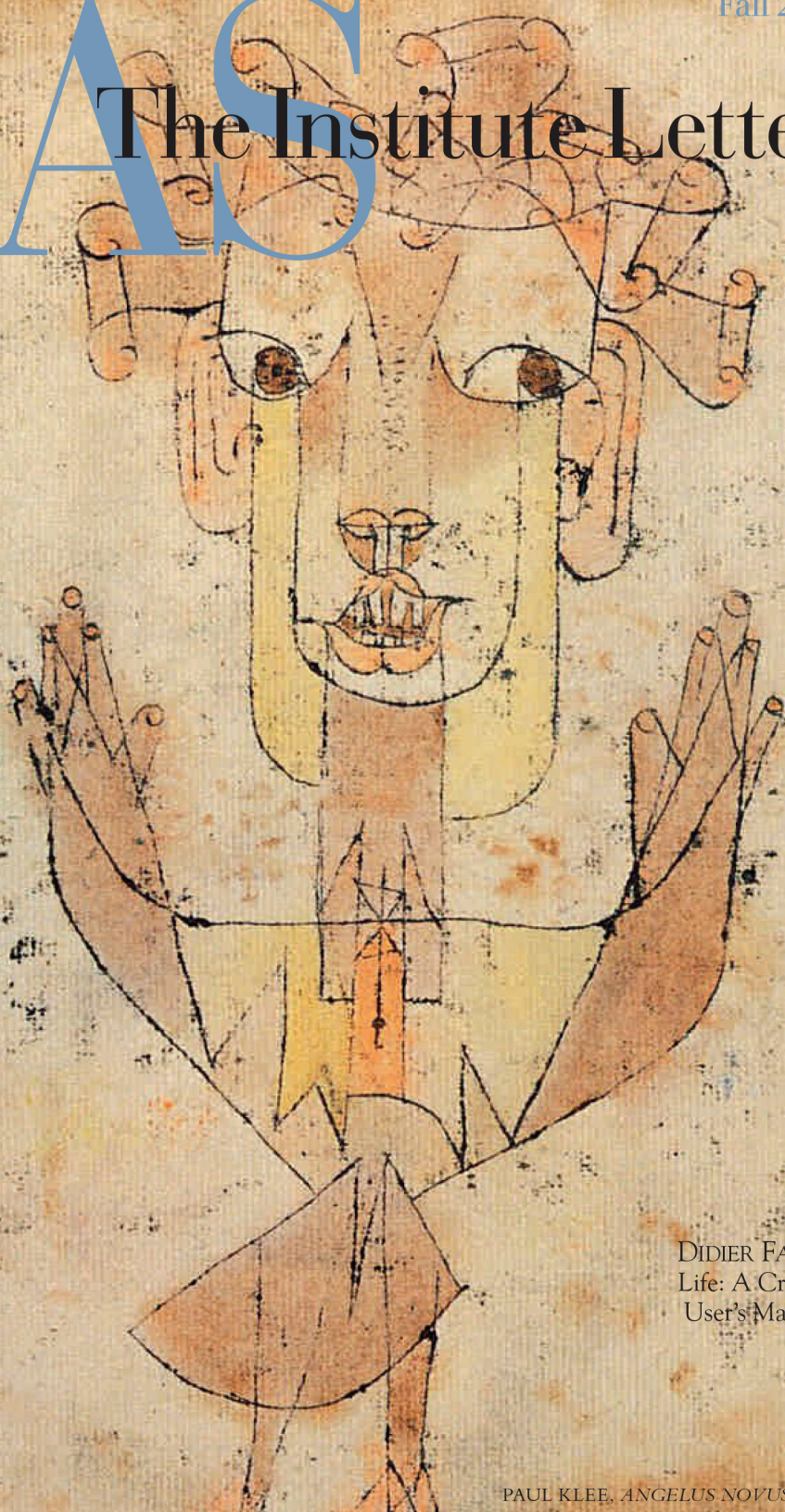


Fall 2018

# IAS

## The Institute Letter



DIDIER FASSIN  
Life: A Critical  
User's Manual

PAUL KLEE, *ANGELUS NOVUS*, 1920

AKSHAY VENKATESH  
The Topology of Locally  
Symmetric Spaces

JOAN WALLACH SCOTT  
The Persistence of  
Gender Inequality

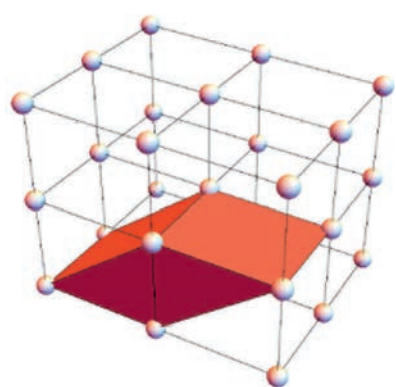
MYLES W. JACKSON  
The Porous Boundaries  
Between Science and Culture





## What Information Might the Topology of Locally Symmetric Spaces Contain?

*Exploring a crossroads for many different strands of mathematical thought*



A basic cell

BY AKSHAY VENKATESH

In 2017–18, I led a special program about *analysis and topology on locally symmetric spaces* as a Distinguished Visiting Professor in the School of Mathematics. Locally symmetric spaces are the home of the Langlands program—a set of overarching and interconnected conjectures connecting representation theory to number theory, first proposed in 1967 by Robert Langlands, now Professor Emeritus in the School of Mathematics. These spaces have become a crossroads for many different strands of mathematical

thought, and the special program placed particular focus on two of these areas:

- *Analysis* on locally symmetric spaces. The motivation to study this comes both from the Langlands program, and from analytic number theory. The techniques are drawn from representation theory and analysis on manifolds, among other fields.
- *Topology* of locally symmetric spaces. Here the subject is guided again by a

*(Continued on page 16)*

## Science and Culture: From Gene Patenting to Physics, Technology, and Public Policy

*How can the histories of controversies affect decisions being made today?*

BY MYLES W. JACKSON

My work in the history of science probes the porous boundaries between science and culture over the past two centuries. Much of it gestures toward the role of history in public policy. I am interested in having the historian at the table while a scientific controversy is ongoing. We historians are rather good at illustrating that controversies have histories: how we arrived at where we are today is very informative. There have always been, and always will be, alternatives. The types of questions I am interested in investigating include: how stable are the concepts of ownership and knowability over time, extended to the molecular level of DNA? What has been the influence of natural scientists, engineers, and scientific instrument makers on musical aesthetics from the early nineteenth century to the rise of computer music? How have their interactions changed the relationships between composer, performer, and musical instrument? How do partisan beliefs intermingle with the specialization of technical and scientific knowledge, social status, and the politics of labor?

*(Continued on page 14)*



## Life: A Critical User's Manual

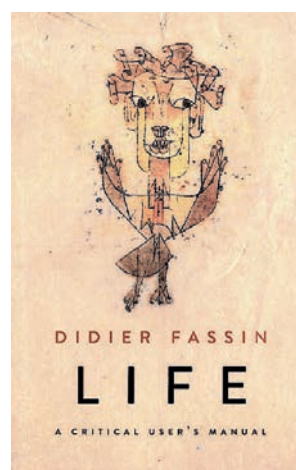
*A reflection on the treatment of human lives in contemporary society*

BY DIDIER FASSIN

“Life is a term, none more familiar. And one almost would take it for an affront, to be asked what he meant by it,” writes John Locke. But he immediately adds: “And yet, if it comes in question, whether a plant, that lies ready formed in the seed, have life; whether the embryo of an egg before incubation, or a man in a swoon without sense or motion, be alive, or no? It is easy to perceive, that a clear distinct settled idea does not always accompany the use of so known a word, as that of life is.”

For Locke, then, the problem is above all that of determining the limits of life: its indistinct beginning in the seed or the egg (around which arguments continue today, in debates about voluntary termination of pregnancy), and its uncertain end in unconsciousness without feeling or movement (questions that would be subsequently raised around the recognition of brain death).

But the attempt to define “life” also raises concerns of a different order, bound up with the multitude of meanings encompassed by the word itself. It denotes at once a property of organized beings, a set of biological phenomena, a time that elapses between birth and death, and a range of events that fill this temporal space, to say nothing of metonymic or metaphorical uses when we refer to the lives of great men, or the life of objects. Are we talking about the same thing in



each case? Is the life of a human being a fact of the same order as the life of the cells that constitute it? To be sure, the commonsense understanding does not tangle itself up in complications, and everyone understands more or less what is meant, amid the multifarious senses of the term, by expressions such as life sciences, life expectancy, life in the country, or the life of ideas, in each of which the word has a different meaning. The same cannot be said, however, of philosophers, who appear at an impasse when attempting to consider life as conceived, for example, by a biologist together with life as interpreted by a novelist.

The problem is articulated with clarity by Georges Canguilhem: “Perhaps it is not possible, even today, to go beyond this first notion: any experiential datum that can be described in terms of a history contained between its birth and its death is alive, and is the object of biological knowledge.” This seems a simple definition. Yet it brings together quite heterogeneous elements, which highlight a semantic tension. Knowledge and experience, biology and history: this is the great dualism inherent in life. And Hannah Arendt pointed to a similar duality: “Limited by a beginning and an end, that is, by the two supreme events of appearance and disappearance within the world, it follows a strictly linear movement whose very motion nevertheless is driven by the motor of biological life which man shares

*(Continued on page 12)*



# News of the Institute Community

NICOLA DI COSMO, Luce Foundation Professor in East Asian Studies in the School of Historical Studies, has co-edited *Empires and Exchanges in Eurasian Late Antiquity: Rome, China, Iran, and the Steppe, ca. 250–750* (Cambridge University Press, 2018), with MICHAEL MAAS, Member (2000–01) and Visitor (2011) in the School.

DIDIER FASSIN, James D. Wolfensohn Professor in the School of Social Science, has authored *Life: A Critical User's Manual* (Polity, 2018) and *The Will to Punish* (Oxford University Press, 2018). Additionally, two of Fassin's books were translated: *Por una repolitización del mundo. Las vidas descartables como desafío del siglo XXI* (translated by Horacio Pons) (Siglo veintiuno, 2018) and *La ragione umanitaria. Una storia morale del presente* (translated by Lorenzo Alunni) (Derive Approdi, 2018).

PATRICK J. GEARY, Andrew W. Mellon Professor in the School of Historical Studies, has been named a corresponding member of the German Archaeological Institute. Additionally, Peking University Press has published *历史记忆与书写*, a Chinese translation of Geary's essay "History, Memory, and Writing."

The University of Maryland Department of Physics and Condensed Matter Theory Center have awarded the 2018 Richard E. Prange Prize and Lectureship in Condensed Matter Theory and Related Areas to JUAN MALDACENA, Carl P. Feinberg Professor in the School of Natural Sciences. Additionally, the Albert Einstein Society has awarded Maldacena the 2018 Albert Einstein Medal.

SABINE SCHMIDTKE, Professor in the School of Historical Studies, has edited *Studying the Near and Middle East at the Institute for Advanced Study, Princeton, 1935–2018* (Gorgias Press, 2018). Additionally, Schmidtke has prepared for publication and introduced *Materials for the Intellectual History of Imāmi Shī'ism in the Safavid Period: A Facsimile Edition of Ms New York Public Library, Arabic Manuscripts Collections, Volume 51985A* (Gorgias Press, 2018), and has authored *Traditional Yemeni Scholarship amidst Political Turmoil and War: Muḥammad b. Muḥammad b. Ismā'il b. al-Muṭahhar al-Manṣūr (1915–2016) and His Personal Library* (UCO Press, 2018).

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Questions and comments regarding the *Institute Letter* should be directed to Kelly Devine Thomas, Editorial Director, via email at [kdthomas@ias.edu](mailto: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/publications](http://www.ias.edu/publications).

Articles from issues of the *Institute Letter* are available online at [www.ias.edu/ideas](http://www.ias.edu/ideas).

To receive monthly updates on Institute events, videos, and other news by email, subscribe to *IAS eNews* at [www.ias.edu/enews](http://www.ias.edu/enews).

The American Philosophical Society has elected to its membership RICHARD TAYLOR, Robert and Luisa Fernholz Professor in the School of Mathematics; AVISHAI MARGALIT, Professor (2006–11) in the School of Historical Studies; and MARGARET LEVI, former Institute Trustee; along with four former Members.

The National Academy of Sciences has elected to its membership MATIAS ZALDARRIAGA, Professor in the School of Natural Sciences, and SANJEEV ARORA, Visiting Professor in the School of Mathematics, along with five former Members.

GILES CONSTABLE, Professor Emeritus in the School of Historical Studies, has been named a Chevalier de la Légion d'honneur of France. Additionally, Forough Publications has published a Persian edition of *Sacrilege and Redemption in Renaissance Florence: The Case of Antonio Rinaldeschi*, originally published in 2005 by Constable and WILLIAM J. CONNELL, Member (2002–03) in the School.

The National Space Society has awarded the Robert Heinlein Memorial Award to FREEMAN J. DYSON, Professor Emeritus in the School of Natural Sciences.

The Graduate Institute of Geneva has awarded the 2018 Edgar de Picciotto International Prize to JOAN WALLACH SCOTT, Professor Emerita in the School of Social Science, for research that has improved our understanding of global challenges and influenced the decisions of policymakers.

MICHAEL WALZER, Professor Emeritus in the School of Social Science, has co-edited *The Jewish Political Tradition: Volume III: Community* (Yale University Press, 2018).

The Shaw Prize Foundation has awarded the 2018 Shaw Prize in Mathematical Sciences to LUIS CAFFARELLI, Professor (1986–96) and Member (2009) in the School of Mathematics, for groundbreaking work on partial differential equations.

Universiteit Leiden has selected ROBBERT DIJKGRAAF, Director and Leon Levy Professor, to receive an Honorary Doctorate, for scientific work and leadership as a science communicator.

The American Historical Association has awarded the 2018 Premio del Rey to MICHELLE ARMSTRONG-PARTIDA, Member in the School of Historical Studies, for *Defiant Priests: Domestic Unions, Violence, and Clerical Masculinity in Fourteenth-Century Catalunya* (Cornell University Press, 2017). Additionally, the Association has awarded prizes to JORGE CAÑIZARES-ESGUERRA, JAMES DELBOURGO, AXEL KÖRNER, and KENDA MUTONGI.

The Royal Netherlands Academy of Arts and Sciences has awarded the 2018 Christiaan Huygens Science Award to ADRIAN HAMERS, Peter Svennilson Member in the School of Natural Sciences.

JUNE HUH, Visiting Professor in the School of Mathematics, has been awarded the Breakthrough Prize's 2019 New Horizons in Mathematics Prize, which recognizes early-career researchers who have produced important work in mathematics.

The International Center for Relativistic Astrophysics has awarded a 2018 Marcel Grossmann Award to RASHID SUNYAEV, Distinguished Visiting Professor in the School of Natural Sciences since 2010.

The International Astronomical Union has awarded a 2017 Ph.D. Prize to BARAK ZACKAY, Infosys Member in the School of Natural Sciences, for work on statistical and algorithmic techniques in observational astronomy.

The Arab World Institute and l'Académie du Royaume du Maroc have awarded a 2018 Grand Prix des Rendez-vous de l'Histoire du Monde arabe to MURIEL DEBIÉ, Member (2016–17) in the School of Historical Studies, for *Le Monde syriaque: Sur les routes d'un christianisme ignoré* (Les Belles Lettres, 2017), co-authored with Françoise Briquel Chatonnet.

The Society for Classical Studies has awarded 2018 Charles J. Goodwin Awards of Merit to HARRIET FLOWER, Member (2001–02) in the School of Historical Studies, for *The Dancing Lares and the Serpent in the Garden: Religion at the Roman Street Corner* (Princeton University Press, 2017), and GIL HAVIV RENBERG, Member (2011–12) and Visitor (2013) in the School, for *Where Dreams May Come: Incubation Sanctuaries in the Greco-Roman World* (Brill, 2017).

The Pershing Square Sohn Cancer Research Alliance has awarded a 2018 Pershing Square Sohn Prize for Young Investigators in Cancer Research to BENJAMIN GREENBAUM, Member (2008–13) and Visitor (2008, 2017) in the Simons Center for Systems Biology in the School of Natural Sciences.

The International Mathematical Union and the Chern Medal Foundation have awarded the 2018 Chern Medal to MASAKI KASHIWARA, Member (1977–78) in the School of Mathematics.

The American Sociological Association has awarded 2018 Barrington Moore Book Awards to KRISHAN KUMAR, Member (2004–05) in the School of Social Science, for *Visions of Empire: How Five Imperial Regimes Shaped the World* (Princeton University Press, 2017), and ANGEL ADAMS PARHAM, Member (2011–12) in the School, for *American Routes: Racial Palimpsests and the Transformation of Race* (Oxford University Press, 2017).

The Royal Society has awarded the 2018 Sylvester Medal to DUSA MCDUFF, Member (2002, 1976) and Visitor (1977–78) in the School of Mathematics and an organizer of the Institute's Program for Women and Mathematics, for leading the development of the new field of symplectic geometry and topology.

The Abdus Salam International Center for Theoretical Physics, the Department of Science and Technology of the government of India, and the International Mathematical Union have awarded the 2018 Ramanujan Prize for Young Mathematicians from Developing Countries to RITABRATA MUNSHI, Member (2009–10) in the School of Mathematics, for profound contributions to analytic number theory.

The University of Hamburg, the Joachim Herz Foundation, and the Deutsches Elektronen-Synchrotron have jointly awarded the 2018 Hamburg Prize for Theoretical Physics to HIROSI OOGURI, Visiting Professor (2015) and Member (1988–89) in the School of Natural Sciences, for outstanding contributions to topological string theory.

Western University has awarded the 2018 Hellmuth Prize for Achievement in Research to MAYA SHATZMILLER, Member (1992) in the School of Historical Studies, for groundbreaking research that has challenged widely held assumptions about the medieval Islamic world.



## Ewine van Dishoeck, Winner of 2018 Kavli Prize, Appointed to Board of Trustees



Ewine van Dishoeck

The Institute for Advanced Study has appointed Dutch astronomer and chemist Ewine van Dishoeck to its Board of Trustees, effective May 5, 2018.

Van Dishoeck is Professor of Molecular Astrophysics at Universiteit Leiden; External Scientific Member of the Max Planck Institute for Extraterrestrial Physics; Scientific Director of the Netherlands Research School of Astronomy; and President of the International Astronomical Union.

Van Dishoeck, who was nominated by the Institute's School of Natural Sciences, succeeds Jeffrey A. Harvey, Enrico Fermi Distinguished Service Professor of Physics at the University of Chicago and a Trustee since 2013.

Van Dishoeck is a leading astrochemist who has been a pioneer of employing molecules to study star and planet formation and understand the universe at the atomic level. Her research has led to key discoveries on how interstellar molecules form, change, and become part of planetary systems. She has developed molecular tools that have become widely used by the scientific community in the field of molecular astrophysics, and she has been involved in developing next-generation instruments, such as the Herschel Space Observatory and the Atacama Large Millimeter Array in Chile.

After earning a B.Sc. in Chemistry, a B.Sc. in Mathematics, an M.Sc. in Chemistry, and a Ph.D. from Universiteit Leiden, van Dishoeck came to the Institute as a Visitor in the School of Natural Sciences from 1984–88. She taught at Princeton University and the California Institute of Technology before returning in 1990 to Universiteit Leiden, where in 2012 she was honored with the inaugural title of Faculty Professor, a role in which she serves as a spokesperson for science.

Soon after her appointment to the Board, the Norwegian Academy of Science and Letters awarded van Dishoeck the 2018 Kavli Prize in Astrophysics, “for her combined contributions to observational, theoretical, and laboratory astrochemistry, elucidating the life cycle of interstellar clouds and the formation of stars and planets.”

Other honors include the Maria Goeppert Mayer Award of the American Physical Society, the Bourke Award of the U.K. Royal Society of Chemistry, the Spinoza Prize of the Netherlands Organization for Scientific Research, the Albert Einstein World Award of Science of the World Cultural Council, and the James Craig Watson Medal of the National Academy of Sciences. Van Dishoeck is a foreign associate of the U.S. National Academy of Sciences, and a member of both the Royal Dutch Academy of Sciences and the German National Academy of Sciences Leopoldina. ■

## Analysis of Ancient Cemeteries Sheds Light on Sixth-Century Barbarians



LEFT: SOPRINTENDENZA ARCHEOLOGICA, BELLE ARTI E PAESAGGIO PER LA CITTÀ METROPOLITANA DI TORINO/RIGHT: FRIEDEN/VIA WINGER

Patrick J. Geary, Andrew W. Mellon Professor in the School of Historical Studies, is Co-PI and lead author of a groundbreaking paper published by *Nature Communications* in September that sheds light on sixth-century barbarian social organization and migration through paleogenomics.

Applying a comprehensive analysis of genetic, historical, and archaeological factors in two sixth-century barbarian cemeteries—one in Hungary and one in Italy—researchers have gleaned new insights into a key era known as the Migration Period that laid the foundation for modern European society. Spanning the fourth to the eighth centuries, this epoch followed the decline of the Western Roman Empire and was a time of major socioeconomic and cultural transformation in Europe. However, despite more than a century of scholarly work by historians and archaeologists, much about the period still remains unknown or is hotly debated, as reliable written accounts are lacking.

This research provides the clearest picture yet of the lives and population movements of communities associated with the Longobards, a barbarian people that ruled most of Italy for more than two hundred years after invading from the Roman province of Pannonia (modern-day Hungary) in 568 C.E. The team's data from the Hungarian cemetery, Szólád, almost doubles the number of ancient genomes obtained from a single ancient site to date. This in-depth genomic characterization allowed the team to examine the relationship between the genetic background of the community and the archaeological material left behind.

“What we have presented in this study is a unique cross-discipline framework for the future: uniting experts from different disciplines to reinterpret and reconcile historical, genomic, isotopic, and archaeological evidence,” says Geary. Read more at [www.ias.edu/press-releases/geary-barbarians](http://www.ias.edu/press-releases/geary-barbarians). ■

## Zaydi Manuscript Tradition Project Receives Major NEH Grant

The School of Historical Studies has received a \$315,000 grant from the National Endowment for the Humanities to support the Zaydi Manuscript Tradition initiative, led by Sabine Schmidtke, Professor in the School of Historical Studies.

The literary tradition of the Zaydi community, a branch of Shi'i Islam that originated in Kufa and later developed in Northern Iran and Yemen, is among the richest and most variegated strands within Islamic civilization and at the same time one of the least studied due to issues of preservation and access. The Zaydi Manuscript Tradition (ZMT) aims to remedy this imbalance by digitizing and housing the Zaydi manuscript culture in its entirety in a single repository and by providing comprehensive and systematic open access for scholars worldwide.

“The breadth and reach of this visionary initiative exemplifies the Institute's commitment to supporting scholarship worldwide by opening up the vast and rich literary tradition of the Zaydi community to scholars both in Yemen and around the globe,” said Robbert Dijkgraaf, Director of the Institute and Leon Levy Professor. “The National Endowment for the Humanities grant provides critical support that will help to further expand this important project.”

“The NEH grant will not only allow for an upsurge in this important field of study, it will also democratize access to the Zaydi manuscript tradition,” Schmidtke added. “For the first time, scholars in Yemen will have unlimited access to their own intellectual, cultural, and religious heritage as reflected in the Zaydi manuscripts preserved in Europe, North America, and the Middle East. As such, the ZMT will



Sabine Schmidtke (right) and Jan Thiele (left) consulting manuscripts of the Glaser collection, Staatsbibliothek zu Berlin

bring about a digital repatriation of the Yemeni/Zaydi manuscript treasures that are otherwise dispersed all over the globe. Perhaps even more importantly, the protection and preservation of an important part of Yemen's cultural legacy, namely its rich manuscript tradition, will be a key element to provide future generations of Yemenis with a firm sense of identity and belonging.”

Initiated in 2017 by the Institute in partnership with the Hill Museum & Manuscript Library at Saint John's University, the ZMT currently comprises 1,450 of the 15,000 codices targeted for inclusion. The NEH grant will allow for the digitization and cataloguing of an additional 540 Zaydi manuscripts held in European libraries and the preparation of 143 microfilm images of manuscripts held at the University of Texas, as well as 1,000 codices

from collections in Yemen, images of which are currently held by the Institute.

The grant will allow the ZMT project to further extend the preservation, dissemination, and study of the mostly unknown Zaydi doctrinal, legal, and historical literature, including the literary legacy of the Mu'tazila, one of the most important rational schools in the history of Muslim theology. The manuscript materials will thus not only have an immediate impact on several fields of scholarship in the humanities but also bring the rational heritage of Islam to the forefront and contribute to a more nuanced picture of the Islamic intellectual tradition and culture among Western observers.

For more information on Schmidtke's ZMT project, visit [www.ias.edu/news/neh-zaydi](http://www.ias.edu/news/neh-zaydi). ■



# Mathematics and Computation

## *Algorithms will rule the Earth, but which algorithms?*

Published here are three slightly edited excerpts from *Mathematics and Computation*, a new book by Avi Wigderson, Herbert H. Maass Professor in the School of Mathematics, soon to be published by Princeton University Press (online draft available at [www.math.ias.edu/avi/book](http://www.math.ias.edu/avi/book)). These excerpts are chosen to briefly introduce the reader to the Theory of Computation, Computational Complexity Theory, and the new breed of machine learning algorithms discussed in the adjoining article on the Theoretical Machine Learning program at IAS.

The Theory of Computation (ToC) is the study of the formal foundations of computer science and technology. This dynamic and rapidly expanding field straddles mathematics and computer science. Both sides naturally emerged from Turing's seminal 1936 paper, "On computable numbers, with an application to the Entscheidungsproblem." This paper formally defined an *algorithm* in the form of what we call today the "Turing machine." On the one hand, the Turing machine is a formal, mathematical model of computation, enabling the rigorous definition of computational tasks, the algorithms to solve them, and the resources these require. On the other hand, the definition of the Turing machine allowed its simple, logical design to be readily implemented in hardware and software. These theoretical and practical sides influenced the dual nature of the field. On the mathematical side, the abstract notion of computation revealed itself as an extremely deep and mysterious mathematical notion, and in pursuing it ToC progresses like any other mathematical field. Its researchers prove theorems, and they follow standard mathematical culture to generalize, simplify, and follow their noses based on esthetics and beauty. From the practical side, the universal applicability of automated computation fueled the rapid development of computer technology, which now dominates our life. This rapidly evolving world of computer science and industry continuously creates new models, modes, and properties of computation, which need theoretical understanding and directly impact the mathematical evolution of ToC, while ideas and techniques generated there feed back into the practical world.

The Theory of Computation is a vast field. Many of its subfields are directly connected with applications. These develop formal, mathematical foundations and theories of *programming languages, operating systems, hardware, networking, databases, security, robotics, and artificial intelligence*, as well as numerous efficient algorithms and algorithmic techniques to solve the basic problems arising in these fields. These models and algorithms contribute directly to the amazing variety of ways in which computers affect our lives. Many other subfields of ToC develop computational models and theories of various natural and manmade processes, interacting with scientific disciplines, including *biology, physics, economics, and social sciences*. Indeed, once such processes are viewed as *information processes*, the computational lens shines a powerful new light, which in all these disciplines revives and revises basic questions, beliefs, and theories. These growing interactions lead to better understanding of the natural world.

A central core area of ToC is *computational complexity theory*, which is often motivated by but is typically furthest removed from the applications and is the most intimately connected with mathematics. Complexity theory's initial charge was the understanding of efficient computation in the most general sense: *what are the minimal amounts of natural resources, like time, memory, and others, needed to solve natural computational tasks by natural computational models*. In response, it developed a powerful toolkit of algorithmic techniques and ways to analyze them, as well as a classification system of computational problems in *complexity classes*. It has also formulated natural long-term goals for the field.

With time, and with internal and external motivations, computational complexity theory has greatly expanded its goals. It took on the computational modeling and understanding of a variety of central notions, some studied for centuries by great minds, including *secret, proof, learning, knowledge, randomness, interaction, evolution, game, strategy, coordination, synchrony*, and others. This computational lens often resulted in completely new meanings of these old concepts. Moreover, in some of these cases the resulting theories predated, and indeed enabled, significant technological advances. Also, some of these theories form the basis of interactions with other sciences.

Thus, starting with the goal of understanding what can be efficiently *computed*, a host of natural long-term goals of deep conceptual meaning emerged. What can be efficiently learned? What can be efficiently proved? Is verifying a proof much easier than finding one? What does a machine know? What is the power of randomness in algorithms? Can we tap into natural sources of randomness and use this power? What is the power of quantum mechanical computers? Can we utilize quantum phenomena in algorithms? In settings where different computational

entities have different (possibly conflicting) incentives, what can be achieved jointly? Privately? Can computers efficiently simulate nature, or the brain?

So, it is pretty certain that algorithms will rule the Earth, but which algorithms? For decades, computer scientists have been designing and analyzing algorithms, which underlie the computer revolution that affects every aspect of our lives. These are gems of human invention. But recently, a combination of remarkable computing power, important optimization techniques, and massive data, has enabled a new breed of algorithms, which arise in machine learning. In short, algorithms as technological products. Tech and medical companies, as well as governments, invest enormous funds and effort in these new algorithms.

In stark contrast to the elegant, concise algorithmic gems, which were man-made, many new algorithms simply "create themselves," with relatively little intervention from humans, mainly through interaction with massive data. This contrast with "classic" algorithm design is heightened as these new algorithms are typically (and perhaps necessarily) gigantic, and very poorly understood by humans. I am referring of course to the "deep networks," a common name to heuristics modeled after networks of neurons.

These self-taught algorithms attempt to solve numerous problems that are often hard to formally define, such as finding "significant signals" in huge data sets that are often extremely noisy—be they financial, astrophysical, biological, or the Internet. The structure one may want to extract/uncover may be clusters, correlations, geometric or numerical patterns, etc., or completely unexpected ones. These may represent, e.g., familiar faces or objects in pictures, groups of friends and interests in social media, market performance of companies in the buying and selling of stocks, effects of treatments or genetic defects in biological data, and illuminating interactions of matter and energy in physical observations.

This is no place to give a proper description of the deep nets and their training process. It suffices to say that today their size can get to millions of gates and wires between gates. Each connection has a strength parameter that the training process attempts to optimize. In short, training is a huge optimization problem with an ill-specified goal and numerous degrees of freedom in the heuristics driving the attempted optimization. This "black magic" works extremely well only in relatively few cases so far. But in a growing number of cases it greatly outperforms any human-designed algorithm. It is extremely interesting when such a self-taught program can label by name the essential content of arbitrary pictures taken by humans, nearly as well as humans would. It is very impressive that another such program, after playing against itself a billion games of Go, can now beat the world's best human players. Great progress by such programs is made on human language understanding and translation, and perhaps their fastest growth is felt in "Data Science," where these programs play ever more important roles in actual scientific discovery. Indeed, one wonders at what point they will be able to better articulate the new scientific laws uncovered and pursue their consequences like medical drugs and treatments, food and energy supply, etc., also without human help.

The main point I find fascinating and challenging on this front, and for which the theory of computation can and should contribute, is a theoretical understanding of such algorithms. This understanding should include ways to make their training more principled and efficient, and developing models and tools to assess their performance and output quality. A major challenge is to understand why and for what tasks are deep networks successful, and what are their limitations. Further, it is of crucial importance given their growing prevalence in systems humans crucially depend on, to explore how to make them *fair* (and what this means), how susceptible they are to adversarial data and how to protect against it. Of course, the size and complexity of deep nets may put limits to how well they can be theoretically understood (much like massive creations of nature as the brain and other biological systems). Indeed, it is not unlikely that the theoretical study of deep nets (on which, unlike animals, experimentation is free from the Declaration of Helsinki guidelines) will help in better understanding biological systems and vice versa.

Given our current ignorance (namely, gaps between upper and lower bounds) regarding many well-posed important problems, I have no doubt that there is plenty more room for the discovery of algorithmic gems which we can easily understand, appreciate, and use. To drive this point home, let me note in conclusion that no deep-nets would exist without a few great algorithmic gems embedded in practically all of them, including the extremely efficient *back propagation* and *gradient descent*. ■

*Avi Wigderson is a widely recognized authority in the diverse and evolving field of theoretical computer science. His main research area is computational complexity theory, which studies the power and limits of efficient computation and is motivated by fundamental scientific problems.*



# Establishing a Theoretical Understanding of Machine Learning

*Program at IAS aims to explain the why and how of algorithms with enormous power*

“It’s kind of like physics in its formative stages—Newton asking what makes the apple fall down,” says Sanjeev Arora, Visiting Professor in the School of Mathematics, trying to explain the current scientific excitement about machine learning. “Thousands of years went by before science realized it was even a question worth asking. An analogous question in machine learning is ‘What makes a bunch of pixels a picture of a pedestrian?’ Machines are approaching human capabilities in such tasks, but we lack basic mathematical understanding of how and why they work.”

The core idea of machine learning, according to Arora, involves training a machine to search for patterns in data and improve from experience and interaction. This is very analogous to classic curve-fitting, a mathematical technique known for centuries. Training involves algorithms, the theoretical foundations of which are of great interest in mathematics (see related article, page 4). “Machine learning is a very important branch of the theory of computation and computational complexity,” says Avi Wigderson, Herbert H. Maass Professor in the School of Mathematics, who heads the Theoretical Computer Science and Discrete Mathematics program. “It is something that needs to be understood and explained because it seems to have enormous power to do certain things—play games, recognize images, predict all sorts of behaviors. There is a really large array of things that these algorithms can do, and we don’t understand why or how. Machine learning definitely suits our general attempts at IAS to understand algorithms, and the power and limits of computational devices.”

Since 2017, Arora has been leading a three-year program in theoretical machine learning at the Institute for Advanced Study, supported by a \$2 million grant from Eric and Wendy Schmidt. This year, Arora’s team consists of two postdoctoral Members, Nadav Cohen and Sida Wang, both of whom were involved in the program in 2017. Arora’s theoretical machine learning group is specifically focused on fundamental principles related to how algorithms behave in machines, how they learn, and why they are able to make desired predictions and decisions. In spring 2019, they will be joined by Visiting Professor Philippe Rigollet, Associate Professor of Mathematics at the Massachusetts Institute of Technology, and Visitor Richard Zemel, Professor of Computer Science at the University of Toronto and Research Director of the Vector Institute of Artificial Intelligence. Next year, fifteen to twenty Members will join the School’s special year program “Optimization, Statistics, and Theoretical Machine Learning” to develop new models, modes of analysis, and novel algorithms.

Why has machine learning become so pervasive in the past decade? According to Arora, this happened due to a symbiosis between three factors: data, hardware, and commercial reward. “Leading tech companies rely on such algorithms,” says Arora. “This creates a self-reinforcing phenomenon: good algorithms bring them users, which in turn yields more user data for improving their algorithms, and the resulting rise in profits further lets them invest in better researchers, algorithms, and hardware.”

With intense progress and momentum in the field coming from industry, the number of machine learning researchers who are trying to establish theoretical understanding is relatively small. But such study is essential—for reasons beyond its tantalizing connections to questions in mathematics and even physics. “Imagine if we didn’t have a theory of aviation and could not predict how airplanes would behave under new conditions,” says Cohen, current Member in the theoretical machine learning program. “Soon you will be putting your life in the hands of an algorithm when you are sitting in a self-driving car or being treated in an operating room. We can’t yet fully understand or predict the properties of today’s machine learning algorithms.”

The most successful model of machine learning, known as deep learning, came to dominate the field in 2012, when neural networks, also called deep networks or more broadly referred to as deep learning models, were shown by a team of researchers in Toronto to dramatically outperform existing methods on image recognition. Since then, deep learning has led to rapid industry-driven advances in artificial intelligence, such as self-driving cars, translation systems, medical image analysis, and virtual assistants. When an artificially intelligent player developed by Google DeepMind beat Lee Sedol, an eighteen-time world champion, in the ancient Chinese strategy game Go in 2016, the machine utilized inventive strategies not foreseen or utilized by humans in the more than two millennia during which the game has been played. “Human intelligence and machine intelligences will very likely turn out to be very different,” says Arora, “kind of like how jet airplanes are very different from birds.”

“Deep” in this context refers to the fact that instead of going directly from the input to the output, several processing levels are involved until the output is

achieved. Training such models involves algorithms known as gradient descent or back propagation, which enable the parameters to be tuned—think of a refraction eye exam to determine a prescription lens—in such a way that the output gets increasingly closer to the desired outcome. This model is inspired loosely by interconnected networks of neurons in the brain, although the brain’s exact workings are still unknown.

The sheer size of deep learning models, which outstrips human comprehension, raises important computational and statistical questions, as well as how to comprehend what the deep model is doing. The group at the IAS is focusing on such issues. The year-long special program in 2019–20 will focus on the mathematical underpinnings of artificial intelligence, including machine learning theory, optimization (convex and nonconvex), statistics, and graph theoretic algorithms, as well as neighboring fields such as big data algorithms, computer vision, natural language processing, neuroscience, and biology.

Arora and Behnam Neyshabur, a Member in the theoretical machine learning program in 2017–18, have been studying questions related to generalization, the phenomenon whereby the machine, after it has been trained with enough samples—images of cats versus dogs, for example—acquires the ability to produce the correct answer even for samples it has never seen before, as long as they are similar enough to the training examples. This is surprising because the number of tunable parameters in today’s models vastly exceeds the number of available training samples. Classically, such situations with huge models were believed to be susceptible to overfitting—when models fit themselves too closely to the peculiarities of training samples and then fail to predict well on new unseen data. Arora and Neyshabur’s coauthored paper from summer 2018 shows that the “effective size” of today’s trained deep nets may be smaller than the number of tunable parameters in the model. Their theory pinpoints ways in which subparts of deep nets are redundant and allows simple and provable compression of the model. This goes some way to explaining the absence of overfitting.

Another major ongoing activity in the IAS group is understanding how machine learning models can develop understanding of language. Arora and his Members have designed new techniques for capturing the meaning of sentences. “Our sentence embeddings involve simpler, more elementary techniques that compete with deep net algorithms,” says Arora. “These alternatives to deep learning are much more efficient, understandable, and transparent.”

IAS Member Sida Wang is interested in new models of interactive learning, specifically those where computer systems learn to respond to commands in human language. These differ from existing systems such as Siri in that the human speaker may converse in a completely different style or language than the ones involved in training the system. In Wang’s models of interactive learning, the behavior of machines and humans adapts to feedback received by each. The formal treatment is borrowed from game theory: the interaction is modeled as a cooperative game where the system and the user cooperate toward their shared goal of mutual comprehension. Wang has working prototypes of such systems, including one

that creates a virtual world in which a user can give commands, such as “stack three blue blocks,” to which the system learns to respond. He has also created a talking spreadsheet, which likewise learns to understand simple directions, such as “add vertical grids,” from a few rounds of interaction. “The systems have no in-built rules about natural languages,” says Wang. “I developed a learning algorithm and invited people on the internet—non-experts—to use the program and thus train it.”

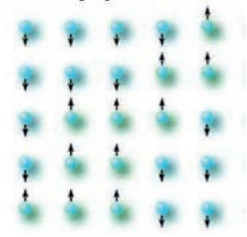
The program at the Institute taps into the strengths of the theoretical machine learning program that Arora has established with colleagues at nearby Princeton University where he is Charles C. Fitzmorris Professor of Computer Science. Arora has recruited machine learning postdocs to join the IAS community as Members where they have access to and interact with fellow leaders in mathematics, physics, cosmology, systems biology, social science, and the humanities.

“Being at the Institute was very different. It was really peaceful and allowed me to think about new ideas without being interrupted or stressed out about other things,” says Neyshabur. “Physics is one of the closest areas to machine learning. Given the complexity of the models involved, we need to approach the problems the way physicists do. It was very useful to have conversations while at IAS with physicists who are also working on machine learning problems.”

Member Nadav Cohen is interested in exploring connections between machine learning and quantum physics. He recently published a paper with colleagues on

*(Continued on page 6)*

*state of  
many particles*



*func over  
many pixels*



Member Nadav Cohen with colleagues has formulated a unified representation of functions over many elements, for example pixels, and quantum states over many particles. The unified framework formed the basis for an equivalence between deep neural networks, which realize functions over many elements, and tensor networks, which simulate quantum states over many particles.



# Black Holes, Quantum Information, and the Structure of Spacetime

*A conversation with Juan Maldacena*

In the last six months, Juan Maldacena, Carl P. Feinberg Professor in the School of Natural Sciences, has received three major awards: the Lorentz Medal of the Royal Netherlands Academy of Arts and Sciences; the 2018 Einstein Medal from the Albert Einstein Society in Bern; and most recently the Richard E. Prange Prize and Lectureship in Condensed Matter Theory and Related Areas.

The awards have recognized his groundbreaking contribution to the understanding of the quantum physics of black holes. Maldacena conjectured in 1997 a deep connection between gauge theories, which describe the world of particle physics at the microscopic scale, and quantum gravity, which describes the physics of gravitational forces of the universe. Known as the anti-de Sitter/conformal field theory (AdS/CFT) correspondence, or gauge/gravity duality, it is one of the most actively studied topics in theoretical physics with more than 10,000 citations, making it among the most-cited papers in science over the last two decades.

More recently, Maldacena and Leonard Susskind proposed in 2013 that certain black hole paradoxes, related to the Hawking information paradox, could be resolved if outgoing particles and the black hole are connected by wormholes. Often referred to as “ER=EPR,” the paper connects two works that Einstein authored at the Institute in 1935. “ER” refers to a paper written by Einstein and Nathan Rosen (an IAS Member at the time) that suggests that black holes could come in pairs connected by Einstein-Rosen bridges, or wormholes. “EPR” refers to a paper written by Einstein, Boris Podolsky (also a Member at the time), and Rosen, which points out the quantum mechanical property of entanglement. Maldacena and Susskind’s concept proposes that entanglement and wormholes create spacetime, which emerges from connected bits of quantum information. The following is an edited Q&A with the Institute Letter.

**IL:** First of all, congratulations on your recent awards. Obviously, your research has been recognized for some time (a MacArthur Fellowship in 1999, the Dirac Prize and Medal in 2007, the Fundamental Physics Prize in 2012, among many others), but is there a reason we are seeing so much recognition of your work at this particular moment?

**JM:** Oh, I don’t know [laughter]. In condensed matter physics and in several other areas of physics, one is interested in understanding the behavior of particles that are strongly interacting and described by quantum mechanics. Quantum theory is easy to analyze when the particles are almost free, but when the particles are strongly interacting, it is difficult—there could be all kinds of different surprising behavior. The AdS/CFT correspondence or gauge/gravity duality relates certain very strongly interacting systems to a theory of gravity. In this way, it converts a problem that is difficult on the quantum mechanical side to a problem that is relatively simpler on the gravity side.

**IL:** When you say condensed matter physics, what types of materials are we talking about that are applicable?

**JM:** One problem, for example, that people are interested in is high-temperature superconductivity. But there could be some new materials people are trying to design that have strong interactions. And also, with the possible advent of quantum computers, these materials would be able to be designed more or less at will.

Where the theory could help in high-temperature superconductivity is in understanding the phenomenon better, and maybe finding new instances of the phenomenon, or finding even some behaviors that we don’t know now that are possible.

An example of a relationship between the two is what Douglas Stanford has studied. He found a connection between quantum chaos and the physics of black holes and the physics near the horizons of black holes.

**IL:** And when we are talking about black holes, we aren’t talking about the black holes that cosmologists study. . .

**JM:** That’s right. These are black holes that exist in other auxiliary universes, which are very small, relatively small. The interesting thing is that these very strongly interacting systems can behave as if they are creating their own universe. It is a theory of a universe in a bottle.

**IL:** And by very small, can you provide some context?

**JM:** The problem is that it is difficult to define the scale, because it could mean different things. They are small in the sense that they exist in a lab, but they are also small in the sense that, in the theory of gravity, there is a fundamental distance scale where the classical description of spacetime breaks down due to quantum mechanical effects. The idea is that the overall size of the universe, in units of this distance, is also relatively small. Our universe is very big compared to this fundamental distance, which is  $10^{-33}$  cm. This is a distance that is very, very small, while the overall size of the universe is much bigger than that.

**IL:** When you say that these are in a lab, do they actually exist in a lab, or is it a theoretical lab?

**JM:** It is a theoretical lab, for now. They could somehow exist in a lab, in the future, when quantum computers are a little better than they are today or people find more ingenious ways to create them.

**IL:** Are these theories for black holes in a theoretical lab connected to real black holes?

*(Continued on page 7)*

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## MACHINE LEARNING *(Continued from page 5)*

links between deep learning and quantum entanglement with implications for network design. One of the main contributions was to show that tensor networks, which are a common computational tool in quantum physics, are equivalent to deep learning architectures. The equivalence paved a way for using well-established concepts and tools from quantum physics for theoretical study of deep learning. Specifically, Cohen and colleagues employed the concept of quantum entanglement for studying dependencies of deep network models between input elements (e.g., pixels of an image) and applied quantum min-cut/max-flow results for analyzing the effect of a deep network architecture on the entanglement it supports, leading to new practical guidelines for deep network design.

“I consider this a once-in-a-lifetime opportunity,” says Cohen of his time at the Institute. “The Institute is so intimate, I am able to interact extensively with other mathematicians and physicists, which would not be possible in a typical computer science department or corporate lab. I am able to meet physicists, exchange ideas, have lunch with them. I have a lot of interest in what they do, and there is a lot of interest in what I do.”

One such physicist is Guy Gur-Ari, a Member in the School of Natural Sciences in 2017–18 who was working on research related to quantum field theory, quantum gravity, and black hole physics. In April, he gave a talk at IAS, “Good and Bad Analogies of Physics in Deep Learning,” on the extent that deep learning models are similar to complex physical systems. He is now a research scientist working in machine learning at Google. Similarly, Dan Roberts, a Member in the School of Natural Sciences in 2016–18, was working on quantum information theory, black holes, and how the laws of physics are related to fundamental limits of computation before he joined Facebook AI Research as a research scientist in February.

In 2018–19, several physicists are focusing their research in part on machine learning, primarily applying machine learning to physics problems: Kyle Cranmer is using machine learning techniques in his research in high-energy physics; Brant Robertson is applying machine learning and computational methodologies to

large astronomical data sets; and Yuan-Sen Ting is using theoretical modeling, observational astronomy, and machine learning in his research on the evolution of the Milky Way.

Given artificial intelligence’s resources, reach, and ability to exceed the performance of any individual, its societal implications are immense and unpredictable. “I think machine learning is most certainly going to cause great disruption in our society, but we are not good at recognizing the full impact,” says Arora. “Five years ago, everyone thought that Twitter and Facebook were going to lead to the end of tyranny. How naïve were we?”

As corporations and governments centralize enormous amounts of data that can be processed at very high speeds by algorithms that humans don’t fully comprehend, Wigderson points to the possible fault lines involved.

“There are issues of privacy and of fairness, because these networks will be used to predict, for example, if someone is likely to pay off their bank loan, or to commit another crime,” says Wigderson. “Machine learning is going to be applied everywhere, and we need to find out its limits, its fragility points. At this stage deep nets is a phenomenon that we observe and experiment with (as scientists), but we don’t quite understand. It is a phenomenon in search of a theory, and this is a huge scientific and societal challenge.” ■

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**Recommended Viewing:** As part of the 2017–18 activities, Sanjeev Arora organized a public lecture series at IAS focused on theoretical machine learning, which included talks by him and Richard Zemel, Visitor in the School and a Professor of Computer Science at the University of Toronto where he serves as Research Director of the Vector Institute of Artificial Intelligence; Yann LeCun, Facebook’s chief artificial intelligence scientist and founder of the Facebook AI Research lab; and Christopher Manning, Thomas M. Siebel Professor in Machine Learning and Professor of Linguistics and of Computer Science at Stanford University. Videos are available at [www.ias.edu/ideas/machine-learning](http://www.ias.edu/ideas/machine-learning).



*Are they in theory the same?*

**JM:** They are the same in the sense that they are governed by the same equations, but they are not the same in other details. In a black hole that exists in nature, there are other particles, like electrons and photons, forming the ordinary matter that exists around the astrophysical black holes. This is different than the type of matter that could exist around these other black holes. What they have in common is that both are described by a dynamical spacetime. In both cases, there is a certain spacetime that can be curved. In both cases, there is this notion of having a horizon, and in both cases, there is a Hawking radiation. The Hawking radiation is not very important for very big astrophysical black holes, for example, where their temperatures are smaller than the temperatures around it. The temperature is not very important. But it is a more important effect for these smaller theoretical black holes.

**IL:** *Why are you interested in studying black holes theoretically? What is the burning question?*

**JM:** The reason we are studying these quantum aspects of black holes is to understand the quantum mechanical nature of spacetime. That is not important for astrophysical black holes, but it is very important for the beginning of the Big Bang. Understanding quantum aspects of black holes could be helpful for understanding the beginning of the universe—that is the hope, that is the big-picture, long-term program.

**IL:** *How has thinking about black holes and spacetime changed since you started working in the field?*

**JM:** Black holes were thought to be something that existed somewhere else in the universe and were produced by the four-dimensional gravity that we experience. Now we can associate them to a physical system that does not contain gravity, such as a superconductor or some other system made of subatomic particles. And if these systems are interacting strongly enough, they can generate their own spacetime, and then the black holes can exist.

**IL:** *What does it mean when we hear that spacetime is emergent and not fundamental?*

**JM:** Spacetime being fundamental means that you make the assumption or the hypothesis that it exists, and from there you then construct your theory. Emergent means that it is not something you started from.

**IL:** *When did this idea of emergent spacetime take form? Was it because of the AdS/CFT correspondence?*

**JM:** There were different indications. But I would say mainly through research in string theory. The gauge/gravity duality was another example of this.

My opinion is that spacetime looks emergent when you start from quantum particle theory, but it could be that there is an alternative description where spacetime is also fundamental, and the two descriptions are just two different ways of describing the same system. That is the idea of duality. It means that the same theory can be described in terms of different building blocks. Another analogy for this is that you could describe a novel, let's say, in English, or you could describe it in French, but it is the same novel.

**IL:** *You wrote about “ER=EPR” and quantum entanglement for the Institute Letter in 2013. What advances have been made since then?*

**JM:** That article was about entanglement and wormholes and I think the main update is a paper by Ping Gao, Daniel Louis Jafferis, and Aron Wall (School of Mathematics Member, 2014–17), who realized that there was a way to make this wormhole traversable. The basic idea is that if you have two systems that are very far away—they are not interacting but they are entangled—then you have a wormhole. But if the wormhole is not traversable, that means you cannot travel through the wormhole. If you try to travel through the wormhole, you die. But they realized that if you bring these two systems near each other, and you let them interact a little bit, then you can go through this wormhole.

I recently wrote a paper with Alexey Milekhin and Fedor Popov where we have constructed a solution of the Standard Model, which is the theory of particles in our universe, that has this feature. From the outside, it looks like two black holes, and it has a wormhole connecting them, a traversable wormhole. It would have to be very microscopic, so it is a very tiny thing. It is just a solution of the equations.

**IL:** *So it is not on the scale you would think of in terms of science fiction . . .*

**JM:** No, we would not be able to travel through these wormholes. We would be able to send elementary particles through them. These wormholes are very, very tiny, smaller than the smallest distances we can see today.

**IL:** *Are we talking about quantum information surviving this traversable wormhole?*

**JM:** Well, the theory is that quantum information would survive falling into any black hole, and would be reprocessed, and so on. This process of going through the wormhole is closely connected to something called quantum teleportation, which is something that was discovered in the '80s. It is the ability to transport quantum information via entanglement, and also some classical communication. Quantum teleportation was invented and suggested as a way to make communication secure. It is an unbreakable code because the information goes through a wormhole that cannot be seen from the outside.

**IL:** *What does gravity seem to know about quantum mechanics?*

**JM:** Black holes obey the laws of thermodynamics. And that fact comes from Einstein's equations. Somehow Einstein's equations know about the laws of thermodynamics when you consider a black hole. And this looks very strange, because when Einstein wrote his equations, he wasn't thinking about information or averages, or randomness, or anything like this. These were just classical equations, and the fact that these equations know about thermodynamics is very surprising.

**IL:** *Are you finding that more physics Members are interested in quantum computing?*

**JM:** We have people who are applying some quantum information theory techniques to the study of black holes. We don't have anyone that does quantum computing, per se. But I am a member of a collaboration that has some people doing this, and we have organized workshops where people doing quantum computing come here. Prospects in Theoretical Physics this summer explored connections between quantum computing and black holes. One of the speakers was Scott Aaronson (School of Mathematics Member, 2004–05), who will be involved in a workshop that we will hold in December. We held a similar workshop on black holes and quantum information last year. One of the organizers of this year's workshop is Jonathan Oppenheim who works in quantum information theory.

**IL:** *What does it mean when a black hole is referred to as a quantum computer?*

**JM:** You can think of an ordinary system, even nature, as a kind of machine. And when you have an ordinary machine, it is useful to understand how information is traveling through the machine. It is useful to think of how different parts relate to each other, and how the motion of one relates to the motion of the other.

The detailed dynamical laws tell you how this happens but understanding the flow of information is something basic that constrains how the machine can work. Nature is quantum mechanical, so the machine obeys the laws of quantum mechanics. To understand how information travels around this machine, you have to talk about quantum information. It is information that is subject to the laws of quantum mechanics, and you are trying to understand how it travels through the machine. The goal is to understand how quantum information travels through spacetime. In fact, we think that the geometry of spacetime itself is reflecting properties of this quantum information.

Ultimately, we want to understand a black hole as a system that obeys the rules of quantum mechanics, and how those rules are consistent with the rules of gravity. They seem to be very different, and there are some paradoxes that haven't been resolved yet. We are trying to understand how the view of black holes as a quantum computer is consistent and compatible with the view of black holes that comes from Einstein's theory of general relativity. ■

**Recommended Viewing:** For more information about black holes, quantum information, and the structure of spacetime, view the public lecture “The Cool Alter-Ego of a Black Hole” by Professor Juan Maldacena and Member Douglas Stanford (recently named by *Science News* as one of ten “Scientists to Watch,” age 40 or under, who are shaping the science of the future) followed by a panel discussion with IAS Director Robbert Dijkgraaf at [www.ias.edu/ideas/maldacena-blackholes](http://www.ias.edu/ideas/maldacena-blackholes). Lectures from PiTP 2018, “From Qubits to Spacetime,” may be viewed at [www.ias.edu/ideas/pitp-qubits-spacetime](http://www.ias.edu/ideas/pitp-qubits-spacetime). Some videos from the quantum information and black holes workshop held in December 2017 are available at [www.sns.ias.edu/quantum-information-workshop-2017/schedule](http://www.sns.ias.edu/quantum-information-workshop-2017/schedule).



Juan Maldacena at Prospects in Theoretical Physics 2018



# The Persistence of Gender Inequality

## *How politics constructs gender, and gender constructs politics*

BY JOAN WALLACH SCOTT

The question I pose in this talk is why—despite decades (indeed centuries) of social protest, policy initiatives, educational reform, nongovernmental organization activity, national and international legislation—gender inequality persists. The most dramatic and disturbing examples of this persistence have come with the revelations of the #MeToo movement which, at its best, has unveiled the use of sex as a tool of power (in the workplace, the academy, sports, the arts ...). Lest we be tempted to attribute this behavior to a few individual bad actors, there are also statistics to document a culture of male entitlement: wage gaps, vast discrepancies in political representation, high rates of domestic violence, glass-ceilings at the topmost levels of corporate leadership, a growing number of attacks by organized religious and political groups on women's reproductive rights and even on academic gender studies programs. Writing in the *New York Times* a few months ago, the U.S. feminist Vivian Gornick expressed her despair at the lack of progress: "As the decades wore on, I began to feel on my skin the shock of realizing how slowly—how grudgingly!—American culture had actually moved, over these past hundred years, to include us in the much-vaunted devotion to egalitarianism." It is not only American culture, of course, the evidence comes from all over the world: the project of gender equality remains unrealized despite concerted efforts to achieve it. Modernity, secularism, democracy—these have not ushered in the reign of equality they promised, at least not when it comes to gender (or, for that matter, class or race).<sup>1</sup> Why?

Some of the reasons usually offered to explain the persistence of gender inequality include large abstractions: patriarchy, capitalism, male self-interest, misogyny, religion. These are, of course, useful categories to work with, but none of them can account for how deep-rooted these inequalities are in our psyches, our cultures, and our politics. My alternative explanation, based on psychoanalytic and political theory, has to do with the ways in which gender and politics are interdependent: a naturalized belief in the necessary and immutable difference of the sexes provides legitimation for the organization of other social and political inequalities; in turn the legitimation invoked by politics, establishes the immutability of biology. Whether taken as God's word or Nature's mandate, gender—the historically and culturally variable attempt to insist on the duality of sex difference—becomes the basis for imagining social, political, and economic orders. In this representation of things, to question the asymmetry of the sexes as a biological fact is to threaten an entire political order.

Before I explain what I mean by the interdependence of gender and politics, I want to define "politics" and "gender." Politics is easier. It refers to relations of power, especially as they are embodied in law and the organization of the nation-state. In democracies, this has to do with the question of representation: who is represented and how, as well as who gets to be a representative.

Defining gender, in contrast, is not an easy task since its meaning has been difficult to pin down. The authors of the third edition of the *American Heritage Dictionary* (1992) gave up trying, pointing out that the distinction between sex and gender might be "useful in principle, but is ... by no means widely observed, and considerable variation in usage occurs at all levels."

Gender was the term taken up by second-wave feminists who wanted to insist that biology ought not to determine the roles attributed to women and men. If sexed bodies were about nature, gender was about culture, about the ways different cultures attributed meaning to those sexed bodies. It followed from this that biology ought to be irrelevant in the allocation of resources, in access to education and jobs, and to political representation. Some of us went further, insisting that the biological difference of sex had no inherent meaning apart from its representation as (or by) gender. As Judith Butler put it in her now classic *Gender Trouble*, "If the immutable character of sex is contested, perhaps this construct called 'sex' is as culturally constructed as gender; indeed, perhaps it was always already gender, with the consequence that the distinction between sex and gender turns out to be no distinction at all." The psychoanalyst Jean Laplanche made an even stronger argument: it is gender, he says—the attribution of the primary male/female distinction by adults to a child's genital organization—that establishes the social and psychic meaning of those body parts. Laplanche refers to an

"illusory" or phantasmatic anatomy by which he means not that anatomy doesn't exist, but that—as Jacqueline Rose explains it—sexual difference is "figured" only as anatomical difference. Visible anatomical difference, she writes, "becomes the sole representative of what that difference is allowed to be. It thus covers over the complexity of the child's early sexual life with a crude opposition in which that very complexity is refused or repressed." Put in other terms, we might say that biology obscures the workings of gender as the true source of the meanings of the difference of sex.

For me, as a historian, this means asking of any society or culture *how* the difference of sex is being defined and regulated, as well as what ends it is seeking to secure. Gender is a question, not a given, in the research I do.

This is not the case for many political activists and commentators, who tend to take the fixity of biology for granted. The reference by journalists to a "gender gap" is an example—it connotes nothing more than differences in the behavior or treatment of women and men. And the fixed biological meanings of "woman" and "man" are presumed even when exposing inequality is the goal. In many of these reports, the focus is on local "cultures" of inequality, when those are actually

the effects of large-scale economic and geopolitical processes that take sex difference as fixed, and so reproduce the discrimination the reformers seek to end. But without changes in the structures that underlie poverty and inequality—by using impoverished women in the global South as a source of cheap labor, by causing large flows of international migration and massive transfers of population and wealth—it is difficult to imagine how what these international organizations refer to as "women's empowerment" can be achieved. Lack of critical attention to these large structural issues, which are based on (and so reproduce) the implicit notion that the difference of sex is a fact of nature, is one of the reasons inequality persists.

What these commentators sometimes ignore is that "gender" necessarily implies a critique of the certainty of biology, and so suggests intolerable instability to the forces of order. That is why, in the backlash apparent in many countries today, they have launched a sustained attack on the so-called "theory of

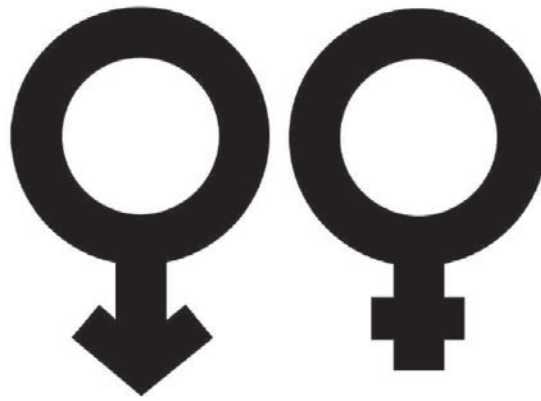
gender," likening it to a communist conspiracy to topple the world order. At the United Nations Conference in Beijing in 1995, the Catholic delegates fixated on the idea that "gender" opened the door to homosexuality. Peru's spokesman insisted that "sexual rights refer solely to heterosexual relationships." And the Vatican insisted that if the term had to be used at all, the meaning of gender must be "grounded in biological sexual identity, male or female."<sup>2</sup> During the discussions of the drafting of the Rome Statute which created the International Criminal Court (ICC) in 1998, "gender" was singled out for special consideration, while terms like "political," "racial," "national," "ethnic," "cultural," "religious," "wealth," "birth," and "age," were taken to be self-evident and in need of no clarification.<sup>3</sup> Long negotiations were required to find exactly the right wording—a wording whose awkwardness reflects the controversies the words were crafted to resolve. Article 7(3) of the Rome Statute defines gender this way:

For the purposes of this Statute, it is understood that the term 'gender' refers to the two sexes, male and female, within the context of society. The term 'gender' does not indicate any meaning different from the above.<sup>4</sup>

The phrase "two sexes" was a concession to the Right; "within the context of society" was meant to mollify social constructionists. The final sentence seems to me to convey deep anxiety about the uncontrollable nature of gender. Gender could mean much more than "two sexes, male and female"; its exact referent had therefore to be repeatedly specified and that might not be enough. Even if the referents were restricted to anatomical men and women, the idea that they are defined "within the context of society" calls into question any self-evident biological claim.<sup>5</sup>

This example of the tortured attempt to contain the possibilities of "gender" leads to my argument that the interdependence of gender and politics is an explanation for the persistence of inequality based on sex. The stakes are clearly very high for maintaining a biologically based definition of the difference of sex—more so these days, it seems, than in decades past. This is because the very legitimacy of political systems—at least in modern democracies—has been based on an appeal to the

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TO QUESTION THE ASYMMETRY OF THE  
SEXES AS A BIOLOGICAL FACT IS TO  
THREATEN AN ENTIRE POLITICAL ORDER.



natural and immutable difference of sex. How has this worked?

For an answer, I turn to Freud and to Lacanian readings of Freud, on the one hand, and to the political theorist Claude Lefort, on the other. In both cases, I suggest that the clue is indeterminacy: the indeterminacy—the enigma—of sexual difference, and the indeterminacy—the uncertainty—of the embodiment of authority in democracies. Each uses the other to provide stabilized meaning where none exists: in this way, politics constructs gender, and gender constructs politics.

According to psychoanalysts—the difference of sex is ultimately inexplicable. It is the riddle that defies fixed meaning, the understanding that always seems to escape control, the dilemma that gives rise to myth and fantasy. It is the place where questions about the relationship of mind and body are confounded, where the individual and the social are inseparable. The Slovenian philosopher Alenka Zupančič puts it this way: “... The sexual is not a separate domain of human activity or life, and this is why it can inhabit all the domains of human life.” The point is that sex and sexual difference are not simply metaphors for other areas of human activity; they are always already imbricated in those other domains.

Precisely because sexual difference is so central to the representation of social relationships and because it cannot be circumscribed, great effort has been expended to fix its meaning: the body becomes the indisputable determination of the social meanings of masculinity and femininity, and then entire social and cultural edifices are built on the shaky foundations of so-called immutable gender difference.

What makes all of this interesting for historians like myself (and I hope others of you as well) is that stability cannot be secured. The illusory nature of anatomical sex difference—its ultimate undefinability—introduces ambivalence, anxiety, indeterminacy, and instability into these organizing conceptual systems. The social rules that announce and enforce the meanings of the difference between women and men insist that they refer to the timeless truth of anatomical genital differences. But the only truth there is about these differences is that their meanings are ultimately impossible to secure. Anthropologists and historians have shown that the traits and roles attributed to men and women have varied across cultures and time; philosophers have grappled with the ways in which perception informs the lived experience of a material body; psychoanalysts have taught us to be skeptical of the power of normative regulation to contain the unruly operations of the unconscious. Gender, they argue, does not reflect the dictates of bodies. Rather, it attributes to those bodies meanings that are inevitably contested by psychic processes (drives, fantasy, unconscious identification). These result in sexualities that do not conform to normative regulations. Gender, from this perspective, does not base its social roles on the imperatives of physical bodies; rather it is a historically and culturally variable attempt to provide a grid of intelligibility for sex, and—beyond sex—for the intelligibility of systems of political rule.

The emergence of modern democratic nation-states demonstrates starkly the imbrication of gender and politics. The end of absolutism and, with it, the loss of its legitimating religious authority introduced a new uncertainty into political representation. Possession of the phallus, the symbol of the ruler's power, was no longer the prerogative of God's representative on Earth. And, as the reign of kings (and the occasional queen) gave way to representative systems of government (parliaments, constitutional monarchies, republics, democracies), the physical body of the ruler as the incarnation of sovereignty was replaced by a set of disembodied abstractions: state, nation, citizen, representative, individual. The French political theorist Claude Lefort puts it this way: “the locus of power becomes an empty place ... it is such that no individual and no group can be consubstantial with it—and it cannot be represented.” The impossibility of representation, he continues, leads to a permanent state of uncertainty: “The important point is that democracy is instituted and sustained by the dissolution of the markers of certainty. It inaugurates a history in which people experience a fundamental indeterminacy as to the basis of power, law and knowledge and as to the relations between *self* and *other* at every level of social life...” In the abstract, the impossibility of power's embodied representation is clear. But for those who implemented the system, the question of *who* was charged with articulating and enforcing the decrees remained.

It is here that Freud's theorizing (in *Totem and Taboo* especially) helps shed some light on the reasons that *men* became the embodiments of political authority in democratic polities. It is important to stress here that Freud is offering a theoretical fiction—a myth, if you will. His interpretation is a way of accounting for what he takes to be an evident truth of political psychology. In his mythical account, there was a primal father (a king) whose power lay in his monopoly of

all pleasure; lesser men eventually kill (and in Freud's version eat) him in order to gain the access that they have been consistently denied. By devouring the father figure, the men retrospectively become brothers. Freud says that in this way they “accomplished their identification with him, and each of them acquired a portion of his strength.” Coming into their own as adults required the sexual initiation that the father had forbidden them: an appropriate woman of their own. The brothers institute a prohibition of incest to ensure that this woman will not be a mother or sister, all of whom had been game for the primal father's seductions. The rule of the sons then replaces the absolutism of the father, some form of fraternity overthrows the reign of the king. In Freud's terms an “ideal father” replaces the primal father, it is he (or they—the sons acting collectively to achieve this ideal) whose actions must protect society from a return of excess. There were nonetheless continuing rivalries among the brothers and these were managed by assigning to each a smaller, tamer version of what they rebelled against. The laws of marriage, in this vision, ensured that each brother had his own woman and that no brother had more than one. In the realm of the psyche, shared political power depends on the disciplining of sexuality by marriage, the containment of desire within a socially beneficial familial unit. In the political realm, the idea of abstract individualism rests on a presumed sameness (whatever

the social differences among men—and not all men, only those, usually white, whose higher rationality defined them as autonomous individuals).

Whose sexuality is at issue in the wake of the parricide? There are two possibilities and they are related. The first, suggested by the work of French psychoanalyst, Jacques Lacan, is that the danger of excess lies with the brothers, who compete among them-

selves in order that one of them will be able to exercise the slain father's power. Freud noted that the rivalry among the brothers continued after the father's death. “Each of them would have wished, like his father, to have all the women to himself.” This fantasy, the notion that his likeness to the father exempts one of the brothers from castration (and so gives him access to all the women)—Lacan calls it the “phallic exception”—is ever-present, expressed not only in adulterous liaisons, but in all manner of political contests in which candidates seek to display the signs of their exceptionalism, and so to demonstrate their unique possession of the phallus, now equated literally and mistakenly with the physical organ. (Here we might think of Silvio Berlusconi and Donald Trump, surrounded by all those glittering women, as striving to reincarnate the deposed father's monopoly of power, making law even as they transgress law; Trump's continued insistence that “his” is bigger than any of his rivals.) The apparent claim to an individual man's uniqueness is actually a collective male fantasy—and therein of course lies the trouble. Since there is no individual body that can act as the concrete referent for power—as the king's did when he was considered the divinely ordained occupant of the throne—the question of how to discern possession is an open and anxious one. The emphasis on reason and (some) men's brains as the sign of this power, I suggest, is a displacement of that anxious question from the pulsating genital regions to the lofty heights of abstraction, reason

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LACK OF CRITICAL ATTENTION TO THESE  
LARGE STRUCTURAL ISSUES, WHICH ARE  
BASED ON (AND SO REPRODUCE) THE  
IMPLICIT NOTION THAT THE DIFFERENCE OF  
SEX IS A FACT OF NATURE, IS ONE OF THE  
REASONS INEQUALITY PERSISTS.



This article is a slightly edited excerpt of the lecture given on the occasion of the awarding of the Edgar di Picciotto International Prize of the Graduate Institute of Geneva to Joan Wallach Scott (left), Professor Emerita in the School of Social Science, on September 25, 2018. The honor recognizes internationally renowned academic leaders whose research has improved our understanding of global challenges and

influenced the decisions of policy makers. She is the first woman to receive the prize whose previous winners are Amartya Sen, Saul Friedländer, and Paul Krugman. The full video of her lecture, “Gender Equality: Why Is It so Difficult to Achieve?” may be viewed at [www.ias.edu/scott-picciotto](http://www.ias.edu/scott-picciotto). Scott joined the Institute Faculty in 1985, and has challenged the foundations of conventional historical practice, including the nature of historical evidence and historical experience and the role of narrative in the writing of history, from gender and questions of difference to underlying ideological systems. Her most recent book is *Sex and Secularism* (Princeton University Press, 2017).



becomes the distinguishing feature of masculinity. Indeed, masculinity (referring concretely to the sex of the primal father and symbolically to the phallus he wielded) remained the criterion that the band of brothers insisted upon. The French socialist-feminist Jeanne Deroin, who was prevented on the grounds of her sex from running for office during the Revolution of 1848, pointed to the dilemma that men faced as they at once avowed and denied their bodies as justification for their exclusive power. Responding to Pierre-Joseph Proudhon's comment that women legislators made as much sense as male wet-nurses, she asked, "and what organs are necessary for becoming a legislator?" Proudhon did not reply.

The other possibility, the one seized on by early political theorists, is that women represent the danger of excess that the brothers now have to guard against. In this scenario, the appetites of the primal father are, in effect, attributed to women's provocation. She is Eve, the seductress, the initiator of the Fall. It is women who threaten to subvert men's rationality, to lure them off course. Rousseau warned in *Emile* that, unlike men, women could not control their "unlimited desires." It was only the imposition of modesty that prevented "the ruin of both [sexes]," otherwise women's lust would lead mankind to "perish by the means established for preserving it." For Rousseau (and many others) it is not only the channeling by modesty of women's sexuality into restrained displays of affection, but the institutionalization of the separation of spheres—the literal containment of women's unruly desire within the walls of the home as critical to the proper functioning of the state.

The two possibilities are, of course, linked. Lacan points out that, in the realm of the unconscious, women's desire serves to confirm men's possession of the phallus, both personally and politically. Without her, there is no proof of his potency. But the proof must remain indirect, at least at the level of public representation, where men's claim to equality rests on abstraction (on the presumed sameness of the brothers) and all sexuality is located concretely in women's bodies. Women's desire confirms men's possession of the phallus; that so-called private relation of familial sexual intimacy, in turn, establishes men's potency and so their right to political power. From this follows all manner of legislation regulating (and even emancipating) sex, sexuality, marriage, and the like. These are psychic investments in sexual difference, expressed in terms of science and politics, but it is their psychic quality—a quality that exceeds conscious control—that helps account for the persistence of inequality despite our best efforts.

The emergence of modern nations brought with it a new insistence on the immutability of gender roles and the policing of sexual activity to keep them in place. Historians working on Germany, France, England, and the United States have observed the "hardening" of the lines of gender differentiation as an aspect of an overall emphasis on divisions of labor from the eighteenth century on. On the one hand, the natural difference of sex was the referent that provided legitimation for men's political authority: "Is it to men that nature confided domestic cares?" asked a French revolutionary in 1793, when outlawing women's political clubs, "Has she given us breasts to feed our children?" On the other hand, men's political authority was evidence for nature's mandate: those who opposed granting suffrage to women saw it as a denial of the very masculinity that citizenship conferred. So it was that an irate journalist demanded of French suffragist Hubertine Auclert in 1877: "Is it our resignation as men that dame Hubertine asks of us? Let her say it frankly."

The difference of sex, in other words, was the key to the seeming resolution of the impossibility of the representation of political power that Lefort theorizes; without it, the illusion of certainty cannot be sustained. But it is not a definitive resolution since there is no stable meaning for the difference of sex—hence the repeated expressions of anxiety about whether the extension to women of education and various civil rights (divorce, inheritance of property, guardianship of children) would obliterate the lines of sexual difference and make women and men "the same." This confusion of the sexes, according to one American medical commentator, posed to the nation the terrifying danger of "moral anarchy." In the wake of World War I, historian Mary Louise Roberts writes, "the blurring of the boundary between 'male' and 'female'—a civilization without sexes—served as a primary referent for the ruin of civilization itself."

### THE EMERGENCE OF MODERN NATIONS BROUGHT WITH IT A NEW INSISTENCE ON THE IMMUTABILITY OF GENDER ROLES AND THE POLICING OF SEXUAL ACTIVITY TO KEEP THEM IN PLACE.



An irate journalist demanded of French suffragist Hubertine Auclert in 1877: "Is it our resignation as men that dame Hubertine asks of us? Let her say it frankly."

We can hear that anguished prophecy of the end of times echoing to our own day from opponents of feminist and queer theories, who argue that historicizing established norms about women and men is an assault against the very foundations of civilized life. To take only two examples: during those debates I cited earlier that led to the creation of the International Criminal Court, one commentator noted that if the word gender were allowed to refer to anything beyond biologically defined male and female, the Court would be in the position of "drastically restructuring societies throughout the world." This same concern about the radical potential of gender to challenge the established meanings of sex difference was expressed by the opponents of a French curriculum that aimed at gender equity in 2011 and of France's law on gay marriage in 2013. The "theory of gender," they argued, "by denying sexual difference, [would] overturn the organization of our society and call into question its very foundations."

The "theory of gender" does not deny sexual difference, but it does historicize it. It says that gender consists of historically specific articulations defining male and female that aim to settle the indeterminacy associated with sexual difference by directing fantasy to secure the stability of some political or social

end. Challenges to these articulations elicit not only adamant insistence about their immutability, but an intensification of the policing of regulatory norms.

There are many examples to offer—I've already referred to the ways in which Berlusconi and Trump present themselves as primal fathers, offering to fix everything that is wrong in their nations simply by the exercise

of their inordinate powers. If we defer to them (as wives to husbands, children to fathers), they promise to provide all the security we need in return. It is not the analogy to asymmetrical family relations that demonstrates my point in these cases, it is the bold assertion of exceptional masculinity as the cure for economic distress, social division, and the threat of terrorism that illustrates the mutually constitutive relationship of gender and politics. It is precisely at moments of

great political instability that invocations of gender (not always the same ones, not always in the same way) appeal to deep psychic investments and, in that way, seek to stabilize the political system. (In Poland, Brazil, Italy, the U.S., and Hungary, authoritarian rulers have targeted women's rights as part of their campaigns. In Hungary, Victor Orban is proposing to ban the teaching of gender studies in universities and any mention of the word gender; in Bulgaria, a UNESCO approved gender equity curriculum has just been banned by the Bulgarian academy of sciences and the ministry of education.)<sup>6</sup>

The importance of the difference of sex as a ground for politics is one of the legacies of modernity and for that reason it has been hard to change. It is embedded in our psyches as well as in our understanding of politics. The appeal to a natural difference of sex has been one of the legitimating claims of those wielding political power, and the attribution of gender to nature has served to lend an air of stability to inherently unstable political systems. Where does that leave those of us intent on achieving gender equality across our societies? With an insight

about the operations of gender ideology that is not a plan of action, but perhaps a guide to formulating more complex strategies in specific situations. We need to figure out how to address the instabilities inherent in the categories of *both* politics and the difference of sex. These are instabilities, uncertainties, and anxieties that are at once psychic and political. They not only demand resolution but—because resolution is ultimately impossible—they may allow us to identify possibilities and openings for change. ■

- 1 "Women Still Hold Tiny Minority of Senior Roles in Financial Services," *The Guardian*, September 2, 2018, <https://bit.ly/2CaT7Xj>
- 2 United Nations, *Report of the Fourth World Conference on Women, Beijing, 4-15 September 1995. Chapter V, section 10(b), iii; section 25, iii; section 11.* (Consulted in 1999).
- 3 Valerie Oosterveld, "The Definition of 'Gender' in the Rome Statute of the International Criminal Court: A Step Forward or Back for International Criminal Justice?" *Harvard Human Rights Journal* 18 Spring 2005, pp. 55–84.
- 4 Rome Statute of the International Criminal Court, July 17, 1998.
- 5 Interestingly, the translations of the word in the final document vary: In French, the translation of gender is *sexe*. In Spanish it is *genero*; in Russian a transliteration—"gender"; and in Arabic, *nau' al-jins*, which means type of sex or character of sex (*nau* hedges the sex in this translation).
- 6 "Bulgarian Academy of Sciences Researchers on the Campaign Against a Project on Gender Equality," LeftEast, <https://bit.ly/2yyGFNG>



# Make Yourselves Gods

Sex, secularism, and the radiant body of early Mormonism

BY PETER COVIELLO

On April 5th, 1841, a young woman stood beneath an elm tree in far western Illinois. This was Louisa Beaman, twenty-six, and at this point in her life an orphan. Her father had died in Kirtland, Ohio, in 1837; her mother, only a few months before, in 1840. In the aftermath of that latter calamity, Beaman had gone to live with her sister Mary, and with Mary's husband, Joseph Bates Noble and it was that man, Joseph Noble, who now stood before her. But not only him.

Joseph Noble was a devout Mormon. He had moved from New York to Kirtland in 1834, with the earliest Mormon émigrés, had suffered the reversals and disappointments—indeed the terrors—of Mormon displacement. (During the ghastly Missouri War of 1838, governor Lilburn Boggs issued his infamous “extermination order”—“The Mormons must now be treated as enemies, and must be exterminated or driven from the state if necessary for the public peace”—and the Mormons were in fact massacred, at Haun's Mill.) But in 1840 something extraordinary happened to Joseph Noble. As if in recognition of this longstanding devotion, the prophet himself had shared with him a momentous secret. None other than Joseph Smith (author, prophet, leader) had personally instructed him, Noble reported years later, in “the principle of celestial or plural marriage, or a plurality of wives.” Smith's startling request was that Noble perform the sealing between Smith and Noble's orphaned sister-in-law, Louisa. This would be, according to later testimony, “the first Marriage Ceremony according to the Patriarchal order of Marriage ever performed in this dispensation.” (Smith appears to have been married polygamously to two other women by this time.) The honor of the request could not have been lost on Noble. “In revealing this to you,” Smith is reported to have said to Noble, “I have placed my life in your hands, therefore do not betray me.”

Noble did not betray the prophet, though his treatment of his orphaned sister-in-law is a matter considerably more equivocal. In what Todd Compton calls the “family tradition” of her future husband, Brigham Young, Beaman is said to have “asked the Lord in fervent prayer for a testimony concerning the principle.” In this version, such testimony was given to her, and she accepted it.

And so she found herself under an elm tree, on a day in early April, standing before her brother-in-law and the prophet Joseph himself. And yet this was to be a queerer than ordinary wedding, and not only because it was by design a rebuke to, and a supersession of, any merely civil rite, or even because the groom was himself already a married man. In part as a measure of the severity of these disruptions of the normative frame of antebellum social and sexual life, Louisa Beaman attended her marriage in disguise. But not just any disguise. In a journal entry decades later, Franklin D. Richards would write, “Br. Joseph B. Noble being the master of ceremonies was present and During the visit related that he performed the first sealing ceremony in this Dispensation in which he united Sister Louisa Beaman to the prophet Joseph in May—I think the 5th day in 1841 during the evening under the Elm tree in Nauvoo. The Bride disguised in a coat and hat.” Louisa Beaman—who would go on to be a figure of defining importance in early Mormon feminism—was married to the prophet, in “the first Marriage Ceremony according to the Patriarchal order,” disguised as a man.

Mormonism, as this delectable tableau suggests, is one of those historical phenomena always over-performing itself, disturbing the parameters that separate the fictive from the putatively real—recalling to us, that is, the historicity of our categories. (Smith has something of this in mind when he writes, “No man knows my history. I don't blame you for not believing my history. If I had not experienced what I have, I could not have believed it myself.”) The book I am now finishing tells the story of the Mormons from the period of their emergence as a dissident sect, notable as much for their post-Protestant heterodoxy as for a dramatically non-normative sexual imagination, through to their renunciation of polygamy at century's end. That 1890 renunciation, with which the Mormons at last attained statehood for Utah—transforming them into reluctant monogamists and enfranchised U.S. subjects—marked, too, the culmination of a fantastically vexed history, in which the Mormons had appeared by turns as heretics, sex-radicals, American Mohammedans, racialized refugees, anti-imperialists, colonizers, and eventual white nationalists, protected in their citizenship less by the secular state's offer of official “toleration” than by the complex wages of a sovereign

whiteness. The pitch of the book, you could say, is that the Mormons were, in certain precise ways I wish to specify, deviant, *queer*—a queer populace emerging before the advent of erotic categories like hetero- and homosexuality—and that this is so much the case that we can profit greatly, both historically and conceptually, by approaching them through the idioms of queer theory, queer historiography, and queer critique. Marked out in their committed derangements of normative intimacy as not only pervers but, in that, as *dubious white people*, Indian-like, Asiatic, Mohammedan, the Mormons make for an especially vivid chapter in the racial history of American sexuality.

But there's more. For as I try to show in some detail, Mormon depravity was read most commonly as both cause and effect of a deranged practice of what I will call *bad belief*: a failure, in all, to hew to the coordinates of religion as they came to be assembled under the aegis of secularism. The book is in this respect a kind of polemic. Speaking in concert with a wealth of practitioners of postsecular critique (Talat Asad, Saba Mahmood, Tomoko Masuzawa, Joan Scott, John Modern), the book uses the story of the Mormons to vivify a counter position about what secularism is: not what results from the dissolution of religion in public life; not the happy extirpation of benighted orthodoxy; nor quite a climate of pluralistic fragilized belief, or scene of fair play among theological options; nor again a sociality anchored in a capacity for adjudication and free choice among the multiplying possibilities for belief in a rationalizing and therefore disenchanted world and, therefore, a liberated world. The unceasing attacks on Mormonism, and the specific terms in which they were prosecuted, bring into exceptional focus a contrary rendering of secularism as, rather, a “normative sociality” and “disciplinary structure,” one intimately involved in the harnessing of the terrain of ritual, practice, belief, and spirit to the imperatives of a settler colonial empire coming to understand itself more

and more entirely in the framework of a redemptive liberalism. (Secularism, I will suggest, is a sententious story imperial liberalism likes to tell about itself.) So secularism, in this iteration, will mark out the styles of *adapted*, *enforced compatibility* with liberal rationality that allow a given set of belief-practices to come into legibility as “religion” at all, rather than as, say, credulity, fanaticism, superstition, backwardness, “fundamentalism,” or any of the other sub-varieties of *bad belief*.

Secularism, I'm going to suggest too, has flesh and sinew, has a body; the radiant body of early Mormon theology does not accord with it. Again, these interwoven, mutually indicating perversions—bad sex, bad belief—were *racializing*: made up, in fact, the very grammar, the stuff and substance, of nineteenth century racialization. Listen to Representative Justin Morrill,

using polygamy and its counterfeited religiosity to argue against Utah statehood in 1856: “Under the guise of religion this people has established and seek to maintain and perpetuate, a Mohammedan barbarism revolting to the civilized world.” The Mormons help us bring into focus not just an economy, or a discursive regime, but a *biopolitics*: a technology of power that (as Foucault renders it) optimizes the life of populations, suturing the self-disciplining of individual bodies to larger groupings made coherent through their statistical regularities as projected over gulfs of time larger than the life-span. Crucially, biopower differentiates sharply among those orders of life that improve the species, and so are meant to flourish, and those that, because they are figured as *threats* to the health of vigor of a “general population,” are marked out contrastingly as degenerate, unimprovable, expendable life. The story of the Mormons, who were only barely not exterminated in nineteenth-century America, throws into stark relief what I call the biopolitics of secularism.

(If you want to tell a story about the disciplinary force of secularism, the Mormons are a great object: they begin as a pure form of *bad belief* and emerge in the following century as the paradigmatic case of *good religion*. My book is about what has to happen to make that so.) ■

This article is an excerpt from *Make Yourselves Gods: Sex, Secularism, and the Radiant Body of Early Mormonism*, an Occasional Paper by Peter Coviello, Member (2017–18) in the School of Social Science. The full paper, and others, can be found at [www.sss.ias.edu/publications/occasional](http://www.sss.ias.edu/publications/occasional). Coviello's book on the subject, *Make Yourselves Gods: The Unfinished Business of American Secularism—a Mormon Story*, will appear in 2019 from the University of Chicago Press.



Joseph Smith

IF YOU WANT TO TELL A STORY ABOUT THE DISCIPLINARY FORCE OF SECULARISM, THE MORMONS ARE A GREAT OBJECT: THEY BEGIN AS A PURE FORM OF BAD BELIEF AND EMERGE IN THE FOLLOWING CENTURY AS THE PARADIGMATIC CASE OF GOOD RELIGION.



with other living things and which forever retains the cyclical movement of nature. The chief characteristic of this specifically human life, whose appearance and disappearance constitute worldly events, is that it is itself always full of events which ultimately can be told as a story, establish a biography.” Cyclical movement of nature and worldly events, biology and biography: these are the two series that make life an entity at once overdetermined in its material dimension and indeterminate in its course. In effect, one incorporates humans into a vast community of living beings, on the same level as animals and plants, while the other makes them exceptional living beings by virtue of their capacity for consciousness and language.

Can this binarism be resolved? Is it possible to think of life as biology and life as biography together? For two thousand years, philosophers have applied themselves to this question. They have successively considered life as animation of matter, following Aristotle, as a mechanism generating movement, with Descartes, and as a self-maintaining organism, as did Kant. They thus moved from a vitalist representation to a mechanistic interpretation, and finally to an organicist approach, each with a different medium: the soul or breath, then the body and fluids, and finally the organs and the internal milieu. However, the point in each of these various interpretations was to pursue an interrogation of the relationship between the living and the human, between the infrastructure of the former and the superstructure of the latter, as it were. For Hegel in particular, “‘life’ is a transitional concept that relates the realm of nature to the realm of freedom,” as Thomas Khurana puts it, since while it is constrained by biological elements it can, through a process of self-organization, produce the autonomy required for the realization of a biographical journey.

In contrast to these earlier attempts to articulate the two dimensions of life, over the last century, the opposition between the two trends has hardened, leading to an apparently irremediable division between the two.

As regards life in the biological sense, it was in the mid-twentieth century that, through the unlikely intervention of quantum mechanics theorist Erwin Schrödinger, the study of living beings shifted in scale, and hence also in perspective. Henceforth, the physicist turns biologist, his analysis descending to the molecular level, his method borrowing from thermodynamics, and atomic structure becoming a code whose innumerable permutations make possible the diversity of living beings and the creation of order out of entropic chaos.

While validating this theory, the discovery of the DNA double helix a few years later constituted the foundation for a new conception of life, now based on information and its replication. Fifty years later, the recent decoding of the human genome has further refined this concept. Even contemporary epigenetics does not fundamentally challenge this paradigm, since the influence of context on genetic inheritance, which it seeks to account for, operates through molecular mechanisms that modify the expression of genes. In other words, biochemistry and biophysics, which are now integral strands of biology, produce theories based on an increasingly intensive molecularization of the living matter, albeit not excluding systemic approaches at a higher level of complexity in microbial populations. At the same time, research into the origins of life focuses both on the emergence of living beings on Earth during the Precambrian period and on the possibility of finding signs of life elsewhere in the universe. This research strives to understand how inert molecules were able to transform into organic molecules with the capacity to replicate themselves so as to generate nucleic acids, and seeks to assemble spectral libraries drawn from living terrestrial organisms. On the one hand, microbiologists are searching for the “last universal common ancestor” of all cells, and the environment conducive to its transformation. On the other, astrobiologists seek “potential biosignature gases” that would point to the presence of life on the exoplanets of other solar systems. In both cases, science comes to meet the imagination of men and women, and the prospect of discovering the ultimate origin of life, or signs of extraterrestrial life, even in the form of molecules rather than identifiable beings, inspires dreams and drives requests for funding. In short, in the exploration of life as biological phenomenon, the shift from conjecture to experiment, from the macroscopic to the microscopic, and from bodies to molecules, has progressively reduced the understanding of life to its most basic material unit—an assemblage of atoms—while at the same time expanding it massively in time and space: human beings are, indeed, dissolved in a temporospatial network of molecular components of life which appeared several billion years ago and may be present in other parts of the universe.

With life as biography, we find a quite different story—more fragmentary, less cumulative. We can, however, identify certain moments, such as the arrival of the novel in literature, and some features, including an increasingly anxious questioning as to how one should write about life and lives. On the one hand, the novel, as it developed from the eighteenth century onward, constituted life for the first time not only as an interesting subject but also as a “detachable thing,” as Heather Keenleyside puts it in her discussion of *Tristram Shandy*. It frames life as a more or less linear unfolding of events, through which the subjectivities of the characters are formed, whether in Jane Austen’s novels of manners, Goethe’s bildungsroman, or a

## On the Inequality of Lives

“The subject of this text is indeed as the title states: it deals with life—and with lives. It would be easy, and certainly on one level true, to state that this is the guiding principle of a career that began in medicine and then diverted to anthropology: in turning from the teachings of biology to the gathering of biographies, I have moved from the life of organs to the life of human beings. But there is more to it than the fortunes of a professional trajectory. For my way of scrutinizing life through forms of life, ethics of life, and the politics of life is not neutral. It is marked by the theme of inequality—the inequality of lives which, from my childhood in a public housing project to my discovery of non-Western societies through the extreme poverty I encountered in Indian cities, has formed my worldview. In fact this book could, perhaps more explicitly, have been titled ‘On the inequality of lives.’”—DF, *Life: A Critical User’s Manual*, “Acknowledgments”

little later, the great literary projects of Balzac and Zola, who reconstitute a society at a particular time through the life stories of individual characters more or less connected to each other. In its most complete as well as most radical expression, with Proust, the autobiographical account becomes life itself, a life magnified by the creative labor of writing: this is what he calls the true life, the life that, by virtue of convention and habit, we risk passing over, to the extent that one might die without ever having recognized it. On the other hand, in the social sciences, from the very beginning, alongside the important developments in theory and methodology by the founders of the discipline, the life story has played a central part, whether it be reconstituting the trajectory of a Polish peasant, in the case of William Thomas and Florian Znaniecki, or recounting the history of a Mexican family, as does Oscar Lewis. But it was particularly from the 1980s onwards that, as the reaction against structuralism came together with feminist critique and postcolonial studies, the demand arose, in anthropology as elsewhere, for recognition of individuals, their history, their truth, and their words. The narrative turn was also a subjectivist turn. One should no longer speak in the name of subalterns, but rather make their voice heard—with the singular difficulty, particularly for historians, that their lives have often disappeared without leaving a trace in the archives. But a few decades later, a contestation of the life story and its identification with life began to emerge, both in literature, through a deconstruction of the narrative form in Samuel Beckett’s work, and in the social sciences, in the form of Pierre Bourdieu’s challenge to the biographical illusion. Life as a coherent form became an object of suspicion.

Two life lines, then. For the purposes of clarity rather than classification, let us call the first one naturalist, the second humanist. My aim, in attempting this brief description of how they developed, is to point out the existence of two approaches that appear, at least in the first analysis, increasingly irreconcilable. The life studied by the biophysicist no longer bears any relation to that imagined by the novelist, even if some novelists incorporate biological elements into the fabric of their narratives, and some biologists venture, with varying success, into literature. The objects astrobiologists deal with, namely the molecules that indicate a presence of life, bear little relation to the subjects encountered by sociologists, namely individuals who recount the facts of their lives, even if, in the first case, the search for some presence of life is not unconcerned with the search for non-human intelligence, and in the second, sociologists can make the life sciences laboratory the focus of their research. We are far from the Aristotelian, Cartesian, Kantian, and Hegelian projects.

Considering these vicissitudes of the concept, is an anthropology of life imaginable, or even desirable? Here we have to start from a paradox. Although anthropologists have always been interested in the lives of their interlocutors, in terms of both way of life and life stories, they have rarely made those lives a specific and legitimate object of their research. The lives that they studied synchronously, through the culture within which they unfolded, or diachronically, through the stories that reconstructed them, served as empirical material for their analysis of kinship, myths, social structures, religious practices, or political institutions. Even in its most embodied manifestations, such as biographies, the aim was principally to understand trajectories, situations, emotions. Life itself was rarely seen as an object of knowledge on the same level as the other categories constituting their discipline. It was a sort of vehicle or medium that allowed them access to concepts and realities deemed more significant or more relevant for the description and interpretation of societies.

In recent decades, however, anthropologists have started to construe life as object, principally considered in either the naturalist or the humanist form described above. On the one hand, within the context of the great body of research emerging from the social studies of science, life has been approached in the same way as by researchers in the biological, physical, and even information sciences—in other words, as living matter. Anthropologists have analyzed the knowledge, practices, and

(Continued on page 13)



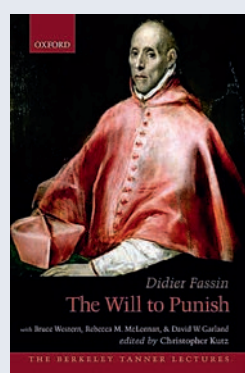
objects of life sciences, focusing among other things on genomics and epigenetics, stem cells and cell death, hereditary conditions and regenerative medicine, the development of artificial intelligence, and the use of neuroscience in criminology. In other words, they have been endeavoring to understand and interpret the leading-edge research into the various manifestations of life. On the other hand, in the more traditional domain of social or cultural anthropology, there has been a proliferation of monographs on the life of individuals based on the everyday detail of their existence, in geographical contexts that vary widely but are often marked by the ordeals of poverty, sickness, and misfortune. There have been studies focused on the death of children in Brazilian favelas and the affliction of extreme poverty in rural India, on the destitution of the Ayoreo Indians of Paraguay and suicide among the Inuit of northern Canada, on the feeling of loss in the aftermath of the civil war in Sierra Leone and the tribulations of wounded veterans returning from war in the

United States. In these studies, life is generally presented not only in its subjective dimension, as experienced by these men and women, but also in terms of the objective conditions through which society contributes to shaping and treating it. In other words, apart from a few attempts to combine the naturalist and humanist approaches, for example, in medical anthropology, where sickness sits at the meeting point of biology and biography, the two life lines have largely been deployed as parallel avenues of anthropological research. Yet these approaches are not conceived as anthropologies of life as such, but rather as anthropologies of life sciences and of life experiences respectively.

In order to render an account of life that does justice to the complexity of its multiple dimensions while at the same time representing it with a degree of unity, I therefore propose to analyze and relate three conceptual elements of those dimensions: forms of life, ethics of life, and politics of life. Each of these opens up an anthropological fact of life. Beyond the contradictory interpretations proposed by exegetes, forms of life, as outlined by Wittgenstein, reveal the tension between the specific modes of existence and a common condition of humanity: the experience of refugees and migrants offers one tragic illustration. Unlike the concept of the ethical life inherited from Greek philosophy, ethics of life extend Walter Benjamin's reflection on the sacralization of life as supreme good: the higher principle of humanitarian morality that consists in saving people threatened by disaster, epidemic, famine, or war here collides with the opposite rationale based on the honor of sacrificing oneself for a cause on the battlefield, in a suicide attack, or by hunger strike. Finally, taking up an illuminating idea that was never fully followed through, politics of life reformulates Foucault's notion of biopolitics: contrary to the dogma of sacred life which should render it beyond price, it is possible to put a monetary value on human existence, and this varies according to the gender, social class, ethnic background, and geographical origin of the individual.

So, if it is true, as Perek suggests in *Life: A User's Manual*, that it is the pattern that determines the parts rather than the opposite, the theoretical framework behind each of these three concepts derives from a reflection on the treatment of human lives in contemporary societies. One theme underlies this reflection: inequality. As I hope to show, this theme binds together the biological and the biographical, the material and social dimensions of life—in other words, the naturalist and the humanist approaches. What I propose, then, is not an anthropology of life, which I deem an impossible project, but rather an anthropological composition formed of three elements which when assembled, like a jigsaw puzzle, reveal an image: the inequality of human lives. ■

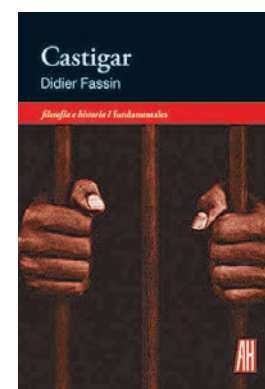
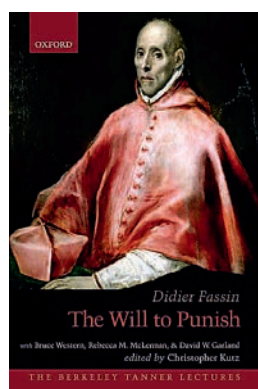
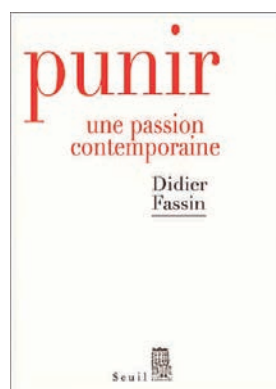
*This article is a slightly edited excerpt of Life: A Critical User's Manual (Polity, 2018) by Didier Fassin. An anthropologist, sociologist, and physician, Fassin has been James D. Wolfensohn Professor in the School of Social Science since 2009. His current work is on the theory of punishment, the politics of life, and the public presence of the social sciences. Recognized with the 2018 NOMIS Distinguished Scientist Award, Fassin will use the corresponding grant to implement an international project that will analyze contemporary crises from a global perspective.*



## The Will to Punish

Recently, societies have become more repressive, their laws more relentless, their magistrates more inflexible, independently of the evolution of crime. In this book, using genealogical and ethnographic approaches, anthropologist Didier Fassin addresses the major issues raised by this punitive moment through an inquiry into the foundations of punishment. Asking three simple questions: What is punishment? Why punish? Who is punished? he initiates a critical dialogue with

moral philosophy and legal theory about the definition, justification, and distribution of punishment. Discussing various historical and national contexts, mobilizing ten years of research on police, courts, and prisons, and taking up the legacy of Friedrich Nietzsche and Michel Foucault, he shows that the link between crime and punishment is a historical artifact, that the response to crime has not always been the infliction of suffering, that punishment does not only proceed from the rational logics used to legitimize it, that more severity in sentencing often means increasing social inequality before the law, and that the question, What should be punished?, always comes down to the question, Whom do we deem punishable?—and whom do we want to be spared? Rejecting the triumphant penal populism, this investigation proposes a salutary revision of the presuppositions that nourish the passion for punishing and invites us to rethink the place of punishment in the contemporary world. This volume is based on the Tanner Lectures on Human Values that Didier Fassin delivered at the University of California, Berkeley. The theses that he develops in it are discussed by criminologist David Garland, historian Rebecca McLennan, and sociologist Bruce Western, to whom he responds in a short essay asking: What is a critique of punishment?



## What's in a Translation?

The five versions of the same volume presented here in French, English, German, Italian, and Spanish, could serve as a pretext for a reflection on the work of translation—not only of words, but also of ideas, contexts, and images. The French title (literally: *Punishing. A Contemporary Passion*) was adopted in Italian and Spanish, but the English one (*The Will to Punish*) was preferred for the German edition because of its Nietzschean evocation. The French and German books have deliberately sober covers, connoting academic rigor in these national editorial codes, whereas the other three use images, chosen with the author, which represent different dimensions of retributive politics, with El Greco's Great Inquisitor of Spain, the arm of a statue of Justice in Frankfurt, and the hands of a prisoner on cell bars in an anonymous prison, for the English, Italian, and Spanish versions, respectively. Moreover, each volume includes specific elements, also introduced by the author, which are related to the particular punitive context of the corresponding country so as to better situate the relevance of the text for the readership. Thus, rather than mere transpositions in a different language, such translations are partial re-inventions, involving distinct references, imaginations, and facts. (Christine Pries is the translator for *Der Wille zum Strafen*; Lorenzo Alunni for *Punire*; and Antonio Oviedo for *Castigar*.)—DF



Specifically, I am working on two projects, one in the history of molecular biology and biomedical research and one in the history of physics and technology. Both projects necessitate a disciplined interdisciplinarity, which ties together a myriad of fields from the humanities, social sciences, and natural sciences. The types of histories of science I write attempt to explain scientific and technical content in terms of its historical context. In so doing, I draw upon the methodological tools provided by historians, natural scientists, philosophers, sociologists, and anthropologists.

I am fascinated by the way in which molecular biology has challenged traditional legal and scientific concepts and practices, such as knowability, ownership, genetic information, and knowledge sharing. Gene patenting and genetic information offer us prime examples of the instability of ownership and knowability. During the early 1980s, when genes were initially awarded patents by the United States Patent and Trademark Office, the Japanese Patent Office, and the European Patent Office, the procedure was to isolate a gene, determine the function of its protein product by biochemical assays, and then patent it.

The procedure first required knowability (i.e., knowledge of what the gene coded for) before ownership could be granted: one needed to know what one owned. By the 1990s, that had changed. Broad utility patents were being issued for rather vague statements about a gene's utility. That is to say that one could obtain a patent for a gene, coded for a protein whose precise function remained unclear. In this case, one owned something before one precisely knew what one had.

With this change in the relationship between ownership and knowability came a change in expertise. Previously molecular biologists and their "wet" skills, techniques, and practices had been necessary to define the function of the gene product and therefore its utility. By the 1990s, their authority had been controversially usurped by a generation of computer scientists who had invented algorithms to find gene sequences with unprecedented rapidity and who had begun to model proteins using computer graphics with a view to find structural homologies and deduce similar functions. The tools and skills of the computer scientist were now seen as both necessary and sufficient to ascertain knowability.

This transformation in expertise raises a number of interesting questions. Does the sequence (or genetic information, specifically the genetic code as it appears in the patent description) trump materiality to convey ownership? Do patent owners forfeit their right to ownership if they patent an incorrect sequence, an occurrence much more common than one might believe? Is the gene sequence sufficient to determine protein function? How has bioinformatics changed both intellectual property and the discipline of molecular biology? How has gene patenting thwarted knowledge sharing and encouraged secrecy?

Theories of ownership have become particularly relevant now that personal genomics companies are selling access to their databanks containing their clients' genetic information to various interested third parties such as Big Pharma. There are also fears that some companies might sell their anonymized data to insurance companies. While one may naïvely think that these customers "own" their DNA, the situation is much more complicated. Companies such as 23andMe and AncestryDNA are presently at the center of another controversy in biomedical research, namely how we understand human diversity.

Comparing the DNA sequences of various populations represents the most recent episode in a centuries-long tradition of human classification based on the biology of difference. This history often evokes painful memories, which include the eugenics movement and the Tuskegee Syphilis Experiment. Rather than basing the biology of difference on external characteristics, some (but certainly not all) molecular biologists are asking whether internal DNA sequences might be more accurate and precise. And should we define different populations with different genetic markers as "races"? Can one ascertain the "race/races" of an individual from her DNA? What are the sociopolitical implications if one can? What are they if one cannot?

Personal genomics companies advertise directly to U.S. consumers, who wish to find out about their ancestry and possible ailments, which might afflict them in



Nineteenth-century *handwerker* and optician Joseph von Fraunhofer demonstrates his spectroscope. Whether one considered Fraunhofer's work *science* depended, in part, on one's views about his social status.

their future. A number of biomedical researchers are less interested in ancestry and more interested in how different diseases affect different populations. These scientists are also keen on tracing human migration over a period of tens of thousands of years. DNA is a type of historical archive, and the skills of molecular biologists enable us to read and understand it. These biomedical researchers are certainly not racist. On the contrary, many of them argue that the field of race and genomics is about redressing the sins of the U.S. medical community's past, when marginalized populations suffered greatly. Interestingly, there has been pressure from different sectors to use race as a proxy for human genetic diversity.

For the National Institutes of Health, requiring data on the safety and efficacy of drugs on women and people of color is important medically: the white male should no longer stand as the universal symbol for health. The use of race now, unlike the past, is about inclusion, not exclusion. Critics, however, maintain that—even if one could precisely define "race"—we might be reentering a dangerous age of genetic essentialism. And many point to the fact that Big Pharma and personal genomics companies capitalize on using race as a potent marketing tool.

My second project deals with the history of physics and technology. I am currently working on the relationship between music, the natural sciences, and engineering over the past two centuries. It is a continuation of my earlier work on the triangular exchange between physicists, musicians, and instrument makers in nineteenth-century Germany. I am particularly interested in analyzing how scientists and engineers helped shape musical aesthetics. For example, during the late 1820s, the physicist Wilhelm Eduard Weber mathematically determined the specifications of a reed pipe, which in the hands of an experimental physicist was used to test directly the ratio between the increase in pressure and density of the sound

wave. Such a value was critical to the study of adiabatic phenomena, or ones in which heat is neither liberated nor absorbed.

In the hands of an organ builder, those specifications produced a compensated reed pipe, which meant that the organist could increase the volume of the pipe without increasing its pitch. Organs could now be rendered expressive, marking an important aesthetic change of the mid-nineteenth-century organ performance. The work of the nineteenth-century doyen of physics and physiology, Hermann von Helmholtz, directly led to the duplex scaling tuning technique patented by C. F. Theodore Steinway in 1872, a fact that the Steinway & Sons advertised when selling their highly coveted pianos. Helmholtz provided piano makers with the theoretical calculations of the relationships of the intensities of upper partials to the fundamental tone given the length of time a piano hammer comes in contact with a piano string. Steinway was able to draw upon Helmholtz's guidelines to generate sympathetic resonance in the non-speaking portion of a string, thereby creating the proper upper partials in their correct intensities, resulting in a much richer tone.

During the late 1920s and '30s in the city of Berlin, a group of applied physicists, physiologists, engineers, and musicians tinkered away inventing new musical instruments and genres. The technical expertise of radio engineers, combined with the musical expertise present in the Berlin Hochschule für Musik (Conservatoire) and the financial backing of German electrical companies and the Prussian Ministry of Science, Art, and Popular Education, enabled the production of a new electric musical instrument, the *trautonium* invented by the physicist and engineer Friedrich Trautwein. It could be used for microtonal pieces and could mimic the timbre of numerous more traditional instruments. Engineers, physicists, and physiologists working on the analysis, synthesis, and broadcasting of speech and music on the radio provided musicians with the long-coveted ability to generate new tones. And musicians borrowed techniques used by physiologists and physicists in order to create new types of music.

Rather than considering the *trautonium* an example of *entartete Musik*, or "degenerate music," the Nazis embraced the instrument, which was often featured on the radio and even made an appearance at the ceremonies of the Berlin Olympic Games in 1936. Various versions of the *trautonium* survived after the war, the most famous of which was the *Mixtur-Trautonium*, built by the performer, physicist, and composer of film scores Oskar Sala, who had worked with Trautwein in Berlin. It is perhaps best known for being featured in *The Birds*, the classic film produced and directed by Alfred Hitchcock in 1963. The screeching sounds of the birds as well as the flapping sounds of their wings were not natural, but were artificially generated by the *Mixtur-Trautonium*.

The collaboration between physicists, radio engineers, and composers lasted well

(Continued on page 15)

Myles W. Jackson joined the Institute for Advanced Study as a Professor in the School of Historical Studies in July 2018. His research intersects science, technology, aesthetics, history, and society and his scholarship, which interweaves economic, commercial, and scientific insights, has had lasting impact. He is noted for his cross-disciplinary methodology and range of study—from the artisanal production of scientific knowledge in nineteenth-century Germany to issues of intellectual property, knowledge sharing, race and genomics, the interactions between musicians, natural scientists, and radio engineers, and bioengineering in recent decades.



after the end of World War II. One only needs to think of *musique concrète*, created by the composer and radio engineer Pierre Schaeffer and the composer Pierre Henry at the Club d'Essai studio of the Radiodiffusion Télévision Française in Paris, or the collaboration between the composer Herbert Eimert, the aforementioned Trautwein, the information-theory physicist and acoustician Werner Meyer-Eppeler, the sound engineer Robert Beyer, and the composer Karlheinz Stockhausen at the Cologne Studio für elektronische Musik of Westdeutscher Rundfunk (Studio for Electronic Music, West German Radio), or the music for magnetic tape of John Cage and Bebe and Louis Barron and the tape music of Otto Luening and Vladimir Ussachevsky that dominated the New York music scene in the early 1950s.

Over a period of two hundred years, the relationship between performer, composer, and musical instrument maker has been completely transformed. On July 25, 1926, the avant-garde composer Paul Hindemith wound up a Welte-Mignon reproducing piano (similar to a player piano) at a performance in Donaueschingen in the Black Forest and left the stage, allowing the instrument to execute the piece. The piano finished the composition, and there was an uneasy silence. Should the crowd applaud? There was no human sitting there, only a machine. Finally, after an embarrassingly long pause, a quiet applause broke out, and it grew louder. The audience cried out “da capo.” And sure enough, the piano played the piece again, as precisely as it did the first time. The machine (in this case a musical machine) had become the virtuoso. The cult of the nineteenth-century virtuoso, epitomized by Niccolò Paganini and Franz Liszt, had now been usurped by the machine.

In 1930, the avant-garde composer Edgard Varèse, who collaborated with physicists and engineers and visited Bell Telephone Laboratories several times, (in)famously declared that the performer, the virtuoso, should no longer exist: she would be better replaced by a machine—and he was convinced one day, thanks to science and technology, that would indeed happen. And the wondrous sounds produced by radio laboratories after World War II are now generated by computers. A musical instrument maker looks more like computer engineer in this case. A number of my former students, who are composers, boast that they cannot really play a traditional musical instrument. They learned the craft of composing on the computer.

A second theme in the history of physics and technology that has always interested me is the complex and historically contingent relationship between scientific skill, science and technology transfer, the communicability of scientific knowledge, and the politics thereof. In this particular case, I am interested in what happened throughout the nineteenth century with the hope of coming to terms with those relationships today. What is the status of manual labor vis-à-vis intellectual labor? What types of intellectual skill can be mechanized?

Questions concerning the management of such labor are predicated upon whether that labor is communicable and if so, how. The implications of these questions are tremendous. How should scientific knowledge be taught to future scientists and engineers? How can technological, commercial firms achieve the critical balance between public and private knowledge to ensure market success and future viability? Answers to these affected the discipline of physics. In the nineteenth century, a professional class of (nearly exclusively) men began to emerge—the scientists—who dedicated themselves to the study of nature. As specialization of labor began to increase in society in general and within the scientific enterprise in particular, issues involving the nature and status of artisanal knowledge with respect to scientific knowledge and its management became more and more relevant and indeed politically charged. The politics of labor can offer insights into how these issues were solved then and into how those solutions affect decisions being made today.

One of my earliest projects analyzed the importance of artisans (scientific instrument makers) to the discipline of nineteenth-century astronomy. It was a story about social class, manual skill, mechanization, patent laws, and the Industrial Revolution. It was also a depiction of the relationship between manual and intellectual work at a time when both types of work were undergoing profound changes. What was the status of craft knowledge vis-à-vis the knowledge of experimental natural philosophers? Although instrument makers were critical to the advancement of nineteenth-century science, why were they often (although not always) denied the recognition and privileges of experimental natural philosophers?

I used the work of the Bavarian *handwerker* and optician Joseph von Fraunhofer as a heuristic tool to trace the ever-changing contours between science and culture. In both Bavaria and Britain during the 1820s and '30s, heated debates raged about the status of skilled artisans within experimental natural philosophy. The political responses of several leading British experimental natural philosophers to Fraunhofer's artisanal optics mapped nicely onto various aspects of British society, such as mechanization, royal patronage of the sciences, industrial efficiency, and patent laws.

Differing responses to precision-technological practice in the nineteenth century were deeply embedded in more encompassing political beliefs. Whether one considered Fraunhofer's amalgamation of the secret and craft traditions to be science depended, in part, on one's views about his social status.

### A NUMBER OF MY FORMER STUDENTS BOAST THAT THEY CANNOT REALLY PLAY A TRADITIONAL MUSICAL INSTRUMENT. THEY LEARNED THE CRAFT OF COMPOSING ON THE COMPUTER.

While I hope the histories that I write are interesting and informative, their morals are certainly politically relevant and resonate today. Biological entities were not always patentable or seen as commodities. Similarly, human genetic variation does not necessarily need to be linked to so-called racial differences. Historians need to point out that neither the patenting of genes nor the categorization of human difference as racial is inevitable. We are obliged to inform others of times when alternatives were presented only to be erased from the collective memory. Based on my work on gene patenting I was asked by the American Civil Liberties Union to write a deposition for the Southern Court of New York on why precedent cases invoked by supporters of gene patenting were not actually applicable to genes. District Court Judge Sweet agreed with us, and genes were deemed non-patentable. The case was appealed and went all the way to the United States Supreme Court, and I was asked to co-author an *amicus curiae* brief. On June 13, 2013, the

Supreme Court argued unanimously (9–0) that genes merely excised from the genome are not patent eligible as they contribute nothing to the art. cDNA copies of those genes, however, are products of human hand in the laboratory and are therefore patent eligible.

Similarly, as a result of my work on craft knowledge, I entered into an interesting collaboration with mathematicians, physicists, and engineers at the Fraunhofer-Institut für Techno- und Wirtschaftsmathematik (Fraunhofer Institute for Industrial Mathematics) in Kaiserslautern, Germany. They were able to construct a robot that could cut precious stones more precisely than their human counterparts. What are the socioeconomic ramifications of such an invention? What would happen to the jewelers who would be replaced? How could they be retooled most efficiently? Where could their expertise be most effectively channeled? How could a historian analyze that process, and along those lines, what is the relationship between intellectual and manual labor that would ensure both the well-being of the workers as well as the market efficiency of the company purchasing the robot? I hope to continue this research by discussing with German politicians and employees of the Bundesministerium für Arbeit und Soziales (Federal Ministry of Labor and Social Affairs) how Germany has been so successful in retraining its labor force. I very much look forward to pursuing all of these passions at the Institute for Advanced Study, the Faculty and annual Members of which provide an amazing array of intellectual acumen in history, the social sciences, mathematics, and natural sciences upon which I shall draw. ■



Myles Jackson

The history of science has been a field of research at the Institute beginning in the early fifties with the active support of J. Robert Oppenheimer, then Director of the Institute, who saw it as a bridge between the various schools. The appointment in 1950 of Otto Neugebauer, a historian of Egyptian and Babylonian mathematics and astrology, was followed in 1964 by Marshall Clagett, a specialist of medieval science, and in 1998 by Heinrich von Staden, a classicist and historian of science with a particular focus on ancient Greek medicine, now a Professor Emeritus in the School.

“Myles is an extraordinary addition to our Faculty at the Institute,” said Robbert Dijkgraaf, Director and Leon Levy Professor. “With his scope of knowledge and multi-sphered approach, Myles will further the Institute's presence in the field of history of science in ways only he is able to imagine and coalesce, stimulating new interactions with humanists and scientists that lead to revelatory research and deeper understanding.”

“Myles's indefatigable energy on behalf of his field of study, his exceptional range, his enthusiasm in establishing bridges with other fields, his stellar international status, his reputation for mentorship, and his collegiality make him an ideal appointment for the continuation of history of science in the School of Historical Studies,” commented Yve-Alain Bois, Professor in the School.

For more information about Myles Jackson's research, accomplishments, and previous academic appointments, most recently at New York University, please visit the press release about his appointment at [www.ias.edu/press-releases/jackson](http://www.ias.edu/press-releases/jackson).

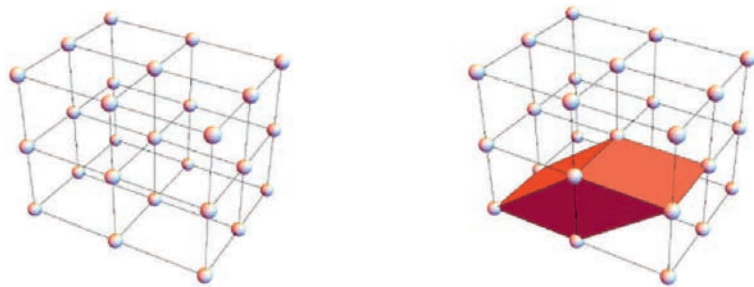


conjecture of Langlands that relates the cohomology of locally symmetric spaces to algebraic varieties. Understanding subtler features of this conjecture was a central theme of the program.

The program was broad and represented several parallel intellectual directions. For coherence, I will focus on just one theme, which suggests that the relationship between the topology of locally symmetric spaces and the arithmetic of algebraic varieties is much richer than expected.

### An example of a six-dimensional locally symmetric space

To understand an example of a locally symmetric space, imagine trying to describe the structure of a three-dimensional crystal, i.e., a collection of objects arranged in a repetitive pattern. In nature, there are a bewildering number of variants of crystal structure. The example given here concerns crystals of a simple type, namely, those that arise from *stacking copies of a basic cell*, as in the picture below.



(a) crystal

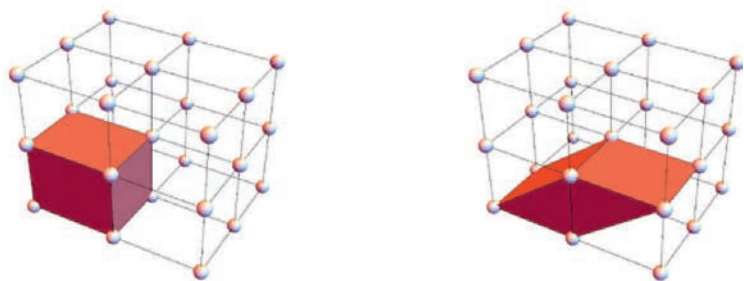
(b) basic cell

How can we describe this basic cell, which is called a *parallelepiped*, without the aid of a picture?

We need to give three lengths and three angles. These six numbers completely describe a crystal. If I tell you to construct a crystal whose basic cell has side lengths 2, 2, 3 inches, with the first two sides at an angle of 80 degrees, the last two sides at an angle of 85 degrees, and the first and last at an angle of 75 degrees—there is no remaining ambiguity. You have enough information to go and make a model for this basic cell, and then, by stacking the cell on top of itself, you will reconstruct the crystal.

However, *many different basic cells can give rise to the same crystal*. See the figure below for an illustration. In the example just given, many other sets of measurements would lead to the same model. *This indeterminacy is what makes the situation mathematically complicated.*

Now suppose that we make a map of all the possible crystals of this type. Each point on the map describes a specific crystal structure; points on the map are close to one another when their crystal structures are very similar. The resulting map is a basic example of a locally symmetric space. The fact that it requires six coordinates to describe a crystal structure makes this locally symmetric space six-dimensional.



(a) one basic cell

(b) different basic cell

The map is difficult to visualize and work with, because of the indeterminacy mentioned above. One way to work around this would be to fix some way to decide between different basic cells—to settle on a procedure whereby we would only ever use basic cell (a) in the diagram above, for instance. By doing this, we can ensure that each crystal is now represented by a unique collection of six numbers—three lengths and three angles—but the cost is that these numbers must satisfy a complicated collection of constraints.

Mathematically, then, this map of possible crystals looks like a polyhedron, but in six dimensions rather than three. Although hard to picture, we at least know that points on the map represent crystal structures.

This example can be modified in many ways, giving other examples of locally symmetric spaces. For one thing, one can impose specific symmetry axes on the crystal. Or we can work in a different dimension entirely. Each modified situation provides another example of a locally symmetric space, with a corresponding map of all the crystal structures.

### Their place in mathematics

Locally symmetric spaces can thus be considered as maps of potential crystal structures. (The mathematical term is *lattice*, instead of *crystal*.) They sit at a busy crossroad in mathematics. They provide special but highly interesting example cases in a number of disciplines, including Riemannian geometry, topology, algebraic geometry, and representation theory. But perhaps their richest and deepest interaction is with number theory. I will focus on one small part of this interaction, the relationship between: (i) the topology of locally symmetric spaces, and (ii) the arithmetic of algebraic varieties.

For (i) the topology of locally symmetric spaces, imagine one crystal structure (call it *A*) slowly morphing until it turns into another one (call it *B*). (To do this, choose a unit cell for *A* and imagine slowly altering its lengths and angles until it turns into the unit cell for *B*.) How do we draw this process on our map? The initial structure and the final structure are both points on the map and the process of morphing corresponds to a *path* between these two points.

But, as I have emphasized above, there are many choices of a basic cell for crystal *A*. Suppose we had chosen a different one. We can still slowly alter its lengths and angles so it turns into the basic cell for crystal *B*. This will give us *another* path from *A* to *B* on our map. These paths are *essentially* different—there is no intermediate between them. Choosing between them is like deciding to go around an obstacle by going to its left or by going to its right: there is nothing in between.

Topology is concerned with quantifying how many “essentially different” types of paths there can be on our map. It also quantifies higher-dimensional versions of the same question: a path is a one-dimensional structure, but we may also ask how many “essentially different” two-dimensional figures can be drawn on our map, and so on.

Now I will explain (ii) the arithmetic of algebraic varieties, which means the study of polynomial equations with integer coefficients, for example

$$(1) \quad x^3 + 2y^3 + 3z^3 = 6.$$

Langlands made the striking prediction that a certain count of solutions to this equation is, in fact, encoded in the topology of locally symmetric spaces.

How do we count solutions? If we permit  $x, y, z$  to be arbitrary real numbers, or even whole numbers, the number of solutions may well be infinite. We may avoid this problem by considering the *last digits* of  $x, y$ , and  $z$ . How many possibilities are there for these last digits? They can’t all be zero—if they were all zero, then the lefthand side of equation (1) would end with a zero, and thus could not equal 6. But (for example) the last digits could all equal 1; or the last digits of  $x, y, z$  could be 9, 7, 3 respectively. It turns out that there are exactly one hundred possibilities for the last digits of  $x, y, z$ .

This type of counting (based on so-called modular arithmetic) looks rather odd, and it is hard to see why it is a sensible thing to do. But, whatever it is, it is a procedure that belongs to an entirely different world than the geometric objects we described previously. Thus, it is miraculous that (in a way I won’t specify) this count of one hundred possibilities shows up, in a very different way, when studying the topology of a certain locally symmetric space.

### The special year

I will now explain, somewhat impressionistically, one of the themes of the 2017–18 special year. An algebraic variety is, by definition, just a system of polynomial equations, such as (1) above. A very influential idea of Alexander Grothendieck is that these can be broken up into basic building blocks called *motives*. The building blocks capture some, although not all, of the information about the variety. For example, the count we did above (how many possibilities for last digits?) can be indicated by the building blocks of the variety. On the other hand, if we ask a more geometric question like “What does the graph of  $x^3 + 2y^3 + 3z^3 = 6$  look like?” it cannot be answered using these building blocks alone. Now, as with many other things, it is much harder to fit the blocks together than it is to break them apart! Speaking a little loosely, the information needed to fit motives together is measured by a very subtle theory that was proposed by former IAS Member Alexander Beilinson and put in its modern form by the late IAS Professor Vladimir Voevodsky—the theory of *motivic cohomology*.

One keystone of the Langlands program is a relationship between the topology of locally symmetric spaces and the theory of motives. It was this idea that we tried to illustrate in the previous section.

Now, a key goal of the special year was to push this relationship even further. Not only does the topology of locally symmetric spaces contain information about motives (building blocks of algebraic varieties), but it *also* appears to carry very delicate information about motivic cohomology (which encodes how these blocks fit together). This seems to be a deeper phenomenon, and I find it very surprising. Evidence for it appeared several times over the course of the year—in

(Continued on page 17)



lectures of Alexander Goncharov, Romyar Sharifi, and myself—although in somewhat different guises each time. The ultimate goal, then, is to make a bridge between the topology of locally symmetric spaces and (a small part of) the world of motivic cohomology. This bridge would carry traffic in both directions: both sides are quite mysterious, but in very different ways! While this bridge must be in some way a part of the Langlands correspondence, much remains to be done in order to understand what it is, where it comes from, and exactly how it fits in with other known phenomena. ■

*Akshay Venkatesh joined the Institute for Advanced Study as a Professor in the School of Mathematics in August 2018 on the heels of receiving a 2018 Fields Medal. A mathematician who has worked on many topics at the interface between number theory and other fields, including representation theory, dynamics, and algebraic topology, Venkatesh is currently examining new algebraic structures related to the topology of locally symmetric spaces.*



Akshay Venkatesh

“The Fields Medal is an incredible honor for a young mathematician, and the Institute is exceptionally pleased that Akshay Venkatesh has received this most deserved recognition,” commented Robbert Dijkgraaf, Director and Leon Levy Professor, on August 1 when Venkatesh was awarded a 2018 Fields Medal by the International Mathematical Union. “Akshay is an extraordinarily talented mathematician whose profound and diverse contributions underscore his leadership in the field. As a Professor at the Institute, he will help shape the direction of mathematics as a whole.”

The Fields Medal is awarded every four years to scholars less than forty years old on the occasion of the International Congress of Mathematicians to recognize outstanding mathematical achievement for existing work and for the promise of future achievement. Of the sixty individuals who have received the Fields Medal as of 2018, forty-two have been affiliated with the Institute.

“Akshay is a mathematician who opens up new directions,” said Richard Taylor, Robert and Luisa Fernholz Professor in the School of Mathematics, speaking of Venkatesh’s appointment to the Faculty as of August 15. “His great mathematical breadth, his eye for surprising new connections, and his enthusiasm for collaboration with a wide range of different mathematicians will make him a wonderful asset for the School of Mathematics and its Members.”

Peter Sarnak, Professor in the School and Venkatesh’s Ph.D. thesis adviser at Princeton University, added, “Among Akshay’s singular talents is to uncover the essence, as well as novel variations, of various powerful techniques and to implement them in settings that no one imagined possible. His new tools have allowed him and others to resolve or to address some long-standing problems in number theory.”

His appointment underscores the centrality of number theory and representation theory, the fields in which Venkatesh is a leading figure, to the past, present, and future of the School of Mathematics, in the tradition of the groundbreaking work carried out by Armand Borel, Harish-Chandra, Atle Selberg, Carl Siegel, André Weil, and Hermann Weyl.

As part of the 2017–18 special program, Venkatesh delivered a series of lectures on his recent conjectures that relate the cohomology of locally symmetric spaces to the motivic cohomology of algebraic varieties, which he has verified in various special cases. They provide, among other things, new algebraic structures (in the context of non-Shimura varieties) related to the method of Professor Richard Taylor and Andrew Wiles, frequent IAS Member, for analyzing deformations of Galois representations. Venkatesh’s tantalizing theory in these contexts promises to be part of the big picture relating automorphic forms on general arithmetic locally symmetric spaces and Galois representations, further building on the conjectures of Robert Langlands, Professor Emeritus in the School and 2018 Abel Prize recipient (see related article, this page), which have guided efforts in this area for more than fifty years.

For more information about Akshay Venkatesh’s research, accomplishments, and academic appointments, most recently at Stanford University, please visit the press releases about his appointment ([www.ias.edu/press-releases/venkatesh](http://www.ias.edu/press-releases/venkatesh)) and Fields Medal ([www.ias.edu/press-releases/venkatesh-fields](http://www.ias.edu/press-releases/venkatesh-fields)).

## A Mathematical Rosetta Stone

*On the enormous impact of the revolutionary Langlands program*

BY ROBBERT DIJKGRAAF

The hardest science has the softest forms. Mathematics is often seen as a growing body of definitions, axioms, formulas, and theorems, all fitted together with the greatest precision. Each new proof adds extra crossbars and tightens the nuts and bolts so that the tower becomes even stronger and can reach higher.

But this view of mathematics as a logical construction project lacks an important element. Growth is not haphazard and autonomous. Even though there is no chief architect, at least not here on Earth, there are visions that guide the building process. Some of the greatest mathematicians in history have become famous for their conjectures, formulas, or statements that are possibly true, dotted lines that suggest the next steps.

In addition, there are even bigger blueprints for the entire structure, deep intellectual undercurrents that run through many generations and disciplines. Such a mathematical “program” is a diffuse collection of interconnected facts, suggestions, and relationships, all pointing to something far greater and undefined. Some parts are proven, others are only conjectures, and nobody knows exactly how far the vision extends. It is precisely this soft side that provides mathematical guidance.

Robert Langlands was celebrated in Oslo and around the world on May 22 when H.M. King Harald V presented the eighty-one-year-old mathematician with this year’s Abel Prize, awarded by the Norwegian Academy of Science and Letters and known as the Nobel Prize in mathematics.

Langlands, who works in Einstein’s former office, has been a Professor at the Institute for Advanced Study for more than forty-five years. He discovered in the late 1960s a deep connection between two completely different parts of mathematics: on the one hand, numbers and their relations, on the other hand, geometrical patterns and their symmetries. You could say that he discovered an Escher print in arithmetic.

IT IS AS IF TWO CHEFS COOKING WITH TWO ENTIRELY DIFFERENT RECIPES, INGREDIENTS, AND METHODS OF PREPARATION, PRODUCED EXACTLY THE SAME DISH.

It is difficult to convey the enormous impact of his revolutionary idea. Langlands showed how the same formula can originate from two entirely different worlds of thought. To employ another metaphor: it is as if two chefs cooking with two entirely different recipes, ingredients, and methods of preparation, produced exactly the same dish. The shock is even more powerful because one recipe uses only the simplest ingredients: the integers 1, 2, 3, etc.

Most mathematicians are Platonists. They believe that mathematics is discovered, not invented. In a timeless world of pure logic, formulas and relations exist waiting to be found. A mathematician digs like an archaeologist in the sand in search of hidden treasures. Most of us are happy with a pot shard. A few people encounter a stone that turns out to be a part of a temple. But what happened with Langlands almost never happens: he found a Rosetta Stone. The original stone was found in Egypt by a French soldier of Napoleon and contains a text written in both ancient Egyptian hieroglyphics and Demotic script, and ancient Greek. In the mathematical variant, these inscriptions have been replaced by numbers and geometric figures.

The discovery of such a dictionary is extremely valuable, because it enables one to translate the problems of one language into the concepts of the other. If you are lucky, the perspectives and tools of one world can be used to solve a difficult question from another world. It is striking that Langlands speaks many languages fluently, among them French, German, Russian, and Turkish. Speakers of multiple languages have a sense for the expressiveness and limitations of individual idioms as well as the universal concepts that connect them.

Nobody knows the exact size or extent of the Langlands program. It keeps growing. In the meantime, it has already borne many fruits, with the most striking result being the proof of Fermat’s Last Theorem by Andrew Wiles in 1995—a conjecture that remained unproven for more than three centuries.

Will there ever be an overarching view that brings all elements together? Langlands’s program is now the Indian parable of the blind men and the elephant. One man feels the trunk, a second a tusk, the others a piece of leg, ear, skin, or tail. Each has his own idea about what this object is—a snake, a tree, a wall, a piece of rope? Langlands imagined an elephant more than fifty years ago and mathematicians, even physicists, have been trying to combine the pieces and expand his picture of it ever since. ■

*Robbert Dijkgraaf, Director of the Institute for Advanced Study and Leon Levy Professor since July 2012, is a mathematical physicist who has made significant contributions to string theory and the advancement of science education. This article is a translation of a column that first appeared in NRC Handelsblad. He is an author, with Abraham Flexner, of The Usefulness of Useless Knowledge.*



# Antiquities in the Dining Hall

*A few modest and beguiling artifacts*

BY KATHLEEN M. COLEMAN

Four late Roman mosaics hang in Simons Hall. They come from the environs of Antioch in the northernmost part of the Roman province of Syria. Faculty, Staff, Members, and Friends eat their lunch in the company of a pair of rams, whose busts seem to be reading a book propped up on a pair of wings in front of them (Fig. 1). Ranged on the same wall are two geometric mosaics; a fourth mosaic, also geometric but considerably bigger, hangs at the end of the Dining Hall. Originally, these mosaics were each part of a much larger floor, so we are seeing them shorn of their context and displayed in a vertical position. This is their new life: new continent, new millennium, new background, new plane.

Antioch was founded in 300 B.C.E., fifteen miles upstream from the mouth of the river Orontes. It flourished throughout the Hellenistic period to become the fourth largest city of the Roman Empire, surpassed in size and significance only by Constantinople, Alexandria, and Rome. When early in the twentieth century the Department of Art and Archaeology at Princeton University was planning a major excavation in the Mediterranean basin, Antioch seemed a likely source for grand buildings and elegant sculpture.

In 1930, the Antiquities Service of Syria, which was a French mandate territory, granted Princeton a concession to excavate at Antioch for six years. A Committee for the Excavation of

Antioch-on-the-Orontes was formed, comprising the Baltimore Museum of Art, the Worcester Art Museum, and the Musées Nationaux de France, under the direction of Princeton, which took responsibility for conducting the excavation and publishing the results. Despite the Great Depression, funds were raised, and on March 4, 1932, digging began. In 1936, the concession was renewed for another six years and extended to include the port city of Seleucia Pieria.

The modern city of Antakya lies in Hatay Province, on the boundary between Syria and Turkey. This area simmered with ethnic tensions throughout the 1930s. In 1939, after a referendum, Hatay was transferred to Turkey, whose laws regarding the dissemination of archaeological finds were more stringent than Syria's. But Turkey agreed to honor the agreement struck with Syria, whereby half the finds from the dig could be exported, as long as the other half stayed behind. Upon the outbreak of the Second World War, excavation ceased.

Grand buildings and fine sculpture eluded the excavators. Most of the finds were mosaics, a practical and attractive form of flooring in the ancient world, but not generally considered "fine art," either then or now. When Antioch was devastated by a series of earthquakes in the sixth century, the floors survived, protected by the rubble on top of them. Some of the mosaics that were exported to the United States were distributed to institutions that had helped to fund the dig; others were sold. Mosaics from the environs of Antioch can be found across the United States, from Harvard to Honolulu. The Institute made its purchase in 1971, when Princeton University put up some of the finds for sale to fund the cataloguing and preservation of the rest. Homer Thompson, then a Faculty member in the School of Historical Studies, was instrumental in

the acquisition. On offer were both figural and geometric mosaics. A clear preference for geometric matches the Institute's reputation for math and physics.

The Antioch mosaics are composed of *tesserae* (cubes) of marble and limestone, mixed with some slate and terracotta, with highlights in colored glass. The oldest mosaic at the Institute, from the third or fourth century C.E., is a nine-foot segment of a geometric border from the port city of Seleucia that originally framed a central panel depicting the sea deities, Oceanus and Tethys (Fig. 2). (A misidentification of the female deity caused the house to be named the House of Oceanus and Thetis by the excavators.) A careful look at the lower left of the mosaic shows that the Institute's fragment belongs to a corner, since the black edging along the bottom turns at ninety degrees, and so the pattern of alternating beige and cream squares set on the diagonal must have continued downwards (from our perspective) following the edging.

The other two panels on the east wall, dating from the fifth or sixth century, are both from the House of the Rams' Heads in the elite suburb of Daphne in the hills south of Antioch. One comprises a geometric border of overlapping circles, framed by a white band edged in grey that is in turn surrounded by a geometric border in a "trellis" pattern (Fig. 3). A grey-brown patch halfway along the white band at the top suggests an ancient repair—filling a hole was more important than matching the color—and the outer grey edging

on the right has a kink in it that may betray an adjustment mid-course when two artisans starting from opposite ends realized that their rows of *tesserae* might not meet in the middle.

The eponymous fragment from a frieze of rams' heads incorporates motifs from the Sasanian culture of modern Iran (see Fig. 1). A similar frieze in the House of the Phoenix, dated to the late fifth century, shows that the "books" that the rams appear to be reading were originally intended to depict the ribs of the wings in which they are set. Mosaic cannot replicate the subtlety of a painter's brushstrokes, but details such as the curve of the rams' cheeks or the differentiation between the iris, whites, and inner corner of their eyes shows what can be achieved by juxtaposing different colors or adjusting the direction of a row of *tesserae*. The red and white wave pattern underneath the frieze is noteworthy for its *trompe l'oeil* effect of competing colors receding and advancing. The riotous acanthus scroll below that, populated by cupids, animals, and fruit (on the Institute's fragment, the leg of a cupid is partially visible), appears upside down from our perspective, but this is a means of compensating for the limitations involved in depicting a three-dimensional image on a flat plane: wherever a viewer stood on the floor, either the rams' heads or the busy acanthus scroll would be the right way up.

The Institute's largest mosaic, previously on loan to Miss Fine's School on Bayard Lane, dates from the early sixth century (Fig. 4). It comes from the House of the Phoenix, also in Daphne, and consists of a continuous pattern of interlocking cables forming circles alternating with concave squares, each cable tying off neatly along the bottom. It is edged with a wide border of octagons in a slightly different

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Fig. 1: House of the Rams' Heads, Daphne: fragment of frieze with rams' heads



Fig. 2: House of Oceanus and Thetis, Seleucia: geometric fragment





Fig. 3: House of the Rams' Heads, Daphne: geometric fragment (detail)



Fig. 4: House of the Phoenix, Daphne: geometric fragment

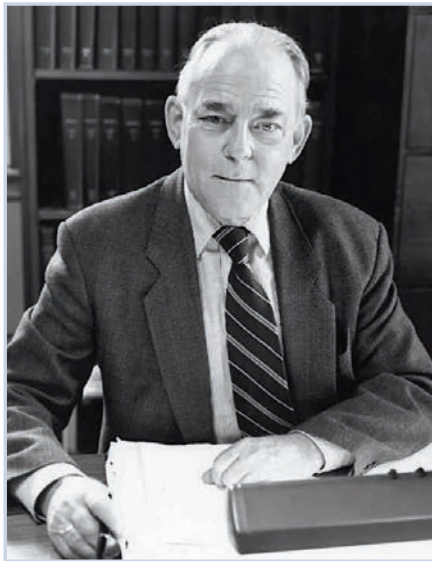
range of colors. The effect of walking on such an apparently multidimensional surface might well contribute to a displaced sense of gravity.

The Institute is intimately associated with scholarship on Antioch. A definitive history of the ancient city, spanning almost a millennium, was composed by Glanville Downey (Member, 1956–57 and 1936–40), and the monumental publication of the entire corpus of mosaics was accomplished by Doro Levi, a refugee from Fascist Italy (Member, 1941–45 and 1938–39). Their labors are also part of the story of these modest and beguiling artifacts, whose survival, enabled by the tragedy that befell their owners, lends grace to the communal life that everyone at the Institute is privileged to share. ■

Kathleen M. Coleman, Elinor Lunder Founders' Circle Member (2017–18) in the School of Historical Studies, is James Loeb Professor of the Classics and Chair of the Department of the Classics at Harvard University. A more detailed account of the Institute's mosaics, amply illustrated, is available as a separate pamphlet, "Late Roman Mosaics at the Institute for Advanced Study," at [www.ias.edu/ideas/coleman-mosaics](http://www.ias.edu/ideas/coleman-mosaics). Research for this project was enabled by the generosity and expertise of the curators and archivists in the Shelby White and Leon Levy Archives Center, the Princeton University Art Museum, the Antioch Expedition Archives, and the Blegen Library at the American School of Classical Studies at Athens. The photographs were taken by Bruce M. White.

## Christian Habicht (1926–2018)

Acclaimed historian and leading expert on the Hellenistic Period



Christian Habicht

Christian Habicht, a celebrated historian of the Hellenistic period and leading authority on Greek epigraphy, died at the age of ninety-two on the morning of August 6, 2018, in Princeton, New Jersey. He was Professor Emeritus in the School of Historical Studies at the Institute for Advanced Study, where he served as Professor from 1973 until he retired in 1998.

Habicht's remarkable contributions to ancient history shed light on Athenian society in the centuries between the fall of the Athenian Empire and the establishment of the Roman Empire.

"The Institute has lost an extraordinary scholar, mentor, collaborator, and dear friend," said Robbert Dijkgraaf, Director and Leon Levy Professor. "Professor Habicht possessed an exceptional depth of knowledge that he cultivated and shared throughout his life. His scholarship illuminated the past and greatly increased our understanding of humanity. Together with his wife Freia, he was a dedicated member of the Institute community. We can be proud that he regarded us as his intellectual home. He will be deeply missed."

Angelos Chaniotis, Professor of Ancient History and Classics, stated, "With his studies on Athenian elite families from Alexander to Cleopatra, Christian Habicht redefined the study of Athenian history. His book on

the Hellenistic ruler cult is such an unsurpassed scholarly achievement that an English translation was published sixty years after its first edition. Although Christian Habicht hated to be in the center of attention, his research of more than sixty years has placed him in the center of scholarly attention in a variety of fields, from Greek society to Hellenistic royalty, from the traveler Pausanias to the orator and statesman Cicero, and from the epigraphy of Thessaly and Asia Minor to Greek religion. He was also a pioneer in the use of electronic media in epigraphic and prosopographical studies. His published work is of lasting value and will remain an inspiration for ancient historians."

During his tenure at the Institute, Habicht welcomed colleagues from all over the world and assiduously championed their work, providing insights that will continue to inform scholars for generations to come. At a 2006 symposium in Athens celebrating Professor Habicht's eightieth birthday, Stephen V. Tracy, a former director of the American School of Classical Studies at Athens and a frequent Member and Visitor in the School of Historical Studies, recalled, "It is no exaggeration to say in my own case that Christian Habicht not only facilitated my work, he literally enabled me to continue it when it had been stalled for years because of the impossibility of working here in Athens." Tracy added, "Doubtless all of you could tell similar tales of Professor Habicht's generosity and kindness, not to mention his brilliance."

Habicht was born in 1926 in Dortmund, Germany. He received his Ph.D. in Ancient History in 1952 from the Universität Hamburg where he held positions from 1952 to 1961. He then served as a Professor (1961–65) at the Philipps-Universität Marburg. Prior to joining the Institute as a Member in the School of Historical Studies in 1972–73 and being appointed Professor in the School in 1973, Habicht was Professor (1965–73) and Dean of the Faculty of Arts (1966–67) at the Universität Heidelberg. Explaining what led him to Greek epigraphy, Habicht observed, "To me, epigraphy came naturally with research for my doctoral dissertation. The field is much larger than editing inscriptions and commenting upon them; it provides fertile soil for all kinds of social and economic studies, for onomatology, dialectology, grammar, for religion and ritual, and so much more."

On joining the Institute Faculty, Habicht assumed responsibility for the extensive collection of squeezes that Benjamin Dean Meritt, then Professor in the School of Historical Studies, had amassed to form a major research center in Greek epigraphy at the Institute. In 2010, Habicht wrote, "The total number of squeezes from the Epigraphical Museum [in Athens] amounts to 8,532 pieces in the IAS collection. It is rivaled only by those from the Athenian Agora." He added, "The total of the Institute's collection comes to some 25,000 squeezes and makes it in fact 'second only to that in Berlin.'" This was a moderate estimate of the catalogue of squeezes, which today is the basis for a digitization project that will make the collection freely accessible online.

Habicht authored books on Hellenistic ruler cults, on the Maccabees, on Cicero, and on Pausanias, and he was the editor of hundreds of previously unpublished inscriptions from the most important places in Greece and Asia Minor. One of his works, *Athens from Alexander to Antony*, published in 1997, was described by the *New York Review of Books* as "the standard work on the subject for the next thirty years." Habicht's work was recognized for its profound impact on formerly held views. In a passage from *Athens from Alexander to Antony*, he writes, "An old and widespread view, still current among some scholars, holds that the outcome of the Battle of Chaeronea in 338 B.C.E. spelled the end of 'the Greek city.' However, a large and constantly increasing body of unambiguous evidence from Hellenistic inscriptions has proved this erroneous without a doubt ... these cities as well as hundreds of smaller communities remained viable and vital political organisms."

Habicht's more than two hundred articles cover topics from the fifth century B.C.E. to the fourth century C.E. He contributed the introduction and explanatory notes to a new bilingual edition of Polybius's *The Histories*—the six volumes were published in 2010–12. An updated English edition of his doctoral dissertation, submitted in German in 1951, was published as *Divine Honors for Mortal Men in Greek Cities: The Early Cases* by Michigan Classical Press in 2017.

Habicht's work was acknowledged with many awards, fellowships, and other honors during his lifetime, including appointments as Sather Professor (1982–83) at the University of California, Berkeley, and Honorary Counsellor of the Archaeological Society of Athens (1998). Habicht received the London Hellenic Society's Criticos Prize (1997), the American Philosophical Society's Henry Allen Moe Prize in the Humanities (1996), and the Reuchlin Prize (1991), awarded by the Heidelberg Academy of Sciences and Humanities and the city of Pforzheim. He was a member of the Academy of Athens, the Heidelberg Academy of Sciences and Humanities, the American Philosophical Society, the British Academy, and the German Archaeological Institute.

Habicht is survived by his wife, Freia Habicht; their daughter, Susanne Habicht [predeceased by husband Dündar Erenler] with children Yilmaz Erenler and Sahin Erenler; their son Christoph Habicht [predeceased by wife Vera] with children Daniel Habicht, Tobias Habicht and wife Lena Haug-Habicht with daughter Paula, Sofia Habicht, Sebastian Habicht, Johanna Habicht, and Alessandra Habicht; and their son Nik Habicht and wife Carol. ■