength resides in its equality.

The Declaration also conveys another lesson of paramount importance. It is this: language is one of the most potent resources each of us has for achieving our own political empowerment. The men who wrote the Declaration of Independence grasped the power of words. This reveals itself in the laborious processes by which they brought the Declaration, and their revolution, into being. It shows itself forcefully, of course, in the text's own eloquence.

When we think about how to achieve political equality, we have to attend to things like voting rights and the right to hold office. We have to foster economic opportunity and understand when excessive material inequality undermines broad democratic political participation. But we also have to cultivate the capacity of citizens to use language effectively enough to influence the choices we make together. . . .

. . . The single most transformative experience I had came from teaching the Declaration of Independence not to my bright-eyed undergraduates but to my life-tested night students. I sometimes taught it as part of the U.S. history unit, sometimes as part of the literature unit, and sometimes as part of the writing unit. Like the huge majority of Americans, few of my day students had ever read its 1,337 words from start to finish. None of my night students had.

I started teaching the text instrumentally. That is, I thought it would be useful. These students with jobs were busy. The Declaration is short. No one would complain about the reading. I could use it to teach history, writing, or political philosophy. And so I began.

My night students generally entered into the text thinking of it as something that did not belong to them. It represented instead institutions and power, everything that solidified a world that had, as life had turned out, delivered them so much grief, so much to overcome.

As I worked my way through the text with those students, I realized for the first time in my own life that the Declaration makes a coherent philosophical argument. In particular, it makes an argument about political equality. If the pattern of books published on the Declaration is any indication, we have developed the habit of thinking about the Declaration mainly as an event, an episode

in the dramatic unfolding of the American Revolution. But it makes a cogent philosophical case for political equality, a case that democratic citizens desperately need to understand.

What exactly is political equality?

The purpose of democracy is to empower individual citizens and give them sufficient control over their lives to protect themselves from domination. In their ideal form, democracies empower each and all such that none can dominate any of the others, nor any one group, another group of citizens.

Political equality is not, however, merely freedom from domination. The best way to avoid being dominated is to help build the world in which one lives—to help, like an architect, determine its pattern and structure. The point of political equality is not merely to secure spaces free from domination but also to engage all members of a community equally in the work of creating and constantly recreating that community. Political equality is equal political empowerment. Ideally, if political equality exists, citizens become cocreators of their shared world. Freedom from domination and the opportunity for cocreation maximize the space available for individual and collective flourishing.

The assertion that the Declaration is about such a rich notion of political equality will provoke skepticism. Is it not about freedom? The text, after all, declares *independence*.

The Declaration starts and finishes, however, with equality. In the first sentence, the Continental Congress proclaims that the time has come for the people, which they now constitute, to take a “separate and equal” place among the powers of the earth. The last sentence of the Declaration finds the members of the Continental Congress, as representatives of their newly designated “states,” “mutually” pledging to each other their lives, their property, and their sacred honor. They stake their claim to independence—to freedom—on the bedrock of an egalitarian commitment to one another. Only on the basis of a community built with their equality can they achieve their freedom.

And, of course, there is also the all-important second sentence, which begins, “We hold these truths to be self-evident, that all men are created equal.”

As my night students metabolized the philosophical argument and rhetorical art of the Declaration, many of them, and I along with them, experienced a personal metamorphosis. They found themselves suddenly as political beings, with a consciousness that had previously eluded them. They built a foundation from which to assess the state of their political world. They gained a vocabulary and rhetorical techniques for arguing about it.

In reading the document with me, my students in fact regifted to me a text that should have been mine all along. They gave me again the Declaration's ideals—equality and freedom—and the power of its language. They restored to me my patrimony as well as their own, and ours. ■



COOPERATING IN WARFARE (Continued from page 10)

win, and that it matters both practically—e.g., in building good will and reciprocity with opponents, whether they end up vanquished or one's conquerors—and morally.

I want to note just two interesting tensions caused by an ethic of cooperation in warfare. The first is between cooperation and wanting to win the war. Cooperation with the enemy may delay victory or diminish one's prospects of winning at all, as militaries restrain themselves from doing everything they can to win. Cooperation can also take valuable resources that can otherwise go toward fighting and ending the war; for example, during WWII, some German POWs in the United States were kept in better conditions and had a higher standard of living than the American civilians who lived around those camps.

In addition, one major purpose of such cooperation is to reduce overall harm, yet it may be that cooperation sometimes increases the damage. For example, the stereotypical full-frontal, open engagement of eighteenth and nineteenth century European confrontations—soldiers dressed in national uniforms, lined up in formation, shooting in unison—did not adapt well to developments in technology, especially long-range, more accurate artillery. The tragedy of pre-existing tactics (which arose in part from reciprocal cooperation over various issues) meeting new technology can be seen, for example, in the Napoleonic Wars, the Battle of Solferino (whose horrors led to the Red Cross's creation), the American Civil War, and the WWI trenches when fighting did take place.

The second tension lies in how the ethic of cooperation has worked its way into practical thinking about just war theory. For example, U.S. drone operators are often uneasy about their work. Contrary to common belief that the video

game-like quality of their experience desensitizes them, they feel it viscerally, because they see their targets' faces clearly, track them for days as they go about normal life activities, and get to know them before killing them, in a way that a fighter pilot dropping a bomb from miles up in the air could not. Drone operators have talked about the unfairness of killing their enemies without putting themselves at risk; there is a sense that for it to be fair, they have to be endangered too—in this case, physically present in the battlefield and vulnerable to attack. Even after concerns about other criteria for just war—especially just cause, proportionality, and probability of success—have been satisfied, they are often still uncomfortable. In the context of how war has been waged since the beginning of human history, it is crazy to talk about reciprocal risk in warfare, but it persists. This sense of fairness, which is rooted in a specific notion of reciprocal cooperation, drives many of the questions being asked now about the ethics of drone warfare. The ethic of cooperation in warfare may sit in tension with other aspects of contemporary just war theory that are focused on justice (that the right thing has been done in the right way to the right person), and it raises important questions about what just war theory can and should pursue, and at what expense. ■

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ENVIRONMENT (Continued from page 1)

published as *Science and the Common Understanding* (1954)—it is far from enough when it comes to dealing with the most major complex challenges that are facing us. Still, strangely, the knowledge base for environmental protection was for a long time built quite one-sidedly on science and to some extent technology, as if the understanding of nature's workings would almost inevitably spin off sound policy recommendations and, ultimately, betterment in policy and environmental practice.

True, the domain of environmentally relevant knowledge expanded gradually in the later decades of the twentieth century. After the Rio Conference in 1992, hopes were high for new economic- and incentive-driven public management solutions, but after twenty years of focusing policies on what Maarten A. Hajer in *The Politics of Ecological Discourse* (1995) termed “ecological modernization,” including efforts for green and clean growth, eco-efficiency, decoupling, and the ever-more-sophisticated management of landscapes and species, the world seems to have come to a point where it must again determine pathways to sustainability.

It seems this time that our hopes are tied to the humanities. In February 2012, the Responses to Environmental and Societal Challenges for our Unstable Earth (RESCUE) initiative, commissioned by the European Science Foundation and Europe's intergovernmental Cooperation in Science and Technology program, presented its synthesis report. It gave a high profile to the humanities, arguing that in a world where cultural values, political and religious ideas, and deep-seated human behaviors still rule the way people lead their lives, produce, and consume, the idea of *environmentally relevant knowledge* must change. We cannot dream of sustainability unless we start to pay more attention to the human agents of the planetary pressure that environmental experts are masters at measuring but seem unable to prevent.

Some of the shift toward the human sciences has to do with the fundamental shift in understanding what is represented by the Anthropocene concept (see article, page 13), coined by Crutzen and Stoermer in 2000 (*Global Change Newsletter* 41: 17–18). If humanity is the chief cause of the ominous change, it must surely be inevitable that research and policy will be focused on human societies and their basic functions. After half a century of putting nature first, it may be time to put humans first. Some members of the RESCUE team went on to publish articles geared toward “Reconceptualizing the ‘Anthropos’ in the Anthropocene” and “Reconfiguring Environmental Expertise” for a special issue of *Environmental Science and Policy* (2013).¹

Similar attempts to address the need for change both in the human sciences themselves and in the position the humanities occupy in universities and research policy are seen elsewhere. A major activity, the “Anthropocene Project,” is hosted by the Haus der Kulturen der Welt in Berlin, where a megascale Anthropocene conference was organized during a week in January 2013 and where some one hundred (!) graduate students and postdocs from all over the world will assemble for a super teach-in over ten days in November 2014 with leading Anthropocene scholars of all fields, humanities, technology, natural sciences, social sciences, art, and design.

The environmental humanities

Other initiatives point in the same direction. Considerable energies are going into the emerging concept of *environmental humanities*. This is a broad multidisciplinary approach that signals a new willingness in the humanities to forego the primary focus on disciplines (as in, e.g., environmental philosophy, environmental history) for a common effort in which the relevance of human action is on par with the environmental aspect. Programs or other initiatives for the environmental humanities have already started to emerge in universities in Europe, Australia, and the United States, including Princeton, Stanford, and UCLA. The Consortium of Humanities Centers and Institutes (CHCI), assembling more than seventy humanities centers worldwide, has its own initiative, Humanities for the Environment, which “serves as a network and resource for centers to develop (or extend) program-

ming, research, and dialogue related to contemporary environmental challenges.” Academic initiatives abound and have shown a particular growth trend in the last two or three years. The Transatlantic Environmental Research Network in Environmental Humanities links several universities in the United States and Canada with primarily German counterparts, including the recently established Rachel Carson Center in Munich. The movements are not isolated to the humanities in the narrow sense, they are felt across the human sciences. The Institute's School of

Social Science devoted the year 2013–14 to “The Environmental Turn and the Human Sciences” as their chosen thematic field.

A new journal, *Environmental Humanities*, was launched in 2012; it is based at the University of New South Wales, where there is also an interdisciplinary environmental humanities program. Another one, *The Anthropocene Review*, saw its first issue out as late as 2014; a third, *Resilience: A Journal of the Environmental Humanities*, has also just published its first issue. Several publishers have established new series in the environmental humanities, and volumes are appearing at a steady stream. After decades of very little interest in funding large-scale environmental work in the humanities, funders have started to invite experts on human values, ideas, history, thinking, religion, and communication to bring their knowledge to bear on critical global issues. Norway has started the Cultural Conditions Underlying Social Change (SAMKUL) program. Among its highest-priority areas of interest are the environ-

ment and climate change. In Sweden, the Mistra Foundation for Strategic Environmental Research launched in 2013 the largest-ever program for environmental research in the humanities. The major German initiative at the Rachel Carson Center has adopted the topic on its agenda and also formed a European Alliance for Environmental Humanities with the KTH Royal Institute of Technology in Stockholm, the University of Utrecht, Trinity College, Dublin, and other partners.

Both challenges and fundamental curiosity

The energies in these fields are certainly derived from the challenge-oriented research agenda that is common around the world and not least in the European Union where the new eighty billion euro (about \$100 billion) framework program for research, Horizon 2020, is starting this year and will last for the coming seven years. But equally important are developments within the humanities disciplines themselves. It is quite simply some very engaging and exciting scholarship that draws attention to the environmental humanities, so that when young scholars flock around fields with the “environmental-” prefix or turn in large numbers to Anthropocene events, it is likely a combined effect of intellectual curiosity and an eagerness to get work done that can make a difference, in the positive sense. Some remarkable work on the environment in recent years has already been carried out by humanists. Lawrence Buell at Harvard sparked off the ecocritical movement in literary studies from the 1990s with a string of books, including his *Writing for an Endangered World* (2001). His colleague Ursula K. Heise at Stanford articulated the emerging idea of a global humanity with a planetary conscience in her book *Sense of Place and Sense of Planet* (2008). If this is an emerging idea, the outlook in a few generations may in fact be brighter than we think.

In France, sociologist-philosopher Bruno Latour has been reconfiguring his country's leading policy school, the Sciences Po, putting his ideas of a major environmental turn of the planetary enterprise at center stage, and has in recent years turned into a major champion of the Anthropocene concept. At the Science Policy Research Unit at the University of Sussex, Andy Stirling has invited us to consider what he calls *directionality* as we conceive research policy for economic growth in order to achieve real progress, not just more of the same destructive kind of growth. Literary scholar Rob Nixon at the University of Wisconsin–Madison, argues that a “slow violence” (part of the title of his 2011 book, *Slow Violence and the Environmentalism of the Poor*) plagues the poorest people on Earth, who shoulder a disproportionate share of the burden when the rich outsource their ecological footprint—dumping waste, axing forests, or relocating dangerous workplaces.

Environmental humanists have already begun to challenge established truths. Although ecologists and economists have put considerable hope over the last two decades into the idea that we may be able to defend ecosystem services by translating them into monetary terms, several humanities scholars (in alliance with many skeptical scientists) have presented fundamental criticism of this approach. Uncritically applying the indiscriminately universalizing tool of monetized services risks doing more harm than good to the environment. In particular, it runs the risk of

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Sörlin leading a seminar on the School of Social Science's theme for 2013–14, “Environmental Turn and the Human Sciences”

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marginalizing social groups—and, therefore, civic values—as they try to articulate value-based agendas for defending nature and urban space. Yet another moment when one is reminded of the wisdom of Einstein’s quote: “Not everything that counts can be counted; not everything that can be counted counts.”

The environmental humanities thus also contribute to new developments in the discourse on the relation between knowledge and politics. Already fifteen years ago, Bruno Latour argued for a “new Constitution” where the traditional separation of facts and values should be renegotiated. Work in science and technology studies (STS) over the past decade has provided increasing evidence that the values about society and how it should be governed and where it should be headed is of far greater significance for policy and, not least for a society’s environmental performance, than “facts about nature.” As Harvard scholar Sheila Jasanoff (*Designs on Nature*, 2005; *Science and Public Reason*, 2012) has noted in a summary of the main findings of STS, “better science advice requires more intelligent engagement with politics,” and not the opposite.

This is especially important because of the innate tendency in science advice to attach most of the value to “what is already known, than to what is unknown or outside the reach of the advisers’ immediate consciousness.” As Jasanoff reminds us this disfavors the collection of hard-to-gather social and behavioral evidence and favors continued amassing of measurable facts about the natural world, despite the fact that it is no longer the most pressing concern for policy. The climate crisis is a case in point. We could say that we know enough to act, but the overwhelming pri-

orities of knowledge production remain focused on refining the existing climate knowledge rather than massively turning our attention to how we could equip and empower societies, citizens, and businesses to move away from the danger.

Naturally, if this was a simple thing to do, it would have already happened, which is why the environmental humanities would rather insist on the need to do the work comprehensively. To change fundamentally energy and environmental regimes takes comprehensive work and would involve changes in values and perceptions alongside regime shifts in economics and technology—which is precisely the reason why this intellectual undertaking must be conceived over the long term and on a large scale. It may well be that if we imagined a visitor from some other solar system who came to our marvelous planet and tried to figure out how we could go on so recklessly destroying it, that this visitor would ask us why we didn’t reconsider our entire thinking about what is valuable in life and how societies act to pursue these values. And that visitor would probably also be interested in learning why it is that what people cherish most, family, health, religion, good morals, had so little purchase when it came to maintaining the life conditions that uphold our world. ■

- 1 Gísli Pálsson, Sverker Sörlin, Bronislaw Szerszynski, et al., “Reconceptualizing the ‘Anthropos’ in the Anthropocene: Integrating the Social Sciences and Humanities in Global Environmental Change Research,” *Environmental Science and Policy* 28 (2013): 4–13. <<http://dx.doi.org/10.1016/j.envsci.2012.11.004>>
Sverker Sörlin, “Reconfiguring Environmental Expertise,” *Environmental Science and Policy* 28 (2013): 14–24. <<http://dx.doi.org/10.1016/j.envsci.2012.11.006>>

Curiosities

The Anthropocene: What Is It?

Are Humans a Major and Defining Force on the Geological Scale?

BY SVERKER SÖRLIN

The word “Anthropocene” has had a formidable career in the last few years and is often heard among global change scientists and scholars, in policy circles, green popular movements, and think tanks, and in all spheres where environmental and climate issues are discussed. In the literal, and limited, sense it is a geological concept, on a par with other periods or epochs during the Cenozoic era, such as the Holocene (“Recent Whole,” the period since the last glaciation, ca. eleven thousand years ago). The word *anthropos* (Greek for “human”) in it indicates that humans, as a collectivity across time, serve as a major and defining force on the geological scale.

Whether this is so is a matter of definition, and it is an ongoing and open issue whether this is the case. The Royal Geological Society of London handles these kinds of issues through its Stratigraphy Commission, which expects to be able to present its view on the matter to the Society by 2016. The chief criterion in their search for evidence is whether there will be enough lasting and significant traits left of the “strata” of the Anthropocene to merit it an individual geological period, or epoch (Zalasiewicz et al. 2011). This is less a philosophical or judgmental than an empirical issue. Are the assembled impacts and remnants of human activities in the lithosphere, biosphere, atmosphere, pedosphere (the layer of soils), and cryosphere (the layer of ice) so overwhelming that we can be certain that the “deep future” will still be able to register the strata of humanity embedded into Earth itself?

In its extended understanding “the Anthropocene” is more of a metaphor and a historical, symbolical, and now also a political concept that speaks to the underlying environmental and climate impacts of human societies. In fact, while Holocene was a period marked by a relative stability of climate and most major Earth system parameters, the Anthropocene, it is argued, is marked by more drastic and rapid amplitudes. This was also the reason that atmospheric chemist and Nobel Laureate Paul Crutzen first used the concept during a discussion at a meeting of the Scientific Committee of the International Geosphere-Biosphere Programme (IGBP) in Cuernavaca, Mexico, in February 2000. (The original article in 2000 outlining the concept was by Crutzen with Earth scientist Eugene F. Stoermer, who had used the word in an informal way since the 1980s, and a more widely read version was published by Crutzen in *Nature* 2002; see Steffen 2013.) Crutzen was dissatisfied with the counterintuitive connotations that the concept “Holocene” evoked in this no-longer-so-stable world we humans now live in. In not much more than a decade, the Anthropocene has gone from an esoteric concept to what has been termed an “elevator concept” (Eileen Crist 2013, citing Hacking 2000), i.e., a kind of word that captures enough meaning for anyone to be able to address during a short ride in an elevator and also to take our understanding of the world to a higher level.

Several interesting observations could be made about this extended, and still expanding, usage of the term. One is that it is not entirely new; foresighted

thinkers have for more than a century argued that a period would soon be under way where humans would be central to shaping the Earth (a root of this can be found in Christian doctrine). Another observation is that the universality of the concept and its planetary scale has provoked thinking about humanity as one common category, implying a shared responsibility for the current human predicament. Around this “inadvertent collectivization” of nations, cultures, groups, and individuals past and present, there has been much debate where critics argue that a flaw with the concept is precisely its innate tendency to mask the far-from-even contributions that are made to the impacts on the Earth, and thus also the far-from-even sharing of the fruits that come out of these impacts. In plain words, the poorest people who have contributed least to the Anthropocene seem to bear the brunt of the problems that follow when the growing Earth-system amplitudes are felt—as global warming and more frequent and violent environmental disasters.

A third important observation is the effect of “Anthropocene” on how we conceive of time, temporalities, and responsibility. If we are entering an era when humans change conditions of the Earth, some of our most deeply held ideas and virtues may come in a new light. If the seeking of wealth is linked to perturbations on a global scale, what will this imply for geopolitics and security? The forceful and expansive deeds that marked high social and historical virtues in the past—the “bravery” that “never goes out of fashion,” as William Thackeray told us in the middle of the nineteenth century, when such an idea seemed safe to canvass—may have to be reconsidered as humanity enters a new period.

Some may wish for an Anthropocene where sharing and redistribution become chief virtues. Others may argue that now is the time to make our societies more efficient in order to sustain wealth while not endangering our Earthly guardrails. Still others would be hard headed enough to suggest that the world will become a more violent place where only the strongest will be able to grab enough of the available “space” within the “planetary boundaries” to take a return path toward Holocene stability. In all likelihood, old values, virtues, vices, and political ideals will survive even under the Anthropocene. But their framework conditions will change and perhaps also the relative status of these values. If the Anthropocene turns out to be a nasty place, it will at least be harder to argue for status quo as the human desideratum. Words have power, especially if they stay as defining the world we live in. ■

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Joan W. Scott's Critical History of Inequality

Revealing Implicit Structuring Norms and Challenging Categories of Difference

BY CLYDE PLUMAUZILLE

"Critique will be the art of voluntary insubordination."¹ Epigraph to her essay "History-writing as Critique,"² this quote from Michel Foucault is the key to understanding the epistemological journey of the American historian Joan W. Scott. Professor Emerita at the Institute for Advanced Study in Princeton, Scott is the author of numerous works on gender, feminism, and citizenship. A prolific and dynamic scholar, she has gone from studying social history to studying the history of women and then, in the 1980s, to studying the history of gender, becoming one of the first theorists in the field. With each shift in her historiographical focus, Scott has found the material needed to fuel her critical thought and shed light on the blind spots of social systems from the time of the French Revolution until the present day. Always on the lookout for history's paradoxes, she has spent her entire career combating the naturalization of differences and inequalities that stem from these contradictions.

As a historian and critical feminist, she has called for the concepts used in the social sciences to remain categories of critical intervention within political and academic debates. That's why, from her seminal article "Gender: A Useful Category of Analysis," published in 1986, to the recent publication in France of her book *De l'utilité du genre* in 2012, Scott has continued to highlight the political, social, and even imaginary issues that can only be understood through the conceptualization of sexual difference.³ To that end, she has zeroed in on French republican universalism, making it her preferred field of research, and has regularly weighed in on the public discussions surrounding its paradoxes. The politicization of sexual issues in France during the 1990s and the debates surrounding *parité*, domestic partnerships, and the wearing of Islamic headscarves have allowed her to reflect upon and discuss the reformulation of the republican contract by using real-life examples.

Now that "gender theory" has fallen under attack in France, denounced by its critics as an ideology that destroys the natural order and upsets the political and social balance, it seems fitting, if not crucial, that we take a look back on the ever-changing thoughts of a historian who has contributed greatly to the introduction of the concept of gender within the field of historiography.

"Aspiring to be Clio, we became a subversive version of her."⁴

The definition of identity has long been the common thread in Scott's numerous scholarly projects. Indeed, it was a dissertation on the social and political organization of glassmakers in Carmaux (in Southern France) in the late nineteenth century that earned her a Ph.D. from the University of Wisconsin-Madison in 1969. Fascinated by the lengthy strike that these glassmakers organized in 1895, she seized upon the event to analyze the process by which this social group acquired a consciousness of class and asserted itself politically.⁵ By situating the strike within a larger economic and social history, she pointed out that the unionization and the mobilization of the glassmakers occurred only on an intermittent and limited basis as a reaction to the mechanization of their trade. Building upon the concepts of new social history put forward by British historians E. P. Thompson and Eric Hobsbawm, who sought to understand the creation and experience of the working class, Scott observed that neither the political action of the workers nor their class consciousness constituted a natural and automatic given: they were "the product of struggle and debate."⁶ For Scott, the notion of struggle and debate guards against deterministic and essentialist approaches, thereby allowing for an appreciation of the complexity of individual and collective identities in the history of the working class. Scott's stance in the field of social history

offers a permanent challenge to its foundations and its traditions. From her earliest research, Scott sowed doubt about history's certainties, a practice that she would later define as a permanent fight waged against orthodox knowledge and its routine uses.

This challenge to the blind spots of historical epistemology is reflected in Scott's active participation in American academic feminism. Hired at a time when academic feminism was bursting onto the campus scene, she found unprecedented

creative potential for historical research in the political issues of feminist epistemology. In 1975, while an associate professor at the University of North Carolina at Chapel Hill, Scott and her colleague Louise Tilly tackled an issue long neglected in the history of the working class: women's labor. It was around then that the very first Women's Studies departments were being established in the United States, and the pair belonged to a generation of female scholars who attempted to answer the call of the American feminist movement by seeking an end to the invisibility and marginalization of women on the historical stage. Through their study of women's wage labor, Scott and Tilly did not simply intend to show that women have always worked; they backed up their claims regarding the asymmetric and gendered dimension of the labor market as well.

"Feminist history was never primarily concerned with documenting the experiences of women in the past, even if that was the most visible means by which we pursued our objective," Scott reminds us. "The point of looking to the past was to destabilize the present, to challenge patriarchal institutions and ways of thinking that legitimated themselves as natural."⁷ *Women, Work, and Family* was first published in 1978. Through a statistical and social analysis of three economically different towns in France and England over time, the authors present a history of female labor in the face of changes brought about by industrialization.

Their examination of the interplay between the economic sphere and the familial sphere allowed them to shed light on a central problem of feminism: despite newfound access to wage labor, women remained in a subordinate social position due to the sex-based division of labor. The authors pay close attention to the various aspects of the female worker who is at the same time a wife, a mother, and a pillar of family life. These overlapping identities, converging in the identification of women with the family unit, explain why their economic practices were also subordinated to the needs of the family.

Scott felt that she had reached an impasse when she had finished her work on this project. A focus on economics and family dynamics seemed too limited to grasp the historical persistence of male-female inequalities and even more so to understand the emphasis on the natural, biological, and cultural differences of sex. The future of women's history, she thought, lay in a new historical method better able to respond to these questions. She articulated these thoughts at the 1980 annual meeting of the American Historical Association where she delivered an especially critical assessment of women's history in the United States. Women's history, she argued, had not realized its ambition to transform the practice of history simply by paying attention to women. Examining the social position of women as a function either of economics or ideology produces unsurprising historical narratives in which the exclusion of women becomes the automatic product of capitalism and/or patriarchy. Instead, Scott maintained, what was needed was a broader sense of how ideas about the natural differences of sex were used to put in place and justify relations of power.

Scott was particularly attuned to the critical voices that were proposing analyses exceeding the conceptual limits of the category "woman." Chief among these were the anthropologist and activist Gayle Rubin and the historian Natalie Zemon Davis.⁸ In her pathbreaking article "The Traffic in Women: Notes on the Political Economy of Sex," published in 1975, Rubin sought to deconstruct the apparent naturalness of heterosexuality. Davis, on the other hand, offered a relational study of the sexes and sexual identities that was first printed in a 1976 issue of the journal *Feminist Studies*. But while the challenges of conceptualizing the notion of gender were already being spelled out, Scott lacked the theoretical tools that would enable her to challenge the conventional frameworks of historical analysis.

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Professor Joan Scott at the School of Social Science's twenty-fifth anniversary conference in 1997, "25 Years: Social Science and Social Change"

1. Michel Foucault, "What Is Critique?" *The Politics of Truth* (Semiotext(e), 2007), 47.
2. Joan W. Scott, "History-writing as Critique," *Manifestos for History*, ed. Keith Jenkins, Sue Morgan, and Alun Munslow (Routledge, 2007), 19–38.
3. Among other publications of hers that have been translated into French: Judith Butler, Éric Fassin, and Joan W. Scott, "Pour ne pas en finir avec le 'genre,'" *Sociétés & Représentations* 24 (2007): 285–306; Joan W. Scott, "Ce que la gender history veut dire," *Pensées critiques: dix itinéraires de la revue Mouvements*, 1998–2008 (La Découverte, 2008), 29–47; Joan W. Scott, "Fantasmes du millénaire: le futur du 'genre' au XXI^e siècle," *Clio: Femmes, Genre, Histoire* 32 (2010): 89–117; Joan W. Scott, *De l'utilité du genre* (Fayard, 2012).
4. Joan W. Scott, "Feminism's History," *Journal of Women's History* 16 (Summer 2004): 12.
5. Joan W. Scott, *The Glassworkers of Carmaux: French Craftsmen and Political Action in a Nineteenth-century City* (Harvard University Press, 1974).
6. Joan W. Scott, *Gender and the Politics of History*, rev. ed. (Columbia University Press, 1999), 76.

7. Joan W. Scott, "Feminism's History," *Journal of Women's History* 16 (Summer 2004): 21.
8. Gayle Rubin, "The Traffic in Women: Notes on the Political Economy of Sex," *Toward an Anthropology of Women*, ed. Rayna R. Reiter (Monthly Review Press, 1975), 157–210; Natalie Zemon Davis, "'Women's History' in Transition: The European Case," *Feminist Studies* 3 (Spring–Summer 1976): 83–103.

“Gender: A Useful Category of Historical Analysis”

The epistemological breakthrough came shortly thereafter, when Scott, now a professor at Brown University, joined a reading group with feminist literary scholars who were employing the tools of poststructuralism. The arrival of French theory—Deleuze, Derrida, and Foucault—on American campuses offered Scott a radical change of perspective on history and its methodology as well as the practical means to achieve the conscious break that she had called for at the annual meeting of the American Historical Association in 1980. By calling the “obvious” categories of historical and political debate into question, these philosophers sought to shed light on the normative systems on which they are based.⁹ For Scott, their work was an invitation to historicize all categories. From her perspective, it was not just a question of analyzing the place of women and men in history, but of deconstructing the very categories of “man” and “woman,” which structure society in a binary and unequal system. It would be from then on possible to think of domination in other ways, rather than through objective structures like work or family, which organize domination and reproduce it.

Scott’s “L’ouvrière! Mot impie, sordide...”: Women Workers in the Discourse of French Political Economy, 1840–1860,” a chapter in her 1988 book *Gender and the Politics of History*, is the end result of this shift toward emphasizing the analysis of discursive structures.¹⁰ In it, she examines how, in the nineteenth century, the essentialization of female functions that were seen as being naturally domestic and maternal and the stigmatization of young, single, working women who deviated from this private and conjugal model contributed to the invisibility and the inferiority of women in the labor market. Scott’s new scholarship thus picked up where her work with Tilly had left off. The question of the construction of gender relations and the feminine and masculine categories are restated in terms of discursive constructions. Her former collaborator criticized this deconstructionist methodology as “literary and philosophical,” as exceeding the boundaries of the discipline of history, and as ultimately eschewing class relations in order to attribute everything to gender relations alone.¹¹

A central concept of “the feminist enterprise to denaturalize sex,”¹² gender first entered the lexicon of English-speaking social scientists in the 1970s with the publication of the book *Sex, Gender, and Society* by British sociologist Ann Oakley.¹³ She was one of the first scholars to draw a distinction between biological sex and socio-cultural gender. Gender is defined as being a social and cultural construct. In her milestone 1986 article “Gender: A Useful Category of Historical Analysis,” Scott incorporates this definition into a larger theory of domination.¹⁴ Establishing a critical genealogy of gender practices in the humanities and social sciences, she highlights the evolutions, contributions, and limitations of the concept. Noting the failure of existing theories to explain the persistence of inequalities between women and men, she proposes a new conceptualization of the term situated at the crossroads of feminist humanities and poststructuralist theories. Thus, gender is not only “a constitutive element of social relationships based on perceived differences between the sexes,” but it is also “a primary way of signifying relationships of power,” a field of norms and practices within which or through which power is articulated.¹⁵ Scott’s two-part definition therefore offers an alternative to sociological analyses of sexual social relations, which, despite allowing for the possibility to examine the unequal social structures between the sexes, fails to question the very conceptualization of that difference.

Scott explored avenues opened by Denise Riley in her 1988 book “*Am I That Name?*” which, by cataloguing the variations in meaning bestowed on the category “woman” throughout history, ultimately invites us not to consider the identity of the group “women” as a starting point of feminist thought, but as a “site of contest.”¹⁶ Gender produces meaning, structuring both the concrete and the symbolic perception and organization of all social life. Consequently, Scott proposes to question the use of categories as obvious as “women” and “men,” “feminine” and “masculine” in the production of historical narrative. Gender assignments, because they refer to “nature,” legitimate not only the hierarchies between men and women, but also other social hierarchies associated with relationships of class, race, or sexuality. The feminization of the colonized individual or the worker to justify his or her domination, the masculinization of the militant feminist in order to convey her transgression are discursive processes that allow us to grasp in a situated fashion how “politics constructs gender and how gender constructs politics.”

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The translation of this article into French was instrumental in introducing the analytic concept of gender into France at a time when feminist studies were still struggling to be accepted by the academy.¹⁷ Scott’s conceptualization marked a qualitative and decisive leap forward within the humanities, particularly within the field of history. While there was resistance to an analytic framework that focused primarily on speech and symbols at the expense of material structures of domination, and while many were reluctant to accept a formulation of the concept of gender that was seemingly more neutral than the “social relations between the sexes” or the “difference between the sexes,” the analytic categories and definitions used by most French female scholars at the time nevertheless shared a number of points in common with those proposed by Scott. Christine Delphy, for instance, one of the main theorists of materialist feminism, developed a nearly simultaneous alternative understanding of gender, defining the concept as a social relationship which divides the two sexes into antagonistic “classes.”¹⁸ Far from signaling problematic disagreement within the field of women’s studies, these tensions in the formulation and conceptualization of gender were for Scott representative of the true purpose of feminist questioning. Its “continuing appeal” lay in “its refusal to accommodate the status quo.”¹⁹

Scott, however, had yet to finish destabilizing the history of women and gender. In recent times, psychoanalysis has played a prominent role in her thinking. She has been especially interested in the concept of fantasy, using it to build on Freud’s theories of identity formation. By highlighting the complexities and elemental tensions at play as each individual goes through the process of identifying as male or female, psychoanalysis turns masculinity and femininity into an ongoing chaotic and contingent problem. Scott sees in psychoanalysis the chance to examine the imaginaries and the desires at work in the construction of feminist movements and their political identity. With the notion of “fantasy echo,” which she defines as the echoing throughout history of fantasies of “empathetic identification,” she seeks to identify the unconscious logics at work in the construction of the category “woman” as a “commonality” of feminism.²⁰ In the wake of philosopher Judith Butler, Scott views the history of gender as an object of anxiety, uncertainty, and disagreement in order to trace the constant efforts to hold in place the inevitably shifting boundaries between men and women that pervade society.²¹

Critical Feminism’s Challenge to Republican Universalism

In the wake of Foucault, Scott called for the writing of a history that would operate to reveal the implicit and yet structuring norms underpinning our social and political certitudes by challenging the categories of difference. While gender has long been her preferred starting point, Scott has also invoked race, class, nationality, and sexuality in her works in order to chart hierarchies of domination. With this in mind, she made it her aim to shed light on the paradoxes of universality promoted by French republicanism. From the late 1990s to the late 2000s, from *Only Paradoxes to Offer: French Feminists and the Rights of Man* to *Parité: Sexual Equality and the Crisis of French Universalism* to *The Politics of the Veil*, Scott’s work has offered a critical analysis of how the French republican model has, in the name of universalism, marginalized feminist demands as well as those of sexual and racial minorities.

In her 1998 book *Only Paradoxes to Offer: French Feminists and the Rights of Man*, Scott uncovers and analyzes the paradox which has structured the history of feminism in France since the time of the French Revolution. This paradox is the result of two contradictory universalisms that coexist within republican discourse: abstract individualism and the universalism of sexual difference. The discursive practices

(Continued on page 16)

9. François Cusset, *French theory: Foucault, Derrida, Deleuze & Cie et les mutations de la vie intellectuelle aux États-Unis* (La Découverte, 2003).

10. Joan W. Scott, *Gender and the Politics of History*, rev. ed. (Columbia University Press, 1999), 139–167.

11. Louise A. Tilly, “Gender, Women’s History, and Social History,” *Social Science History* 13 (1989): 451–53.

12. Éric Fassin, “L’Empire du genre,” *Le sexe politique: genre et sexualité au miroir transatlantique* (Éditions de l’École des hautes études en sciences sociales, 2009), 376.

13. Ann Oakley, *Sex, Gender, and Society* (Maurice Temple Smith, Ltd., 1972).

14. Joan W. Scott, “Gender: A Useful Category of Historical Analysis,” *The American Historical Review* 91 (December 1986): 1053–75.

15. *Ibid.*, 1067–69.

16. Denise Riley, “*Am I That Name?*: Feminism and the Category of “Women” in History (University of Minnesota Press, 1988).

17. Joan W. Scott, “Genre: Une catégorie utile d’analyse historique,” trans. Eleni Varikas, *Cahiers du GRIF* 37–38 (1988): 125–53. The same year, the women’s history group at the Centre de Recherches Historiques (Center for Historical Research) produced a theoretical paper discussing a more interpretative history and the reintroduction of the political dimension in thoughts surrounding masculine and feminine. Danièle Voldman, Pierrette Pézerat, Yannick Ripa, Pauline Schmitt-Pantel, Geneviève Fraisse, Rose-Marie Lagrave, Christiane Klapisch-Zuber, Cécile Dauphin, Arlette Farge, and Michelle Perrot, “Culture et pouvoir des femmes: essai d’historiographie,” *Annales. Économies, Sociétés, Civilisations* 41 (1986): 271–93.

18. Her articles from the early 1990s have since been republished in two volumes, Christine Delphy, *L’ennemi principal* (Éditions Syllepse, 2013).

19. Joan W. Scott, “Millennial Fantasies: The Future of Gender in the 21st Century,” *Gender: Die Tücken einer Kategorie*. Joan W. Scott, *Geschichte und Politik—Beiträge zum Symposium anlässlich der Verleihung des Hans-Sigrist-Preises 1999 der Universität Bern an Joan W. Scott*, ed. Claudia Honegger and Caroline Arni (Chronos Verlag, 2001).

20. Joan W. Scott, “Fantasy Echo: History and the Construction of Identity,” *Critical Inquiry* 27 (Winter 2001): 284–304.

21. Judith Butler, *Gender Trouble: Feminism and the Subversion of Identity* (Routledge, 2007).

Margaret Levi and Shirley Tilghman Join Board of Trustees



Margaret Levi

and Public Affairs. Both appointments were effective May 3, 2014.

Levi, a leading American political scientist, earned her A.B. from Bryn Mawr College in 1968 and Ph.D. from Harvard University in 1974. Currently, Levi's research focuses on improving relations between government and citizens, and the effects of a trustworthy government. Levi held the Chair in Politics, United States Studies Centre at the University of Sydney from 2009–13 and is currently an Affiliate Professor. At the University of Washington, she was Director of the CHAOS (Comparative Historical Analysis of Organizations and States) Center and formerly the Harry Bridges Chair and Director of the Harry Bridges Center for Labor Studies. Levi's accolades include

fellowships from the American Academy of Arts and Sciences, the John Simon Guggenheim Memorial Foundation, and the Watson Institute for International Studies at Brown University. Levi served as President of the American Political Science Association from 2004–05 and is on the editorial and advisory boards of leading publications and organizations in the field.

A pioneer in molecular biology, Tilghman served on the Faculty of Princeton University for fifteen years before being named President in May of 2001. Tilghman's research was focused on mammalian developmental genetics, and she now writes on science and education policy. At Princeton, she was an Investigator at the Howard Hughes Medical Institute and the founding Director of the Lewis-Sigler Institute for Integrative Genomics. Tilghman is member of the American Philosophical Society, the National Academy of Sciences, the Institute of Medicine, and the Royal Society of London, and she serves as a trustee of the Carnegie Endowment for International Peace, Leadership Enterprise for a Diverse America, Amherst College, and the King Abdullah University of Science and Technology, and as a director of Google Inc. Tilghman received her B.Sc. in chemistry from Queen's University in 1968 and her Ph.D. in biochemistry from Temple University after two years of teaching secondary school in Sierra Leone, West Africa. ■



Shirley Tilghman

CRITICAL HISTORY OF INEQUALITY (Continued from page 15)

which gave rise to republican universalism during the French Revolution were at the same time accompanied by references to the “natural” differences between the sexes in order to justify the exclusion of women from political citizenship. The universalism of sexual difference thus won out, prevailing over the universalism of abstract individualism and, in doing so, helped to bring about feminism and its paradoxical position within the political sphere. Scott reads the history of feminism differently and envisages it in terms of “discursive processes . . . that produce political subjects, that make agency . . . possible.”²² She shows how the paradox of feminism lies in this dual republican discourse that forces these political subjects to fight as women—and therefore to organize into a feminist movement—for the right not to be regarded as women—and therefore to obtain the same rights as men.

In *Parité: Sexual Equality and the Crisis of French Universalism*, which was published in 2005, Scott shifts her attention to the modern day, reflecting on the difficult relationship between the universality of human rights and the universality of sexual difference. A new chapter in her history of French feminism, *Parité* studies how the notion of equality has been used within the broader context of a crisis of political representation initiated by the issue of immigrant voting rights in the 1980s, then in the debate surrounding the recognition of gay couples' domestic partnership rights, commonly designated as *PaCS*, *Pacte civil de solidarité*, in French. She develops a detailed analysis of the theoretical arguments put forth in favor of *parité* as well as of the debates surrounding this demand. According to her, the reconceptualization by theorists of *parité* of the abstract individual as sexed—man or woman—was an attempt to reformulate universalism and offer a possible answer to the “dilemma of difference.”

Racialization, class, and sexuality are likewise determinations of the individual that republican universalism pretends to ignore or repress. In *The Politics of the Veil*, one of the few books written by Scott that has not been translated into French, she addresses the issue of discrimination experienced by people with immigrant backgrounds in France in light of a 2004 law banning the wearing of “conspicuous” religious symbols in French schools. She highlights how the debates surrounding the headscarf are framed in both racial and sexual terms. Although theoretically a discussion about secularism, the underlying discourse served only to stigmatize the Muslim and, more specifically, Arab populations of France and was aimed first and foremost at women—and the “conspicuous” display of their bodies. Attempts to portray the headscarf as a symbol of the oppression of “the” Muslim woman were for Scott the expression of a sexual nationalism in which secularism and sexual freedom have become synonymous. In a discourse that blames Muslims for the failure of republican integration, “sexuality was the measure of difference, of the distance Muslims had to traverse if they were to become fully French.”²³

Recently, on occasion of the second “*Penser l'émancipation*” colloquium organized by the Université Paris-Ouest Nanterre in February 2014, Scott further elaborated on the issues explored in *The Politics of the Veil*, proposing a genealogy of the racist uses of sexual emancipation over the last few decades in an effort to exclude Muslims and, in particular, to deny them “the right to have rights.”²⁴ She calls attention to the cur-

rent transformations of republican universalism, which now substitute the equality of sexually active individuals in place of previous demands for equality between abstract individuals. In other words, the dilemma is not so much that of the difference between the sexes as it is the difference between sexualities. While Scott defends the necessary sexual character of a democracy, i.e., one that integrates a plurality of sexual practices, she nevertheless suggests that this pluralism is used as a pretext for stigmatizing dominated populations, which seek to be recognized as full members of the Western European nation-states in which they reside.

Because Scott upends contemporary mythologies of republican universalism, her critical feminism and her involvement in the public debate has on occasion been attacked, rather vehemently at times, by a segment of the French intellectual class that views her work as the product of a “noisy” and “cantankerous” radicalism typical of feminism “à l'américaine.” This opposition came to the fore most notably during the Strauss-Kahn scandal in 2011. Denouncing the way French politicians and journalists had sought to downplay the accusation of rape lodged against then International Monetary Fund head Dominique Strauss-Kahn (one journalist in particular had gone so far as to characterize the incident as merely “forced sex with the maid” and so the prerogative of a libertine elite), Scott criticized a certain “French theory of seduction” that rejects the power relations at work in sexuality.²⁵ Her opinion piece for the *New York Times* elicited sharp criticism from Irène Théry, Mona Ozouf, Claude Habib, and Philippe Raynaud, who defended a feminism “à la française,” touting instead “equal rights between the sexes and the asymmetrical pleasures of seduction.”²⁶ The support received by Scott from leading French philosophers, sociologists, and political scientists in the field of gender studies does not allow for this controversy to be chalked up to a simple Franco-American divide.²⁷ In the eyes of her supporters, it is more a question of the opposition between a critical feminism and a conservative feminism that is revealed in moments of sexual politicization. The supposed *modus vivendi* between the sexes in France is an ideological line of defense abstracting the question of sexuality from heterosexual male domination. And here, as elsewhere, the historian in Scott reacts to the present by proposing ways to deconstruct the historical discourses of the French Republic and reveal the inequalities that they can legitimate in relationships between the sexes or in relationships of race or sexuality.

“Feminism is only possible when it is free and critical,” wrote the revolutionary feminist Suzanne Blaise in 1975.²⁸ Using gender as a permanent tool for unveiling inequality, Scott's work persuasively seconds that claim. While her work and the deconstructionist methodology that she favors sometimes tend to place gender more on the side of critical theory than on the side of historical practice, the fact remains that her reflections on the concept and the paradoxes of republican universalism are continually drawn on and reworked in the humanities and the social sciences, above all in the field of history. ■

25. “Trousser les soubrettes,” an old French sexist expression referring to the act of having forced sex with maids, were the words Jean-François Kahn, founder of *Marianne*, used on May 18, 2011, to describe the incident before apologizing several weeks later. Joan W. Scott, “Feminism? A Foreign Import,” *New York Times*, May 20, 2011.

26. Irène Théry, “Un féminisme à la française,” *Le Monde*, May 28, 2011.

27. Joan W. Scott, “La réponse de Joan Scott,” *Libération*, June 22, 2011; Didier Eribon, “Féminisme à la française, ça n'existe pas,” *Libération*, June 30, 2011; See also Mathieu Trachman and Laure Bereni, “Genre: état des lieux,” *La Vie des idées*, 2011: <www.laviedesidees.fr/Genre-etat-des-lieux.html>.

28. The article first appeared in activist journals in 1975. It has recently been republished: Suzanne Blaise, “Reflexions sur le féminisme ou pour un féminisme critique,” *Genre, sexualité & société* 3 (2010): <http://gss.revues.org/1405>.

22. Joan W. Scott, *Only Paradoxes to Offer: French Feminists and the Rights of Man* (Harvard University Press, 1996), 16.

23. Joan W. Scott, *The Politics of the Veil* (Princeton University Press, 2007), 166.

24. Her talk can be found on the online journal *Contretemps*. Joan W. Scott, “Émancipation et égalité: une généalogie critique,” *Contretemps*, 2014: <www.contretemps.eu/interventions/%C3%A9mancipation-%C3%A9galit%C3%A9-g%C3%A9n%C3%A9alogie-critique>

From Fluid Dynamics to Gravity and Back

How the Movement of Water Molecules Corresponds to Ripples in Spacetime

BY SHIRAZ MINWALLA

There is an interesting connection between two of the best-studied nonlinear partial differential equations in physics: the equations of hydrodynamics and the field equations of gravity.

Let's start with a brief review of hydrodynamics. At the microscopic level a tank of water is a collection of, say, 10^{25} molecules that constantly collide with one another. The methods of physics may be used to model this collection of water molecules as follows: we set up equations that track the position and momentum of each of the water molecules and predict their time evolution. These conceptually complete equations have of order 10^{25} variables and so are clearly too difficult to handle in practice.

Does it then follow that tanks of water cannot be usefully studied using the methods of physics? As every plumber knows, this conclusion is false: a useful description of water is obtained by keeping track of average properties of water molecules, rather than each individual molecule.

Think of a tank of water as a union of non-overlapping lumps of water. Each lump is big enough to contain a large number of molecules but small enough so that gross macroscopic properties of the water (energy density, number density, momentum density) are approximately uniform. The fundamental assumption of hydrodynamics is that under appropriate conditions, all the "average" properties of any lump are completely determined by its conserved charge densities (in the case of water, molecule number density, energy density, and momentum density). In particular, the conserved current for molecule number j^μ and the conserved current for energy and momentum $T^{\mu\nu}$ are themselves dynamically determined functionals of local thermodynamical densities in a locally equilibrated system (fluctuations away from these dynamically determined values are suppressed by a factor proportional to the square root of the number of molecules in each lump). The equations that express conserved currents as functionals of conserved densities are difficult to compute theoretically but are easily measured experimentally and are known as constitutive relations.

When supplemented with constitutive relations, the conservation equations $\partial_\mu j^\mu = 0$, and $\partial_\mu T^{\mu\nu} = 0$ turn into a well-posed initial value problem for the dynamic of conserved densities. They are the equations of hydrodynamics. Let me reemphasize that the effect of the ignored degrees on the evolution of conserved densities is inversely proportional to the square root of the number of molecules in a lump, and so is negligible in an appropriate thermodynamic limit, allowing the formulation of a closed dynamical system for conserved densities.

My research concerns how the equations of hydrodynamics pop up in an apparently completely unrelated setting: in the study of the long wavelength dynamics of black holes governed by Einstein's equations with a negative cosmological constant.

Einstein's gravitational equations describe the dynamics of the geometry of spacetime. The ripples of spacetime (gravitational waves) have interesting dynamics even in the absence of any matter. For most of this article, I will be referring to Einstein's equations in the absence of matter.

The simplest solution of the most familiar Einstein equation $G_{\mu\nu} = 0$ is simply flat Minkowskian spacetime. However, the usual Einstein equations can be deformed to admit the so-called cosmological constant term $G_{\mu\nu} = \lambda g_{\mu\nu}$. This deformation, which was first suggested and later rejected by Einstein himself, appears to be needed to model the cosmological expansion of our universe. The observed accelerated expansion of our universe is plausibly explained by the existence of a positive cosmological constant (the equation above with a positive value of λ).

Recent theoretical investigations within string theory have focused attention on Einstein's equations with a negative cosmological constant (negative value of λ). This equation does not have flat space as a solution. Its simplest solution is a highly symmetric spacetime called anti-de Sitter (AdS) space. In this article, I will explore asymptotically AdS solutions of Einstein's equations with a negative cosmological constant in five spacetime dimensions.

Einstein's equations, with or without a gravitational constant, admit a huge variety of black hole solutions. The equations with a negative cosmological constant also admit rather unusual related solutions called black brane. These solutions have finite energy and momentum density rather than a finite energy and momentum. Stationary black brane solutions are analytically well known, and appear in a four-parameter set, labeled by a uniform energy and momentum density.

It is often the case in physics that if a uniform distribution of "something" (a field, the orientation of a spin, etc.) leads to a time independent solution of the equations of motion, then slowly varying configurations of that thing result in slow dynamics. It turns out that this general expectation applies to the distribution of energy and

momentum density on black branes. The exact four-parameter set of time-independent black brane solutions may be generalized to an infinite number of approximate solutions of Einstein's equations. These solutions are characterized by varying (rather than uniform) energy and momentum density fields. The fields are functions of spatial position as well as time, but are constrained to obey dynamical equations. It has been demonstrated that these equations take the form of conservation equations (conservation of the stress tensor in the case of the vacuum Einstein equations), with all components of the stress tensor determined to be a particular functional of the local energy density by an effective constitutive relation.¹ In other words, the long wavelength fluctuations of black branes are governed by the equations of hydrodynamics, with gravitationally determined constitutive relations. This fact is the so-called fluid-gravity correspondence.

The fluid-gravity correspondence was established constructively; there is an explicit construction of an approximate solution to Einstein's equations dual to any fluid flow. The construction of these solutions proceeds in an expansion in derivatives. The procedure that determines the solutions to Einstein's equations also simultaneously determines the constitutive relations to the given order in derivatives.

It turns out that the gravitational solutions that participate in the fluid-gravity correspondence all have regular event horizons; moreover, Hawking's area theorem, which states that event horizons can only stay the same or increase but never decrease, may be used to determine a positive divergence entropy current for fluid flows. This establishes that the fluid flows generated by gravity obey a basic physical requirement; even locally, entropy in such flows never decreases.

Why does the equation that describes the average motion of water molecules in a water tank also govern the ripples of the event horizon of asymptotically AdS black brane? At least in some circumstances, we believe this is because Einstein's equations in the presence of black branes actually describe the averaged dynamics of a large number of underlying microscopic variables. In particular, the AdS/conformal field theory correspondence of string theory proposes that the uniform black brane of negative cosmological constant gravity is dual, in a particular context, to a gas of gluons of a large $U(N)$ gauge theory at large N . The hydrodynamical solutions of fluid gravity are presumably the duals to the fluid flows of this collection of gluons. Fluctuations about these hydrodynamical flows are suppressed by $1/\sqrt{N}$ and may be thought of as quantum gravity fluctuations from the gravitational point of view.

At the conceptual level, the fluid-gravity correspondence suggests a novel view of the role of Einstein's equations in the presence of event horizons. At a more practical level, this correspondence has had a completely unanticipated application in the reverse direction: to the theory of the equations of relativistic hydrodynamics, a subject that was thought to have been closed in the 1930s. Analyses by Lev Landau and Evgeny Lifshitz in the 1930s claimed to have determined the most general form of the constitutive relations of relativistic fluid at first order in the derivative expansion. Motivated by the fluid-gravity correspondence, it has been discovered that the Landau-Lifshitz constitutive relations must be generalized in the case of certain parity violating charged fluids.² In particular, if the fluid charge has a $U(1)$ triangle anomaly, then there are new terms in the constitutive relations of this fluid—roughly in terms of the fluid current proportional to the vorticity—that are completely determined by the anomaly coefficient plus the thermodynamics of the fluid. This discovery may turn out to have experimental consequences (in the study of fluid flows in Brookhaven National Laboratory's Relativistic Heavy Ion Collider experiment, for example, which aims to study the first few moments after the universe's creation), surely a surprising application for the esoteric study of black hole physics in higher-dimensional gravity.³ ■

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1. "Nonlinear Fluid Dynamics from Gravity," Sayantani Bhattacharyya, Veronika E. Hubeny, Shiraz Minwalla, and Mukund Rangamani, *Journal of High Energy Physics* 0802:045 (2008).
2. "Hydrodynamics with Triangle Anomalies," Dam T. Son and Piotr Surowka, *Physical Review Letters* 103, 191601 (2009).
3. "The Fluid/Gravity Correspondence," Veronika E. Hubeny, Shiraz Minwalla, and Mukund Rangamani, arXiv:1107.5780.

Shiraz Minwalla, Member (2013–14) and IBM Einstein Fellow in the School of Natural Sciences, was awarded the 2014 New Horizons in Physics Prize from the Fundamental Physics Prize Foundation. Minwalla, Professor at the Tata Institute of Fundamental Research, Mumbai, was recognized for his pioneering contributions to the study of string theory and quantum field theory and, in particular, for his work in uncovering an unexpected connection between the equations of fluid and superfluid dynamics and Einstein's equations of general relativity.



Shiraz Minwalla has uncovered an unexpected connection between the equations of fluid and superfluid dynamics and Einstein's equations of general relativity.

My Random Walks with Pólya and Szegő

The Making of a Mathematician

BY OLGA HOLTZ

My love affair with George Pólya began when I was seventeen. It was in Chelyabinsk, Russia, and my first year at the university was coming to an end. I had come across a tiny local library with an even tinier math section, which nobody ever seemed to visit, and had taken out most of those math books one by one before I came across *The Book*. It was George Pólya's *Mathematics and Plausible Reasoning*.

By that time I was a total bookworm, having devoured almost a thousand volumes of my parents' home library, mostly fiction. My familiarity with math books was much poorer although, growing up, I had enjoyed Yakov Perelman's popular books for children on math and physics. I was a proud graduate of a specialized math and physics school, the only one in town, and had had a few wins at local olympiads in math and science. A top kid in class as far back as I could remember, I was arrogant as hell.

I read the introduction to *Mathematics and Plausible Reasoning* and its Chapter I standing up next to the bookshelf. It read like a novel. A cerebral one alright, which made you pay quick attention. Chapter I started out in the least orthodox way, comparing mathematical induction to a domino chain. The book endeavored to explain not only what was mathematically true but how and why. I was hooked. Chapter I ended with a list of problems. I solved a couple of them still standing up but quickly came to a halt on Problem 3.

The arrogance kicked in—I had to solve those problems. I still remember carrying that book home after I checked it out. It was late spring, gorgeous weather, bird songs in the air, romantic couples—you get the picture. I was besotted with *The Book*.

The *Book* problems proved to require quite a bit of effort, so I had to wait until summer to properly work on them. In August, I was sent away for three weeks to a place administered by the university where faculty, staff, and students went “to recuperate.” I have zero recollection how this came about. Surprisingly, my parents let me go since I convinced them I needed total concentration to work on my book.

This was my initiation to the mysteries of higher mathematics. Waking up every day, reading Pólya, walking around the lake, turning his problems around in my head until I would find a solution. I shared a room with two cheerful women over forty, which of course seemed very old to me at the time. As far as I can recall, they were mostly interested in male company. After initial distrust followed by observations of my religious fervor toward *The Book*, they deemed me harmless and became exceedingly nice, bringing chocolates and such back after their parties.

I had a blast. I solved all problems on my own, using only the hints given in *The Book*. My arrogance was transformed into patience and respect toward math problems that may require a day, a week, or even years to solve. I finished the book on August 19, 1991, my birthday. It was also the day of the bizarre August Putsch. For two days, the country was in a surreal time warp, most fearing a relapse into a Soviet-like state. When it was over, the sense of relief was quite profound. I must admit, however, that my celebratory mood was largely due to a happy love affair with *The Book*.

A few years passed. I learned quite a bit more about George Pólya and his mathematics. Born a Hungarian Jew, baptized Catholic, grown up agnostic, turned Swiss, turned American, Pólya worked in analysis, mathematical physics, probability theory, geometry, and combinatorics. His passion for teaching led him to write several hugely successful books about mathematical discovery of which *Mathematics and Plausible Reasoning* was one. But his crown jewel was a book written with his coauthor and friend Gábor Szegő, *Aufgaben und Lehrsätze aus der Analysis (Problems and Theorems from Analysis)*. I kept trying to get hold of anything by Pólya that I

could. With the Soviet Union collapsed, education funding scarce, libraries closing, I could not get hold of that book.

Pólya worked in Zürich, Oxford, Cambridge, Princeton, Brown, and Stanford. I cannot describe how these places sounded to me, sitting in Chelyabinsk in 1993 on a “diet” of tea, bread, and sour cream—that was all we had. There was no money either. My parents' life savings were lost in the bank freeze of 1991 (or 92? I am blanking out); no salary or stipends arrived for months. I tutored high school kids

but their parents were going through the same. The powers that be—and regular people in Russia—were quickly losing interest in science. So Zürich, Oxford, Stanford and the like sounded like Eden to me. An academic Eden where you could do mathematics, uninterrupted by worries about money or sour cream. Was that even real? It sounded exotic, thrilling, fantastic. But of course I could never get there—how could I?

When something appears absolutely impossible, it may be quite straightforward. Three years later, with three publications in international math journals, I was admitted to the University of Wisconsin–Madison. (This is another story for another time about how someone completely ignorant can still succeed.) Before leaving Chelyabinsk, I made a trip to my favorite used book store. It had a translation of *Problems and Theorems*! This is how I left for the United States with Pólya and Szegő.

Madison turned out to be a splendid place, very much influenced by Pólya and Szegő's mathematics. I was advised by Hans Schneider, once an Austrian refugee turned British turned American, whose life and career has been just as amazing as that of George Pólya.

I also learned an awful lot from Dick Askey, Walter Rudin, Carl de Boor, and many others there. My only regret about Madison is not overlapping with Isaac Schoenberg, a friend and collaborator of Pólya and Szegő. Schoenberg passed away in 1990.

Life is stranger than fiction, which is no platitude. Years later, I use *Problems and Theorems* to train advanced math majors at the University of California, Berkeley, for the Putnam competition, a North American contest for college students in mathematics. I have visited and worked at all those exalted places I could not even dream about twenty years ago in Russia.

I have even found myself solving some problems that originated with Pólya and Szegő. One recent story of this kind is my joint work with three Russian coauthors,

Maxim Derevyagin, Sergey Khrushchev, and Mikhail Tyaglov, where we obtained a matrix version of a beautiful Szegő theorem about orthogonal polynomials. The original theorem ties up the recurrence coefficients of an orthogonal family to a single integral expression of the underlying measure. As we gradually came to understand, orthogonal polynomials do not have to be scalar-valued but can take matrix values; the theory becomes much more involved but many mathematical facts generalize.

David Damanik, Alexander Pushnitski, and Barry Simon, in their comprehensive survey on matrix-valued orthogonal polynomials, posed a challenge to generalize Szegő's theorem to the matrix setting. Being at the same place (Berlin) at the same time, my coauthors and I could not resist. After a couple of months of Pólya-style plausible—and then rigorous—reasonings, we had a matrix generalization.

Sergey Khrushchev and I are now writing a book about the Laguerre–Pólya class, a fascinating class of entire functions that appears in analysis, combinatorics, number theory, and many other fields. We keep discovering small gems on the way. In one such exploration with Olga Kushel and Mikhail Tyaglov (a Russian job again), we came across a lovely Pólya-and-Szegő-like result about zeros of special polynomials. It generalizes an earlier result of Schoenberg and a much earlier result of Adolf Hurwitz, Pólya's teacher. I recently presented it at IAS. After the talk, Peter Sarnak (Professor in the School of Mathematics) told me, “Too bad that two people who would have really appreciated this work are not around: Pólya and Szegő.”

One possibly apocryphal story told about Pólya is that he really liked to walk and, while on one of his walks, kept bumping into the same couple. The couple finally got annoyed and asked him if he was stalking them. Pólya assured them he wasn't . . . and started thinking about the mathematical implications of this question. He subsequently discovered that a random walk in dimensions 1 and 2—but not higher—is recurrent, i.e., keeps coming back to the same point with probability 1.

My own walks in life, however random, were made so much more meaningful by those recurrent meetings with George Pólya and Gábor Szegő. ■



Olga Holtz

AN ACADEMIC EDEN WHERE
YOU COULD DO MATHEMATICS,
UNINTERRUPTED BY WORRIES
ABOUT MONEY OR SOUR
CREAM. WAS THAT EVEN REAL?

Olga Holtz, Member (2014, 2009–10) in the School of Mathematics, is a Professor at the University of California, Berkeley. She is interested in numerical analysis, matrix and operator theory, approximation theory, algebra and algebraic combinatorics, analysis of algorithms, and computational complexity. Holtz is also the director of the magic-realist film *The Zahir* (her script was inspired by Jorge Luis Borges's short story of the same title) about a young, ambitious academic's search for truth, which she filmed on the Berkeley campus in 2013.

whose work had a profound and far-reaching influence on the study of Islamic art and architecture, and furthered by Crone, who established at the Institute a powerful current of critical studies in early Islamic thought as well as political and religious history. As Professors at the Institute, Grabar and Crone focused on the premodern period and illustrated the critical importance in historical studies of the Near East, and in particular on the cultural, religious, and intellectual history of Islam.

As one of the most prolific scholars of her generation, Schmidtke brings a creative and intensive approach, most notably with manuscript texts, which has revealed new and transformative connections across Islamic culture and history. Nicola Di Cosmo, Luce Foundation Professor in East Asian Studies in the School, noted, "By challenging traditional disciplinary boundaries and by applying rigorous philological methods to the understanding of disparate but interconnected traditions, Sabine Schmidtke has opened new horizons to the study of the philosophy and intellectual history of Islam, not just by her own discoveries, but also by posing the foundations for innovative interpretations and future breakthroughs in a thriving field of Islamic studies."

Robbert Dijkgraaf, Director of the Institute and Leon Levy Professor, added, "We are very excited to welcome Sabine Schmidtke to the Faculty of the Institute. Sabine's impressive dexterity as a scholar and communicator, dynamic leadership, and collaborative spirit will greatly deepen and enhance the range of Islamic studies pursued at the Institute, and will also contribute significantly to this important and growing field."

Schmidtke's own reaction to the appointment was to say, "I am very honored to be given the opportunity to continue my research on the intellectual history of the Islamic world in this unique institution with its long history of fruitful intellectual exchange and in the community of its extraordinary Faculty and Members."

Schmidtke's research has transformed perspectives about the interrelations and connections among different strands of intellectual inquiry, across time, place, religions, and philosophical schools. She has played a central role in the exploration of heretofore unedited and unknown theological and philosophical writings and is regarded internationally as a leading philologist. Over the past fifteen years, Schmidtke has applied rigorous study to the edition and critical analysis of manuscripts in Arabic, Judeo-Arabic, and Persian, and her work extends from Arabic-speaking countries to Israel, Iran, Russia, and Turkey. Through the study of manuscripts found in Iran and Turkey, she has uncovered essential aspects of the influence of Jewish philosophers on late medieval Arabic and Islamic philosophy, and her study of Arabic and Judaeo-Arabic manuscripts has enabled her to recover works considered lost. Schmidtke has utilized these texts to situate their authors within a largely forgotten tradition of Islamic theology, particularly evident in her first book, *The Theology of al-'Allāma al-Hillī* (1991), which combines detailed manuscript studies with a profound knowledge of theology of the eleventh through fourteenth centuries, through which she both explicates al-Hillī's theology and explains it within the competing traditions of earlier generations of theologians, Twelver Shī'is as well as Sunnis. Her ability to provide broad, synthetic surveys of important areas of study beyond the specific confines of Islamic philosophy and discursive theology is evident in a number of critical essays such as "The History of Zaydī Studies: An Introduction," published in *Arabica* (2012), a study that explores two centuries of scholarship and literature on Zaydism, and *Die Bibel in den Augen muslimischer Gelehrter*, published as *Einstein Lectures in Islamic Studies*, no. 1 (2013).

Schmidtke has published a range of monographs, such as *Theologie, Philosophie, und Mystik im zwölfschittischen Islam des 9./15. Jahrhunderts: Die Gedankenwelt des Ibn Abī Ġumhūr al-Aḥsā'ī* (2000), *A Jewish Philosopher of Baghdad: 'Izz al-Dawla Ibn Kammūna (d. 683/1284) and His Writings* (with Reza Pourjavady, 2006), and *Rational Theology in Interfaith Communication: Abu l-Ḥusayn al-Baṣrī's Mu'tazilī Theology among the Karaites in the Fātimid Age* (with Wilferd Madelung, 2006), which address rational theology in Islam, especially Mu'tazilī and Shī'ī, and its repercussions on Jewish intellectuals. In addition to her research on various intellectual strands in the medieval world of Islam, Schmidtke has devoted numerous studies to the historiography of the modern discipline of Islamic studies, such as her annotated edition of *Correspondence Corbin-Ivanow: Lettres échangées entre Wladimir Ivanow et Stella et Henry Corbin, 1947–1966* (1999).

Schmidtke is currently working on the history of Islamic thought in the postclassical period (thirteenth to nineteenth centuries), with a focus on reconstructing the

textual heritage and the intellectual import of the Islamic intellectual world, from Iran and Central Asia to Turkey and Spain. The project is based on the volumes that she has or is about to publish, including the forthcoming "Doctrinal History of Imāmī Shī'ism" (with Hassan Ansari) and "Islamische Theologie: Eine Einführung." In addition, she is engaged in a comprehensive study of the Muslim reception of the Bible, a topic on which she has published extensively over the past five years. Schmidtke's edited and co-edited works provide a sense of the range of her research interests, including *The Yemeni Manuscript Tradition* (in press), *Theological Rationalism in Medieval Islam: New Texts and Perspectives* (in press), *Jewish and Christian Reception(s) of Muslim Theology* (2014), *The Bible in Arabic among Jews, Christians, and Muslims* (2013), *The Neglected Šītes: Studies in the Legal and Intellectual History of the Zaydīs* (2012), *Contacts and Controversies between Muslims, Jews, and Christians in the Ottoman Empire and Pre-Modern Iran* (2010), *A Common Rationality: Mu'tazilism in Islam and Judaism* (2007), and *Speaking for Islam: Religious Authorities in Muslim Societies* (2006). Among her forthcoming edited or co-edited works are "Accusations of Unbelief in Islam: A Diachronic Perspective on Takfīr" (Brill), "Oxford Handbook of Islamic Philosophy," and "Oxford Handbook of Islamic Theology." Schmidtke is prolific in generating editions of manuscript texts with about eighteen volumes published and four or five in the process of being published.

In addition to the caliber and depth of her pioneering research, Schmidtke's leadership in the field is reflected in the many significant international projects for which she has served as the principal investigator, promoter, and coordinator, in collaboration with other scholars. Projects in which she has played a central role include: a European Research Council senior grant on "Rediscovering Theological Rationalism in the Medieval World of Islam" (2008–13); "Interreligious Polemics in the Ottoman Empire and Pre-Modern Iran" (2006–08), through the Gerda Henkel Foundation, which also supported Schmidtke's Membership in 2008–09; and a study of Mu'tazilite manuscripts (2003 to the present), through the Fritz Thyssen Foundation.

Born in Germany, Schmidtke received a B.A. from the Hebrew University of Jerusalem (1986), an M.A. from the School of Oriental and African Studies in London (1987), and a D.Phil. from the University of Oxford (1990). From 1991 to 1999, she was a diplomat at the German Foreign Office. Schmidtke served as Lecturer in Islamic Studies at the Rheinische Friedrich-Wilhelms-Universität in Bonn from 1997 to 1999, where she also received her *Habilitation* (1999). She was Visiting Professor of Islamic Studies at the Freie Universität Berlin from 1999 to 2001, after which time she became Professor. In 2011, Schmidtke founded the Research Unit on the Intellectual History of the Islamicate World, which she still directs. Since 2013, Schmidtke has served as founding Academic Director of the trilateral M.A. program

Intellectual Encounters of the Islamicate World, which is a cooperative initiative of the Freie Universität Berlin, the Hebrew University of Jerusalem, and Al-Quds University (Palestine).

Schmidtke and her work have been recognized by numerous awards and fellowships. In 2002, Schmidtke received the World Prize for the Book of the Year of the Islamic Republic of Iran for her work *Theologie, Philosophie, und Mystik im zwölfschittischen Islam des 9./15. Jahrhunderts: Die Gedankenwelt des Ibn Abī Ġumhūr al-Aḥsā'ī* (2000). She also was awarded the Prize for Scholarly Achievement in the Study of Twelver Shī'ism conferred by the Written Heritage Research Centre (2006) and the Dahlem Research School Award for Excellent Supervision (2011). In 2013, she received a Reinhart Koselleck Grant, awarded to outstanding researchers with a proven scientific track record, for the project "The Other Renaissance: Greek Philosophy under the Safavids (16th–18th centuries C.E.)." In addition to her two visits as a Member at the Institute for Advanced Study, Schmidtke has held many overseas fellowships at institutions such as the Leiden University Centre for the Study of Islam and Society, the Netherlands Institute for Advanced Study in the Humanities and Social Sciences, Tel Aviv University, the University of Pennsylvania, Harvard University, the Scaliger Instituut, and the Israel Institute for Advanced Studies at the Hebrew University of Jerusalem. Schmidtke serves as Editor-in-Chief of *Intellectual History of the Islamicate World* and *Biblia Arabica: Texts and Studies* and is on the editorial and advisory boards of many leading publications and organizations in the field.

—Christine Ferrara, Senior Public Affairs Officer, cferrara@ias.edu



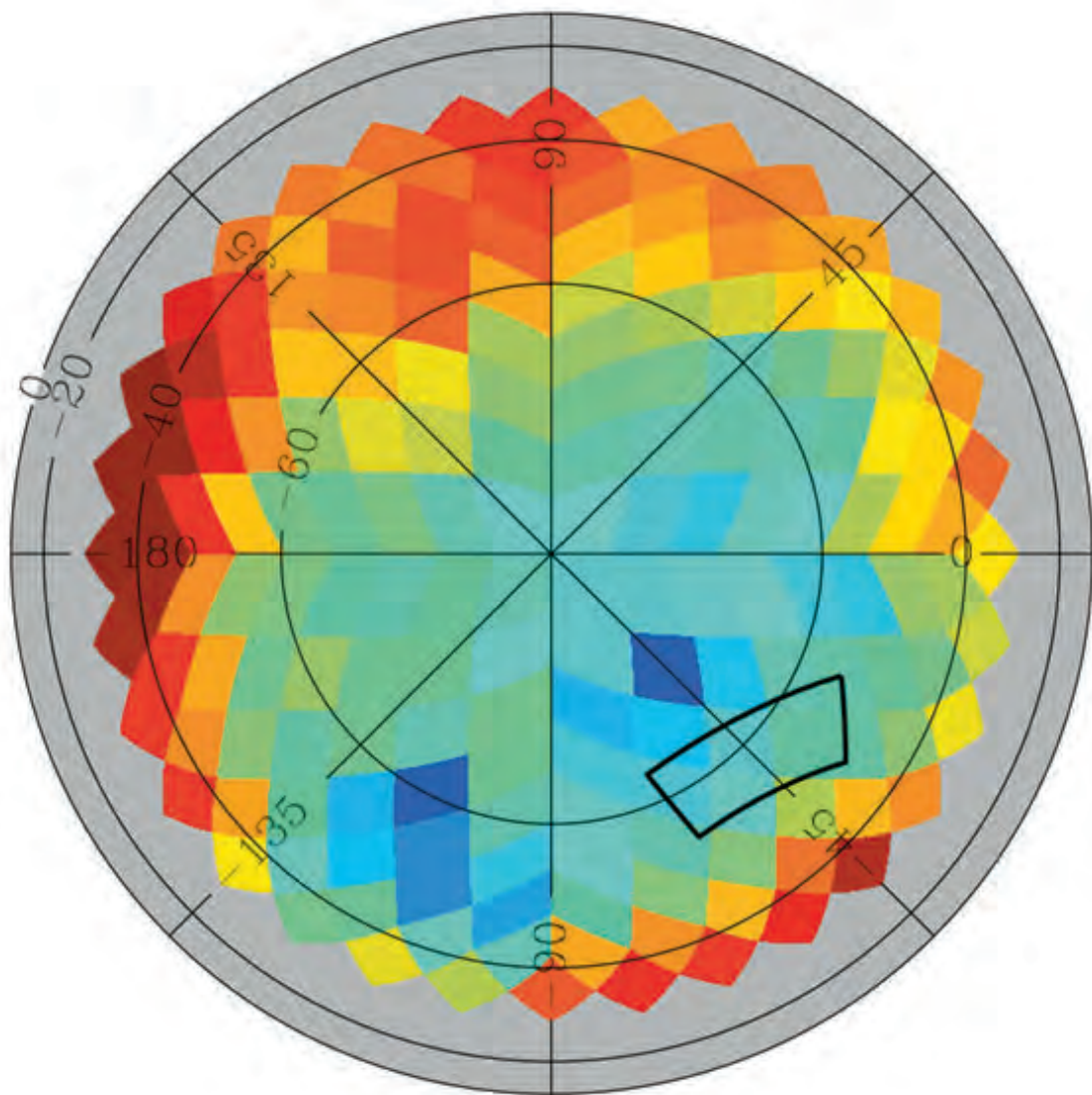
Schmidtke and Patricia Crone (far right) hosted a seminar on Islamic intellectual history in March 2014.

SCHMIDTKE'S RESEARCH HAS TRANSFORMED PERSPECTIVES ABOUT THE INTERRELATIONS AND CONNECTIONS AMONG DIFFERENT STRANDS OF INTELLECTUAL INQUIRY, ACROSS TIME, PLACE, RELIGIONS, AND PHILOSOPHICAL SCHOOLS.

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OR GALAXY DUST?



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