IAS
The Institute Letter

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Economics: Science, Craft, or Snake Oil?

When economists skip over real-world complications, it's as if physicists spoke of a world without gravity.

BARBARA SMALLER/THE NEW YORKER COLLECTION

BY DANI RODRIK

When the 2013 Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (colloquially known as the "Economics Nobel") was awarded to Eugene Fama and Robert Shiller, along with Lars Peter Hansen, many were puzzled by the selection. Fama and Shiller are both distinguished and highly regarded scholars, so it was not their qualifications that raised eyebrows. What seemed odd was that the committee had picked them *together.*

After all, the two economists seem to hold diametrically opposed views on how financial markets work. Fama, the University of Chicago economist, is the father of the "efficient market hypothesis," the theory that asset prices reflect all publicly available information, with the implication that it is impossible to beat the market consistently. Shiller, the Yale economist, meanwhile, has spent much of his career demonstrating financial markets work poorly: they overshoot, are subject to "bubbles" (sustained rises in asset prices that cannot be explained by

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Ellsworth Kelly's Dream of Impersonality

How things that look apparently very simple are in fact much more complex than they seem

BY YVE-ALAIN BOIS

© ELLSWORTH KELLY

Train Landscape *(1952–53) refers to the colors of fields seen from a train.*

Ellsworth Kelly is one of the very first artists whose work I liked. Perhaps he was second, just after Piet Mondrian. One of the things I asked Kelly after we finally met and became friends, close to a quarter of a century ago, was why he had not answered a fan letter that I had written to him in my teens. He remembered the letter. He had received it at a time when he felt isolated, bypassed by a new generation of artists, and he had been struck by the fact that it came from a French teenager living in the middle of nowhere—he thought he might even have kept it. Since Kelly is a demon archivist, he found the darn letter, and he gave me a copy of it, which, unlike him, I immediately misplaced. But I read it, and it was humbling. First, because I realized I had misdated it in my memory, placing it three years too early—probably because the main event it described, my first encounter with his works, at a show of his lithographs at the Galerie Adrien Maeght in Paris, dated from even earlier to 1965. Second, because it was sheer adolescent drivel. At the time of the letter, Kelly was for

(Continued on page 16)

Entanglement and the Geometry of Spacetime

Can the weird quantum mechanical property of entanglement give rise to wormholes connecting far away regions in space?

BY JUAN MALDACENA

In 1935, Albert Einstein and collaborators wrote two papers at the Institute for Advanced Study. One was on quantum mechanics [1] and the other was on black holes [2]. The paper on quantum mechanics is very famous and influential. It pointed out a feature of quantum mechanics that deeply troubled Einstein. The paper on black holes pointed out an interesting aspect of a black hole solution with no matter, where the solution looks like a wormhole connecting regions of spacetime that are far away. Though these papers seemed to be on two completely disconnected subjects, recent research has suggested that they are closely connected.

Einstein's theory of general relativity tells us that spacetime is dynamical. Spacetime is similar to a rubber sheet that can be deformed by the presence of matter. A very drastic deformation of spacetime is the formation of a black hole. When there is a large amount of matter concentrated in a small enough region of space, this can collapse in an irreversible fashion. For example, if we filled a sphere the size of the solar system with air, it would collapse into a black hole. When a black hole forms, we can define an imaginary surface called "the horizon"; it separates the region of spacetime that can send signals to the exterior from the region that cannot. If an astronaut crosses the horizon, she can never come back out. She does not feel anything special as she crosses the horizon. However, once she crosses, she will be inevitably crushed by the force of gravity into a region called "the singularity" (Figure 1a, page 12).

Outside of the distribution of collapsing matter, black holes are described by a spacetime solution found by Karl Schwarzschild in 1916. This solution turned out to be very confusing, and a full understanding of its classical aspects had to wait until the 1960s. The original Schwarzschild solution contained no matter (Figure 1b, page 12). It is just vacuum everywhere, but it has both future and past singularities. In 1935, Einstein and Rosen found a curious aspect of this solution: it contains two regions that look like the outside of a black hole. Namely, one starts with a spacetime that is flat at a far distance. As we approach the central region, spacetime is deformed with the same deformation that is generated outside a massive object. At a fixed time, the geometry of space is such that as we move in toward the center, instead of finding a massive object, we find a second asymptotic region (Figure 1c, page 12). The geometry of space looks like a wormhole connecting two asymptotically flat regions. This is sometimes called the Einstein–Rosen bridge. They realized this before the full geometry was properly understood. Their motivation was to find a model for elementary particles where particles were represented by smooth geometries. We now think that their original motivation was misguided. This geometry can also be interpreted as a kind of wormhole that connects two distant regions in the same spacetime. John Wheeler and Robert Fuller showed that these

(Continued on page 12)

News of the Institute Community

PATRICIA CRONE, Andrew W. Mellon Professor in the School of Historical Studies, has been awarded the 2013 Giorgio Levi Della Vida Medal for Excellence in Islamic Studies from the G. E. von Grunebaum Center for Near Eastern Studies at the University of California, Los Angeles. Crone has also received four major awards for her book *The Nativist Prophets of Early Islamic Iran: Rural Revolt and Local Zoroastrianism* (Cambridge University Press, 2012). The four prizes include the Albert Hourani Book Award, the Houshang Pourshariati Iranian Studies Book Award, the Central Eurasian Studies Society Book Award, and the American Historical Society's James Henry Breasted Prize.

HELMUT HOFER, Professor in the School of Mathematics, has been awarded the 2013 Heinz Hopf Prize for outstanding scientific work in the field of pure mathematics from Eidgenössische Technische Hochschule Zürich. Hofer shares the prize with Yakov Eliashberg, former Member (2001–02) in the School and currently Professor at Stanford University.

SCOTT TREMAINE, Richard Black Professor in the School of Natural Sciences, has been awarded the Tomalla Prize from the Tomalla Foundation for Gravity Research of Basel, Switzerland, in recognition of his extraordinary contributions to general relativity and gravity. Tremaine has generously donated a portion of his prize money to the Institute's School of Natural Sciences endowment.

CAROLINE WALKER BYNUM, Professor Emerita in the School of Historical Studies, has been awarded the Grand Merit Cross with Star of the Order of Merit of the Federal Republic of Germany for her political, social, economic, and intellectual achievements.

Contents

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.

Issues of the *Institute Letter* and other Institute publications are available online at www.ias.edu/about/publications/.

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PHILLIP A. GRIFFITHS, Professor Emeritus in the School of Mathematics, has been awarded the American Mathematical Society's Steele Prize for Lifetime Achievement for his contributions to fundamental knowledge in mathematics, particularly algebraic geometry, differential geometry, and differential equations. Birkhauser Science has published *Rational Homotopy Theory and Differential Forms* (2013), coauthored by Griffiths and John Morgan, Professor at Stony Brook University, The State University of New York.

ROGER W. FERGUSON, JR., a Trustee of the Institute, has received the Adam Smith Award from the National Association for Business Economics. Ferguson is President and Chief Executive Officer of TIAA-CREF.

ELIZABETH ANNE DAVIS, Member in the School of Social Science, has been awarded the Society for Cultural Anthropology's 2013 Gregory Bateson Book Prize for *Bad Souls: Madness and Responsibility in Modern Greece* (Duke University Press, 2012). The Bateson Prize seeks to reward work that is theoretically rich, ethnographically grounded, interdisciplinary, experimental, and innovative.

PATRICIA EBREY, Member in the School of Historical Studies, will receive an Award for Scholarly Distinction from the American Historical Association at their annual meeting in January. Ebrey will share the prize with John Dower, Ford International Professor Emeritus of History at the Massachusetts Institute of Technology.

Among the recipients of the 2013 New Horizons in Physics Prize awarded by the Fundamental Physics Prize Foundation are SHIRAZ NAVAL MINWALLA, Member in the School of Natural Sciences, and FREDDY CACHAZO, former Member (2002–03, 2004–05, 2009–10) in the School. Minwalla was recognized for his pioneering contributions to the study of string theory and quantum field theory, and in particular, his work on the connection between the equations of fluid dynamics and Albert Einstein's equations of general relativity. Cachazo was cited for uncovering numerous structures underlying scattering amplitudes in gauge theories and gravity.

JONATHAN MITCHELL, Member in the School of Natural Sciences, has been awarded the Ronald Greeley Early Career Award in Planetary Science from the American Geophysical Union.

JOÃO BIEHL, former Member (2002–03, 2005–06, 2012–13) in the School of Social Science, has been awarded the J. I. Staley Prize from the School for Advanced Research for his book *Vita: Life in a Zone of Social Abandonment* (University of California Press, 2005). The Prize honors books that cross subdisciplinary boundaries within anthropology and reach out in new and expanded interdisciplinary directions. Biehl is Susan Dod Brown Professor of Anthropology, Woodrow Wilson School Faculty Associate, and Co-Director of the Program in Global Health and Health Policy at Princeton University.

CHARLES BOSK, former Member (2003–04) in the School of Social Science, has been elected to the Institute of Medicine, one of the nation's highest honors in biomedicine. Bosk is Professor of Sociology and Professor of Anesthesiology and Critical Care in the Perelman School of Medicine and Senior Fellow of the Leonard Davis Institute of Health Economics at the University of Pennsylvania.

Of Historical Note

On January 4, 1955, Edward R. Murrow visited the Institute for Advanced Study to interview J. Robert Oppenheimer, the Institute's third Director. The following is an excerpt from their conversation; the full video is available at http://ow.ly/reFUS:

MURROW: I have heard you describe [the Institute] as a "decompression chamber."

OPPENHEIMER: Well, it is for many people. There are no telephones ringing, and you don't have to go to committee meetings, and you don't have to meet classes and—especially for the few people who are here for life—the first years are quite, quite remarkable, because most people depend on being interrupted in order to live. The work is so hard and failure is of course, I guess, an inevitable condition of success. So they're used to having to attend to other people's business. When they get here, there is nothing of that, and they can't run away. It's to help men who are creative and deep and active and struggling scholars and scientists to get the job done that it is their destiny to do. This is a big order, and we take a corner of it. We do the best we can. ■

SUBO DONG, former Member (2009–13) in the School of Natural Sciences, has been selected for China's 1000 Talents Program, which aims to recruit foreign experts in science and technology. Dong is Bairen Research Professor at the Kavli Institute for Astronomy and Astrophysics at Peking University.

The 2014 Fundamental Physics Prize has been awarded to MICHAEL B. GREEN, former Member (1970–72) in the School of Natural Sciences, for opening new perspectives on quantum gravity and the unification of forces. Green, who is currently Lucasian Professor of Mathematics at Cambridge University, shares the prize with John Schwarz, Harold Brown Professor of Theoretical Physics at the California Institute of Technology. ANDREW STROMINGER, former Member (1970–72) in the School and Institute Trustee (2003–08), and CUMRUN VAFA, former Member (1994) in the School of Mathematics, were named as 2014 Physics Frontiers Prize laureates by the Fundamental Physics Prize Foundation for their numerous deep and groundbreaking contributions to quantum field theory, quantum gravity, string theory, and geometry.

MAURO F. GUILLÉN, former Member (1998–99) in the School of Social Science, along with four others, has been awarded the Aspen Institute's Faculty Pioneer, which honors educators who demonstrate a willingness to deeply examine the relationships between capital markets, firms, and the public good. Guillén is Director of the Joseph H. Lauder Institute of Management and International Studies at the University of Pennsylvania.

HIMANSHU RAY, former Member (2010–11) in the School of Historical Studies, has been awarded the Humboldt Foundation's Anneliese Maier Research Award, which honors outstanding achievement in the humanities and social sciences and seeks to strengthen German scholarship's international ties. Ray is Professor at Jawaharlal Nehru University in New Delhi.

The IAS Questionnaire: Charles Simonyi

The Hungarian-born computer software pioneer, philanthropist, and Chairman of Intentional Software Corporation and the Institute's Board of Trustees has twice visited the International Space Station, amounting to a total of twenty-eight days in space. His father, Károlyi Simonyi, was a physicist and electrical engineer whose book A Cultural History of Physics (AK Peters, 2012) was first published in Hungarian in 1979.

What makes you curious? Immanuel Kant talked about the "moral law within"; I sense that curiosity is also within us like the moral law.

Whom do you most admire and why? J. S. Bach: creator of sublime beauty who worked very hard. Michael Faraday: an intuitive, self-taught genius.

Outside of your own, which field interests you most? I am very interested in physics and the visual and musical arts.

How do you determine your focus? That is hard: focus is an investment, one has to think of the long-term payoff, but also to make the portfolio diversified.

What is the most surprising thing you've learned? I was pretty surprised when I learned that differentiation and integration are opposite (inverse) operations. More recently, Moore's law on the improvement of computer chips and the law's extensions to storage and bandwidth continually amazes me.

How do you free your thinking? I fix things, back to the basics, tangible stuff.

What question would you most like answered? It would be great to know what will be the next step beyond the Standard Model—we may not have to wait very long now.

How has the Institute influenced your perspective? I can sleep well because when Big Questions arise, we have a place to go for the answers.

What is your least favorite characteristic? Ignorance of history. There is no excuse.

Hermann Weyl, who served on the Institute Faculty from 1933 until his death in 1955, once said, "My work always tried to unite the truth with the beautiful, but when I had to choose one or the other, I usually chose the beautiful." If you had to choose between truth or beauty, which would you choose and why? Maybe this is a false dichotomy since "beauty is truth, truth beauty." But I understand what Weyl may have thought; beauty is a deep reflection in the human psyche, an incredible heuristic with general utility, while truth is a simpler concept, more utilitarian.

What is the purpose of knowledge? To satisfy our curiosity.

What have you ignored that turned out to be crucial? That time flies.

What is your most treasured possession? My wedding ring.

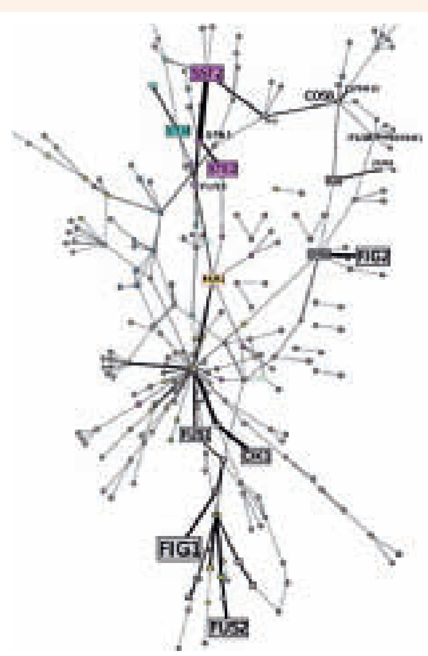
How do you play? With my wife, we do jigsaw puzzles. It is very much like science: progress spreads from fixpoints and from lucky accidents step-by-step, with lots of pattern matching. She is much better than I.

Which three words best describe the Institute? Long, wide, deep.

Understanding Networks and Defining Freedom

From capturing interactions and inferring the structure of data to determining the infringement of freedom

In November, the Association of Members of the Institute for Advanced Study (AMIAS) sponsored two lectures by Jennifer Chayes, Member (1994–95, 97) in the School of Mathematics, and Quentin Skinner, Member in the Schools of Historical Studies (1974–75) and Social Science (1976–79). All current and former Institute Members and Visitors are members of AMIAS, which includes some 6,000 scholars in more than fifty countries. To learn more about the organization, upcoming events, and opportunities to support the mission of the Institute, please visit www.ias.edu/people/amias/. Following are brief summaries of the lectures by Chayes and Skinner; full videos are available at http://video.ias.edu/2013-amias-chayes and http://video.ias.edu/2013-amias-skinner/.



Gene regulatory networks are the source of many human diseases. How do we infer network structure from partial data? What is the network most likely to have produced the little bit that we can see?

AGE OF NETWORKS

***Jennifer Chayes**, Distinguished Scientist and Managing Director of Microsoft Research New England and New York City:*

Everywhere we turn, networks can be used to describe relevant interactions. In the high-tech world, we see the internet, the world wide web, mobile phone networks, and online social networks. In economics, we are increasingly experiencing both the positive and negative effects of a globally networked economy. In epidemiology, we find disease spreading over ever-growing social networks, complicated by mutation of the disease agents. In problems of world health, distribution of limited resources, such as water resources, quickly becomes a problem of finding the optimal network for resource allocation. In biomedical research, we are beginning to understand the structure of gene-regulatory networks, with the prospect of using this knowledge to manage many human diseases.

In her lecture, Chayes discussed models and techniques that cut across many disciplinary boundaries and gave a general perspective of some of the models that are being used to describe these networks, the network processes that are being studied, the algorithms that have been devised for the networks, and the methods that are being developed to indirectly infer network structure from measured data.

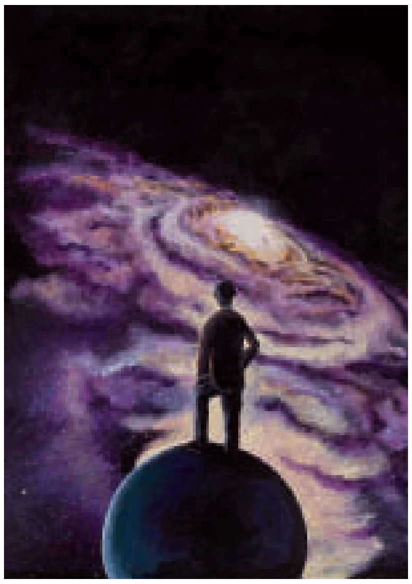
HOW SHOULD WE THINK ABOUT FREEDOM?

***Quentin Skinner**, Barber Beaumont Professor of the Humanities at Queen Mary, University of London:*

The usual practice of defining the concept of individual freedom in negative terms as "absence of interference" is in need of qualification and perhaps abandonment. Because the concept of interference is such a complex one, there has been much dispute, even within the liberal tradition, about the conditions under which it may be legitimate to claim that freedom has been infringed.

In his lecture, Skinner considered these disputes, and then focused on those critics who have challenged the core liberal belief about absence of interference. Some doubt whether freedom is best defined as an absence at all, and instead attempt to connect the idea with specific patterns of moral behavior. Others agree that freedom is best understood in negative terms, but argue that it basically consists in the absence not of interference but of arbitrary power. In concluding his talk, Skinner drew some implications of this view for democratic government.

"A number of democratic states are practicing, without the consent or even knowledge of their citizens, systematic powers of surveillance. . . . If citizens begin to self-censor in the face of these powers, because, for example, of not knowing what use may be used of their emails and wanting to be sure of keeping out of trouble, they will have limited their own freedom of expression. They will have colluded in the undermining of their freedom." ■



This original painting was created by Robbert Dijkgraaf, Director of the Institute and Leon Levy Professor, to commemorate the celebration in Freeman Dyson's honor, "Dreams of Earth and Sky." The title is taken from a book written in 1895 by Konstantin Tsiolkovsky, a Russian schoolteacher who worked out the mathematics of interplanetary rocketry in the nineteenth century. "The Earth is the cradle of the mind," Tsiolkovsky wrote, "but we cannot live forever in a cradle."

Infinite in All Directions

In 2013, Freeman Dyson celebrated his ninetieth birthday and also marked his sixtieth year as a Professor at the Institute for Advanced Study, the longest tenure of any Faculty member in the Institute's history. When Dyson first arrived as a Member in 1948, the Institute was less than twenty years old. "Dreams of Earth and Sky," a conference and celebration conceived by Dyson's colleagues in the School of Natural Sciences and held September 27–28, provided a perspective on his work and impact across the sciences and humanities. The program featured a range of talks on mathematics, physics, astronomy, and public affairs that reflect both the diversity of Dyson's interests and his ability to open new dialogues.

The son of composer Sir George Dyson and Mildred Atkey, Dyson was born in Crowthorne, England, on December 15, 1923. He worked as a civilian scientist for the Royal Air Force in World War II, and graduated from Cambridge University in 1945 with a B.A. degree in mathematics. He went on to Cornell University as a graduate student in 1947 and worked with Hans Bethe and Richard Feynman. One of Dyson's most notable contributions to science was the unification of the three versions of quantum electrodynamics invented by Feynman, Julian Schwinger, and Sin-Itiro Tomonaga. Dyson then worked on nuclear reactors, solid state physics, ferromagnetism, astrophysics, and biology, looking for problems where mathematics could be usefully applied. Author of numerous articles and books about science for the general public, he has also been heavily invested in human issues, from arms control and space travel to climate studies. Dyson once remarked that he was "obsessed with the future." His keen observations and sense of wonder, which have inspired generations here at the Institute and beyond, are powerful testaments to the freedom provided by the Institute to follow one's future, wherever it may lead. ■

The Absolute Elsewhere

Immersed in Freeman Dyson's World

Punch *cartoon inspired by seven-year-old Freeman Dyson*

BY PIA DE JONG

In 1930, the British satirical magazine *Punch* published a cartoon of a boy, lying on his side on the lawn, reading a book on relativity. When asked where his sister is, he replies, "Somewhere in the absolute elsewhere."

That boy was the seven-year-old Freeman Dyson. He did not understand why his father had sent his remark to *Punch*. It was after all technically correct. What was so funny about it?

Dyson grew up to be a world-famous mathematician, physicist, astronomer, and an elegant writer. For sixty years, he has worked at the Institute for Advanced Study. On December 15, he will be ninety. An elfin man with pointed ears and mischievous blue eyes, he still walks faithfully to his office every morning, invariably dressed as the British boarding school boy he once was—with a tweed jacket and tie.

To celebrate Dyson's ninetieth birthday, a conference was held in his honor at the Institute. He himself gave it the title "Dreams of Earth and Sky." The speakers, also all chosen by him, were just as exciting as the Jules Verne books he devoured as a child—until he realized that they lived only in science fiction.

Thus, I find myself immersed in his fascinating world. I hear the English Astronomer Royal, Martin Rees, talk about alternative universes. I see a map of the nearest stars where extraterrestrial life might really exist. Magic formulas, the interior of the Earth, climate change, nuclear disarmament, life on Mars—ideas that are often as controversial as those of Dyson himself. But also with an equally infectious enthusiasm about everything there is to discover. If I were a child, Dyson would be my hero, and I would want to be an astronomer. Happily, there are many children in the audience.

In the event's dinner program, the title page of a book that Dyson wrote at the age of nine is printed: *Sir Phillip Roberts's Erolunar Collision* describes an expedition to the moon to prevent a collision with the planet Eros. There is also a picture of the older Dyson at the launch of the Russian Soyuz rocket. His daughter Esther was the back-up astronaut. How much he himself would have wanted to go into space.

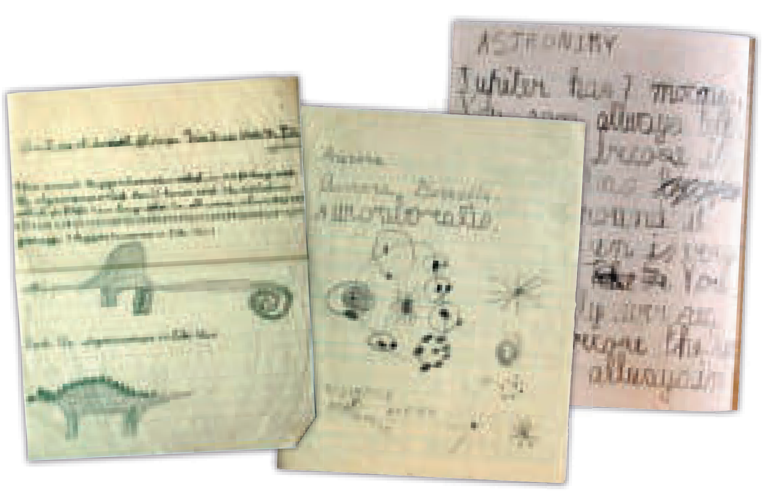
On the cover of the program is an intriguing painting. We see Dyson from the back, standing on top of planet Earth and we look over his shoulder at a universe full of stars, nebulae, and black holes. He looks like a child in the body of an old man. He reminds me of The Little Prince on his single asteroid B-612. Dreaming, thinking, imagining. Somewhere in the absolute elsewhere.

At dinner he talks about how in the 1950s he went to San Diego to design nuclear-powered missiles to travel to Saturn. He and his colleagues would say that they no longer wanted to look at the universe through a keyhole but would rather pull the door to the cosmos wide open. He still regrets that the U.S. government decided to go no farther than the moon on a conventional rocket.

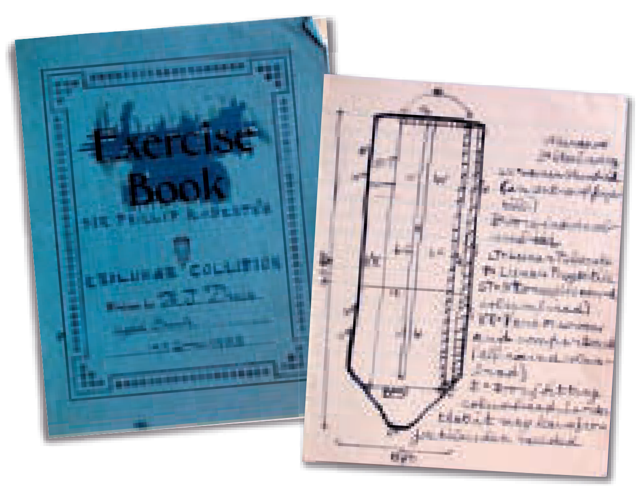
At the end of the evening, Freeman's son, the writer George Dyson, addresses the group. "I'll tell you how to recognize a genius," he says with a glance at his nearly ninety-year-old father, surrounded by his six children and sixteen grandchildren all nibbling on little sugary asteroids from his birthday cake. "A genius is someone who as a child acts like a grown-up, and as a grown-up acts like a child." ■

Novelist and columnist Pia de Jong is the author of Lange Dagen (Long Days)*, translated in Italian as* Verso Nord, and Dieptevrees (Fear of Depths)*. She has won several prizes for her short stories and poems. She has contributed to the* Fianciële Dagblad (The Financial Daily)*, the* Huffington Post*, and the* Washington Post*. She currently writes a weekly column for the Dutch newspaper* NRC*, called Flessenpost (Notes in a Bottle), about her life in the United States, available at www.piadejong.com/.*

Freeman Dyson in 1934 (age ten)

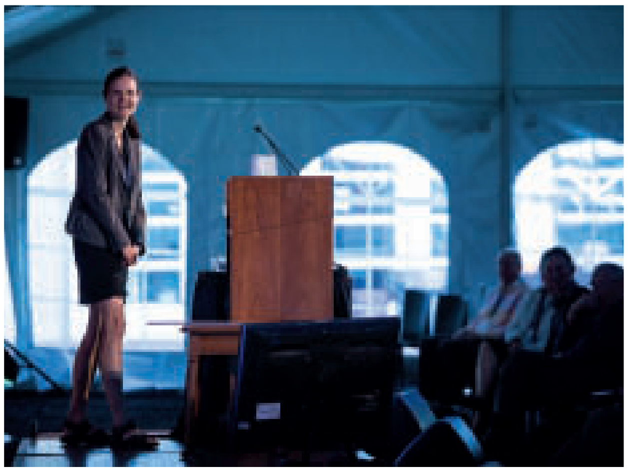


Astronomy and dinosaur sketches created by Dyson in 1929 (age five)



Cover and rocket sketch from Dyson's unfinished science fiction story "Sir Phillip Roberts's Erolunar Collision," 1932–33 (age eight–nine)

Dreams of Earth and Sky: A Celebration for Freeman Dyson


DAN KOMODA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GEORGE DYSON

You and I

BY MARY ANN HOBERMAN

Read by Clara Dyson (above)
at the Institute Dinner Celebration
for Grandpa's 90th Birthday, September 27, 2013

Only one I in the whole wide world
And millions and millions of you,
But every you is an I to itself,
And I am a you to you, too.

But if I am a you and you are an I
And the opposite also is true,
It makes us both the same somehow,
Yet splits us each in two.

It's more and more mysterious,
The more I think it through:
Every you everywhere in the world is an I,
Every I in the world is a you.


DAN KOMODA


DAN KOMODA


ANDREA KANE


DAN KOMODA


DAN KOMODA


ANDREA KANE

Freeman Dyson's family, friends, and colleagues from around the world gathered at the Institute on September 27 and 28 for a birthday celebration that featured a two-day program of talks and a special dinner.

Clockwise from top left: Kathrin Bringmann presenting a mathematics lecture on "Dyson's Rank, Harmonic Weak Maas Form, and Recent Developments"; Dyson's granddaughter, Clara, reading the poem "You and I" at Dyson's birthday dinner; Freeman Dyson; a celebratory toast; Martin Rees describing the possibility of multiple universes in his lecture "Our Universe and Others"; George Dyson (center), in conversation with Danny Hillis (left) and Siobhan Roberts; Esther Dyson; Dyson's grandchildren enjoying the Institute campus; Imme Dyson; Dyson blowing out the candles of his birthday cake, surrounded by his grandchildren.

Recommended viewing: Videos of the talks given by George Andrews, Kathrin Bringmann, Sidney Drell, William Happer, Russell Hemley, Joseph Kirschvink, Joel Lebowitz, Amory Lovins, William Press, Martin Rees, Sara Seager, and H. T. Yau during "Dreams of Earth and Sky" may be accessed at: http://video.ias.edu/dyson-dreams/.

Pursuing the Monster

What lies beneath a structure with an unimaginable 196,883 dimensions?

BY SIOBHAN ROBERTS

In 1981, Freeman Dyson addressed a typically distinguished group of scholars gathered at the Institute for a colloquium, but speaking on a decidedly atypical subject: "Unfashionable Pursuits."

> The problems which we face as guardians of scientific progress are how to recognize the fruitful unfashionable idea, and how to support it.
>
> To begin with, we may look around at the world of mathematics and see whether we can identify unfashionable ideas which might later emerge as essential building blocks for the physics of the twenty-first century.*

He surveyed the history of science, alighting eventually upon the monster group—an exquisitely symmetrical entity within the realm of group theory, the mathematical study of symmetry. For much of the twentieth century, mathematicians worked to classify "finite simple groups"—the equivalent of elementary particles, the building blocks of all groups. The classification project ultimately collected all of the finite simple groups into eighteen families and twenty-six exceptional outliers. The monster was the last and largest of these exceptional or "sporadic" groups.

The first of the sporadic simple groups was discovered in the nineteenth century by French mathematician Émile Mathieu. It wasn't until 1973 that two mathematicians—Bob Griess at the University of Michigan and Bernd Fischer at Universität Bielefeld—independently predicted the existence of the monster. They did this in a manner similar to how physicists predicted the existence of the Higgs boson, the quantum of the Higgs field molasses that pervades the ether and endows elementary particles with mass. And just as physicists long hunted the Higgs boson, so too did the prediction of the monster send mathematicians hunting for information, confirmation, any crumbs or clues about the monster's existence.

It didn't take long before John Conway, then at Cambridge, now at Princeton University, came back with the monster's order, its number of symmetries:

$$8 \cdot 10^{53}$$

or

$$2^{46} \cdot 3^{20} \cdot 5^{9} \cdot 7^{6} \cdot 11^{2} \cdot 13^{3} \cdot 17 \cdot 19 \cdot 23 \cdot 29 \cdot 31 \cdot 41 \cdot 47 \cdot 59 \cdot 71$$

or

808,017,424,794,512,875,886,459,904,961,710,757,005,754,368,000,000,000

And possessing these 808 sexdecillion or so symmetries—not infinity by any means, but heading in that direction—the monster certainly did not reside in anything close to our three-dimensional space. The monster lives, or more precisely acts, in an unimaginable 196,883 dimensions.

Further clues came in 1978 when Concordia University's John McKay noticed that 196,883+1=196,884—elementary addition, perhaps, but 196,884 was a number of considerable significance in modular functions, a faraway land on the other side of the mathematical ocean. Conway and Simon Norton (then both at Cambridge) pursued McKay's observation as more than mere numerology. They proposed their monstrous moonshine conjectures—"moonshine" because the conjectures seemed illicit and illegal, as well as illuminating—and marshaled evidence to support the unexpected relationship between these two mathematical structures. The moonshine conjectures also postulated that given the evidence, there should be something underpinning the monster. Conway had discovered a group, Co_1, in 24-dimensional space that was underpinned by the Leech lattice, a structure that arises in number theory and coding theory. Beneath the Mathieu group M_{24} lay the error-correcting Golay code. What underlay the monster?

In 1981, a few days before his talk, Dyson received in the mail the final installment of a long paper by Griess confirming the monster's existence. Griess, while a Member at the Institute (1979–80, 1981, 1984), had constructed the monster as a group of rotations in 196,883-dimensional space (and in the process producing the Griess algebra expressly for that purpose). Conway later simplified this construction—one among many re-imaginings of the monster to follow.

"What has all this to do with physics?" Dyson asked in his talk.

> Probably nothing. Probably the sporadic groups are merely a pleasant backwater in the history of mathematics, an odd little episode far from the mainstream of progress. We have never seen the slightest hint that the symmetries of the physical universe are in any way connected with the symmetries of the sporadic groups. So far as we know, the physical universe would look and function just as it does whether or not the sporadic groups existed. But we should not be too sure that there is no connection. Absence of evidence is not the same thing as evidence of absence. Stranger things have happened in the history of physics than the unexpected appearance of sporadic groups. We should always be prepared for surprises. I have to confess to you that I have a sneaking hope, a hope unsupported by any facts or any evidence, that sometime in the twenty-first century physicists will stumble upon the monster group, built in some unsuspected way into the structure of the universe. This is of course only a wild speculation, almost certainly wrong.

But Dyson, as it turns out, is almost certainly right.

At the International Congress of Mathematicians in the summer of 1998, Richard Borcherds, now at Berkeley (previously at Cambridge and previously a Ph.D. student of Conway's), received the Fields Medal for his proof of the moonshine conjectures. At the ceremony, mathematical physicist Peter Goddard—Director (2004–12) and now a Professor at the Institute—delivered the laudation. Borcherds in his proof had made critical use the "no-ghost theorem" by Goddard and Charles Thorn (at the University of Florida). "Displaying penetrating insight, formidable technique, and brilliant originality, Richard Borcherds has used the beautiful properties of some exceptional structures to motivate new algebraic theories of great power with profound connections with other areas of mathematics and physics," said Goddard. "He has used them to establish outstanding conjectures and to find new deep results in classical areas of mathematics. This is surely just the beginning of what we have to learn from what he has created."

Borcherds's creation fulfilled Dyson's hope that the monster would somehow be embedded into the structure of the universe, or at least took it a step in that direction. His proof demonstrated that the monster is the symmetry group not of a lattice or a code but of conformal field theory, part of the mathematical language of string theory.

For some, this is *raison d'etre* enough for the monster. For others, like Conway, the monster remains a mystery. Conway has tried to read some of the work linking the monster to conformal field theory, but he doesn't find it helps with the question of why the monster exists. In his view, conformal field theory is too complicated to understand, and thus too complicated to be the only answer.

Dyson, for his part, offered another possibility in concluding his talk:

> The only argument I can produce in its favor is a theological one. We have strong evidence that the creator of the universe loves symmetry, and if he loves symmetry, what lovelier symmetry could he find than the symmetry of the monster? ■

* The colloquium was sponsored by the Humboldt Foundation, and Dyson's talk was reprinted in its entirety in *The Mathematical Intelligencer*, Vol. 5, No. 3, 1983.

Siobhan Roberts, a Director's Visitor at the Institute, is currently finishing a biography of Princeton mathematician John Horton Conway, to be published by Bloomsbury in spring 2015. She is the author of King of Infinite Space: Donald Coxeter, The Man Who Saved Geometry, *which won the Mathematical Association of America's 2009 Euler Prize for expanding the public's view of mathematics.*

The Daily Lives of Artists and Scientists

The art of letting truth drag you toward it

On November 12, at the opening of the Large Hadron Collider exhibition at the Science Museum in London, Nima Arkani-Hamed, Professor in the School of Natural Sciences, met with novelist Ian McEwan for a conversation aimed at finding the common ground between art and science. The following is an edited excerpt; a video of the full interview is available at http://ow.ly/rsHX7/.

Ian McEwan: Here is a major difference. I'm well aware in science how important it is to be first. Being second with the structure of DNA would consign you to the dustbin of history, whereas every novelist knows that you're in a self-sustaining world in which whatever you say is so. It's for others to accept it or reject it. I often pity those scientists who are in a race just to get on the public record for the first time—days, weeks before someone else—and your life can be transformed. Crick and Watson are a perfect case of this. If [Linus] Pauling had got there before them we wouldn't have heard of Jim Watson. It's a tougher world.

Nima Arkani-Hamed: One thing about originality at an even baser level is how easy it is to be original, how much innate, intrinsic talent is needed to be able to do something. And here we [scientists] have an advantage—there's this thing out there that we're not inventing but discovering. And because of that all you have to do is get somewhere in the neighborhood of the truth. You don't have to get particularly close to it, you just have to know that it's there and then you have to not fight it and just let it drag you in toward itself. If you're very talented, you might hack your way there more quickly. If you're less talented, you might have to pinball around, and it takes a little longer. ■

Churchill and the Bomb

Winston Churchill doubted whether politicians would be equal to the challenge of such powerful weapons.

BY GRAHAM FARMELO

In the early evening of March 15, 1933, a group of London socialites gathered in a Westminster mansion to hear a special lecture on the latest developments in nuclear science. The talk was chaired by Winston Churchill. The speaker—Churchill's friend Frederick Lindemann, a friend of Einstein's and a professor of physics at Oxford University—discussed John Cockcroft and Ernest Walton's recent artificial splitting of the atom and James Chadwick's discovery of the neutron. Churchill had foreseen an important role of this subatomic particle fifteen months before in his essay "Fifty Years Hence," read widely in Britain and North America. He had told his readers in this article that scientists were looking for "the match to set the [nuclear] bonfire alight."

"Fifty Years Hence" was by no means the only article in which Churchill looked forward to the nuclear age. He first did so in 1927 in another popular article, "Shall We All Commit Suicide?" where he alluded to the weapon envisaged by his friend H. G. Wells in the novel *The World Set Free*, where the term "atomic bomb" first appears. A decade later, Churchill warned four million readers of the *News of the World in Britain* that nuclear energy may soon be harnessed. He was right: Otto Hahn and Fritz Strassmann, working in Hitler's capital, discovered nuclear fission eight weeks after Churchill's piece appeared.

Franklin Roosevelt (front left) and Winston Churchill (front center) in Quebec, September 1944; both leaders ignored Bohr's warnings.

Of all the international leaders who were to become involved in the early development of nuclear weapons, none was better prepared than Churchill. He had foreseen them, warned of the challenges they would pose to international leaders, and had a strong record of encouraging the military to make the most of new science. His nuclear scientists were behind him, more than willing to drop their research and join the fight against Hitler. Soon, Churchill became the first national leader to be advised by his scientists that nuclear weapons could be built—a way of making such a bomb was first discovered in March 1940 by two physicists at Birmingham University, both officially classified as "enemy aliens," less than two months before Churchill became Prime Minister.

In "Fifty Years Hence," Churchill had doubted whether politicians would be equal to the challenge of such powerful weapons:

> Great nations are no longer led by their ablest men, or by those who know most about their immediate affairs, or even by those who have a coherent doctrine. Democratic governments drift along the line of least resistance, taking short views, paying their way with sops and doles, and smoothing their path with pleasant-sounding platitudes.

Now, under pressure of leading a country at war, he himself was about to see whether he would be up to that challenge. Given his familiarity with the concept of nuclear weapons, it was remarkable that he recognized the importance of working closely with the United States in building the first ones, only three years later, in April 1943. By then, it was obvious that the British could not possibly build the Bomb alone during the War, and the gargantuan Manhattan Project was surging ahead, with the British playing only a relatively minor role. Churchill had been able to make only very limited political use of the nuclear bomb established by his nuclear scientists. He did, however, strike a secret deal with President Roosevelt at Quebec in August 1943 that required both British and American leaders to approve the first use of the weapon. Churchill later agreed that the Bomb could be used on Japan, a decision he never regretted.

The idea of writing *Churchill's Bomb* first occurred to me in the spring of 2008. This was soon after I completed my biography of the theoretical physicist Paul Dirac, who set aside most of his research in the early 1940s to work on the British nuclear project. Dirac was among the dozens of scientists who did something remarkable—in only weeks, they switched most of their research from their curiosity-driven studies of subatomic physics to investigating how to make nuclear bombs, working entirely in secret for their government. I became fascinated in the nexus of international politics and nuclear science, especially by Churchill's dealings with his scientists and also with American leaders, notably Presidents Franklin Roosevelt, Harry Truman, and Dwight Eisenhower.

At that time, I had little sense of the size of the project I had taken on, though I was soon to be disabused of my ignorance. I found that there is already an enormous literature on Churchill, along with several authoritative accounts of the early history of the Bomb and dozens of academic papers probing the fine details of the nuclear policies pursued by the first nations to build the weapons. In this mountain of literature, however, no one had brought Churchill's role to the fore and highlighted his dealings with his nuclear scientists. In order to write *Churchill's Bomb*, I had to spend some three years delving not only into Churchill's huge archive but into the papers, biographies, and memoirs of the three American presidents and some two dozen nuclear physicists. Among the leading scientists in the story were several colorful characters—a gift for a biographer—including foremost nuclear pioneer Ernest Rutherford, his experimentalist students Patrick Blackett, John Cockcroft, and James Chadwick, and his only theoretician protégé, Niels Bohr, known to British government officials as "the great Dane."

Of all the international leaders who were to become involved in the early development of nuclear weapons, none was better prepared than Churchill.

Bohr is one of the story's leading characters. It was he who had the crucial insight into the fission of uranium nuclei that opened the path toward the first nuclear weapon; he who became the most thoughtful counselor to the leading British and American scientists working on the project; he who first saw clearly that the Anglo-American policy of producing the Bomb without informing their Soviet ally would almost certainly lead to an expensive and dangerous arms race after the War; and he who was allowed to explain these worries to Churchill and Roosevelt, neither of whom took his views seriously, to the disappointment of several leading scientists working on the Manhattan Project, including its scientific director, J. Robert Oppenheimer, later a Director of the IAS.

In the course of researching the book, I used dozens of archives, especially in the United Kingdom and the United States. One especially rich source of gems is the Institute's Shelby White and Leon Levy Archives Center, which includes correspondence that illuminates Institute Director Frank Aydelotte's attempt to provide an academic sanctuary to Bohr, soon after he escaped from Nazi-occupied Denmark in September 1943. A remarkable letter, which I found in the UK National Archive, from Bohr's British colleague Wallace Akers to a colleague, indicated why the great Dane did not accept Aydelotte's offer of an appointment at the Institute—it would not be wise to work alongside Faculty member Albert Einstein, whose tongue on top-secret matters concerning the Bomb could be disconcertingly loose.

Churchill's thinking about nuclear weapons changed rapidly after it became clear in the early 1950s that both superpowers would soon have the hydrogen bomb, making possible what would become known as "mutually assured destruction." In February 1954, toward the end of his second term as British Prime Minister, Churchill read a report on a speech by Sterling Cole, Chair of the U.S. Joint Committee on Atomic Energy, which first brought home to him the extent of the H-bomb's destructiveness. This realization drove him, in his final months on the international stage, to urge the Soviet and American leaders to meet with him with the aim of easing the tensions of the Cold War, to reduce considerably the risk of a conflagration. He became a pioneer of détente, though an unsuccessful one, and left office privately fearing that nuclear war was all but inevitable.

The threat of the H-bomb was the theme of his last great speech in the House of Commons, on March 1, 1955. He began by looking back proudly on his record of keeping abreast of nuclear science, citing prophetic words he had written almost a quarter of a century before in "Fifty Years Hence." This was not an occasion to express regret. I have often wondered, however, what Churchill felt when, preparing for his speech, he re-read the astonishingly far-sighted comments he had made about the possibility of nuclear weapons almost a decade before they became viable. As a nuclear visionary, Churchill had been more effective as a writer than as a politician. ■

Graham Farmelo is a By-Fellow at Churchill College, Cambridge. He wrote much of Churchill's Bomb *(Basic Books, 2013) and his biography of Paul Dirac,* The Strangest Man *(Basic Books, 2009), as a Director's Visitor at the Institute. You may listen to a podcast of Farmelo and Nima Arkani-Hamed discussing the future of physics at http://ow.ly/rsKK8/.*

From a War on Terrorism to Global Security Law

What happened when the United Nations Security Council passed Resolution 1373 to fight terrorism but failed to define it?

BY KIM LANE SCHEPPELE

On December 11, 2003, when asked in a press conference whether his Iraq policy was consistent with international law, President George W. Bush joked, "International law? I better call my lawyer; he didn't bring that up to me."

But, in fact, since the 9/11 attacks, the United States government had aggressively constructed a new body of international law: global security law. While the Bush administration is probably best known for its CIA black sites, extraordinary rendition, and defense of torture, those policies were in fact rather short-lived, lasting a handful of years at most. By contrast, global security law not only still exists but is becoming ever more entrenched. More than a decade after the attacks, global security law remains one of the most persistent legacies of 9/11.

On September 28, 2001, the United Nations Security Council passed Resolution 1373. Operating under Chapter VII of the UN Charter, which makes resolutions binding on all member states (noncompliance is at least theoretically subject to sanctions), the Security Council required states to change their domestic law in parallel ways to fight terrorism. Previously, the Security Council had typically directed states' actions or urged states to sign treaties, but it had not directed changes in countries' domestic laws. With Resolution 1373, the Security Council required states to alter some of the most sensitive areas of national law, like criminal law and domestic intelligence law.

Under Resolution 1373, all 192 members states of the United Nations were required to make terrorism a serious crime in domestic law, along with conspiracy to commit terrorism, aiding and abetting terrorism, providing material support for terrorism, inciting terrorism, and other ancillary offenses. Yet the Security Council failed to provide a definition of terrorism that would have confined these new crimes to either the perpetrators or the actions implicated in the 9/11 attacks. Not surprisingly, states proceeded to enact a proliferation of very different terrorism offenses, ranging from narrowly defined crimes to political crimes so broadly framed that they included all government opponents in their purview.

Without substantial constitutional traditions, some countries defined terrorism to be virtually any politically motivated challenge to the state, which almost entirely overlapped with the field of political dissent. For example, Vietnam defined a terrorist as anyone who "oppose(s) the people's administration and infringe(s) upon the lives of officials, public employees, or citizens." In Brunei, a terrorist is "any person who … by the use of any firearm, explosive, or ammunition acts in a manner prejudicial to public safety or to the maintenance of public order or incites to violence or counsels disobedience to the law or to any lawful order."

Still other states criminalized terrorists while exempting freedom fighters, tying the law to the foreign policy of the state. This was true of a number of Arab states that sought to distinguish acts designed to resist Israeli occupation from other violent attacks against state interests. Still other countries dusted off old anti-subversion or anti-communist laws, crossing out "subversion" or "communism" and replacing them with "terrorism."

In addition to criminalizing terrorism, Resolution 1373 required states to gather information about any terrorists or terrorist groups that might be operating in their own territory and to cooperate with the investigations of other states by sharing information. States differed widely in their administration of domestic surveillance and investigation, and each state self-determined the information that was added to global intelligence.

Inconsistent information, from coverage to quality, circulated through international channels, and states acted on the basis of this new data, even if the sources were dodgy. Moreover, states that might have had reasonable legal checks on their own surveillance and tracking of terrorists at home turned their information over to states that were not so scrupulous. For at least five years after Resolution 1373, the Security Council never insisted that countries respect human rights as they shared information or acted on the basis of others' tips. As a result, many states took Security Council resolutions as legal permission (or cover) to do many things in the name of fighting terrorism that they might not have done on their own.

For example, Yemen established a special police force for the purposes of fighting terrorism and later reported that it was establishing a special National Security Agency for controlling terrorism investigations as well. Spain has created a National Counter-Terrorism Coordinating Center for terrorism investigations, which brings together the national police with the Civil Guard (Spain's equivalent of the National Guard) and the military intelligence agency, all with the purpose of sharing information across their databases. New Zealand passed the Interception Capability Act in 2004, which requires that telecommunications hubs for phone and internet systems maintain a capacity to intercept communications and to comply with warrants for surveillance. Canada passed a new anti-terrorism bill in fall 2001, creating investigative hearings enabling judges to collect intelligence from terrorism suspects.

Resolution 1373 also required states to block terrorism financing by freezing assets of individuals and groups on Security Council watch lists to ensure that no funds reached terrorists through domestic channels (which often meant not only using the Security Council's watch list but also honoring other states' watch lists as well) and criminalizing any financing of terrorist activity under domestic law. States were pressed to initiate "automatic" and comprehensive asset freezes against people who turned up on these watch lists, without confirmation that the listing was based on adequate information. The Security Council did not stipulate any concern for individual privacy or due process rights in association with these programs. Those whose assets were frozen had no procedure, domestically or internationally, to challenge the freezes. Individual governments were denied access to the information used by international bodies to list suspects, so they could not hold reasonable hearings to assess whether the freezes were appropriate. Moreover, international bodies (like the Security Council itself) had no judicial mechanisms to determine whether individuals had been wrongly listed. The number of suspects on these lists is quite large. The United States, for example, has frozen the assets of more than ten thousand individuals and groups. Few have had any sort of due process.

Resolution 1373 required states to alter sensitive areas of national law in parallel ways to fight terrorism.

States were also required by Resolution 1373 to block terrorists' use of their territory by suppressing recruitment of terrorists, eliminating their access to weapons, and denying safe haven to any of their members. With no internationally agreed-upon definition of terrorism, the set of groups hit by these measures sometimes expanded to include states' general enemies lists. And because these measures required states to restrict international travel by terrorists, states responded by stepping up border controls, increasing the security of travel documents, and examining claims for refugee and asylum status more closely. Applied to members of al-Qaeda, this interdiction of movement makes sense. But global politics has meant crackdowns on members of many other groups with rights and legitimate reasons to move. Muslim Uighurs, Chechen nationalists, and Palestinian activists (among others) have been added to the lists of many countries that used to think of these groups as freedom fighters.

The passing of Resolution 1373 represented the first time in the history of international law that a nonrepresentative body within an international organization claimed the power to make binding law for all member states. The resulting program launched by Resolution 1373 has encouraged the worldwide creation of new, vague, and politically defined crimes; sanctioned evasion of prior legal limits before state authorities could search places and people; launched massive new domestic surveillance programs to capture electronic communications; encouraged states to spy on people within and across their borders; moved toward preventive detention and aggressive interrogation regimes; and installed new barriers in international migration.

In a major study (for which I was a consultant) to mark the tenth anniversary of 9/11, the Associated Press used its worldwide network of correspondents to find out how many terrorism convictions had resulted from these new criminal laws. The AP found that 119,000 people had been arrested for terrorism offenses since 9/11 and that slightly more than 35,000 people had been convicted on terrorism charges in 66 countries. But more than half of all convictions came from just two countries: Turkey and China. In Turkey, the targets of terrorism investigations were separatist Kurds. In China, the targets were Uighurs, a Muslim minority that has been engaged in an uprising against the Chinese state. Few believe that either the Kurds or the Uighurs are connected with global terrorism of the sort that the Security Council's actions were aimed at stopping. Instead, both are groups with local grievances.

During the past decade, the "one-size-fits-all" mandate of the Security Council has been carried out with wild inconsistency. In many cases, however, this new law has benefited those in power and enabled them to foil their domestic political opponents in conflicts that have had virtually nothing to do with 9/11. The new landscape of international public legality now puts extraordinary international legal pressure on constitutionalism and on domestic constitutional values. Repressive states have used repressive law for repressive purposes, highlighting the danger of issuing a common set of commands to an extremely diverse group of states. More than a decade after 9/11, global security law is still setting the framework for some of the most worrisome legislation around the world. ■

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Economic, Political, and Social Outcomes of Community-Driven Development

How has Afghanistan's largest development program affected democratic processes, counterinsurgency, and the position of women?

BY RUBEN ENIKOLOPOV

Each year, billions of dollars in foreign aid are directed to the developing world. Assistance comes in a variety of forms, but one particular method of delivery—community-driven development (CDD)—which came about as a response to large-scale top-down initiatives that were criticized for failing to empower aid recipients, has become especially popular. This approach emphasizes involvement of local communities in planning decisions and controlling investment of resources. Beyond benefiting communities with their involvement in planning decisions and the investment of resources, CDD is intended to encourage sustained participation through local representative institutions, thus improving social capital and local governance.

The CDD approach is particularly popular in the context of weak or fragile states, in which government bureaucracy often fails to provide public goods and services. From 1996 to 2003, World Bank lending alone for such projects rose from $325 million to $2 billion per year, reaching $30 billion in total as of 2012, toward the support of four hundred programs with CDD components in ninety-four countries. Yet, rigorous empirical evidence of CDD value remains limited.

My work with Andrew Beath from the World Bank and Fotini Christia from the Massachusetts Institute of Technology contributes to understanding the effectiveness of this approach by assessing the impact of a large-scale CDD program in Afghanistan known as the National Solidarity Program (NSP). NSP is the country's largest development program, implemented in over thirty-two thousand out of Afghanistan's thirty-nine thousand villages at a cost of over $1 billion. Funded by a consortium of international donors and administered by the Afghan national government, its aim is to both improve the access of rural villagers to critical services and to create a structure for village governance centered on democratic processes and female participation.

IMAGE COURTESY OF FOTINI CHRISTIA

The mandating of female participation by the NSP has resulted in increased male acceptance of women in public life as well as broad-based improvements in women's lives, although there is no evidence that it has affected the position of women within the family.

In that regard, a democratically elected, gender-balanced council is created in each village to determine, in consultation with local residents, which village-level development projects they would like to implement. Communities then receive grants of up to $60,000 to implement their selected projects, which range from drinking wells and irrigation canals to small bridges, roads, or micro-hydro electric generators.

A democratically elected, gender-balanced council is created in each village to determine, in consultation with local residents, which village-level development projects they would like to implement. Communities then receive grants of up to $60,000 to implement their selected projects, which range from drinking wells and irrigation canals to small bridges, roads, or micro-hydro electric generators.

To provide reliable measures of program efficacy, we employed a randomized field experiment, which provided rigorous estimates of program results across a broad range of economic, political, and social indicators. Specifically, at the start of the study half of the five hundred eligible villages were randomly selected to receive the program and another half were assigned to the next financing cycle that took place four years later.

Random assignment of villages into treatment and control groups ensured that there were no significant differences between them before the start of the program, allowing for any differences after program implementation to be attributed to the consequences of the program.

To see how these changed over time, we measured the outcomes of interest in three waves: before the start of the program, midway through its completion at the two-year mark, and after its completion at the end of four years. Since we were interested in a variety of different outcomes, ranging from access to goods and services to security and attitudes toward national government and the social status of women, we measured effects using extensive surveys administered to more than thirteen thousand respondents in each of the waves.

Our results suggest that NSP had important positive outcomes despite the pressing challenges presented by the fragile state context of Afghanistan but also proved limited in achieving a certain range of effects. Specifically, NSP-funded utilities projects delivered substantial increases in access to drinking water and electricity but infrastructure projects proved less effective. In particular, irrigation and transportation projects had little effect on crop yields or on the ability to get goods to the market. As a result, NSP had limited impact on objective economic measures such as consumption or asset ownership. Project implementation and the accompanying infusion of resources, however, delivered a short-term economic boost. This stimulus also improved villagers' perceptions of central and sub-national government as well as of foreign actors such as nongovernmental organizations and International Security Assistance Force soldiers. However, the influence of NSP on perceptions of government weakens considerably following project completion, which suggests that government legitimacy is dependent on the regular provision of public goods.

Recommended Reading: The final report for the National Solidarity Program (NSP) impact evaluation, which reports estimates of the effects of NSP across a broad range of economic, social, and institutional outcomes, was released in August 2013 and may be accessed at www.nsp-ie.org/results.html/.

NSP's participatory methods also improved acceptance of democratic processes, including increasing the number of community members who vote in national elections, the proportion of male villagers preferring elections, the frequency of meetings of representative councils, and the number of village members who are willing to challenge or change leadership decisions. We also find that the mandating of female participation by NSP—and the consequent female involvement in project implementation—results in increased male acceptance of women in public life as well as broad-based improvements in women's lives, encompassing increases in participation in local governance, access to counseling, and mobility. These and other economic, institutional, and social outcomes of NSP further drive increases in girls' school attendance and in women's access to medical services, as well as in improved economic perceptions and optimism among women in NSP villages. We found, however, no evidence that the program affects the position of women within the family.

One of the most important findings of our study is that development aid provided through NSP worked as a counterinsurgency tool. We find that the program led to a reduction in violence two years after the start of the program, although the effect becomes less pronounced two years later. Notably, this result was confined to preventing the spread of violence in villages that were not marked by insurgency at the start of the program and did not reduce insecurity in villages that were already plagued by high levels of violence before the program's introduction.

Overall our results suggest that a community-driven development program can not only improve access to basic services but also can advance certain social outcomes, such as the status of women in communities or even the level of insurgent activity. This is a very important finding, which suggests that properly designed development interventions can have a positive impact not only on economic but also on social outcomes. However, the long-term success of such interventions is likely to be dependent on continued and regularized government engagement and funding that would institutionalize the role of newly created village councils and allow them to keep serving as an important community tool to deliver public services and solve community challenges in a participatory manner. ■

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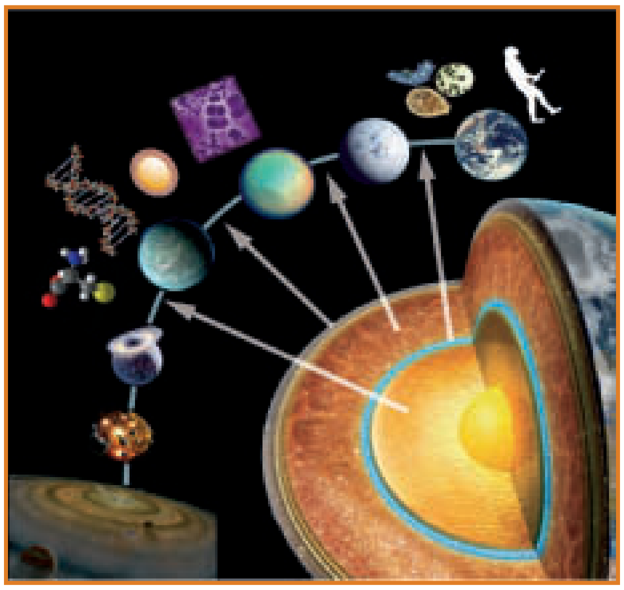
Origins of Life

Equilibrium thermodynamics explains the nature of human-made engines, but what will explain the nature of living matter?

BY PIET HUT

Young children often pose the most interesting questions. “Why are we here?” is one of them. And this question can take on many forms. One of them is “Why is there anything at all?” Another is “Why am I alive?” or “Why am I me?”

These questions are closely connected to central questions in natural science. In my opinion, there are three, and all three are concerned with origins. After all, “Why is there X?” is closely related to “Where does X come from?” So what are the most interesting puzzles about origins? I would say: the origin of matter; the origins of life; and the origin of consciousness.



EARTH-LIFE SCIENCE INSTITUTE (ELSI), TOKYO INSTITUTE OF TECHNOLOGY

Would something resembling life originate in other systems that are large enough in terms of space and time, starting with a few simple building blocks and some simple rules governing their interactions?

To put it in the form of questions: “Where did matter come from?” “How did matter become alive?” and “How did living beings develop the capacity to ask these three questions?” Fortunately, modern science is now making inroads toward providing at least some answers to some aspects of these questions, while suggesting more precise ways to pose the questions.

The first question concerns cosmology, the branch of astrophysics that studies the origin of the universe. In this area, enormous progress has been made. Thanks to very precise observations, from space as well as from the ground, the general Big Bang picture has been validated empirically as an accurate description of how the universe evolved, from a very early time, going back to at least the first microsecond after the current universe was born.

The theory of the Big Bang has a number of free parameters, most of which are now known to high accuracy. To give you a sense of the precision of those details, we can take the age of the universe. Only twenty years ago, we knew that the value was somewhere between ten and twenty billion years. However, now we know that the Big Bang happened 13.80 billion years ago, with an estimated error of less than 0.04 billion years. This implies a remarkable accuracy of better than 0.3 percent.

Of course, knowing what happened during the nearly fourteen billion years after the birth of the universe, from the first microsecond on, doesn’t mean that we know what happened deep within that first microsecond, nor does it mean that we know how and why the universe came into being. But at least we are now able to formulate the question of the origin of the universe in a much more precise way, having pushed back the uncertainty into the very first fraction of a second. With respect to the question of the origins of life, we are nowhere near anything resembling the kind of progress that cosmology has made. And the question of the origin of consciousness is even more of a mystery.

Could the origin of life be seen as a kind of phase transition, from simplicity to complexity, with organic chemistry just one specific example?

Why so? Well, we know what matter is, and the only question is where it came from. We sort-of think we know what life is, but surprisingly, we can’t agree on a definition (see, for example, http://en.wikipedia.org/wiki/Life#Definitions). In terms of consciousness, we can study electrical and chemical processes in the brain, arriving at a third-person objective description of what living matter in a brain does. But does that tell us what consciousness is? The first-person experience of consciousness is so different from any third-person description of changes in brain states that it begs the question of how and why the two are related, even if we had complete information about how they are correlated.

Coming back to the origins of life question, we can formulate it as follows. On the early Earth, how did the transition from chemistry to biology take place? Most likely, there was no specific point at which one could say: this combination of molecules in this setting was not yet alive, while in the next combination somehow life had arrived. A more reasonable guess is that there was a more gradual transition, or series of transitions, at the end of which most everyone would agree that life had been formed. Hence, the term “origins” is considered more appropriate than “origin.”

So how did geochemistry transform into biochemistry? There are three leading scenarios. As a mnemonic at least, they parallel the three human interests in shelter, food, and procreation. One school argues that it began with cell walls, forming the equivalent of little test tubes, providing shelter within which more and more complex chemical reactions could take place, building up more and more complex molecules, without their being watered down within the surrounding environment.

Another school asserts the notion that metabolism came first, in the form of a primitive network of processes that consumed food and energy, leading to modest growth of whatever the first living organisms were on Earth. A third school maintains that replication was the initial step, in the form of what is called an RNA world, where particular RNA molecules began to copy themselves before attracting more complex processes, including forms of simple metabolism, to join in the making of simple cells.

For me, there are two related questions that are at least as interesting as the question of the origins of life. One is the question “What is life?” As I mentioned earlier, nobody has ever succeeded in given a convincing definition of life, as opposed to non-living matter. You could rephrase this as “What is the essence of life?” An analogy here might be helpful.

If you had asked James Watt, in 1875, to describe the essence of steam engines, he might have given an answer in terms of pistons and wheels and pullies, or perhaps, more abstractly, in terms of pressure exerted by steam caused by heating water with fire.

It took fifty years before Sadi Carnot gave a much more abstract description (known as the Carnot cycle), in which he showed not only how steam engines actually work, but also what the potential limits were on the efficiency of steam engines. After another quarter century, the concept of entropy was introduced by Rudolf Clausius, and yet another twenty-five years later, Ludwig Boltzmann showed how the macroscopic notion of entropy is related to microscopic molecular motion.

It took a full century to reach deep insight into the principles underlying the steam engine, from Watt to Boltzmann. My guess is that it may easily take a century from James Watson and Francis Crick’s discovery of the molecular structure of DNA to arrive at a truly fundamental understanding of the nature of living matter, on a par with insights provided by equilibrium thermodynamics for human-made engines.

A further sharpening of the question of the origins of life is the question “Why life?” Whether or not, and how, life originally came into being on Earth, and possibly on other planets, there is a still deeper question of why life is possible at all. What is it about matter, as a collection of protons, neutrons, and electrons, with some relatively simple interactions between them, that given enough time it can spontaneously give rise to living organisms? Is there something specific to protons and neutrons that they can form the ninety-two elements of the periodic table that occur in nature? Is there something special about carbon chemistry that has allowed life as we know it?

In more general terms, would something resembling life originate in other systems that are large enough in terms of space and time, starting with a few simple building blocks and some simple rules governing their interactions? Could such spontaneous emergence even be a generic property of large enough relatively simple systems?

A physicist would phrase these questions in terms of phase transitions, such as the freezing of water into ice. In that case, the disordered motion of H_2O molecules in water spontaneously gives rise to the much greater form of order present in ice or in snow crystals.

Similarly, would a large enough simple system show spontaneous changes, from initial disorder to the order of living organisms? Could the origin of life be seen as a kind of phase transition, from simplicity to complexity, with organic chemistry just one specific example?

These are the kind of questions that I am currently exploring, together with some of the visitors in my Program in Interdisciplinary Studies, who often stop by for a few months, weeks, or days at a time. Several of them are affiliated with a new research center at the Tokyo Institute of Technology’s Earth-Life Science Institute (ELSI) (www.elsi.jp/), which I helped found last year as one of the Principal Investigators on the original proposal to the Japanese Ministry of Education. ELSI is now recruiting up to twenty new postdocs with backgrounds in astrophysics, geology, chemistry, biology, physics, or any other area related to the origins of life. ■

Professor Piet Hut’s research is focused on computational astrophysics, in particular multiscale multiphysics simulations of dense stellar systems; interdisciplinary explorations in the areas of cognitive science and philosophy of science centered around questions involving the nature of knowledge; and the question of the origins of life, on Earth as well as elsewhere in the universe.

Painting Time: Impressionism and the Modern Temporal Order

How quickening brushwork arose from the industrialization of time

BY ANDRÉ DOMBROWSKI

André Dombrowski, Assistant Professor at the University of Pennsylvania, began writing his second book, about impressionism's relationship to the then new techniques of time-keeping, while a Member (2012–13) in the School of Historical Studies.

It is often said that impressionism sought to make represented time and the time of representation coterminous. With its seemingly quick and unpolished touch, it gave the modern cultures of speed their first appropriately modernist forms. But art historians have rarely if ever interrogated the concrete histories and technologies of time (and time keeping) that underwrote this seismic stylistic shift or to inquire into the links between quickening brushwork and the nineteenth century's industrialization of time. This is especially remarkable given the fact that two key scientific events in the measuring of modern time—the advent of quantifiable nervous reaction time in France around 1865 and the standardization of universal time in 1884—overlap so precisely with the history of impressionism, its rise in the mid-1860s, and the turn toward postimpressionism around the mid-1880s.

I propose an intimate correlation between the new subjectivizations of impressionist picture-making and the period's growing regulation of time. Impressionism evinced an acute awareness of the particularly modern pressures of time. It chronicled the constant shifts in weather, the seasons and time of day, while heroizing the new practices of leisure time, the "time-off" from work. Proposing that the flux of visual experience could be distilled into forms compatible with Western easel painting, it nonetheless portrayed a seeming urgency of execution and a concomitant disrespect for the protocols of pictorial finish. All these figurations of freedom from temporal and pictorial constraints seemed in clear contrast to the electro-technical world of the modern clock during the so-called Second Industrial Revolution—or "The Age of Synergy" as Vaclav Smil calls the decades after 1860—and its drive toward a global telegraphic connectivity and exchange of goods. The regulation of time had been a crucial component of the Industrial Revolution from its eighteenth-century origins, especially after scheduled trains started running in the 1820s, but never before had the demand for temporal precision been as pervasive a feature of modern culture as in the age of electricity and global wiring, travel and commerce, starting in the 1860s and 1870s.

What does our critical vocabulary of the movement's embellishments of time—speed of execution, instantaneity, momentariness, presentness, and so on—evoke historically? The language of impressionism's early reception is filled with temporal metaphors that still require more careful unpacking.

Impressionism's aesthetic play with the laws and markets of time became possible only at a moment in history when the precise marking of time itself fully regulated commodity form: marketed as a coordinated system first through pneumatic and later through electrically coordinated city-wide clocks (as sold, for instance, by the Parisian *Compagnie générale des horloges pneumatiques*, which not only offered clocks but the continual upkeep of their precision as well). The style's fusion of paint and time could have the wider cultural resonance it eventually gained only once time itself became fully quantifiable and its visibility recognized as a scientific—and economic—fact of modern global life. Impressionism is one of the period's crucial aesthetic innovations born of the "product" time, deeply aware of time's new prominence in urban life and its public clocks, train schedules, and so forth. "Seven twenty-three! Only seven more minutes until soup would be served," claimed a character in Paul Alexis's novel *Madame Meuriot* (1891) as just one of the many seemingly gratuitous indications of temporal order that help structure a complicated plot of adultery.

Impressionism's relation to technology, science, industry, and modernity can be seen in its iconography—the representations of clocks in Edgar Degas's or Paul Cézanne's work or the trains that populate so many an impressionist canvas—and in its representation of leisure and industry, with the factories in the modern landscape and the lives lived away from work amidst their growing presence, as is the theme of much crucial art historical investigation, from T. J. Clark's influential work on the period to more recent studies, such as James H. Rubin's inquiry into impressionism's industrialized landscapes. But I am more interested in locating an economy of time in impressionism on a stylistic level as well as on a semantic one, what I want to call impressionism's "social forms": in its new logics of brushwork and composition, redefinitions of the standards of painting, and translations of modern experience, just as much as in its modern subject matter of industrialized culture.

Specifically, what does our critical vocabulary of the movement's embellishments of time—speed of execution, instantaneity, momentariness, presentness, and so on—evoke historically? The language of impressionism's early reception is filled with temporal metaphors that still require more careful unpacking as to the range of their sociocultural meanings: in 1883, Jules Laforgue called impressionism painting "in fifteen minutes"; Félix Fénéon affirmed that it was "four o'clock" in Georges Seurat's *A Sunday Afternoon on the Island of La Grande Jatte*; and in 1876, the critic Arthur Baignères called impressionism "a kind of telegraphic mechanism" that fixed impressions like "the letters of a dispatch on azure-colored paper." How did it come to pass that such chronometric coordinates became a central tool in the exegesis of early modernist painting even if they could not be fully confirmed visually? Why have they so often survived into our accounts of the movement as in such influential books as Richard Brettell's *Impression: Painting Quickly in France 1860–1890* (2000) or Virginia Spate's *Claude Monet: The Color of Time* (1992)?

Impressionism emerged at the precise moment when the scientific measurement of the speed of sensory transmission, of "reaction time," became possible. Claude Monet's early, oft-considered unfinished and "failed" attempts at bringing impressionism into the large-scale format of his *Déjeuner sur l'herbe* (ca. 1865) can be seen in light of "psychometry's" proof that there was no instantaneity of nervous transmission. Auguste Renoir's and Monet's depictions of the bathing spot of La Grenouillère encapsulated precise meanings of the "now" at the time, and such modern temporal frames can be seen in dialogue with the painters' pictorial demands for a more "speedy" execution. One of the most popular and trendy leisure spots of the late Second Empire, La Grenouillère became the site of contestation over definitions of the "present" and the "now" as a unit in time and the possible temporal *durée* of a phenomenon like the ever-changing experience of modernity. The collapse of an impressionist aesthetic into the postimpressionist order and systematicity of pointillism in the mid-1880s occurs at precisely the advent of global standardized time, set at the Meridian conference in Washington in 1884 with representatives from most industrialized nations present including France. George Seurat and Paul Signac's pictorial world of the synchronized "dots" of color—a pictorial innovation we generally agree first emerged in 1885—was hardly conceivable outside the frame of the universal hour and its invisible if crucial regulation of a global system of temporal and spatial units.

My study of the history of impressionism and the history of the period's construction of time engages in a new way the twinned aspirations of freedom from and fears of regulation so typical of the modern world—something that could stand as a metaphor of impressionist picture-making itself. Impressionism's high-keyed temporal anxiety—its conflation of represented time, experienced time, and the time of representation—is one of the period's most sensitive registrations of industrial time's regulatory power. ■

METROPOLITAN MUSEUM OF ART

ART INSTITUTE OF CHICAGO

Left: Claude Monet's La Grenouillère *(1869) captures the "now" as a unit in time and the ever-changing experience of modernity.*

Right: Pointillism's synchronized "dots" of color, as seen in George Seurat's A Sunday on La Grande Jatte *(1884–86), reflects the advent of a global system of temporal and spatial units.*

wormholes are not traversable, meaning it is not possible to physically travel from one side of the wormhole to the other. [3] We can think of this configuration as a pair of distant black holes. Each black hole has its own horizon. But it is a very particular pair since they are connected through the horizon. The distance from one horizon to the other through the wormhole is zero at one instant of time. Let us consider two observers, Alice and Bob, outside each of the black holes. For a brief moment in time, the horizons of the two black holes touch, then they move away from each other. Alice cannot send a signal to Bob if she stays outside the horizon of her black hole. However, Alice and Bob could both jump into their respective black holes and meet inside. It would be a fatal meeting since they would then die at the singularity. This is a fatal attraction.

Wormholes usually appear in science fiction books or movies as devices that allow us to travel faster than light between very distant points. These are different than the wormhole discussed above. In fact, these science fiction wormholes would require a type of matter with negative energy, which does not appear to be possible in consistent physical theories.

In black holes that form from collapse, only a part of the Schwarzschild geometry is present, since the presence of matter changes the solution. This case is fairly well understood and there is no wormhole. However, one can still ask about the physical interpretation of the solution with the two asymptotic regions. It is, after all, the general spherically symmetric vacuum solution of general relativity. Surprisingly, the interpretation of this solution involves the paper by Einstein, Podolsky, and Rosen (EPR) written in 1935 [1]. By the way, the EPR paper shows that Einstein really did very influential work after he came to the IAS (see article, page 13).

The EPR paper pointed out that quantum mechanics had a very funny property later called "quantum entanglement,"or, in short, "entanglement." Entanglement is a kind of correlation between two distant physical systems. Of course, correlations between distant systems can exist in classical systems. For example, if I have one glove in my jacket and one in my house, then if one is a left glove, the other will be a right glove. However, entanglement involves correlations between quantum variables. Quantum variables are properties that cannot be known at the same time; they are subject to the Heisenberg uncertainty principle. For example, we cannot know both the position and the velocity of a particle with great precision. If we measure the position very precisely, then the velocity becomes uncertain. Now, the idea in the EPR paper is that we have two distant systems; in each distant system, we can measure two variables that are subject to the uncertainty principle. However, the total state could be such that the results of distant measurements are always perfectly correlated, when they both measure the same variable. The EPR example was the following (Figure 2). Consider a pair of equal-mass particles with a well-defined center of mass, say $x = 0$, and also with a well-defined relative velocity, say $v_{rel} = v_A - v_B$. First, a small clarification. The Heisenberg uncertainty principle says that the position and the velocity cannot be known at the same time. When we have two independent dynamical variables—two independent positions and two independent velocities—then it is possible to know the position of one and the velocity of the other. Since the center of mass and relative position are independent variables, then it is indeed possible to start with the state that EPR postulated. Now for the more surprising part: let us say that two distant observers, call them Alice and Bob, both measure the positions of the respective particles. They find that if Alice measures some value x_A, then Bob should measure $x_B = -x_A$. On the other hand, if Alice measures the velocity v_A, then we know that Bob should measure the definite velocity $v_B = v_A - v_{rel}$. Of course, Alice and Bob should each make a choice of whether they want to measure the velocity or the position. If Alice measures the position and Bob the velocity, they find uncorrelated results. Note that when Alice decides to measure the position, Bob's particle, which could be very distant, seems to "decide" to have a well-defined position also. On the other hand, when Alice measures the velocity, Bob's particle "decides" to have a well-defined velocity. At first sight, this would seem to allow instantaneous communication between Alice and Bob. It would seem that Alice can encode a message of zeros and ones by deciding to measure either her particle's position or velocity and then all that Bob has to do is to see whether his particle has well-defined position or velocity. However, it is possible to show that Bob cannot "read" such a message. These correlations do not allow us to send signals faster than light.

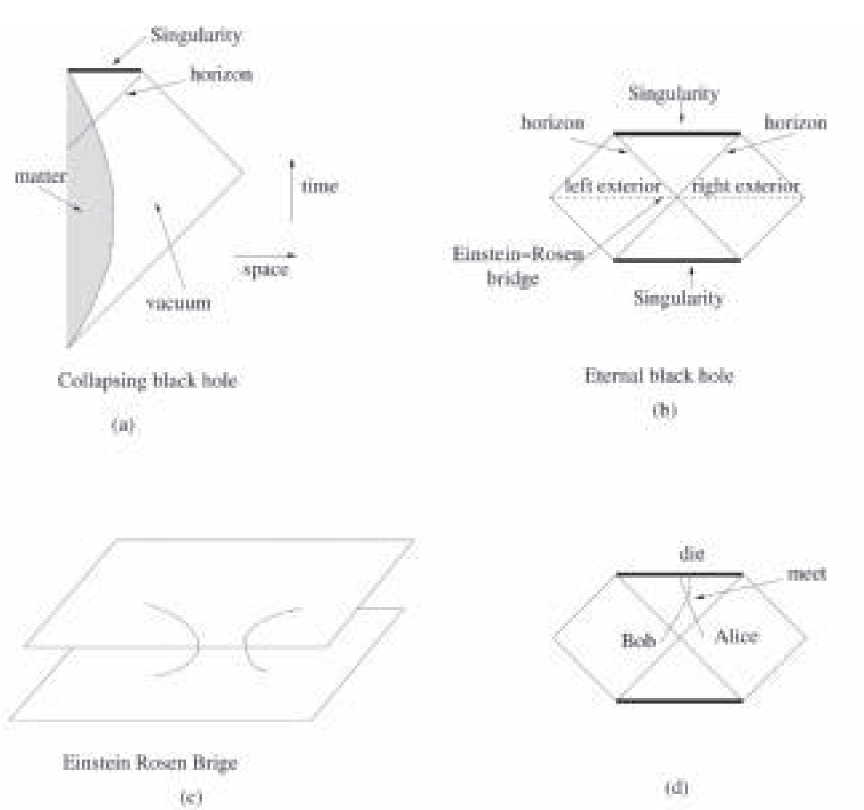


Fig. 1: In (a) we see a spacetime diagram representing a collapsing black hole. We only represent the time and radial directions. At each point in the diagrams, there is also a sphere. Forty-five degree lines represent the direction of propagation of light signals. The shaded region contains the collapsing matter. The thick line is the "singularity." Black holes that are actually formed in our universe are represented by such spacetimes. In (b) we see the diagram for the full eternal black hole. It has two asymptotically flat regions, one to the left and one to the right. Each of these regions looks like the outside of a black hole. The Einstein-Rosen bridge is the spatial section of the geometry that connects the two sides at a special moment in time. In (c) we represent the spatial geometry of the Einstein-Rosen bridge. In (d) we have Bob and Alice jump into their respective black holes and meet in the interior.

Fig. 2: The set up for the EPR experiment. We generate two particles at $x = 0$ moving with relative velocity v_{rel}. Alice and Bob are two distant observers who can choose to measure either the position or velocity of their respective particles. They do this many times, always starting from the same state. Alice finds a very random set of possible results for the measurement of the position of her particle and a similarly random set when she decides to measure the velocity. Similar results hold for Bob. However, when both Alice and Bob measure the positions, they are perfectly correlated. The same holds when they both measure the velocity.

Entanglement appears to be a very esoteric property of quantum mechanical systems. But in the past twenty years, people have found many practical uses for these correlations. Among them is the possibility of Alice and Bob communicating secretly while making sure that the NSA (National Security Agency) is not eavesdropping on the communication.

Let us now return to black holes. There is an important feature of black holes that arises when one considers them as quantum mechanical objects. In 1974, Stephen Hawking argued that quantum mechanics implies that black holes have a temperature, with smaller black holes having a higher temperature. A small enough black hole can be red-hot. In fact, one can even have a white black hole! This is a theoretical prediction that has not yet been verified experimentally because the black holes that are naturally produced by the collapse of stars are too cold for this radiation to be measurable. This thermal property of black holes has an important consequence. As we have known since the nineteenth century, temperature is due to the motion of a large number of microscopic constituents of the system. Thus, black holes should have microscopic constituents that can be in a large number of possible quantum mechanical configurations or "microstates." In fact, we think that black holes, as seen from the outside, behave as ordinary quantum mechanical systems.

One can consider, therefore, a pair of black holes where all the microstates are "entangled." Namely, if we observe one of the black holes in one particular

(Continued on page 13)

Juan Maldacena, who first came to the Institute as a Member in 1999, has been a Professor in the School of Natural Sciences since 2002. He continues to study a relationship he has proposed between quantum gravity and quantum field theories in an effort to further understand the deep connection between black holes and quantum field theories as well as connections between string theory and cosmology.

The Advent and Fallout of EPR

An IAS teatime conversation in 1935 introduces an ongoing debate over quantum physics.

"Einstein Attacks Quantum Theory" read the *New York Times* headline of May 4, 1935. The article continued:

> Professor Albert Einstein will attack science's important theory of quantum mechanics, a theory of which he was a sort of grandfather. He concludes that while it is "correct" it is not "complete." With two colleagues at the Institute for Advanced Study here, the noted scientist is about to report to the American Physical Society what is wrong with the theory of quantum mechanics. The quantum theory with which science predicts with some success inter-atomic happenings does not meet the requirements for a satisfactory physical theory, Professor Einstein will report in a joint paper with Dr. Boris Podolsky and Dr. N. Rosen.

Two years after he joined the Institute's Faculty, Einstein coauthored the referenced paper "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" with Podolsky and Rosen, generally referred to as EPR. Einstein had recruited Podolsky and Rosen as Members of the Institute in 1934. In a letter dated November 10, 1933, to Abraham Flexner, the Institute's founding Director, Einstein described Podolsky as "one of the most brilliant of the younger men who has worked and published with [Paul] Dirac."

In his application to the Institute in February 1934, Rosen (writing in the third person) described his interest in studying fundamental problems of physics.

> While it is true that a year is a short time when one is working on such problems, it is hoped that it may at least serve to provide him with a satisfactory start along the lines mentioned so that he may be able to continue the work afterward. Although the applicant is interested in independent research, he would like to carry on his work in contact with Prof. Einstein, who has kindly given his consent.

According to the late physicist Asher Peres, whose Ph.D. thesis adviser was Rosen (with whom Einstein later built the Einstein–Rosen bridge in general relativity):

> One day, at the [Institute's] traditional 3 o'clock tea, Rosen mentioned to Einstein a fundamental issue of interpretation related to entangled wave-functions. Einstein immediately saw the implications for his long-standing disagreement with [Niels] Bohr. As they discussed the problem, Boris Podolsky joined the conversation, and later proposed to write an article. Einstein acquiesced.
>
> In the winter of 1935, just prior to the publication of the EPR paper, Dirac (a Member at the time), Einstein, and Oswald Veblen (a fellow Institute Professor), wrote letters of recommendation on Podolsky's behalf to Louis T. More, Dean of the Graduate School of the University of Cincinnati, where Podolsky soon was appointed Assistant Professor of Mathematical Physics. On March 20, 1935, Einstein wrote:

> I am happy to be able to tell you that I estimate Podolsky's abilities very highly. His clear mind enables him to express every matter in the field of physics in a clear and original way. In addition, he is an independent investigator of unquestionable talent. I have just finished a piece of research with him and another colleague, and have had ample opportunity to learn to appreciate Podolsky's knowledge and ability.

Podolsky, in fact, penned the EPR paper, which quickly became a centerpiece in the debate over the interpretation of quantum theory, a debate that continues today. Einstein wasn't thrilled with the approach taken by Podolsky, who submitted the paper to *Physical Review* on March 25. In a letter dated June 19, 1935, to Erwin Schrödinger, Einstein wrote, "For reasons of language this [paper] was written by Podolsky after several discussions. Still, it did not come out as well as I had originally wanted; rather, the essential thing was, so to speak, smothered by the formalism [*gelehrsamkeit*]."

Podolsky went on to commit a grave blunder, in Einstein's view, when he leaked the advance report of the EPR findings published by the *New York Times*. The newspaper subsequently printed a statement by Einstein, in which he stated that the information "was given to you without my authority. It is my invariable practice to discuss scientific matters only in the appropriate forum and I deprecate advance publication of any announcement in regard to such matters in the secular press." According to Peres, Einstein was so upset by Podolsky's indiscretion that he never spoke with him again.—*Kelly Devine Thomas, Senior Publications Officer, kdthomas@ias.edu*

Recommended Reading: Dennis Overbye writes about the latest debates involving the quantum mechanical property of entanglement—originating with the EPR paper and arriving at Juan Maldacena's most recent findings with Leonard Susskind (see article, page 1)—in a recent *New York Times* article, "A Black Hole Mystery Wrapped in a Firewall Paradox"; visit http://ow.ly/nWftw/.

QUANTUM ENTANGLEMENT *(Continued from page 12)*

microstate, then the other has to be in exactly the same microstate. A pair of black holes in this particular EPR entangled state would develop a wormhole, or Einstein-Rosen bridge, connecting them through the inside. The geometry of this wormhole is given by the fully extended Schwarzschild geometry. It is interesting that both wormholes and entanglement naively appear to lead to a propagation of signals faster than light. But in either case this is not true, for different detailed reasons. The net result is the same: we cannot use either of them to send signals faster than light. This picture was developed through the years starting with work by Werner Israel [4]. Most recently, Leonard Susskind and I emphasized this ER=EPR connection as a way to resolve some apparent paradoxes regarding the black hole interior [5, 6].

There are several interesting lessons regarding this picture of geometry emerging from entanglement. Perhaps the deepest one is that the peculiar and strange property of quantum mechanical entanglement is behind the beautiful continuity of spacetime. In other words, the solid and reliable structure of spacetime is due to the ghostly features of entanglement. As we entangle two systems with many degrees of freedom, it seems possible to generate a geometric connection between them, even though there is no direct interaction between the two systems. ■

1 "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" Albert Einstein, Boris Podolsky, Nathan Rosen (Princeton, Institute for Advanced Study), *Physical Review* 47 (1935) 777–80.

2 "The Particle Problem in the General Theory of Relativity," Albert Einstein, Nathan Rosen (Princeton, Institute for Advanced Study), *Physical Review* 48 (1935) 73–77.

3 "Causality and Multiply Connected Space-Time," Robert W. Fuller (Columbia University), John A. Wheeler (Princeton University), *Physical Review* 128 (1962) 919–29.

4 "Thermo Field Dynamics of Black Holes," Werner Israel (Cambridge University, D.A.M.T.P.), *Physics Letters A* 57 (1976) 107–10.

5 "Cool Horizons for Entangled Black Holes," Juan Maldacena (Princeton, Institute for Advanced Study), Leonard Susskind (Stanford University, Institute of Theoretical Physics and Department of Physics), Jun 3, 2013. e-Print: arXiv:1306.0533.

6 "The Black Hole Interior in AdS/CFT and the Information Paradox," Kyriakos Papadodimas, Suvrat Raju. e-Print: arXiv:1310.6334.

The Nativist Prophets of Early Islamic Iran

The Nativist Prophets of Early Islamic Iran: Rural Revolt and Local Zoroastrianism *(Cambridge University Press, 2012) by Patricia Crone, Andrew W. Mellon Professor in the School of Historical Studies, has received numerous major awards (see page 2 for details). The book, part of which is excerpted here, examines the Iranian response to the Muslim penetration of the Iranian countryside, the revolts triggered there, and the persistence of religious ideas over two millenia in Iran.*

Monotheism had been on the rise for some six hundred years in the Near East and Mediterranean by the time the Muslims arrived, having triumphed on the Graeco-Roman side of the border and being well on the way to repeating its success on the Iranian side; but it had also been affected by paganization, in the sense of a tendency for the divine to split into an inaccessible reality and mediator figures, and for the divine to flow into this world in other forms as well. This trend is observable in Judaism in Philo (d. A.D. 50) and has been postulated for the Jews of Mesopotamia as well in this book. It is certainly observable in Christianity itself, based as it is on a great violation of the ontological rules [described above]. But the trend intensified thereafter. By the third century we see it in Judaism, Christianity, Greek and Aramaic paganism, and Gnosticism, and it still had not abated by the sixth. Everywhere there was a tendency for mediator figures to appear (and also for demons to proliferate). The heavens—an elaborate multistoried structure by now—had come to be filled with a huge number of angels. Many were just heavenly messengers without names, or on the contrary mere names for powers that magicians wished to invoke, but others were identified with attributes of God's such as his wisdom, spirit, or reason/speech (*logos*), or with deified humans such as Enoch or Jesus, and still others with former deities such as Apollo, Shamash, Bel, Nanai, or the gods of the *mushrikūn* in the Qur'ān. The mediators in heaven generated counterparts on Earth in the form of divine incarnations, emissaries, and other recipients of divine power such as messiahs, apostles, wonderworkers, spirit-bearers, and saints: these last were beginning to populate the heavens too. Christ apart, angels and saints, strictly separated from God himself, were the two forms in which Christians (and eventually Muslims) found it possible to accept a whole swarm of intermediaries between God and mankind.

Intermediaries proliferated on Earth because people hankered for direct contact with the divine, by touch, sight, or feeling, or by angelification or deification of themselves (magical recipes were available). Accounts of heavenly journeys were hugely popular across the entire religious spectrum. Everywhere people hoped to ascend to the celestial realm, at least for immortal life there after death, but preferably also for a visit in the here and now; and heavenly journeys usually involved face-to-face encounters not only with angels, but also with God himself. The guest in heaven would also be initiated into divine secrets such as the workings of the cosmos, past and future events, or the meaning of all things, and great power might be obtained on such journeys if one could accomplish them (but they were difficult and dangerous). The dominant mood was one of wanting out of this world. Above all, people wanted to get out of their own bodies, which kept them captive in the circumscribed world of mundane needs, chaining them to a daily treadmill with its endless demands, and holding them hostage to the powers that be…

fundamentals), and are often driven by "behavioral" rather than rational forces. Could both these scholars be right? Was the Nobel committee simply hedging its bets?

While one cannot read the jury's mind, its selection highlighted a central feature of economics—and a key difference between it and the natural sciences. Economics deals with human behavior, which depends on social and institutional context. That context in turn is the creation of human behavior, purposeful or not. This implies that propositions in economic science are typically context-specific, rather than universal. The best, and most useful, economic theories are those that draw clear causal links from a specific set of contextual assumptions to predicted outcomes.

So financial markets behave sometimes like Fama's theory and sometimes like Shiller's. The value of their respective theories is that they discipline our understanding of what type of financial market behavior to expect under specific conditions. Ideally, they also help us choose which model/theory we should apply in a particular conjuncture, although this happens too rarely as I will explain below. (Aptly, the third laureate, Lars Peter Hansen, was given his prize for devising statistical techniques to test whether markets behave in a fully rational fashion.)

What is true of finance is true also of other fields within economics. Labor economists focus not only on how trade unions can distort markets, but also how, under certain conditions, they can enhance productivity. Trade economists study how globalization can reduce or increase, as the case may be, inequality within and across countries. Open-economy macroeconomists examine conditions under which global finance stabilizes or destabilizes national economies. Development economists study conditions under which foreign aid does and does not reduce poverty. Training in economics requires learning not only about how markets work, but also about market failures and the myriad ways in which governments can help markets work better.

NEWSART

It is surprising that very little research is devoted in economics to what might be called economic diagnostics: figuring out which among multiple plausible models actually applies in a particular, real-world setting.

WHEN ECONOMISTS MISBEHAVE

The flexible, contextual nature of economics is both its strength and its weakness. The down side was in ample display during the buildup to the global finance crisis and its aftermath. As the world economy tumbled off the edge of a precipice, critics of the economics profession rightly raised questions about its complicity in the crisis. It was economists who had legitimized and popularized the view that unfettered finance was a boon to society. They had spoken with near unanimity when it came to the "dangers of government over-regulation." Their technical expertise—or what seemed like it at the time—had given them a privileged position as opinion makers, as well as access to the corridors of power. Very few among them had raised alarm bells about the crisis to come (Robert Shiller was one such Cassandra). Perhaps worse, the profession failed to provide helpful guidance in steering the world economy out of its mess. Economists' opinion on Keynesian fiscal stimulus never converged, ranging from "absolutely essential" to "ineffective and harmful."

Many outsiders concluded that economics was in need of a major shake-up. Burn the textbooks and rewrite them from scratch, they said.

The paradox is that macroeconomics and finance did not lack the tools needed to understand how the crisis arose and unfolded. In fact, without recourse to the economist's toolkit, we cannot even begin to make sense of the crisis. What, for example, is the link between China's decision to accumulate large amounts of foreign reserves and a mortgage lender in California taking excessive risks? It is impossible to decipher such interrelationships without relying on elements from behavioral economics, agency theory, information economics, and international economics. The academic literature is chock-full of models of financial bubbles, asymmetric information, incentive distortions, self-fulfilling crises, and systemic risk. Pretty much everything needed to explain the crisis and its aftermath was in fact in the research journals! But in the years leading up to the crisis, many economists downplayed these models' lessons in favor of models of efficient and self-correcting markets, which resulted in inadequate government oversight over financial markets. There was too much Fama, not enough Shiller.

Economists (and those who listen to them) became over-confident in their preferred models of the moment: markets are efficient, financial innovation transfers risk to those best able to bear it, self-regulation works best, and government intervention is ineffective and harmful. They forgot that there were many other models that led in radically different directions. Hubris creates blind spots. The economics of the profession was fine; it was the sociology that needed fixing.

Recommended Reading: This essay is based on a number of previously published Project Syndicate pieces by Dani Rodrik, available at www.project-syndicate.org/columnist/dani-rodrik/.

ECONOMISTS AND THE PUBLIC

Non-economists tend to think of economics as a discipline that idolizes markets and a narrow concept of (allocative) efficiency at the expense of ethics or social concerns. If the only economics course you take is the typical introductory survey, or if you are a journalist asking an economist for a quick opinion on a policy issue, that is indeed what you will encounter. But take a few more economics courses, or spend some time in advanced seminar rooms, and you will get a different picture.

Economists get stuck with the charge of being narrowly ideological because they are their own worst enemy when it comes to applying their theories to the real world. Instead of communicating the full panoply of perspectives that their discipline offers, they display excessive confidence in particular remedies—often those that best accord with their own personal ideologies.

In my book *The Globalization Paradox* (W. W. Norton, 2011), I contemplate the following thought experiment. Let a journalist call an economics professor for his view on whether free trade with country X or Y is a good idea. We can be fairly certain that the economist, like the vast majority of the profession, will be enthusiastic in his support of free trade.

Now let the reporter go undercover as a student in the professor's advanced graduate seminar on international trade theory. Let him pose the same question: Is free trade good? I doubt that the answer will come as quickly and be as succinct this time around. In fact, the professor is likely to be stymied by the question. "What do you mean by 'good?'" he will ask. "And good for whom?"

The professor would then launch into a long and tortured exegesis that will ultimately culminate in a heavily hedged statement: "So if the long list of conditions I have just described are satisfied, and assuming we can tax the beneficiaries to compensate the losers, freer trade has the potential to increase everyone's well-being." If he were in an expansive mood, the professor might add that the effect of free trade on an economy's growth rate is not clear, either, and depends on an altogether different set of requirements.

A direct, unqualified assertion about the benefits of free trade has now been transformed into a statement adorned by all kinds of ifs and buts. Oddly, the knowledge that the professor willingly imparts with great pride to his advanced students is deemed to be inappropriate (or dangerous) for the general public.

Consider some of the issues that we have to confront when we take on board just one of these complications—the redistributive consequences of globalization. To pass judgment on distributional outcomes, we need to know about the circumstances that cause them. We do not begrudge Bill Gates or Warren Buffett their billions, even if some of their rivals have suffered along the way, presumably because they and their competitors operate according to the same ground rules and face pretty much the same opportunities and obstacles. We would think differently if Gates and Buffett had enriched themselves not through perspiration and inspiration, but by cheating, breaking labor laws, ravaging the environment, or taking advantage of government subsidies abroad. If we do not condone redistribution that violates widely shared moral codes at home, why should we accept it just because it involves transactions across political borders?

Similarly, when we expect redistributive effects to even out in the long run, so that everyone eventually comes out ahead, we are more likely to overlook reshufflings of income. That is a key reason why we believe that technological progress should run its course, despite its short-run destructive effects on some. We might also want to consider the consequences for others around the world who may be made significantly poorer than those hurt at home. When, on the other hand, the forces of trade repeatedly hit the same people—less educated, blue-collar workers—and benefit the relatively wealthy abroad, we may feel less sanguine about globalization.

Too many economists are tone-deaf to such distinctions. They are prone to attribute concerns about globalization to crass protectionist motives or ignorance, even when there are genuine ethical issues at stake. By ignoring the fact that international trade sometimes—certainly not always—involves redistributive outcomes that we would consider problematic at home, they fail to engage the public debate

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properly. They also miss the opportunity to mount a more robust defense of trade when ethical concerns are less warranted.

Economics instruction suffers from the same problem. In their zeal to display the profession's crown jewels in untarnished form—market efficiency, the invisible hand, comparative advantage—economists skip over the real-world complications and nuances. It is as if introductory physics courses assumed a world without gravity, because everything becomes so much simpler that way. Downplaying the diversity of intellectual frameworks within their own discipline does not make economists better analysts of the real world. Nor does it make them more popular.

ECONOMICS HIJACKED

When the stakes are high, it is no surprise that battling political opponents use whatever support they can garner from economists and other researchers. That is what happened recently when conservative American politicians and European Union officials latched on to the work of two Harvard professors—Carmen Reinhart and Kenneth Rogoff—to justify their support of fiscal austerity.

Reinhart and Rogoff had published a paper that appeared to show that public-debt levels above 90 percent of GDP significantly impede economic growth. Three economists from the University of Massachusetts at Amherst then did what academics are routinely supposed to do—replicate their colleagues' work and subject it to criticism.

Along with a relatively minor spreadsheet error, they identified some methodological choices in the original Reinhart–Rogoff work that threw the robustness of their results into question. Most important, even though debt levels and growth remained negatively correlated, the evidence for a 90 percent threshold was revealed to be quite weak. And, as many have argued, the correlation itself could be the result of low growth leading to high indebtedness, rather than the other way around.

Reinhart and Rogoff strongly contested accusations by many commentators that they were willing, if not willful, participants in a game of political deception. They defended their empirical methods and insisted that they are not the deficit hawks that their critics portrayed them to be.

The Reinhart-Rogoff affair was not just an academic quibble. Because the 90 percent threshold had become political fodder, its subsequent demolition also gained broader political meaning. Despite their protests, Reinhart and Rogoff were accused of providing scholarly cover for a set of policies for which there was, in fact, limited supporting evidence. Clearly, better rules of engagement are needed between economic researchers and policymakers.

One approach that does not work is for economists to second-guess how their ideas will be used or misused in public debate and to shade their public statements accordingly. For example, Reinhart and Rogoff might have downplayed their results—such as they were—in order to prevent them from being misused by deficit hawks. But few economists are sufficiently well attuned to have a clear idea of how the politics will play out. Moreover, when economists adjust their message to fit their audience, the result is the opposite of what is intended: they rapidly lose credibility. This is clearly what has happened in the globalization debate, where such shading of research is established practice. For fear of empowering the "protectionist barbarians," trade economists have been prone to exaggerate the benefits of trade and downplay its distributional and other costs. In practice, this often leads to their arguments being captured by interest groups on the other side—for example, global corporations that seek to manipulate trade rules to their own advantage. As a result, economists are rarely viewed as honest brokers in the public debate about globalization.

SO WHAT KIND OF SCIENCE IS ECONOMICS?

The firestorm over the Reinhart–Rogoff analysis overshadowed what in fact was a salutary process of scrutiny and refinement of economic research. Reinhart and Rogoff quickly acknowledged the spreadsheet mistake they had made. The dueling analyses clarified the nature of the data, their limitations, and the difference that alternative methods of processing them made to the results. Ultimately, Reinhart and Rogoff were not that far apart from their critics on either what the evidence showed or what the policy implications were.

So the silver lining in this fracas is that it showed that economics can progress by the rules of science. No matter how far apart their political views may have been, the two sides shared a common language about what constitutes evidence and—for the most part—a common approach to resolving differences.

Economics, unlike the natural sciences, rarely yields cut-and-dried results. Economics is really a toolkit with multiple models—each a different, stylized representation of some aspect of reality. The contextual nature of its reasoning means that there are as many conclusions as potential real-world circumstances. All economic propositions are "if-then" statements. One's skill as an economic analyst depends on the ability to pick and choose the right model for the situation. Accordingly, figuring out which remedy works best in a particular setting is a craft rather than a science.

Recommended Viewing: "Past, Present, and Future of Economic Convergence," a lecture given by Dani Rodrik at the Institute in October, may be viewed at http://video.ias.edu/2013-10-25-rodrik/.

One reaction I get when I say this is the following: "how can economics be useful if you have a model for every possible outcome?" Well, the world is complicated, and we understand it by simplifying it. A market behaves differently when there are many sellers than when there are a few. Even when there are a few sellers, the outcomes differ depending on the nature of strategic interactions among them. When we add imperfect information, we get even more possibilities. The best we can do is to understand the structure of behavior in each one of these cases, and then have an empirical method that helps us apply the right model to the particular context we are interested in. So we have "one economics, many recipes," as the title of one of my books puts it (*One Economics, Many Recipes: Globalization, Institutions, and Economic Growth*, Princeton University Press, 2007). Unlike the natural sciences, economics advances not by newer models superseding old ones, but through a richer set of models that sheds ever-brighter light at the variety of social experience.

It is surprising, therefore, that very little research is devoted in economics to what might be called *economic diagnostics*: figuring out which among multiple plausible models actually applies in a particular, real-world setting. Economists understand well the theoretical and empirical predicates of, say, Fama's or Shiller's models; but they lack systematic tools to determine conclusively whether it is one or the other that best characterizes Wall Street today or mortgage markets in 2007, for example. When they engage the real world, this leads them to render universal judgments rather than conditional ones—picking one model over the other instead of navigating amongst them as the circumstances require. The profession places a large premium on developing new models that shed light on as yet unexplained phenomena; but there seems little incentive for research that informs how appropriate models and remedies can be selected in specific contexts. My colleagues and I have brought such ideas to bear on problems of growth policy in developing countries. But clearly this ought to be part of a much more general research agenda. Over time, of course, good economists develop a knack for performing the needed diagnostics. Even then, the work is done instinctively and rarely becomes codified or expounded at any length.

Unfortunately, empirical evidence in economics is rarely reliable enough to settle decisively a controversy characterized by deeply divided opinion—certainly not in real time. This is particularly true in macroeconomics, where the time-series data are open to diverse interpretations. Those with strong priors in favor of financial market efficiency, such as Eugene Fama, for example, can continue to absolve financial markets from culpability for the crisis, laying the blame elsewhere. Keynesians and "classical" economists can continue to disagree on their interpretation of high unemployment.

But even in microeconomics, where it is sometimes possible to generate precise empirical estimates using randomized controlled trials, those estimates apply only locally to a particular setting. The results must be extrapolated—using judgment and a lot of hand waving—in order to be applied more generally. New economic evidence serves at best to nudge the views—a little here, a little there—of those inclined to be open-minded.

"One thing that experts know, and that non-experts do not," the development economist Kaushik Basu has said, "is that they know less than non-experts think they do." The implications go beyond not over-selling any particular research result. Journalists, politicians, and the general public have a tendency to attribute greater authority and precision to what economists say than economists should really feel comfortable with. Unfortunately, economists are rarely humble, especially in public. And it does not help that what gets academic economists ahead in their career is cleverness, not wisdom. Professors at top universities distinguish themselves not by being right about the real world, but by devising imaginative theoretical twists or developing novel evidence. If these skills also render them perceptive observers of real societies and provide them with sound judgment, it is hardly by design.

So economics is both science and craft. Ironically, it is the neglect of the craft element—aiming to elevate economics' status as science—that occasionally turns it into snake oil. ■

Political economist Dani Rodrik joined the Institute as Albert O. Hirschman Professor in the School of Social Science in July. His work bridges the realms of theory and public policy by combining rigorous research with an innovative examination of ideas across the field of economics from the consequences of globalization to the role of national institutions, the challenges of inequality, and the tensions between the market and the state. His current research centers on the future of economic growth and the role of ideas in political economy.

me the purest representative of pure abstraction, whatever that is supposed to be. This interpretation was in fact reinforced by a groundbreaking essay on the artist's French years, written by John Coplans, then chief editor of *Artforum*. It was one of the first things I read when I arrived in America as an exchange student, in the summer of 1969. Coplans, in this excellent article, had said nothing of the "figurative" origin of the many works he was describing (and publishing for the first time). So I was utterly dumbfounded when I read the expanded, or rather rewritten, version of this text in the monograph he published only two years later, in 1971. I felt literally betrayed (by Coplans certainly but even more so by the artist himself) when I read about the "real" sources of the pictures, which had been reproduced in the book and which I had greatly admired. Too many art historians were always ready to deny the existence of abstraction, reading abstract paintings as if they were little rebuses one could simply decode just as the iconologist decodes the "hidden, textual meaning" of a Renaissance painting. I found it devastating that an artist whom I had always deemed a champion of abstraction would unabashedly admit that the three horizontal bands of a multipanel painting in fact "referred" to the colors of fields seen from a train (*Train Landscape*, 1952–53), that the black lines on a folded screen were the "rendition" of the cast shadows of a railing on a metallic stairway (*La Combe II*, 1950–51), or that his first masterpiece, earlier known as *Construction—Relief in White, Grey and White*, was now to be re-baptized *Window, Museum of Modern Art, Paris* (1949), since indeed it was the most exact duplicate, in reduced size, of one of the windows of the old, pre-Centre Pompidou, Musée National d'Art Moderne.

Feeling betrayed, I sulked for a while, like teenagers do, and then moved on to other things, forgetting about Kelly's high treason but also not paying as much attention to his work as I should have for many years. Then, suddenly, while I was teaching at the Johns Hopkins University in Baltimore, I was plunged back into Kelly-land when visiting the touring retrospective exhibition of his drawings organized by Diane Upright, which came to the Baltimore Museum of Art in 1988. It is then that I really discovered Kelly's early graphic production. My teenage militancy about "pure abstraction" had vanished long ago (I had become an art historian in the meantime, and I knew by then that this was a very inept notion). Seeing the drawings, and thus being offered a glimpse at the process of formation of the paintings, I realized that the "figurative" source of many of the French pictures did not amount to a stylization or distillation of a spectacle seen in the world. I did not understand exactly why this was so, but I was determined to find out.

© ELLSWORTH KELLY

Window of the Museum of Modern Art, Paris, left, and Kelly's re-baptized Window, Museum of Modern Art, Paris *(1949)*

In late 1989–early 1990, I was asked to write an essay for the catalogue of the exhibition of Kelly's French years (1948–54) at the National Gallery of Art in Washington and the Galeries du Jeu de Paume in Paris—an invitation I immediately accepted. This was soon followed by a first visit to Kelly's studio in Spencertown (upstate New York), and then many others, and it is during the yearlong, intermittent discussion we conducted on his Parisian works, that I gradually came to understand the function of the "figurative" origin of many of the French paintings and reliefs—how it had nothing to do with representation but rather with a non-compositional system, which I call the "transfer," and, in turn, how this relates to other non-compositional strategies in his work of this period. In short, I was finally able to absolve Ellsworth from the "high crime and misdemeanor" I had been accusing him of as a teenage prosecutor. The intellectual, visual, and affective pleasure I took in granting this absolution was only the beginning of a wonderful friendship.

I think there is no better introduction to Kelly's work than his earlier years in Paris, especially when it comes to understanding why things that look apparently very simple are in fact much more complex than they seem. This is something that we easily accept from science—no one doubts that the hyper-simple equation $E=mc^2$ is the tip of an immensely complicated iceberg—but we usually have a harder time accepting it from art.

Kelly arrived in Paris in October 1948, on the G.I. Bill. He had studied two years at the Boston Museum School and had grown fed up with painting nudes in live model classes day in and day out. Ironically, he had to register with the École des Beaux-Arts in order to get his monthly check, and paint one more nude to be accepted: he did it effortlessly, but that was his farewell to the traditional course and he never set foot again in the school (where, it was his good luck, no one took attendance!). He had grown fascinated by medieval art while in Boston, and his first months in France were spent visiting as many sites of Romanesque architecture as he could, on a limited budget, or in taking refuge from the cold at the Byzantine Institute, an outpost from Harvard located next to his hotel, where he looked at illustrated manuscripts as well as reports about the conservation of Hagia Sophia's mosaics.

Kelly soon began exploring ways in which he could make a painting without having to invent a composition, without having to involve his subjective taste or agency, without having to decide where to place things and in which order on his canvas. Now, there are several reasons why a young artist working in Europe at this moment of history should want to do that, which amounts to deflating his ego. As I see it, it has a lot to do with his disaffection for the romantic and modernist conception of art as self-expression, as a marker of one's authorship. Three factors have to be taken into consideration here. One is personal and has directly to do with Kelly's interest in medieval and, in particular, Romanesque architecture, which he took to be the work of utterly anonymous craftsmen: it is a different kind of romanticism that is at work here. The two other factors are contextual. First, World War II had just come to a close. In the immediate aftermath of the Holocaust and Hiroshima, it comes as little surprise that young painters would ask: what does it mean to be an artistic subject, an author, at the very moment when the humanity of any individual has been cast in doubt by the massive demonstration of the inhumanity of our whole species? Second, any artist trying to affirm his selfhood in postwar Paris could not but have been sensitive to the fact that the road was blocked by a monster, by a kind of minotaur that was eating alive anyone approaching, a monster that had already "invented everything," or so it was thought at the time. This monster was Picasso and his gigantic output of perhaps as many as 50,000 images had claimed as his all the space of inventiveness. If you started out by erasing yourself, your personality, your genius, and the like, if you started out by pretending you were not there, nobody would be able to come and say that Picasso did it better. There was one thing Picasso did not know how to do and that was how to erase himself, how not to invent, how not to compose.

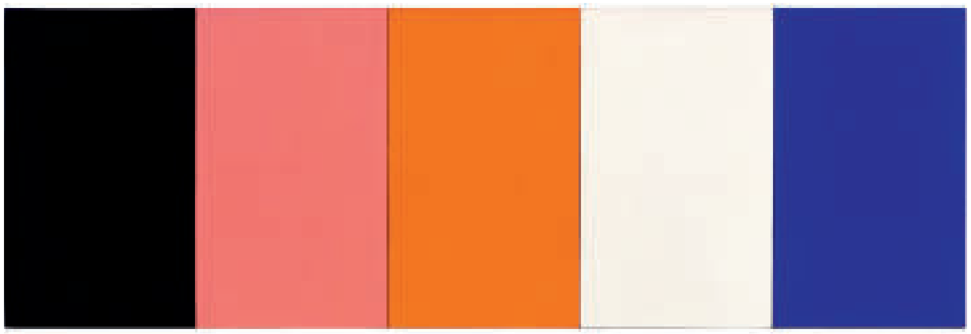
So, throughout his stay in France, Kelly would systematically explore several strategies of not–inventing, of not–composing, of not taking decisions. He applied himself to "invent ways not to invent," and he found out that the number of possibilities were limited. He came up with five, although he fully exploited only four at the time (keeping in reserve the fifth, which would only become his landmark much later). The first, "transfer," which I mentioned earlier, is very simple: rather than composing ex nihilo, the artist selects in the world at large a patterned and flat surface that he reproduces as such on his canvas. He does not *represent* it, but transfers it, as one would do a rubbing of a tombstone inscription (this technique was used by archaeologists before the invention of photography—it is at least 2,000 years old in China). Although the line separating a representation and a transfer is materially very thin, it is conceptually a major one. In addition to transfer, there would also be chance (*November Painting*, 1950), the grid (*Color for a Large Wall*, 1951), and the monochrome panel as unit (*Painting for a White Wall*, 1952). The fifth one, which I call the "silhouette" (*White Plaque*, 1951–55), encompasses his numerous shaped canvases and many reliefs from the early seventies to this day, as well as many of his prints, such as the ones that hang in the Institute's Dilworth Room. Now these non-compositional strategies are not unique to Kelly (though he was certainly the first to use the "transfer" so forcefully), but what is unique to him is that he used them all in Paris in relatively short succession. They yielded formal results that were so diverse—and Kelly was so productive—that the Ariadne's thread of non-compositionality that linked almost all the works he produced in France was completely missed, even by his greatest admirers, until quite recently.

Kelly's diversity does not mean that he ever abandoned a strategy after having stumbled upon the next one as its dialectical offspring. Just as he kept my teenage fan letter, Kelly keeps everything in store, or on his back burner, happy to return to anything he suddenly fancies in his immense repertoire, whenever he feels like it. A painting, or rather a relief, dating from 2002, is based on a piece of folded paper he picked up in the streets around 1955. A drawing in pencil, dating from 1978, is the source of a green shaped canvas in 1986, which he then took as a basis for several prints in 2001 (some of which are in the Dilworth Room), and again for a two panel relief (as late as last year). Kelly's remarkably free attitude toward his past oeuvre, this capacity to revive any of it at any moment, without any chronological consideration for development, or so it seems at first at least, is something that has often puzzled critics. But such a puzzlement, which is closely linked to the diversity of Kelly's production in France, ought to disappear once we understand why these early years are so crucial: it is the time when the artist elaborated his fundamental *matrix*, to use the expression used by my friend and fellow Kelly admirer Benjamin Buchloh. This matrix is the sum of the four and then five strategies that I identified. One could even say that it is the *product* rather than the sum of these strategies, for the taxonomy I proposed is porous.

In hindsight, it might seem very strange that Mondrian, the twentieth-century master of compositional balance if there is one, at least during the "classical phase" of neo-plasticism (until 1932), would have been invoked as the pictorial mentor of young Kelly, the enfant-terrible of non-composition. But the reason might be that the production of both artists faced—and still faces, to some extent—a common misinterpretation in which the abstractness of their works is denied, in which their works are seen as figurative or representational. Kelly's works enact a very different concept of abstraction than Mondrian's since it can encompass the transfer within its matrix; these works are essentially abstract nevertheless, and certainly not representational.

But even for works that contain some imagery, it is often a quasi-random secondary effect, a byproduct of Kelly's various work processes. *Tricot* and *Maillot Jaune* of 1957, for example, are based on a sketch of what Kelly was seeing, while sitting in an armchair, through the aperture of a window in his studio. He remembers it as an advertisement for Nickerbocker bier on a wall on the other side of the street (once again it is a flat pattern that caught his eye, a pattern he could easily transfer). It is only after the fact that he associated these shapes with the image of a tank-top and thought the association droll enough to convey it in the title of these two works. In other words, Kelly does not need imagery, but he does not shun it either: the grid is as much already-made (as a common trope of modernism) as the window of the Musée National d'Art Moderne. As already-made material, they all are grist for his voracious mill, fuel for his production engine, the matrix, which is an endlessly open system. So open, in fact, that it is often something in the world at large that suddenly begins to look Kelly-like. Any work of art by another artist (as well as a past one by himself, but that is rarer) can be submitted to the same dissolution of its identity and become prey to the matrix. Visiting an exhibition of paintings with Kelly is often to be alerted by him to this or that particular shape (generally interstitial) in a picture, or to this or that color combination. These are shapes or color combinations that one has failed to notice because, in order to perceive them one has to forget the image—something Kelly can do effortlessly, because the real background against which these shapes and color combinations stand out for him is not the picture from which his perception excerpts them but the vast mental storage in which he keeps everything his matrix has produced, including, as I mentioned before, tiny little sketches made years before for paintings, reliefs, or sculptures that were not realized. I remember specifically joking with him, while visiting an exhibition of van Gogh's portraits in his company and hearing him associate a detail of one of the canvases on view to one of his recent works, that he should make sure to remember that van Gogh had not copied him. (Though in fact one could say that van Gogh is in debt to Kelly—not van Gogh the long-dead man, but van Gogh the oeuvre *as we see it now*—benefiting from Kelly's work as well as from that of many other artists of the twentieth-century. But that is the story of modernism as a whole.)

As I mentioned at the outset, Kelly was at first shy about revealing the "sources" of his transfers—as a young, insecure artist, he felt that people would not understand his quest for impersonality, for non-agency. Then, during the heyday of Minimalism, in the 1960s, and in order to differentiate himself from the younger artists of this movement, he revealed his method (in the Coplans book), which eventually led to the misconception that is rampant today (to the artist's regret) and which I am trying to fend off. Was it a mistake, via Coplans, to have brought us in the loop? I do not think so, for in revealing the sources of his transfers, Kelly gave us the opportunity to understand that his quest had nothing to do with representation but with denaturalization, defamiliarization. The transfer is an index, in the semiotic conception of the term—it implies a relation of co-presence, at some point, between the sign and its referent (just as a footprint in the sand tells that a human being has been there). But in Kelly's transfers this referenciality of the sign is denied or at least not considered of the slightest interest. He likes shadows or reflections for their odd shapes, and the fact that these shapes are already-made, but is not concerned by the possibility of inferring from them what it is that they are shadows or reflections of.



Painting for a White Wall *(1952)*

This severing of the physical link between referent and indexical sign—which amounts to the splitting of the indexical sign from its usual function of communication—is what happens almost by itself in the particular mode of transfer that is cropping, as in *Maillot Jaune* and *Tricot*. Kelly's use of cropping has nothing to do with this paean to the subjective and transitory nature of experience—especially since, as one must always remember, what he crops is always flat (if it involves the visual field, and not, as is most often the case, a particular surface in it, it is the visual field as perceived with only one eye). More importantly, perhaps, is the fact that the cropping is itself an involuntary accident, almost like a hiccup or a Freudian slip of the tongue—the sudden "apparition" of a shape as it strikes a chord for being unrecognizable, for being recognized as something the artist consciously knows it is not. Either this shape echoes something already caught in the web of the matrix, or it appeals to Kelly for its potentiality as a score for a new piece, but a score whose material performance in the real world, an "already-made" unperceived by anyone but him, is only the material proof that it can, indeed, exist on its own. The process by which the "already-made" shape is suddenly available to Kelly—while it escapes most of us—is one of defamiliarization, of what the Russian formalists called *ostranenie*. It came upon the young Kelly years before he became an artist, and the strong memories he has about several childhood experiences is perhaps the reason his work remains so fresh. I'll quote two such memories, but there are many more:

> I remember that when I was about ten or twelve years old I was ill and fainted. And when I came to, my head was upside down. I looked at the room upside down, and, for a brief moment I couldn't understand anything until my mind realized that I was upside down and I righted myself. But for the moment that I didn't know where I was, it was fascinating. It was like a wonderful world.

And this, recalled by Hugh Davies, Director of the San Diego Museum of Contemporary Art:

> On Halloween night in 1935, in rural Oradell, New Jersey, the twelve-year-old Ellsworth Kelly was trick-or-treating with friends in their neighborhood after dark. Upon approaching a house from a distance, he said: "I saw three colored shapes—red, black, and blue—in a ground-floor window. It confused me and I thought: 'What is that?' When I got close to the window, it was too high to look in easily and I didn't want to be peeking. I was very curious and came at the window obliquely, and chinned myself up, only to look into a normal furnished living room. When I backed off to a distance, there it was again. I now realize that this was probably my first abstract vision—something like the three shapes in your *Red Blue Green* painting."

The cropped view of a bourgeois interior seen by the young Kelly as peeping Tom is not the "source" of the San Diego painting. But these recollections offer perfect examples of the kind of defamiliarization allowed by the matrix, a kind of defamiliarization wonderfully analyzed by Maurice Merleau-Ponty in the *Phenomenology of Perception*, when he wrote that "to put an object upside down is to remove its signification from it" and noted how difficult it is, when walking along an avenue, "to see the spaces between the trees as things and the trees themselves as background."

Of course, Kelly's initial quest for impersonality ultimately failed—nothing is more recognizable than a work of his, and nothing is more idiosyncratic than what he picks up as foil for his art in the spectacle of the world at large. In doing so, he teaches us that there are many more ways to see than we are apt to admit. His art, among other things, is an injunction to explore in our own terms an expanded field of vision. ■

Yve-Alain Bois, Professor in the School of Historical Studies since 2005, is a specialist in twentieth-century European and American art. He is currently working on several long-term projects, including a study of Barnett Newman's paintings, the catalogue raisonné of Ellsworth Kelly's paintings and sculptures, and the modern history of axonometric projection. This article was excerpted from a talk Bois gave to the Friends of the Institute for Advanced Study in the Institute's Dilworth Room, where several Kelly prints on loan from the artist are on display.

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Dreams of Earth and Sky
A Celebration for Freeman Dyson

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Juan Maldacena
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Yve-Alain Bois
Ellsworth Kelly's Dream
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