IAS | THE INSTITUTE LETTER

Fall 2023

Benjamin Greenbaum
What is Non-Self?

Chris Hamilton
Dynamics in Translation

Jonathan Allan
The Curriculum of the Woods

Abbey Ellis
Grafting New Stems

ANDREA KANE

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Contents

COVER IMAGE

An image of two humanoid figures parallel to one another, their palms touching, their eyes closed in mirrored contemplation. Behind them is the magnified image of a cell, rendered in distinct shapes and patterns that seem to hypnotize the eye, as they coil ever more tightly toward center. Artist **Danielle Taphanel** is a self-taught, disabled digital artist who specializes in organic, dream-like imagery. They reside in the upper Midwestern U.S. with their partner and three cats.

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ANDREA KANE

We are entering a place whose space-time is different from that of the 'normal world,' in that it is entirely dedicated to the possibilities of thought, and specifically, to the possibilities of your thought and discovery.

It is easy enough to sense the distinctiveness of the space. I don't just mean our residences [and] offices… designed to hold us together with the potential for both solitude and encounter.… I mean also the roughly 600 acres of field, forest, and meadow that shelter us from the business of the everyday world utility and action, replacing the purposeful lines and angularities of that world with fractal leafiness and winding paths that invite peripatetic cogitation.

The darkness of the night sky, the presence of fox and deer, the bluebirds, and orioles… help us feel that the space of the Institute is not quite that of the world we came from.

The Institute is a *locus amoenus*, a special place, special in its space, in its temporality, and in its constant commitment to the value of engagement with and debate over ideas. Wherever in the world you come from—and you come from many places—I trust you will agree: this special temporality, the time of mind, and this constant commitment to the testing of ideas are rare.

David Nirenberg, Director and Leon Levy Professor, during welcome remarks delivered to 2023–24 scholars

Meet our Scholars

Weishun uses tools from statistical physics to study both the brain and AI. "Both are just networks of basic units called neurons," he says.

Weishun Zhong
School of Natural Sciences

"I've always been interested in technology: I built my first computer at twelve and was a hacker in my prior career in the U.S. intelligence community."

Lindsey D. Cameron
School of Social Science

As a researcher Shiyue enjoys, in her words, "the freedom to wonder about fascinating things in nature, and the connections with other minds from around the world."

Shiyue Li
School of Mathematics

"Amid vital political debates about the meaning of truth, it has never seemed more important to me to study the contexts under which scientific knowledge is produced, shared, lost, and preserved."

Brad Bolman
School of Historical Studies

A New Year, Enumerated

On this page, you'll find quantifications of life at the Institute. One illustrates this year's cohort: 272 new and returning scholars, hailing from 47 countries, who represent 105 institutions. Let not the numbers on this page deceive you; the abundant excellence that these researchers represent cannot be immediately deduced from statistics alone. Our scholars for the year 2023–24, who range from promising postdocs at the beginning of their research journeys to world-leading mid-career and senior professors, represent the very tops of their respective fields. They arrive here, from all over the world, united across disciplines by a common cause to push the boundaries of knowledge and engage in the open exchange of ideas.

We invite you to sample from the smorgasbord of these ideas in the Meet our Scholars Q&As. Get a bitesize overview of work which traverses the boundaries between natural and artificial intelligence, currently taking place in the School of Natural Sciences; get a flavor of the work conducted by a self-described hacker turned scholar from the School of Social Science on the subject of Uber and the gig economy.

And, while the number of cookies eaten at teatime may seem vast, you will learn such figures are nothing compared to those considered by a scholar from the School of Mathematics with an interest in combinatorics, namely the mathematics of counting and arranging, involving quantities too large to be counted in the traditional way. When you have had your fill of all things numerical, travel back in time to question

Scan to read the full interviews with each scholar

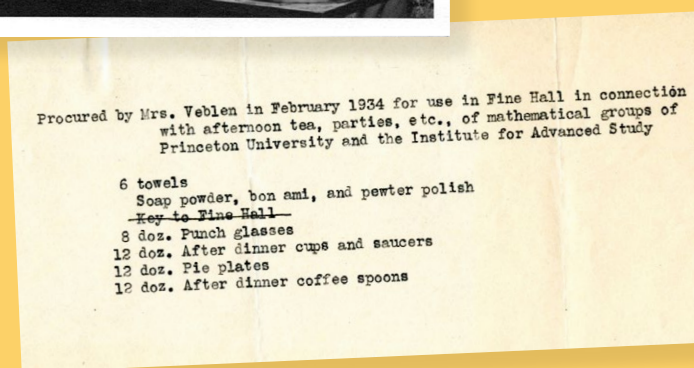
Elizabeth Veblen serving tea at her summer house in Maine.

IAS ON Instagram

instituteforadvancedstudy

Each weekday at 3:00 pm, chalk is laid down and keyboards set aside as IAS scholars relocate to the Fuld Hall Common Room for a daily ritual of tea, cookies, and conversation.

It is thought that the IAS tradition of serving tea began with Elizabeth Veblen, wife of Oswald Veblen, founding Faculty member in the School of Mathematics. This document (right) lists the items that she procured for use with tea service in Fine Hall, the building on the Princeton campus where the Institute's School of Mathematics was based prior to the construction of Fuld Hall in 1939.



Procured by Mrs. Veblen in February 1934 for use in Fine Hall in connection with afternoon tea, parties, etc., of mathematical groups of Princeton University and the Institute for Advanced Study

6 towels
Soap powder, bon ami, and pewter polish
~~Key to Fine Hall~~
8 doz. Punch glasses
12 doz. After dinner cups and saucers
12 doz. Pie plates
12 doz. After dinner coffee spoons

the origins of ideas about organisms in the School of Historical Studies.

One of the unique aspects of this special place is the lack of rigidity. Here, ideas are as free and fluid as tea at three o'clock. Here, endless curiosity is the telos, and you are constrained only by the amount of space at your nearest blackboard.

This academic year, there are some exciting drivers of this curiosity. The School of Mathematics will host a special year on the *p*-adic arithmetic geometry, bringing together a mix of people interested in various facets of the subject with an eye toward sharing ideas and questions across fields. And the 2023–24 theme seminar of the School of Social Science will explore ways to account for the expansion, rise, and influence of "the platform" in global society.

Another new source of queries and discoveries is the most recent Institute Faculty appointment: Maria Hsiuya Loh, who joined the School of Historical Studies in July. Her appointment continues a rich tradition of art historical research at IAS, inaugurated by Professors Erwin Panofsky and Millard Meiss, who are counted among the 456 art historians who have graced the Institute's doors since its founding in 1930.

These enumerations and the research interests that go far beyond them beget a theorem, one that concludes with the distillation of the Institute's mission—to provide a borderless beacon where discovery is vast and varied. Our 2023–24 cohort will no doubt advance our global collective intellect in ways that, even though the year has already begun, remain impossible to foresee. ■

Scan to follow IAS on Instagram and keep up with the latest news, research, and campus updates

The teatime tradition continued throughout the 1980s (as seen above) and remains a beloved part of IAS life today.

Institute by Numbers

47
countries represented by this year's cohort

1945
year the Institute's first woman of color (張王承書) began her term

1
blockbuster movies filmed on campus in 2022

456
scholars of art history at IAS since 1930

1,406.5
square feet of blackboards added to campus by Rubenstein Commons

828,000
number of cups of tea served on campus, 2008–2023

1,242,000
number of cookies served on campus, 2008–2023

Our OPPENHEIMER

April 2022 saw Hollywood come to the Institute. Cillian Murphy, Emily Blunt, Robert Downey Jr., Tom Conti, and other big names visited campus to shoot scenes for Christopher Nolan's *Oppenheimer* biopic, a film based on the life and complex legacy of past IAS Director J. Robert Oppenheimer. Many iconic IAS locations were transformed for the occasion: Fuld Hall Common Room received a 1950s makeover and the Institute Woods and pond were another hive of activity. In the film, the pond, the construction of which took place during Oppenheimer's directorship, formed the setting for conversations between Oppenheimer and founding IAS Professor Albert Einstein.

Prior to and during filming, members of IAS staff helped to support the production team. Staff from the Institute's Shelby White and Leon Levy Archives Center played a key role, providing archival images of key filming locations to aid with the historical accuracy of the set dressing. The arrival of the film crew on campus and the subsequent release of the movie in July 2023 also generated significant excitement among IAS scholars.

The following comments from Members and Visitors across all four IAS Schools provide insight into what it was like to share the campus with the production team, and highlight our community's reactions to the film:

ALL IMAGES MELINDA SUE GORDON/UNIVERSAL PICTURES

One small detail I particularly enjoyed in Oppenheimer *was a conversation between Oppenheimer and his student, Hartland Snyder, about their work on gravitational contraction (which led to a paper famously published on the same day that Germany invaded Poland). This paper was one of the first to identify that a collapsing star will form a singularity, if its mass exceeds a certain threshold. A first estimate for that threshold was worked out earlier the same year, in a pair of papers by Oppenheimer and his student George Volkoff and by Caltech professor Richard Chace Tolman (who was also featured in the movie). Now referred to as the Tolman-Oppenheimer-Volkoff (TOV) limit, this provides the dividing* *mass between whether an object can stably exist as a neutron star, or whether it must collapse to a black hole. My own research focuses on the structure of neutron stars and the TOV limit is an essential—but still uncertain!—piece of this puzzle."*

Carolyn Raithel
John N. Bahcall Fellow (2020–24), School of Natural Sciences

As I sat in an Italian movie theater to see Oppenheimer, *just like its protagonist I felt torn by dilemma. I experienced a feverish alternation of conflicting feelings and judgments. On the one hand, I felt a sense of discomfort over several aspects, both ethical and cinematographic; on the other, I felt very strongly the emotion of seeing one of the places—if not the place—that I cherish the most in the world, the Institute, on the big screen.*

For obvious reasons, I do not feel ready to entrust my understanding of crucial historical events to a movie. Especially these ones. But I am ready instead, despite my discomfort, to recognize in Nolan's work something fundamental: the power that only great art has to profoundly destabilize us in our beliefs, visions, and feelings, for better or worse. It is something to be grateful for."

Lorenzo Alunni
Wolfensohn Family Member (2022–23), School of Social Science

In attempting to describe my year as a Member at IAS to curious friends and family, I was often met with a mixture of confusion and disbelief. The total freedom to pursue interesting ideas and the liberation from teaching and other commitments seemed improbable enough, but when I began to describe the pond and Woods, long lunches and teatime, as well as the presence of innumerable brilliant colleagues, their brows furrowed. It simply seemed too good to be true. Was my imagination just running away with me? Since Oppenheimer, *though, the site of my stories has become a real location, a place where famous actors pretending to be famous scientists once strolled. 'The place from the movie,' they now exclaim, 'looks nice!'"*

Whitney Laemmli
Andrew W. Mellon Foundation Fellow (2021–22), School of Historical Studies

While at the Institute, I occupied an office that once belonged to Albert Einstein. It stood in for the Director's office in the movie. For months before the filming, I had crew members stopping by to check the lighting, the view of the gardens, and admire the wonderful space. They were always very pleasant people, living in their own world. ("I just came from a shooting in NY with J.Lo!") At the same time, they treated me with a certain reverence, and were somewhat disappointed to learn that I was not the Director and I was not working on top secret projects like Oppenheimer. Of course, they must have figured that even if I was, I would not tell them. After one visit from the crew, I returned to my office to see "Thanks! C. Nolan" written on my blackboard. (I left it for several weeks and my visitors even took photographs of it.) The date it appeared, however, was April 1!"

László Székelyhidi
Member (2003–04) and Distinguished Visiting Professor (2021–22), School of Mathematics

One of the things that I found most special about the movie was that I could connect with many of its characters: I'd been following them professionally for decades. One such figure was Philip Morrison, who was a professor at MIT when I was a graduate student, and with whom I almost worked for my Ph.D. thesis. Morrison is one of the founders of gamma-ray astronomy, which looks for radioactive species using their gamma-ray emissions. During the Manhattan Project, he was responsible for bringing the pit of plutonium to the Trinity test site. He once related to me how he had placed the pit in its box, feeling the warmth of the plutonium in his hands. He assured me that the radioactivity was modest because the pit was nickel-plated, but his description resonated with me as I watched this same scene unfold in the movie."

Adam Burrows
Member (2023–24), School of Natural Sciences

For more scholar reactions, explore the digital issue: ias.edu/news/our-oppenheimer.

A WORD FROM NIRENBERG

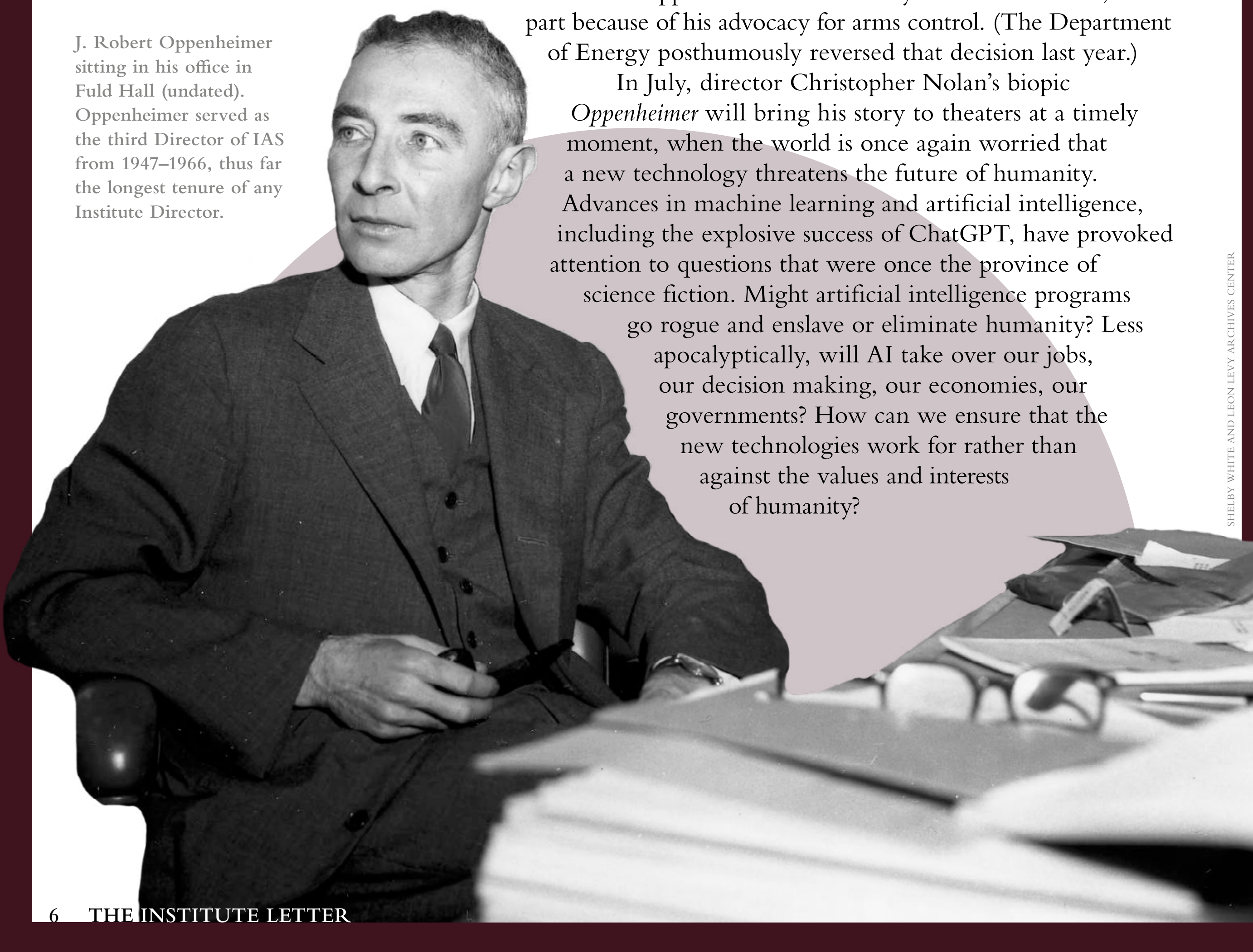
Before the release of Christopher Nolan's Oppenheimer, *Director and Leon Levy Professor David Nirenberg wrote for the* Wall Street Journal *about Oppenheimer's advocacy for the important role the humanities have in the development of science and technology.*

J. ROBERT OPPENHEIMER'S DEFENSE OF HUMANITY

From the moment the atomic bomb was dropped on Hiroshima in August 1945 until his death in 1967, J. Robert Oppenheimer was perhaps the most recognizable physicist on the planet. During World War II, Oppenheimer directed Los Alamos Laboratory, "Site Y" of the Manhattan Project, the successful American effort to build an atomic bomb. He went on to serve for almost 20 years as Director of the Institute for Advanced Study in Princeton, NJ, home to some of the world's leading scientists, including Albert Einstein.

In the popular imagination, Einstein came to represent unalloyed optimism about the capacity of human genius to uncover the secrets of the cosmos. Oppenheimer played a grimmer role, standing for the dangers of advancing science. After the successful test of the "Gadget," as the first atomic bomb was called, he is said to have quoted the Bhagavad Gita: "Now I am become death, the destroyer of worlds." Much of his subsequent career would be spent advising humanity how not to be annihilated by the powers of the atom he had conquered. The advice was not always well received: The Atomic Energy Commission stripped him of his security clearance in 1954, in part because of his advocacy for arms control. (The Department of Energy posthumously reversed that decision last year.)

In July, director Christopher Nolan's biopic *Oppenheimer* will bring his story to theaters at a timely moment, when the world is once again worried that a new technology threatens the future of humanity. Advances in machine learning and artificial intelligence, including the explosive success of ChatGPT, have provoked attention to questions that were once the province of science fiction. Might artificial intelligence programs go rogue and enslave or eliminate humanity? Less apocalyptically, will AI take over our jobs, our decision making, our economies, our governments? How can we ensure that the new technologies work for rather than against the values and interests of humanity?



J. Robert Oppenheimer sitting in his office in Fuld Hall (undated). Oppenheimer served as the third Director of IAS from 1947–1966, thus far the longest tenure of any Institute Director.

SHELBY WHITE AND LEON LEVY ARCHIVES CENTER

To answer these questions, the most important part of Oppenheimer's life isn't his work on the atomic bomb but his less dramatic tenure running the Institute for Advanced Study. When Oppenheimer arrived as director in 1947, *Life* magazine published "The Thinkers," a story about the Institute calling it "the most important building on earth." That was hyperbole, but it is true that Oppenheimer joined a community of giants, many of whom shared the sense that humanity was at a technological turning point that might bring about its destruction.

Einstein, a Professor at the Institute from 1933 until his death in 1955, dedicated much of his final decade to the political and ethical questions raised by the new physics of fission and fusion. Another Faculty member who merits a biopic is the Hungarian immigrant John von Neumann, who worked on both the atomic bomb and its more powerful successor, the hydrogen bomb. After the war, he built the world's first stored-program computer—work that started in the basement under Oppenheimer's office.

Von Neumann, too, was deeply concerned about the inability of humanity to keep up with its own inventions. "What we are creating now," he said to his wife Klári in 1945, "is a monster whose influence is going to change history, provided there is any history left." Moving to the subject of future computing machines he became even more agitated, foreseeing disaster if "people" could not "keep pace with what they create."

Oppenheimer, Einstein, von Neumann and other Institute Faculty channeled much of their effort toward what AI researchers today call the "alignment" problem: how to make sure our discoveries serve us instead of destroying us. Their approaches to this increasingly pressing problem remain instructive.

Von Neumann focused on applying the powers of mathematical logic, taking insights from games of strategy and applying them to economics and war planning. Today, descendants of his "game theory" running on von Neumann computing architecture are applied not only to our nuclear strategy, but also many parts of our political, economic, and social lives. This is one approach to alignment: humanity survives technology through more technology, and it is the researcher's role to maximize progress.

Oppenheimer agreed that technological progress was critical, and provided von Neumann with such extraordinary support that other Faculty complained. But he also thought that this approach was not enough. "What are we to make of a civilization," he asked in 1959, a few years after von Neumann's death, "which has always regarded ethics as an essential part of human life, and… which has not been able to talk about the prospect of killing almost everybody, except in prudential and game-theoretical terms?"

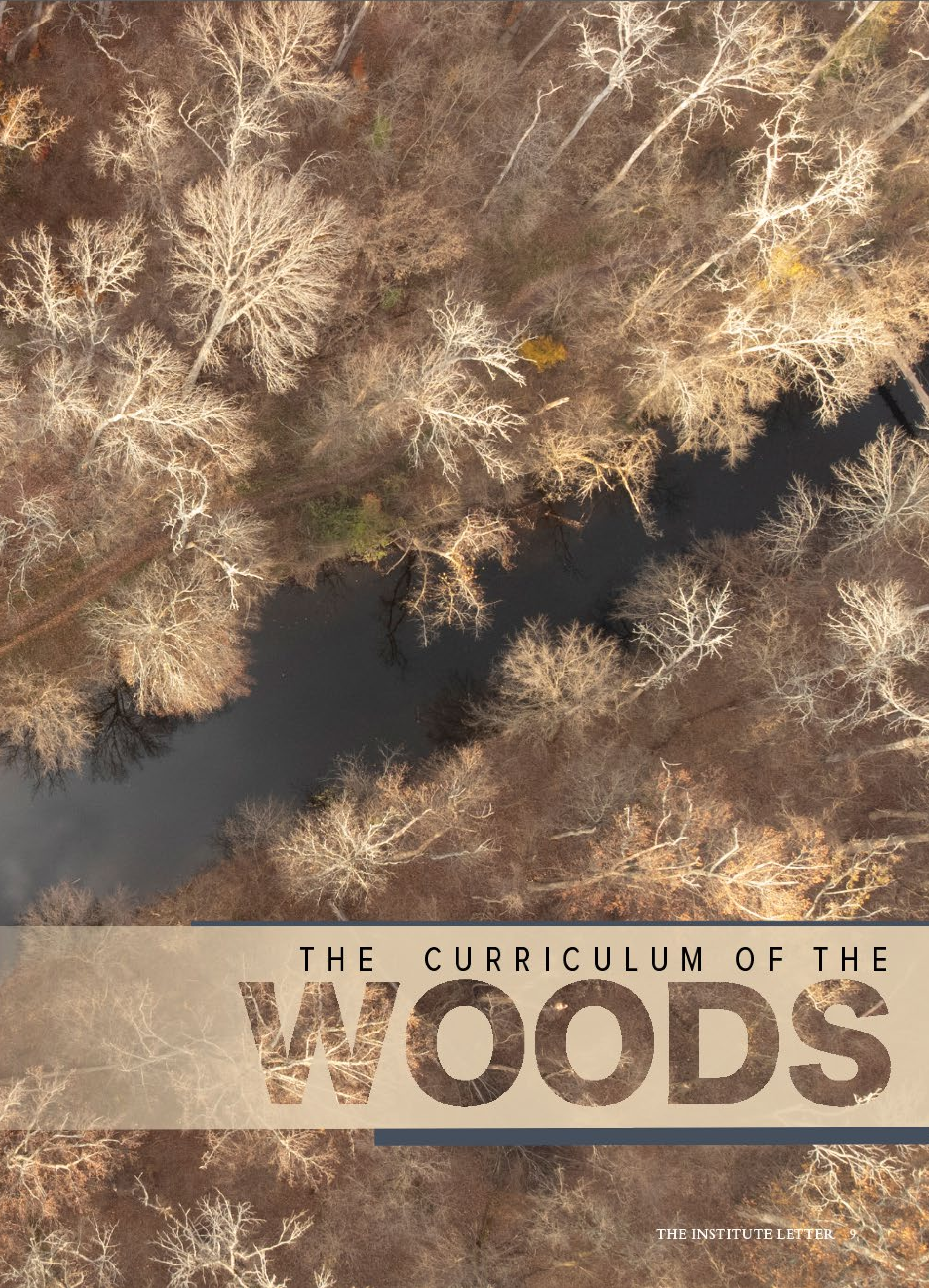
He championed another approach. In their biography "American Prometheus," which inspired Nolan's film, Martin Sherwin and Kai Bird document Oppenheimer's conviction that "the safety" of a nation or the world "cannot lie wholly or even primarily in its scientific or technical prowess." If humanity wants to survive technology, he believed, it needs to pay attention not only to technology but also to ethics, religions, values, forms of political and social organization, and even feelings and emotions.

Hence Oppenheimer set out to make the Institute for Advanced Study a place for thinking about humanistic subjects like Russian culture, medieval history, or ancient philosophy, as well as about mathematics and the theory of the atom. He hired scholars like George Kennan, the diplomat who designed the Cold War policy of Soviet "containment"; Harold Cherniss, whose work on the philosophies of Plato and Aristotle influenced many Institute colleagues; and the mathematical physicist Freeman Dyson. Traces of their conversations and collaborations are preserved not only in their letters and biographies, but also in their research, their policy recommendations, and in their ceaseless efforts to help the public understand the dangers and opportunities technology offers the world.

Today, we need to be reminded that no alignment of technology with humanity can be achieved through technology alone. Artificial intelligence offers an obvious example. Many people are worried that the application of complex and non-transparent machine learning algorithms to human decision-making—in areas like criminal justice, hiring, and health care—will invisibly entrench existing discrimination and inequality. Computer scientists can address this problem, and many are currently working on algorithms to increase "fairness." But to design a "fairness algorithm" we need to know what fairness is. Fairness is not a mathematical constant or even a variable. It is a human value, meaning that there are many often competing and even contradictory visions of it on offer in our societies.

Preserving any human value worthy of the name will therefore require not only a computer scientist, but also a sociologist, psychologist, political scientist, philosopher, historian, theologian. Oppenheimer even brought the poet T.S. Eliot to the Institute, because he believed that the challenges of the future could only be met by bringing the technological and the human together. The technological challenges are growing, but the cultural abyss separating STEM from the arts, humanities, and social sciences has only grown wider. More than ever, we need institutions capable of helping them think together. ■

ELENA MURCHIKOVA



THE CURRICULUM OF THE WOODS

By Jonathan Allan

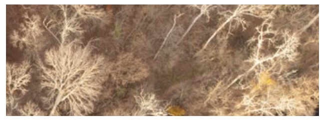
As disinclined as we are toward the laboratory setting at the Institute, preferring instead the theoretical realm of pen and paper, we are flanked by one that is 589 acres: the Institute Woods. There, yellow trout lilies and yellow warblers find themselves in an open-air lab made up of bigtooth aspen, black and sweet gum, oak and hickory, gray birch, beech, elm, and red maple trees. In fall, a migration happens: flocks of undergraduates, like birds on the Atlantic Flyway, arrive from Princeton University in order to conduct a field laboratory exercise in forest succession, one that was hatched in the Woods almost 50 years ago.

Due to the fact that a portion of these lands have never been farmed or logged, with the rest of the acreage in recovery from human disturbance dating back between 80 and 200 years, the Woods, preserved by the Institute for Advanced Study, provides a mixed landscape perfect for studies in the succession of trees. Henry Horn, the founding director of Princeton's Program in Environmental Studies and celebrated naturalist, used it for exactly this reason when he outlined his predictive model for the stages of forest regeneration in 1975. Published in *Scientific American*, "Forest Succession" is now a fixture in the introductory curriculum of Professor Jonathan Levine, Chair of Princeton's Department of Ecology & Evolutionary Biology. The simplicity of Horn's mathematical method allows students to predict thousands of years of forest growth with just an afternoon of fieldwork and a simple calculator: "My laboratory fits into a carpenter's apron," Horn notes.

The activity has students first take a survey of the prevalence of different tree species in the Woods. Next, they observe the tree canopies and their driplines to determine what saplings are found in the vicinity and their quantity. With this data, they start to see what species might replace the current trees. For example, if fifty percent of saplings underneath a beech tree are white oak and a smaller proportion are beech saplings, it is reasonable to predict the abundance of white oak will trend upwards while beech trends downward, the former replacing the latter. Students are then able to take this data and build a matrix of transitions between tree species. Simple multiplication can subsequently propel these predictions into far-flung futures: by multiplying the transition matrix of the forest by the vector of tree species abundances, a picture of succession is generated, one that you can use to fast forward thousands of years.

Understandably, these predictions are imperfect. An afternoon's worth of work does not a forest foretell. There are far too many variables and assumptions that make this picture of succession incomplete. But it is this deficiency that proves to be an important pedagogical tool. It allows the students to ask themselves, why isn't this accurate? What can we change or add to improve the result? In that pursuit, the matrix can be further refined and weighted to take into consideration things like the longevity of different species, changes in the climate, the assemblages of plants and animals and their influence on the soil, susceptibility to insects, and the effects of light on trees with different distributions of leaves. These are the kind of variables that more sophisticated models of forest dynamics incorporate, engendering more exact results.

Modeling complex behavior like this is something Institute scholars are familiar with: discussions of dynamical systems are commonplace here, albeit usually not of the arboreous variety. For instance, the Newtonian three-body problem, which tackles the

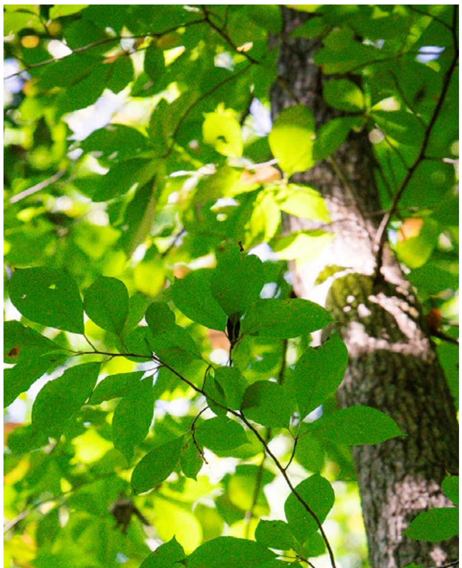


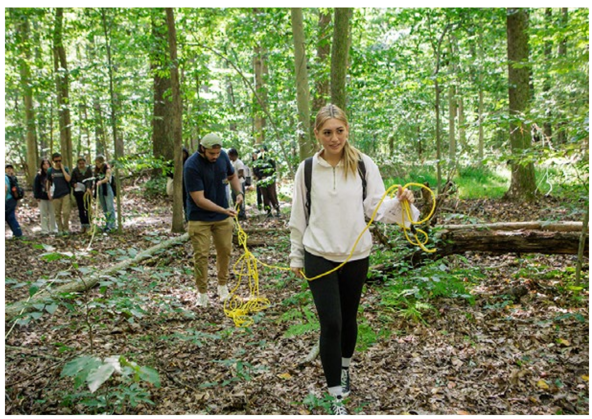
chaotic motion of three massive objects interacting with one another, is a famous problem in dynamics that occupies a number of our Members. A sturdy solution, which currently no one has offered, may be applied to problems of interplanetary space travel.

Forest dynamics, of which forest succession is a major part, can help us with similarly astonishing problems such as climate change. By understanding how forests change, we can understand how best to conserve them. Horn himself makes an argument for this in his paper. Using his findings, he claims that a forest in a state of stasis is not necessarily optimal for its conservation. Successions are paramount. Beech is replaced by oak. A migrating bird seeks a new nest. A laboratory discovers novel tools. But how do these things move forward, and at the same time have preservation in their design?

Take another example found here at the Institute, though in Fuld Hall instead of the Woods: John von Neumann's Electronic Computer Project—which, due to the Institute's lack of laboratory facilities, was housed in the basement—marked one of the most successful experiments in early computing. This achievement in computer science, a field which has transformed our world, also gave birth to the first major models of our climate. The nature of this project, with its successions from general-purpose algorithms to climate science, was dynamic enough to invite unexpected discoveries. While a laboratory project like this, which broke away from the theoretical, was controversial at the Institute, it partook of the Institute's most cherished mission—that of scholarly breakthrough.

It is this ecosystem of discovery that the students strutting through the Woods this fall, who utilize a method inspired and developed on the trails which our earliest Faculty blazed, embody and embolden. Thankfully we have this place, which inspires clear and curious thought, in our backyard, and can continue to learn from it. ■





ANDREA KANE

Grafting New Stems

How the work of Maria Hsiuya Loh cultivates new readings of a great Renaissance artist and of the legacy of art historical scholarship at IAS

BY ABBEY ELLIS

ABBEY ELLIS

Watercolor painting of Laocoön.

Back in 2020, in the midst of making yet another round of edits to my Ph.D. thesis, I put down my pen and picked up a paintbrush. The image shown here was the result: a representation of the face of Laocoön, a Trojan priest best known from the writings of the ancient Roman bard Virgil. Virgil's epic poem *The Aeneid* describes how, toward the end of the Trojan War, Laocoön attempts to warn his people of the Greeks' plot to capture their city by means of a wooden horse. Laocoön meets an untimely end: Virgil details how he and his sons were brutally assassinated by serpents sent by the vengeful goddess Athena, a supporter of the Greek cause, to silence him. Before reading the rest of this article, I invite you to gaze into the marbled face of Laocoön and ask the following questions:

- Do you like this painting? Why, or why not?
- Do you consider it to be authentic or original?
- Does it have value?
- If so, what kind of value?

MAKSIM SOKOLOV

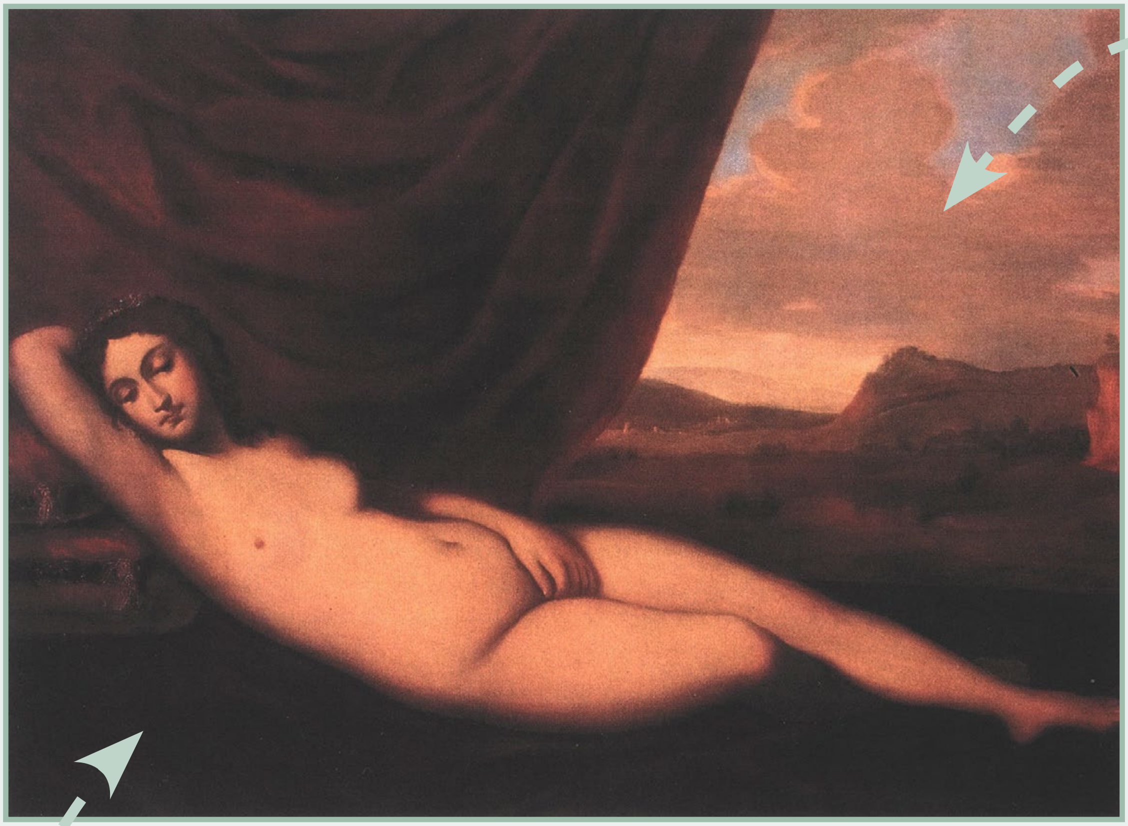
ORLA O'BYRNE

Above: Laocoön and his sons statue group, displayed in the Vatican Museums.
Left: *Priest Cast I* by Orla O'Byrne, on which the watercolor overleaf was based.

Now that you have spent a few moments pondering the image, I can tell you a little more about it. In short, it is a copy of a copy of a copy of a copy of a copy of a copy of an original. More precisely, it is a printed copy of a photograph; of a watercolor painting; of another photograph that I had taken at an art exhibition; of a plaster cast made by artist Orla O'Byrne in Cork, Ireland; of another plaster cast, a teaching model used to train artists at Cork's Crawford Institute of Technology (CIT); of an original piece of ancient Roman sculpture, namely the statue group of Laocoön and his sons excavated in 1506 on the Esquiline Hill in Rome, now exhibited at the Vatican Museums.

At this point, the painting may appear less like a work of art and more like an onion, and there are potentially even more layers than those outlined above. To produce the watercolor, I printed off a hard copy of the photograph that I took at the art exhibition to allow me to better capture the play of light and shade when painting. There is also an unknown number of stages of copying between the CIT's plaster cast and the original Laocoön statue group. It is likely that the CIT's cast is itself modeled on another plaster reproduction. We must also consider whether the Laocoön in the Vatican that we refer to as an 'original' was likewise the result of copying processes. It is doubtful that it was made in a single moment of artistic inspiration in the workshop of the ancient sculptors to whom Roman writer Pliny the Elder attributes the piece. First drafts of sculptures produced in antiquity were regularly made in clay and then translated into the finished marble form. My watercolor could therefore be a copy of a copy of a copy of a copy of a copy of a copy of a copy of a copy of an 'original' that is itself the result of a copying process.

Another question now rears its head: has the revelation of the layers behind the image caused you to reconsider your answers to the questions above? If you answered 'yes' when initially asked 'Do you like it?' do the reasons that you identified still hold true? Or has the label of 'copy' changed how you view the piece? Ideas surrounding originals and copies, great masters and their imitators, and the value of so-called repetitive artworks are just a few of the many themes interrogated in the broad-reaching scholarship of Maria Hsiuya Loh, who joined the IAS School of Historical Studies as Professor in Art History on July 1, 2023.



Padovanino. *Sleeping Venus*. Ca. 1625. Private collection.

As someone with a long-standing interest in reproductive artworks, I was especially intrigued by Loh's first book, *Titian Remade: Repetition and the Transformation of Early Modern Italian Art* (2007). In *Titian Remade*, Loh directs a fresh gaze toward not only the work of famed Italian Renaissance artist Titian (ca. 1488–1576), but also that of another, lesser-known painter, most often described today as one of Titian's imitators: Il Padovanino (1588–1649). Padovanino (born Alessandro Leone Varotari) was celebrated by his contemporaries, particularly for his portraiture. He was dubbed "our rising Titian" by English poet Sir Henry Wotton for his close replication of Titian's characteristic themes, motifs, and style in his works, and his paintings featured in elite art collections all over Europe.

Even a cursory look at Padovanino's oeuvre betrays its contact with Titian's work. In *Titian Remade*, Loh considers Padovanino's *Sleeping Venus* (ca. 1625), which is regularly associated with earlier depictions of the same motif, notably in another *Sleeping Venus* begun by Giorgione and completed by Titian (1508–10) and in Titian's *Venus of Urbino* (1538).

The three works have much in common. In each, the nude body of the goddess of love stretches across the canvas from left to right as she reclines on a pair of cushions. Her left arm and hand are carefully positioned to shield the full extent of her nudity and her right leg is delicately tucked under her left. However, differences also abound. Padovanino's Venus is framed by a sumptuous red curtain on the left, from behind which an unpopulated landscape, complete with rolling hills, emerges on the right. As in Titian's *Sleeping Venus*, the goddess's right arm is tucked behind her head, but in Titian's work, no curtain is present. Venus instead reclines entirely outdoors on a cream cloth. Meanwhile, the setting of the *Venus of Urbino* is a bedroom. Here, Venus's eyes are open, glancing out at the viewer, and a small dog is curled up at her feet. Two maids behind her are shown preparing her dress. The similarities between the three images are not only limited to subject matter. Like Titian, Padovanino contrasts the luxurious, silken fabrics on which his Venus rests with the soft luminosity of her skin.

Each of these renderings of the recumbent Venus has the ability to intrigue and delight a viewer, yet only Titian's works have achieved the status of great masterpieces in art historical literature. Despite being praised as Titian's successor by his contemporaries, Padovanino has been maligned by more recent critics, Loh recounts, as "a belated imitator slinking about in Titian's shadow." In short, Padovanino's paintings have been disparaged for precisely the same repetition of Titian-esque qualities for which they were praised in the past. In her volume, Loh draws attention to this reversal in Padovanino's fortune, inviting her readers to reevaluate the significance of his work.

A method by which one might attempt to rehabilitate Padovanino's reputation is through stressing his originality, highlighting the elements in his paintings that do stray from the Titian-esque and are very much his own. Loh explicitly rejects this approach. Instead, she chooses

Giorgione and Titian. *Sleeping Venus*. 1508–10. Dresden, Staatliche Kunstsammlungen, Gemäldegalerie Alte Meister.

Titian. *Venus of Urbino*. 1538. Florence, Galleria degli Uffizi

to embrace the repetition inherent in Padovanino's work. She encourages her readers to shift their "critical vantage point" and reconsider the legitimacy of drawing such a sharp binary distinction between the concepts of 'master' and 'copyist' and 'original' and 'copy' in the first place.

To introduce these ideas, Loh herself draws on the work of an IAS predecessor. She discusses an often-overlooked essay by Erwin Panofsky, past Professor (1935–68) in the School of Historical Studies, which highlights Panofsky's "fluid model of originals and facsimiles." Panofsky's essay was inspired by museum collections of plaster cast reproductions of sculptures, which had been painted to recall the material of their originals. In his discussion of these casts, Panofsky draws attention to the fact that such objects exist between the binary of "original" and "facsimile reproduction." He described pure white, unpainted plaster casts as true facsimiles, for they were mechanically produced by means of molds and therefore lacked "the insertion of the human hand" in the making process. However, for

Panofsky these same plaster casts existed in an intervening space between originals and copies when they were painted. This is because subjective, human choices were made when the painting of the casts occurred, likely in the precise colors and application of the paint. Painted plaster casts were thus neither wholly original nor fully a facsimile, problematizing the binary distinction that is often drawn between the two.

Significantly, Panofsky also argued that copies, including photographic facsimiles of paintings as well as plaster cast reproductions, possessed their own unique values. He presented these as primarily pedagogical in nature. He argued that by comparing a Cézanne watercolor to a printed reproduction of it, one's understanding of the former work would be enhanced. This is because the comparison with the printed photograph would call attention to "certain attributes" in the watercolor "that would otherwise not have been marked." In pointing out this educational value, Panofsky makes the point that originals and copies, in Loh's words, exist "in a state of mutual dependency." It is obvious that a copy is dependent on the existence of an original to come into being, but Panofsky's essay makes the less obvious observation that our perception of and response to a so-called original work is capable of being transformed through our engagement with a copy.

New shoots can graft onto older portions and, in Loh's words, "transform the nature of both in the same instance."

Loh builds on this foundation laid by Panofsky by drawing on the work of French theorist Gilles Deleuze. Instead of a vertical, hierarchical approach that considers artists such as Padovanino as having been "inspired by" the great artists that preceded them, Loh encourages her readers to consider the relationship between Titian and Padovanino as being like a Deleuzian rhizome. The rhizome is a horizontal subterranean plant stem, characterized by its ability to develop in a nonlinear way. Rhizomatic systems have no specific origin or end: new shoots can graft onto older portions and, in Loh's words, "transform the nature of both in the same instance."

Thinking about Titian and Padovanino as two parts of the same grand, art historical rhizome is likewise transformative for our understanding of both artists. Loh highlights how Padovanino's reputation gained significance because of his references to Titian, describing how his paintings appeal to viewers when "we see Titian in them." She interprets Padovanino's artwork as functioning in a comparable manner to Hollywood remakes such as Terry Gilliam's 1995 film *Twelve Monkeys*. As well as being a remake of Chris Marker's 1962 film *La jetée,* Gilliam's movie contains significant homages to Alfred Hitchcock's *Vertigo* (1958). Loh articulates the pleasure that viewers who have familiarity with Hitchcock's film experience when they encounter the allusions made to it by Gilliam. Unlike forged art pieces, which lose their value if they are successfully identified as such, Loh argues that remakes are instead deliberately referential. Their allusions are intended to be "found out" and enjoyed by their audience. This deliberate repetition is the kind that Loh identifies in Padovanino's work, giving his viewers, steeped in knowledge of Titian, a satisfying feeling of being 'in the know.'

The benefits of Padovanino's association with Titian do not run in only one direction. Loh argues that the repetition of Titian's work by Padovanino and others marked out his paintings as something worthy of being reproduced, increasing their standing as a result. In so doing, she highlights how both artists were transformed by the connections between them. She shows that considering how Titian "influenced" Padovanino is, in fact, the wrong question to ask. Instead, she advocates for a more ready consideration of how each artist changed the way that the other is viewed.

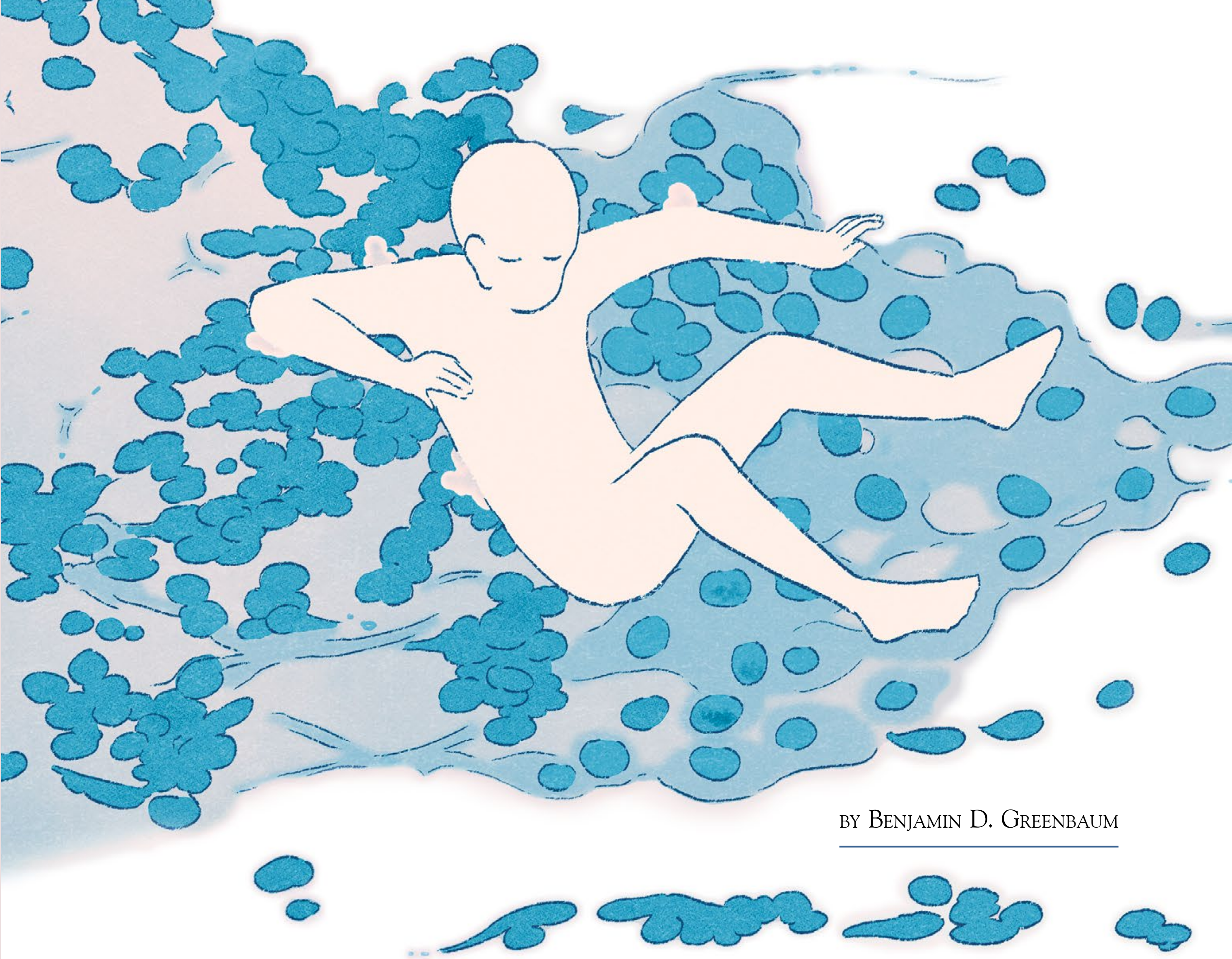
Just as Loh's readers begin to understand Titian and Padovanino anew, as two stems grafted to each other in a state of mutual dependence, they also experience how Loh herself has spliced new roots onto past IAS scholarship, and not only that of Erwin Panofsky. In her consideration of the motif of the reclining Venus, Loh also follows in the footsteps of Millard Meiss, past Professor (1958–75) in the School of Historical Studies, who discussed the same theme in a 1966 essay titled *Sleep in Venice: Ancient Myths and Renaissance Proclivities*.

Titian's representations of Venus more generally were also brought to bear on the interpretation of the IAS seal in a short treatise by Irving Lavin, another past IAS Professor (1973–2019) in the School of Historical Studies, and his wife Marilyn Aronberg Lavin. Represented on the seal are the personified figures of Truth and Beauty, the former clothed, the latter nude. The Lavins' essay highlights how theme of representing two Venuses experienced a resurgence in popularity during the Renaissance and, uncoincidentally, also appeared in one of Titian's most famous paintings, known today as *Sacred and Profane Love*. The Lavins drew this detail into the history of the IAS seal, but noted that it was Panofsky who first outlined the Renaissance resurrection of the motif.

In this rich context of interwoven scholarship, Loh's appointment to the Faculty is sure to see the rhizome of art historical research at the Institute for Advanced Study continue to expand and thrive. ■

Maria Hsiuya Loh, Professor of Art History in the School of Historical Studies, is an internationally recognized expert in the field of early modern Italian art. Loh's expertise also extends to contemporary artists, critics, and filmmakers, but it was her groundbreaking work on originality and repetition that caught the eye of Abbey Ellis, past Visitor (2021–22) and Research Associate (2022) in the School of Historical Studies, due to its relevance to her own research. Ellis's Ph.D. project focused on the modern reception of plaster cast reproductions of ancient sculptures and issues of value and authenticity.

what is NON-SELF?



BY BENJAMIN D. GREENBAUM

EARLIER THIS YEAR, my collaborators and I announced that mRNA vaccines—made famous by COVID-19 and recently awarded the 2023 Nobel Prize in Medicine—showed promise as a therapy for pancreatic cancer in a phase I clinical trial. The collaboration underlying this work originated, in part, from a meeting at IAS on Valentine's Day of 2015, a day that featured a cold extreme enough to freeze the Institute pond. The grim weather also, advantageously, confined indoors a group of mathematicians and theoretical physicists (for whom being cooped up was not unusual), as well as oncologists (whose inability to travel forced them to settle into Institute culture in a way their schedules do not typically allow). This collection of individuals was convened for a series of meetings organized by Arnold Levine, Professor Emeritus in the School of Natural Sciences, to hear from speakers on emerging topics in cancer research that seemed poised for productive collaboration between quantitative scientists and oncology researchers.

I was a Long-term Member in the School of Natural Sciences from 2008 to 2013. The main theoretical question I focused on while at the Institute (and still grapple with today) concerns the immune system. Why does it target one particular molecular feature over another, what does that tell us about genome evolution, and how does that selection affect the evolution of cancer and viruses? In short, I am interested in the theory of self versus non-self discrimination.

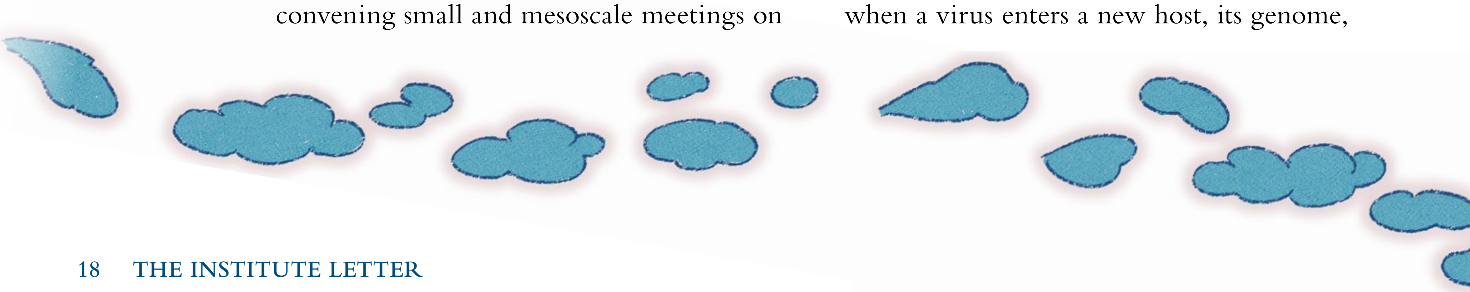
Why does [the immune system] target one particular molecular feature over another, what does that tell us about genome evolution, and how does that selection affect the evolution of cancer and viruses?

Broadly speaking, the immune system works by identifying the presence of pathogens—i.e., that which is not "self"—in the body, in order to combat infection. It seeks to complete this process while leaving cells belonging to the body—i.e., those which can be described as "self"—to complete their normal functions. But, because the immune system's machinery for discriminating between these two states is imperfect, and because, as we and others have shown, pathogens often do their best to mimic that which is self in order to survive, this process is not always successful. Greater understanding of how the immune system discriminates between these two is important in helping the immune system more successfully complete its task.

My theoretical work at the Institute and my continued collaborations there, as in the aforementioned series of meetings, led, perhaps unexpectedly, to an opportunity to apply this line of questioning to cancer. The Institute for Advanced Study allowed for time to reflect on the theoretical, abstract principles that underlie new empirical findings in a way that is difficult to achieve elsewhere. It is also a powerful location for convening small and mesoscale meetings on topics that bring together people to talk to, rather than past, one another. The consequences are not always obvious at the time, but, occasionally, something particularly useful can emerge.

The immune system's successful targeting of "non-self," namely the non-specific features that differ between ourselves and pathogens over evolutionary time scales (innate immunity) and the specific features learned within our lifetime (adaptive immunity), is necessary to combat infection by pathogens, like COVID-19 or influenza. My research at IAS initially focused on innate immunity. The ***innate immune system*** is a genetic system that recognizes patterns that discriminate pathogens from the organisms they infect. At the forefront of innate immunity are pattern recognition receptors that recognize features many pathogens share. For instance, when influenza (a virus with a genome made from RNA, instead of DNA like ours) replicates, it—like any other virus—needs to copy itself and, in doing so, temporarily makes long double-strands of RNA at a length that is rare in our genome. Many organisms have evolutionarily conserved receptors that sense double-stranded RNA in their cells, a hardwired example of self versus non-self discrimination by the innate immune system. By focusing on such non-specific molecular features shared by broad classes of pathogens, the innate immune system is often the first line of defense against a new infection.

During my time at IAS, I studied how the innate immune system alters virus evolution when a virus changes its host, such as during the 1918 influenza or COVID-19 pandemic. One organism's genetic definition of non-self can differ from another organism's definition. For instance, the set of innate receptors in birds (the hosts of influenza) have some differences from those in humans. I, along with other Members, showed how these receptor differences can enforce mimicry: when a virus enters a new host, its genome,



to evade detection by its new hosts' receptors, evolves to look more like the genome of its new host.

When I arrived at the Institute, I worked with Members Raúl Rabadán (2003–09) and Gyan Bhanot (1981–84, 1987–94, 2002, 2003–10) to study the evolution of influenza in humans since 1918. We used this evolutionary history to elucidate how mimicry evolves due to innate immune system differences between humans and birds. Such differences, therefore, also tell us quantitative differences between how self is defined in those two hosts. Using this information in conjunction with inferences of the patterns viruses avoid as they evolve, one can predict which patterns the innate immune system targets. I worked with IAS Members Rémi Monasson (2009–11) and Simona Cocco (2009–11) to build a mathematical theory and predictive evolutionary models around this topic during the end of my time at IAS.[1]

Pathogens can adapt rapidly, their genomes mutating at a faster rate than ours, and an immune system based only on innate immunity would be vulnerable. The adaptive immune system is the arm of our immune system that detects features in pathogens that are not well conserved across evolution. The T cells (and B cells) of the ***adaptive immune system*** recognize antigens, namely short protein regions in pathogens, with great specificity over the course of our lifetime and, in some cases, commit those antigens to memory. Likewise, a vaccine can educate the adaptive immune system as to what antigens it may encounter in the future.

Here's loosely how it works: proteins inside cells are cut into short fragments, called peptides, and are presented on the cell's surface, be they proteins required for normal cell functioning or non-self proteins, like antigens. T cells, via an evolutionary innovation, can seek these antigens and, upon recognition, can destroy the cells containing them. However, the antigen presentation machinery does not discriminate well between presenting self peptides and pathogen peptides. A successful immune response would disproportionately recognize these non-self peptides and eliminate the cells which contain them, while avoiding eliminating cells that only presented self peptides. If the immune system erred on the side of the latter, it would attack our own tissue in a wave of autoimmunity, while if it erred on the side of the former, viruses could gain an advantage by mimicking self-proteins.

How this trade-off is balanced—to recognize infection while avoiding self-destruction—is the subject of the theory of immune ***tolerance***, the mechanisms by which the adaptive immune system learns to inhibit the immune response against self peptides. In the thymus, T cells that recognize self peptides can be eliminated. It had been previously thought that this training of T cells in the thymus was nearly exhaustive, meaning the immune system would play little role against that which is very closely related to self, and would favor peptides dissimilar from self (leaving an opening for rapidly evolving viruses to mimic self peptides).

But our empirical understanding of tolerance has changed fundamentally since theorists first attempted to create mathematical measures quantifying non-self several decades ago. Over the last few decades, a different picture has emerged, one in which many T cells that are capable of recognizing self or near-self peptides survive elimination in the thymus and are, instead, held back by

Broadly speaking, the immune system works by identifying the presence of pathogens—i.e., that which is not "self"—in the body, in order to combat infection. It seeks to complete this process while leaving cells belonging to the body—i.e., those which can be described as "self"—to complete their normal functions.

1 In a story for another time, this work has also had surprising and profound applications in understanding how cancer interacts with the innate immune system.

By starting out as self and evolving in ways the immune system may recognize as "non-self," cancer evolution can illuminate the very boundary between the two states.

mechanisms of a process called negative regulation. Negative regulation, rather than just eliminating T cells that recognize self (or near-self) peptides, instead holds them in check. This means that, if negative regulation could be suppressed, the T cells that recognize near-self peptides could be deployed against pathogens—and cancer.

By starting out as self and evolving in ways the immune system may recognize as "non-self," cancer evolution can illuminate the very boundary between the two states. As cancer cells evolve, they accumulate mutations in their DNA. Those mutations create changes in proteins that give cancer cells their pathological selective advantage over neighboring cells. Yet, at the same time, the very same mutations can make the proteins of those cells different than the proteins the immune system was trained on. These new antigens, created during tumor evolution, are called ***neoantigens***.

Many neoantigens differ from self by only one mutation. Given this close similarity to self-proteins, the older understanding of tolerance could imply this may be too self-similar to mount an effective immune response. Indeed, for many years it was thought that the immune system did not play much of a role in cancer evolution. A fundamental change was the discovery of immune checkpoints, a breakthrough which received the 2018 Nobel Prize in Medicine. This revealed that part of the reason why the immune system could not recognize cancer cells was not that T cells capable of recognition were completely absent, but rather that they had been inhibited via negative regulation. Once negative regulation was restrained, immune recognition of some cancers was now possible.

In the old model of hard tolerance, it may have seemed equally unlikely that the immune system would detect any peptides that are similar to self. However, we have posited that the significance lies in the specific qualities of neoantigens the immune system is able to recognize as cancer cells evolve. In other words, our notion of antigenic distance from self is non-trivial. For the next phase of my research, after IAS, I chose to study how the adaptive immune system recognizes peptides in cancer, investigating what biophysical and chemical features make something that was once self—the proteins in a cancer cell—appear as non-self to the immune system.

That fundamental understanding can then be acted upon by trying to enhance the immune system's capability of recognizing tumors. One logical application is in the selection of targets in an anticancer vaccine, which brings us back to the frigid meeting at IAS. At that meeting, Jedd Wolchok (then at Memorial Sloan Kettering), who had led some of the first clinical trials in immunotherapy, described recent findings on neoantigens and response to immunotherapy. I spoke with him about building mathematical models around immunotherapy response based on the immune system's ability to differentially recognize neoantigens, work on which I then collaborated with past Research Associate (2014–18) Marta Łuksza (to whom I had been introduced by Stanislas Leibler, Professor in the School of Natural Sciences). Shortly thereafter, Jedd's colleagues at MSK, led by Vinod Balachandran, reached out to me to share evidence that, in pancreatic cancer, long-term survivors had unusual immunological activity.

Pancreatic cancer had often been thought of as an immune desert, with little penetrance of the immune cells needed to combat a tumor. It is generally nonresponsive

to immunotherapies—it has relatively few alterations in its DNA and, therefore, less of a chance of generating neoantigens that could elicit an immune response. Many vaccination efforts had, accordingly, been focused on cancer types where the role of the immune system had been better established, such as melanoma and lung cancer. However, the tumors of long-term survivors of pancreatic cancer were showing evidence of T cell infiltration. When our models were applied to this data, we were able to show that the evolution in pancreas tumors of long-term survivors was consistent with selection on neoantigens. Our team has continued to develop and extend such "neoantigen quality" models to understand which features make an altered peptide recognizable to the immune system in a way that alters cancer cell fitness.

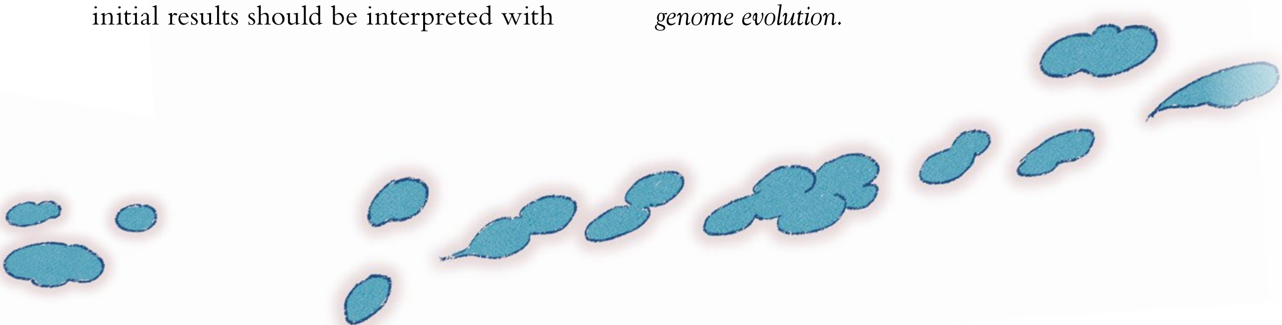
We hypothesized that our results could be an example of spontaneous recognition of neoantigens in a rare subset of patients, a kind of "auto-vaccination." If, in rare cases, the immune system may shape the evolution of pancreatic tumors, perhaps we could boost the immune response to a larger set of antigens in more patients through vaccination. Vinod and I immediately applied for funding to support a clinical trial (which Vinod led) and analyze the results. Many platforms were considered, but it was decided that mRNA vaccines made a promising candidate after a set of meetings with the groups at BioNTech and Genentech.

Each of the 16 trial patients had their tumor removed and flown to Mainz, Germany where a personalized mRNA vaccine was created based on up to 20 mutations specific to that tumor. The trial showed immunological responses in half (of the 16) patients treated. Additionally, our study of the trial's results contained a first of its kind mathematical analysis of the dynamics of T cells responding to a cancer vaccine. While these initial results should be interpreted with caution, as this was a phase I clinical trial,[2] they offer precious data into the action of mRNA vaccines in the setting of pancreatic cancer.

The above work is a recent example of two of the many features that make the Institute special. The trial was conceptualized in 2016, well before COVID-19, when mRNA technology was not particularly well known to the public and its basic effectiveness as a vaccine platform was far less clear. Moreover, as stated above, the decision to attempt vaccination in pancreatic cancer was, in many ways, counterintuitive. So, what was the research path that led to such an unusual effort? It was, in part, due to the unique IAS atmosphere: a line of theoretical inquiry initiated at the Institute, and a set of meetings held there to create collaboration in emerging areas of research. ■

2 Meaning it had no control arm and, thus, shows correlation and not causation.

Benjamin D. Greenbaum was the Eric and Wendy Schmidt Long-term Member in the Simons Center for Systems Biology from 2008–2013. He is an Associate Member of Memorial Sloan Kettering Cancer Center (MSKCC) and an Associate Professor of Physiology, Systems Biology and Biophysics at Weill Cornell Medicine. He has a Ph.D. in theoretical physics from Columbia University. He currently works on how the innate and adaptive immune system impact cancer and virus evolution, how immune interactions effect models of cancer cells fitness, and the role of repetitive elements in cancer and genome evolution. At MSKCC, he started a programmatic effort in Computational Immuno-oncology and is helping to translate his work and that of colleagues into next generation immunotherapies, particularly cancer vaccines. He continues to work on a number of theoretical topics related to the immune system and genome evolution.



DYNAMICS IN TRANSLATION

How the Mathematics of Nuclear Fusion Informs the Physics of Galaxies

BY CHRIS HAMILTON

Should you ever deign to leave the Institute campus and head a few miles north along Route 1, you will arrive at another world-leading facility: the Princeton Plasma Physics Laboratory (PPPL). The Laboratory sprang out of Cold War attempts to control thermonuclear reactions, but since 1951 has been at the heart of U.S. efforts to produce clean energy and ultimately save the planet. Its mission is to develop nuclear fusion as a sustainable energy source, which, if successful, would end our reliance on fossil fuels.

More specifically, fusion scientists are attempting to harness the power latent in *plasma*. Plasma is a fourth state of matter—distinct from solids, liquids, and gases—which can be produced by heating gas to such high temperatures that the electrically neutral atoms comprising it are ripped into their constituent parts: negatively charged electrons and positively charged nuclei, known as ions. Fusion physicists at PPPL inject these electrons and ions into a donut-shaped device known as a tokamak, and then attempt to control their motion using electromagnetic fields. Their aim is to force the ions to collide with each other at high speed and fuse. It is this fusion process that releases excess energy which can then be harnessed outside of the device.

While the practices of the fusion physicists at PPPL may seem completely divorced from the realm of theoretical astrophysics, they are now a regular topic of discussion among the scholars of the Institute's School of Natural Sciences. The reason for this has nothing to do with atomic energy. Instead, it turns out that the mathematical methods developed to exploit the power of the electrons, ions, and magnetic fields in fusion plasmas are precisely the same as those needed to describe the dynamics of stars, spiral arms, and dark matter in galaxies like the Milky Way.

The fields of plasma physics and galactic dynamics are divided by a thick fog of complex jargon and obscure practice, but once one has become fluent in both Plasmish and Galacticese, and has developed a dictionary relating the two, one can pull ideas directly from one field to solve a problem in the other.

Wave-particle interactions, Landau damping, and LBK

That plasma physics and galactic dynamics are intellectually adjacent is not a new discovery. In the 1940s and 1950s, Lyman Spitzer, a founding member of both PPPL and Princeton University's Astrophysical Sciences division, was a reigning master of both fields. In 1972, two past IAS Members in the School of Natural Sciences, Donald Lynden-Bell (2003) and Agris Kalnajs (1979–80), drew extensively on plasma theory to write what I consider to be the greatest paper to date in the field of galactic dynamics: *On the generating mechanism of spiral structure*.[1] Lynden-Bell and Kalnajs's work will be relevant throughout this article, so as a shorthand, I'll refer to them as LBK.

I'm going to explain just one small part of what LBK showed in their 1972 masterpiece, but first I need to tell you about the fundamental plasma theory that inspired them, namely *Landau damping*.[2] This is something that still fascinates mathematicians and physicists today. In fact, Cédric Villani, past Member (2009) in the School of Mathematics, was awarded the 2010 Fields Medal partly for his work on this subject, much of which was completed at IAS.

The best way to understand Landau damping is to take a rather macabre approach. Imagine you are trapped inside a plasma and are desperately shouting for help. Since the plasma medium consists of charged particles, the sound wave produced by your scream (technically known as an *ion-acoustic wave*) would carry its own electric field, whose value is

1 Lynden-Bell, D., & Kalnajs, A. J. 1972, *Monthly Notices of the Royal Astronomical Society*, 157, 1

2 Landau, L. D. 1946, Zh. Eksp. Teor. Fiz

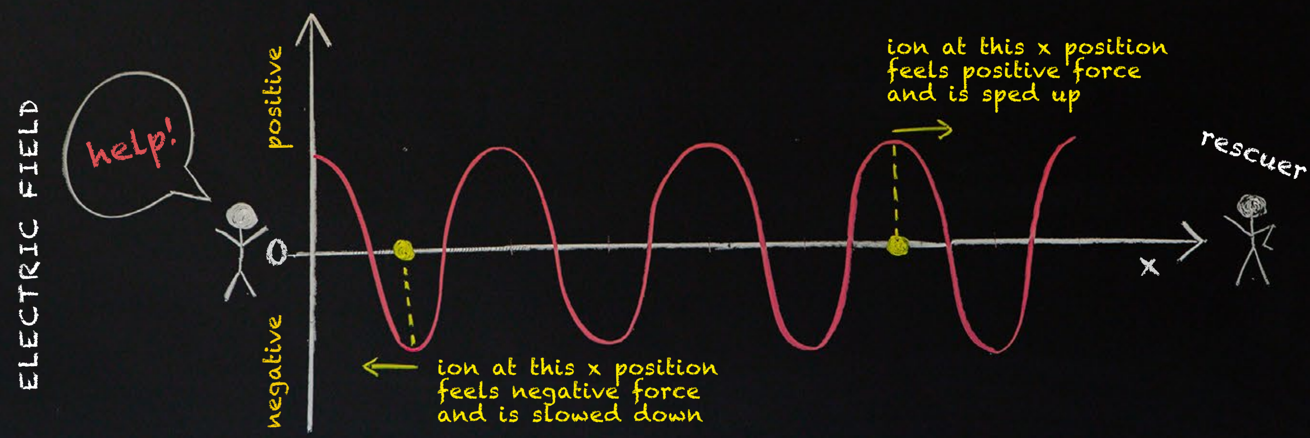


Figure 1

indicated on the vertical axis in Figure 1. The sound wave moves in time from left to right along the *x*-axis. Supposing your rescuers are situated somewhere along the *x*-axis, you might hope that your sound wave will reach them before too long.

But there's a problem. Your sound wave would also interact with other particles within the plasma, such as positively charged ions, which will also be moving along the *x*-axis. At a fixed time, if an ion is located along the *x*-axis at a position where the wave's electric field is negative, then it experiences an opposing force from the wave in the *x* direction, slowing it down. Conversely, if an ion is located at a position where the wave's electric field is positive, it feels a further push from the wave, speeding it up. The total energy of the wave-particle system must be conserved. Thus, if the wave happens to cause the ion to speed up, the energy required to do this must be sucked out of the wave, meaning that the wave decays in amplitude, or *damps*.

For the vast majority of ions, the force that they feel from the wave will sometimes be positive, sometimes negative, and these pushes and pulls will typically cancel each other out. As a result, there will be, on average, no energy transfer between wave and ion, and so no net wave damping will occur. But Landau understood that this is not the case for *all* ions. Instead, a small fraction of the ions *resonate* with the wave, which means that they move along the *x*-axis at very nearly the same speed as the wave does. For these select few resonant ions, the aforementioned cancelling-out never occurs. In fact, Landau showed that for the resonant ions, the overall force they typically feel from the wave is net positive; i.e., on average these ions speed up. Due to energy conservation, the overall force on the wave is, therefore, negative, causing it to decay in amplitude, or *Landau damp*. One consequence of Landau's result is that it can be very difficult to propagate a sound wave through a plasma; or, to put it more dramatically, in plasma, *no one can hear you scream*.

Back to gravity. LBK looked at the mechanism of Landau damping and realized that it also applied to astrophysical systems. Their analysis showed that Landau's mechanism describing the interaction of sound waves, and ions in a plasma can also be used to investigate the evolution of a galaxy's *bar*.

NASA, ESA, AND THE HUBBLE HERITAGE TEAM (STSCI/AURA)

Figure 2

A bar is an elongated agglomeration of millions of stars which exists at the center of a galaxy (Figure 2). Such bars are common in disk-shaped galaxies, including our own, the Milky Way. A bar does not sit inert, but rather rotates around its middle as if it were a solid body, like a gigantic stirring spoon being twirled at the center of a galactic latte. LBK showed that the bar's gravitational field in the galaxy is entirely analogous to the electric field in plasma, and this gravity field interacts with stars and other objects orbiting in the galaxy, just as the electric field interacts with ions. These interactions cause energy to be transferred to and from the bar, which in turn causes the bar to spin

ANDREA KANE

faster or slower. In other words, LBK's theory allows us to understand the spin of bars by treating a galaxy as if it were a gravitational plasma.[3]

The problem with galactic bars

Much of my work at the Institute has also focused on leveraging classic plasma results to solve analogous astrophysical problems. One of the papers of which I am most proud was written alongside my IAS School of Natural Sciences colleagues Elizabeth Tolman (Member, 2020–22) and Lev Arzamasskiy (Member, 2020–23), as well as Vinicius Duarte, a research scientist at PPPL.[4] Now, prior to this project, none of my coauthors had worked on galactic dynamics, and Duarte had never studied astrophysics at all. But I knew they were much more fluent than me in the language of theoretical plasma physics. Thus, they *were* galactic dynamicists already; they just didn't know it yet.

The problem I wished to address concerned the evolution of galactic bars. The central issue—and one that has caused much controversy in the astrophysical community in recent years—is that these bars seem to be spinning too fast.

Figure 3

3 The same trick was pulled off successfully elsewhere. For instance, in the 1970s and 1980s, Peter Goldreich and Scott Tremaine (now both IAS Faculty Emeriti) applied essentially the same ideas in their foundational studies of the interaction between orbiting moons and the rings of Saturn and Uranus, e.g., Goldreich, P. and Tremaine, S. (1979), *Astrophysical Journal*, *233*(3), pp.857–871

4 Hamilton, C., Tolman, E.A., Arzamasskiy, L. and Duarte, V.N., 2023. *The Astrophysical Journal*, *954*(1), p.12

When I say 'too fast,' I mean that the bars we observe in thousands of galaxies external to our own are rotating too rapidly compared to the predictions of our standard cosmological theory. This is the theory of *dark matter*—that mysterious and bewildering *stuff* whose gravitational imprints are rife throughout the universe but which has, so far, eluded our direct capture.

Dark-matter-based cosmology theory tells us that each galaxy is surrounded by a massive, roughly spherical *halo* of dark matter particles (Figure 3). These particles orbit around the galaxy, and interact gravitationally with the spinning bar. Following Landau and LBK, we expect that the dark matter particles that resonate with the bar (i.e., those which orbit the galaxy at the same rate that the bar spins) will suck energy out of it. In other words, trying to spin a stellar bar inside a deep gravitational well of dark matter should be like twirling your coffee stirrer through molasses. Indeed, applying the LBK equations to this problem shows that the spin rate of bars ought to decrease dramatically within the lifetime of the galaxy. This conclusion is corroborated by computer simulations of galaxies surrounded by dark matter haloes: in many of those too, the bars slow down.

Yet the bars that astronomers observe today are spinning fast! This has led some physicists to claim that standard cosmology is in crisis, and that perhaps the dark matter theory should be abandoned altogether.

A partial solution to this problem comes from 1984, when IAS Professor Emeritus Scott Tremaine and Martin Weinberg, past Member (1987–90, 2010) in the School of Natural Sciences, published an update to the LBK theory, which we'll call the TW theory.[5] In particular, TW accounted for the fact that dark matter particles can become 'trapped' in the gravitational field of the bar and dragged along with it. The stronger the gravitational field of the bar is, the more dark matter can be trapped. Further, TW showed that trapped particles do not give or take energy from the bar on average. Thus, when many particles are trapped, the bar will continue to spin fast, and the slowdown predicted by LBK can be avoided.

However, both the LBK and TW theories ignore the fact that, in reality, dark matter particles are not only influenced by the gravity of the bar. That's because real galaxies are messy machines: they also comprise molecular gas clouds, star clusters, spiral arms, and various other bits and pieces of galactic shrapnel which shuffle and nudge the dark matter particles in their vicinity in a process known as *diffusion*. I wondered: how are the classic LBK and

5 Tremaine, S., & Weinberg, M. D. 1984, *Monthly Notices of the Royal Astronomical Society*, 209, 729

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TW results modified if one includes this inevitable diffusion? In fact, do these analytic theories provide any insight into the real problem whatsoever?

Our contribution

It turns out that the aforementioned questions had already been tackled in—you guessed it—plasma physics; more precisely, in the theory of plasma fusion in tokamaks. In plasma physics, it is well understood that resonant interactions between magnetic waves and energetic ions can be interrupted when the ions collide with the background plasma particles and are knocked off course.[6] Several tokamak scientists, including Tolman and Duarte, had previously studied how magnetic wave-particle interactions are modified by this so-called *collisional diffusion*.

Our insight, therefore, was that a galaxy is a kind of gravitational tokamak. We showed that in a galaxy with diffusion artificially set to zero, the general bar-dark matter halo interaction will eventually lead to zero slowdown of the bar, just as TW predicted. But as one adds in even a very small amount of diffusion, the interaction is modified, and the bar's slowdown rate increases dramatically, until eventually it reaches the value predicted by LBK.[7] Thus one can think of TW and LBK as two ends of a spectrum, describing the cases with 'zero diffusion' and 'lots of diffusion,' respectively (even though neither TW nor LBK considered diffusion explicitly).

Next, using the known properties of observed galaxies, we estimated that most bars in the real universe probably sit quite close to the 'zero diffusion' limit. Therefore, they are approximately described by TW theory, which can explain why most of them are spinning rapidly. On the other hand, we also estimated that in computer simulations of those same galaxies, there is significantly enhanced diffusion. (This artificial diffusion is an inevitable consequence of simulating a hugely complex system with finite computational resources.) This means that the galaxies being simulated on the computer are *not* well described by the TW theory. Instead, their extra spurious diffusion puts them closer to the LBK limit. Since LBK predicts slowdown where TW does not, it is natural that the bars in real galaxies would be spinning more rapidly than those in simulations thereof.

Having said this, we cannot claim to have solved the problem of fast-spinning bars. Even though our model is somewhat more sophisticated than the classic works of LBK and TW, it is still a drastically simplified version of a real galaxy, and there are many important effects we did not account for. But by isolating the effect of diffusion, and lifting analogous results from tokamak fusion theory, we were able to gain insight into the bar-halo interaction, and learn something that a brute-force computational experiment might never have revealed.

What's next?

Kleptomania is a bad habit. But I must admit that since the bar-halo project I have continued to co-opt ideas from plasma physics for my own purposes. I have used such ideas to study the strength of galactic spiral arms, to understand the response of barely-stable stellar systems to gravitational perturbations, and to probe the strange orbital distributions of wide binary stars in the Milky Way.

In the future, I hope that the plasma-galactic relationship flourishes in a symbiotic, and not a parasitic, fashion. After all, plasma physicists can also learn from us. Lynden-Bell's famous theory of violent galactic relaxation is these days a mainstay of plasma theory. Villani's work was partly inspired by the discussions of gravitational Landau damping in the bible of my subject, *Galactic Dynamics* by Binney and Tremaine. And with our bar-halo work, we inadvertently provided the most detailed and general study of resonant wave-particle interactions in the presence of diffusion to date, something that can be reclaimed by the plasma theorists and applied in whatever context they see fit.

I cannot predict the outcome of our continuing efforts in reconnecting the plasma and galactic communities, but I do know that therein lies fertile ground. If fusion is one day successful, perhaps our silly study of bars and galaxies will have played a tiny role in saving the planet. Now, whoever said astrophysics isn't useful? ■

Chris Hamilton is a John N. Bahcall Fellow in the School of Natural Sciences. He moved to the Institute in 2021, after completing his Ph.D. at the University of Cambridge, for which he was awarded the International Astronomical Union's Ph.D. Prize. His interests include black hole mergers and the gravitational dynamics of galaxies, globular clusters, binary stars, and planetary systems. He also delivers an annual lecture course on the kinetic theory of stellar systems to Masters students at the University of Oxford.

6 Plasma physicists want to prevent the ions from flying into the walls of the tokamak since this leads to rapid, and very expensive, degradation of the machine. One of the great privileges of being an astrophysicist is that one need not pay attention to such practical concerns.

7 Beyond this, a further increase in the strength of diffusion does not lead to any change in the friction felt by the bar. Technically speaking, the effect of diffusion is to "relinearize" the dynamics by forcing the particles to repeatedly "forget" their previous state, avoiding the buildup of nonlinearities that underlies the TW theory.

ANDREA KANE

FROM THE ARCHIVES

My Journey Through the Archives

BY ZHENGKAI LI (李正楷)

I had the privilege of attending Women and Mathematics (WAM) at IAS this past May. Besides the intelligent female peers, the enjoyable mathematics, and the delectable cuisine, one particular experience stands out in my memory: my initial visit to the archive. During the opening talk for WAM, Caitlin Rizzo, the Institute's archivist, proudly informed us that the first woman of color at IAS—whose name I would later learn was C.S. Wang Chang—could be traced back to 1945; Caitlin encouraged us to come to the Shelby White and Leon Levy Archives Center to explore Wang Chang's profile and the profiles of other women of color, if our time allowed. This piqued my interest immediately, as my former female mathematics professor, who earned her Ph.D. at Harvard, had once mentioned the challenging gender ratio when she was a student. The year 1945 remained on my mind throughout the day, and finally, in the afternoon, I found a moment to visit the archives center. Unfortunately, by the time I arrived, it was almost closing time, so I only managed a brief glimpse of the profile; while I still wasn't sure of the scholar's name, I was able to catch that this remarkable first female scientist of color was born in Shanghai, China, studied physics, and received her Ph.D. from the University of Michigan.

SHELBY WHITE AND LEON LEVY ARCHIVES CENTER

Cheng Shu Wang Chang (張王承書), circa 1948–1949.

Returning to the dormitory, I eagerly shared that afternoon's glimpse with my closest friends. I was determined to find more information about this remarkable individual online so that I could enlighten my friends about her significant contributions. With this goal in mind, I turned to Google and entered the search query "female physicist, Shanghai, University of Michigan." However, the search results led me to a scientist named Chien-Shiung Wu, who, as it turns out, was born in Jiangsu, China, and had no connection to the University of Michigan. As I continued clicking on links that were unrelated to the person I was actually seeking, I couldn't help but regret not remembering the scientist's name with more precision. (In my own defense, this confusion primarily arose from the fact that the Chinese romanization system I had grown up with, Pinyin, was introduced in the 1950s, whereas all the Chinese scientists who visited IAS in the twentieth century had used Wade-Giles as the romanization of their names, and these two systems are quite distinct.)

The mystery surrounding this female scientist continued to occupy my thoughts throughout the night, until I finally seized the opportunity to revisit the archives center the following day in my quest to obtain the correct spelling of her name, C.S. Wang Chang. Once again, I entered her name into Google, hopeful of uncovering a detailed Wikipedia page dedicated to her. Sadly, my efforts yielded meager results. Following an exhaustive search, I recruited Caitlin, who eventually succeeded in identifying the elusive C.S. Wang Chang on Wikidata. Astonishingly, our breakthrough came by sifting through her husband's Wikipedia page, leaving me with a sense of frustration and bewilderment.

Subsequently, I made an attempt to locate her on the Chinese internet by entering "C.S. Wang Chang" into the search bar. As anticipated, the results were disappointing, as Wade-Giles had long fallen out of use in mainland China.

Faced with this obstruction, I turned again to Caitlin, inquiring whether it might be possible to ascertain her name in Chinese characters. To my delight, Caitlin provided me with a signature book of all the

SHELBY WHITE AND LEON LEVY ARCHIVES CENTER

Cheng Shu Wang Chang (張王承書), Sheila Power (later Tinney), Sumi Yukawa (湯川スミ), Cécile Morette (later DeWitt-Morette), and Hideki Yukawa (湯川秀樹), circa 1948–1949.

former members of IAS starting from Albert Einstein. With meticulous scrutiny, I eventually uncovered her distinctive signature—張王承書, with the initial character '張' signifying her husband's surname.

After this extensive journey of discovery, I proceeded to enter her name, "王承書," into the Chinese internet, finally unearthing a comprehensive catalog of narratives recounting her life and contributions, organized chronologically. This outcome defied the norm, as typically Wikipedia boasts a wealth of information compared to the Chinese internet.

I found myself pondering why this situation persisted, where an abundance of valuable information remained unshared solely due to language barriers, an issue that should no longer be a significant concern. It then dawned on me that this predicament was primarily rooted in the transition between different romanization systems.* Consequently, I was inspired to compile a comprehensive list of the scientists I encountered in the signature book. I identified those who had inscribed their names in Chinese characters and were born in China, provided their names in both traditional and simplified Chinese characters, in Wade-Giles, and in Pinyin, and included relevant Wikipedia links, as well as links to Chinese profiles that I could locate on the Chinese internet.

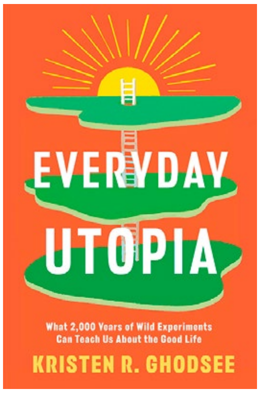
It's important to note that while this list is by no means exhaustive and only covers scientists who were Members until the 1960s who I saw in the signature book, I hope that it may prove beneficial to anyone else interested in delving into the life stories of these Chinese scientists who studied the United States during the twentieth century. My aspiration is that this endeavor will help shed light on their remarkable accomplishments, and make their contributions more widely known, both in the United States and in China. ■

** With the transition from Wade-Giles to Pinyin, our younger generations may struggle to connect certain words from the old system with Chinese characters (if there is even an occasion where younger generations in China need to use the old system). For instance, under the new system, "Chien Shiung" would become "Jian Xiong." Furthermore, the correspondence between Romanization and Chinese characters is not a one-to-one match. To illustrate: when considering pronunciation alone, there are more than 100 Chinese characters that share the same "Chen" pronunciation. Add to this the fact that Chinese characters themselves have undergone changes over time. In the twentieth century, mainland China primarily used traditional Chinese characters. However, in contemporary mainland China, we now predominantly use simplified Chinese characters, while in Hong Kong and Taiwan, traditional Chinese characters are still in use (with slight variations between the two regions). Fortunately, this doesn't pose significant challenges, as traditional and simplified Chinese characters remain quite similar, especially for those whose first language is Chinese. For example, '張' is now written as '张'.*

Scholar	Chinese Character	First time at IAS	Area of Study
P'ei-yüan Chou	周培源	1936–1937	Physics
Tsai-han Kiang	江泽涵	1936–1937	Mathematics
Yue Kei Wong	黄汝琦(?)	1936–1937	Mathematics
Shiing-Shen Chern	陳省身	1943–1944	Mathematics
Ning Hu	胡寧	1943–1944	Physics
Cheng Shu Wang Chang	張王承書	1945–1946	Physics
Hsio-Fu Tuan	段學復	1945–1946	Mathematics
Ky Fan	樊畿	1945–1947	Mathematics
Shih-Tsun Ma	马仕俊	1946 (Spring)	Physics
Li-Fu Chiang	姜立夫	1946–1947	Mathematics
Shien-Siu Shu	徐賢修	1947–1948	Mathematics
Tsung-Sui Chang	張宗燧	1947–1948	Physics
Shih-Hsun Chang	張世勛	1949	Mathematics
Chen Ning Yang	楊振寧	1949	Physics
Tsung Dao Lee	李政道	1951–1952	Physics
Hsien-Chung Wang	王憲鍾	1951–1952	Mathematics
Chung-Tao Yang	楊忠道	1954	Mathematics
Yu Why Chen	程毓淮	1949–1950, 1955	Mathematics
Tai Tsun Wu	吴大峻	1958–1959, 1960	Physics
Su-shu Huang	黃授書	1960–1961	Physics

NB: In Chinese, the traditional format is that of surname followed by first name. Scholars names in characters follow this format.

Zhengkai Li is a graduate student enrolled in the mathematics department at the University of Washington. She achieved her Bachelor of Science in mathematics with the highest distinction from the University of Rochester in 2021.



FROM THE READING LIST

Dreaming up the Good Life with Kristen Ghodsee

Kristen Ghodsee, Member (2006–07) in the School of Social Science, is a dreamer. And she wants readers of her latest book, *Everyday Utopia*, to dream as well: "people are encouraged to use their wildest imaginations to help figure out how to patent more inventions to make more money for corporations or how to better market more Apple products (to use the paradigmatic example of the Steve Jobs's 'Think Different' ad campaign between 1997 and 2002). But ordinary people imagining more just, equitable, and sustainable societies are castigated as unrealistic or hopelessly naïve." Her frustration with the general acceptability of blue-sky thinking in the corporate world and in science and academia, but not in the world of politics, inspired her twelfth book *Everyday Utopia: What 2,000 Years of Wild Experiments Can Teach Us About the Good Life* during the pandemic. While some people were baking sourdough bread or brewing kombucha, Ghodsee, who was unable to travel to Eastern Europe for planned fieldwork, studied utopian communities.

Rather than exploring utopian visions from the top down (as they are often conceived, especially in the twentieth century), *Everyday Utopia* focuses on visions that were, and are, bottom up. Ghodsee believes that smaller changes in the way we organize our individual domestic lives can aggregate into important changes that can help us tackle the most pressing challenges of the twenty-first century—like the climate crisis, the growth of inequality, the epidemic of loneliness and social isolation, and the crisis of care for both the young and the elderly. Most importantly, Ghodsee seeks to bring about a realization that actively dreaming of a better future is a radical political act: "we need social dreamers in the same way that we need water and air. [I want] to convince people that the utopian imagination is a fundamental part of what makes humans human."

This interview has been edited for length and clarity.

Engaging Audiences…

I've written seven very traditional academic monographs published with university presses at Princeton, Chicago, Duke, and Oxford. I was ready to try something different—to speak to audiences beyond academia. I knew that many of my academic colleagues would look down on me for trying to write more accessibly for a general audience, but I felt it was politically imperative to make my research legible to people beyond the Ivory Tower. As a social scientist, I believe that we do our research to interrogate and better understand the human condition. There is always something missing if we don't take the knowledge we've produced and somehow apply it.

…Even Through TikTok

Argh! I don't know the first thing about TikTok. An undergraduate student at Penn created an account for me and, somehow, I ended up with more than ten thousand followers! I have little idea how to use that platform, and unfortunately my student graduated. The reason I don't delete the account entirely is because I've learned that if I want to reach younger readers, I need to meet them in the places where they congregate.

Getting Personal

As an ethnographer, I always write my way into a chapter or article by starting with my own positionality as a researcher—it's essential to reveal how my own point of view and life experience informs the scholarly arguments that I make. In academic writing, I usually cut those bits out from the finished product; sometimes you just need to make an argument and show the evidence.

But other times, the arguments and the evidence are easier to comprehend if they are folded into a story. Some of the personal anecdotes were very uncomfortable, and I had to get used to the idea that my own personal experiences would help readers understand the broader theoretical points that I was making. But in conversations with different readers since the book came out, I've learned that the personal anecdotes do really resonate with people. They also help make the book more accessible, especially when it is being translated into other languages.

Living Utopia Everyday

I'm interested in changes that we can make in our individual lives that will aggregate into broad based social changes without the intervention of the state or mass coordinated social movements. It's like individual young people in our societies deciding not to have children because of the climate crisis, or the precarity of our economies, or their very rational assessment that, in a capitalist society where human worth is measured in dollars, bearing and rearing children is a poor investment. They are not coordinating their choices, but they are making changes in their personal lives that will end up transforming our societies profoundly.

Trading Convenience for Community

I go out of my way to inconvenience myself for the sake of interacting with my community. I realize it is easier to order my groceries online, but I prefer to walk to my local grocery store. And when I get there, I usually refuse to use the automated checkout line. I prefer to interact with a human cashier who makes eye contact with me and engages in even the lightest of small talk. If I am not careful, I know I can get used to never having to interact with actual people, and that I might forget how to [socially interact].

Flexing our Cognitive Capacities for Hope

Hope is an emotion; it is the opposite of fear and anxiety. But it is also a cognitive capacity; it is the opposite of memory. Memory is a cognitive capacity that allows us to remember things in the past. Hope is a cognitive capacity that allows us to imagine ourselves as agents that can influence the future. When I hope, I am imagining a goal and mentally playing with different options for overcoming the various obstacles that prevent me from reaching that goal. So, on a daily basis, I try to spend time day-dreaming—actively just day-dreaming like I used to as a kid. Anarchists have this idea of "prefigurative politics" that I appreciate. They tell us that we should imagine the world that we want to live in, and then live our lives as if that world already existed. That's what I try to do, even just a little bit, every day. ■

The featured excerpt (overleaf) is pulled from Everyday Utopia*'s chapter on private property. Ghodsee lived in a communal house during her grad school days (they cooked for each other four times a week and did grocery shopping and chores as a collective) and, in 1990, spent time at the kibbutz Hatzerim in the Negev desert, Israel, which remains one of the fully communal kibbutzim to this day. She has written for* The Nation *about how the year she spent in Institute housing very much reminded her of her time in this intentional community.*

Ghodsee, a self-proclaimed Trekkie, believes in the power of fiction (particularly science fiction) in offering new ideas about how life could be lived. Aldus Huxley's *Island*, for example, features "mutual adoption clubs" in which families can adopt each other's children, and children, if they are having problems with their own parents, can freely decide to go live with others. Here are her recommendations for other works that are especially useful for pushing the limits of the imagination:

1. Ursula Le Guin's *The Dispossessed*
2. Marge Piercy's *Woman on the Edge of Time*
3. Nick Fuller Googins's *The Great Transition*

On May 24, 2023, Ghodsee delivered a book talk at IAS, with discussion moderated by Joan Wallach Scott, Professor Emerita in the School of Social Science.

EVERYDAY UTOPIA

What 2,000 Years of Wild Experiments Can Teach Us About the Good Life

"My daughter and I are wardrobe communists. Except for my extra three inches of height and my slightly bigger shoe size, we share identical proportions. This means that my closets—carefully curated over the last three decades—occasionally fall victim to the pillage of a quirky Gen Z-er in search of what she considers cool vintage finds. . . . I actually feel a deep joy when I see my grown-up baby wearing a French silk scarf or Vivienne Westwood corset that I splurged on in 1995. Since I only have one child, I suppose she will inevitably inherit all of these things anyway. . . . But then I catch myself and consider that word: inherit. . . . If any one of her peers came to my house and started rummaging through my dresses and sweaters, I would be profoundly uncomfortable. Why? . . . I wonder if there could be a world where I felt as generous with other children as naturally as I felt with my own. What would it take, to quote John Lennon, to 'imagine no possessions'?"

"The odd thing about thinking of private property as a natural proclivity is that our evolutionary ancestors spent the vast majority of our history as hunters and gatherers moving from place to place. . . . Far from being a 'natural' state of innocence, archaeologist and anthropologist David Wengrow and David Graeber suggest that egalitarianism was a chosen way of life, one fiercely defended by ensuring that no one person or group of people could establish arbitrary authority over others."

"The French anarchist Pierre-Joseph Proudhon proposed in his 1840 book, *Qu' est-ce que la propriété?* (*What is Property?*), that: 'La propriété, c'est le vol!' (Propery is theft!). He meant that there was some point in our distant past when we went from living in a world where everyone owned all productive resources (land, trees, bushes, and other aspects of the natural world that could provision the population) in common (to the extent that we can even use the word 'ownership' at all) to a world in which some individual or group cordoned off a parcel of land or guarded an alcove around a waterfall and claimed it for their exclusive use in perpetuity. Even the English philosopher John Locke, a fervent advocate for the necessity of private property in order to encourage industriousness, believed that the appropriation of land or other natural resources for private use was only justified if 'there is enough, and as good, left in common for others.'"

“Around the globe today, there exists a growing network of people bound together by their critiques of materialism, their desire for more egalitarian societies, and a commitment to environmental sustainability. According to the Intentional Communities Directory in April 2022, there were 222 communities in its database that described themselves as ‘communes,’ meaning that members share almost everything.”

“In the United States, Twin Oaks in rural central Virginia was founded in 1967 by some graduate students who read B. F. Skinner’s utopian novel, Walden Two, and decided they wanted to live collectively. The secular community has survived for over fifty years, tucked far away from the mainstream of American society. The community grows food, but they also weave handmade hammocks, make tofu, index books, and sell seeds and plants for income. The one hundred or so members of the community must work an average of forty-five hours per week. . . . Other than a few hours washing dishes, which everyone must do, they are free to choose where and when they want to work as long as all of the necessary labor gets done. . . . In exchange for their labor, members are guaranteed work, shelter, food, and health insurance, as well as access to the community’s shared amenities. Each member also receives a personal allowance of about $100 per month to purchase things not produced by the community: coffee, chocolate, cosmetics, and other personal items. . . . Residents of Twin Oaks share major appliances and equipment, which keeps living expenses low.”

“Twin Oaks maintains a car cooperative that allows members to rent vehicles when needed. They also practice a form of wardrobe communism like me and my daughter. ‘Oakers’ maintain a special room of ‘community clothes’ that is a shared wardrobe that any member can borrow from. Residents return dirty clothes to a communal laundry and the washing, mending, hanging, and sorting of clothes is done by those who receive labor credits for their work. . . . No one is prohibited from having private wardrobes, but clothes owned individually must be laundered or mended by their owners in their free time. . . . Oakers reside with one or two ‘Small Living Groups’ (SLGs) of ten to twenty people each, which function as a sort of surrogate family. Daily interpersonal interactions between residents can be harmonious or acrimonious, just as they are in a normal household, but on a much larger scale. . . . Like many cohousing communities, Twin Oaks has clear protocols for conflict resolution between residents, and members strive to make all decisions by consensus. . . . Oakers wishing to have children must seek permission from the community because each child born is another mouth to feed out of their shared resources, although those wishing to have more children are free to leave at any time. . . . People are free to come and go as they please, but the only thing you can take from the community are your personal possessions, and whatever is left of your monthly allowance.”

“Oakers know that this type of communal living is not for everyone. . . . Reflecting on her more than three decades at Twin Oaks, and the two now-grown sons she raised there, [Kristen ‘Kelpie’] Henderson explained to me: . . . ‘The kids love it here. It’s quite a bit safer to grow up here than in suburbia. Both my boys are happy and well-adjusted. My younger boy went to college at UVA [University of Virginia], and has remarked several times that people have too much money there. I think he’s probably right.’”

Excerpted from *EVERYDAY UTOPIA: What 2,000 Years of Wild Experiments Can Teach Us About the Good Life* by Kristen R. Ghodsee.

News of the Institute Community

Faculty

ANGELOS CHANIOTIS, Professor in the School of Historical Studies, has been elected to the American Philosophical Society and as Associate Member of the Royal Academy of Science, Letters and Fine Arts of Belgium.

ALONDRA NELSON, Harold F. Linder Professor in the School of Social Science, has been honored with the Sage-CASBS Award, presented jointly by Sage Publishing and Center for Advanced Study in the Behavioral Sciences, and has won a 2023 Champions of Freedom Award from the Electronic Privacy Information Center. She also received an honorary doctorate from Northeastern University, and was included in the inaugural TIME100 list of the most influential people in AI.

PETER SARNAK, Gopal Prasad Professor in the School of Mathematics, has received an honorary doctorate from Stockholm University.

SABINE SCHMIDTKE, Professor in the School of Historical Studies, has been elected to the British Academy.

AKSHAY VENKATESH, Robert and Luisa Fernholz Professor in the School of Mathematics, has been elected a member of the National Academy of Sciences.

Emeriti

EDWARD WITTEN, Professor Emeritus in the School of Natural Sciences, has been awarded the Hamburg Prize for Theoretical Physics.

Members

TONI MIKAEL ANNALA, Member in the School of Mathematics, has received the 2023 CMS Blair Spearman Doctoral Prize from the Canadian Mathematical Society.

ANA LUCIA ARAUJO, Member (2022) in the School of Historical Studies, has been named to the Carnegie Corporation of New York's 2023 Class of Great Immigrants.

CHRISTOPHER BONURA, Member (2022–23) in the School of Historical Studies, has been awarded a Rome Prize for 2023–24 by the American Academy in Rome.

Dirac Medal

All four winners of the 2023 ICTP Dirac Medal are past Members of the School of Natural Sciences:

JEFFREY HARVEY (1995–2000, 2005)
IGOR KLEBANOV (2021–22)
STEPHEN SHENKER (2000–01)
LEONARD SUSSKIND (1995, 1997)

JOAN FUJIMURA, Member (1999–2000) and Visitor (2000–01) in the School of Social Science, and **WARWICK ANDERSON**, Member (2005–06) in the School, have been awarded the 2023 Bernal Prize from the Society for Social Studies of Science.

MICHAEL MAGEE, Member in the School of Mathematics, has been awarded the Philip Leverhulme prize in mathematical sciences.

SVITLANA MAYBORODA, von Neumann Fellow (2018, 2021) in the School of Mathematics, received the 2023 Blavatnik Award.

RHACEL PARREÑAS, Member (2015–16) in the School of Social Science, and **VIVIANA ZELIZER**, Member (1996–97) in the School, have received top honors from the American Sociological Association.

RUBINA RAJA, Member (2019) in the School of Historical Studies, was presented with the Friedrich Wilhelm Bessel Research Award.

KAREN UHLENBECK, Distinguished Visiting Professor in the School of Mathematics, has been elected to the Royal Society.

PHILIP VAN DER EIJK, Member (2006) in the School of Historical Studies, has been elected Associé étranger of the Académie des Inscriptions et Belles-Lettres, Paris.

SHING-TUNG YAU, Faculty (1980–84) and **VLADIMIR DRINFELD** Member (1990, 1996–97, 1998) and Visiting Professor (2019–20) in the School of Mathematics, have been awarded the 2023 Shaw Prize in Mathematical Sciences.

Institute

JOHN A. OVERDECK has been elected Chair of the IAS Board of Trustees, succeeding **CHARLES SIMONYI**, who had served as Chair since 2008.

EVE MARDER has joined the Board of Trustees. Nominated by the Institute's School of Natural Sciences, she succeeds **EWINE F. VAN DISHOECK** as Academic Trustee.

RHACEL PARREÑAS, Member (2015–16) in the School of Social Science, has been elected leader of the Association of Members of the Institute for Advanced Study (AMIAS).

RUBENSTEIN COMMONS received an International Architecture Award from the Chicago Athenaeum: Museum of Architecture and Design.

WOMEN AND MATHEMATICS has been selected to receive the 2023 AWM Presidential Recognition Award from the Association for Women in Mathematics.

Past IAS Members Announced as 2024 Breakthrough Prize Laureates

Six of the 2024 Breakthrough Prize winners have past affiliations with the Institute's Schools of Mathematics and Natural Sciences. Now in its twelfth year, the Breakthrough Prize, often dubbed the "Oscars of Science," recognizes the world's top scientists.

JOHN LAWRENCE CARDY, the recipient of the 2024 Breakthrough Prize in Fundamental Physics, was a Member (2003, 2004) in the Schools of Natural Sciences and Mathematics. Alongside his colleague Alexander Zamolodchikov of Stony Brook University, he was praised for his "profound contributions to statistical physics and quantum field theory, with diverse and far-reaching applications in different branches of physics and mathematics."

SIMON BRENDLE, Veblen Research Instructor (2002–03) in the School of Mathematics, was awarded the 2024 Breakthrough Prize in Mathematics for his "transformative contributions to differential geometry," a field which "uses the tools of calculus to study curves, surfaces and spaces." Many of Brendle's results concern the shape of surfaces, as well as manifolds in higher dimensions than those experienced in everyday life.

ROLAND BAUERSCHMIDT, Member (2013–14) in the School of Mathematics, received one of three New Horizons in Mathematics Prizes for his "outstanding contributions to probability theory and the development of renormalisation group techniques."

A further trio of winners have past affiliations with the School of Natural Sciences. **MIKHAIL M. IVANOV**, NASA Einstein Fellow (2021–23); **MARKO SIMONOVIĆ**, Member (2014–18); and **OLIVER PHILCOX**, past visiting graduate student, were among the eight winners of the New Horizons in Physics Prize. The scholars were extolled for their "contributions to our understanding of the large-scale structure of the universe and the development of new tools to extract fundamental physics from galaxy surveys." ■

Eight IAS Scholars Elected as Members of the American Academy of Arts & Sciences

Eight scholars across all four Schools—Mathematics, Natural Sciences, Historical Studies, and Social Science—were elected as members of the American Academy of Arts & Sciences (AAA&S) this past spring, an honor that recognizes accomplishments and leadership in academia, the arts, industry, public policy, and research.

From the School of Social Science, Member (1987–88) and Visitor (2022–23) **LILA ABU-LUGHOD** has joined the 2023 class, along with Members **ANN MCGRATH** (2013–14) and **LAURENCE A. RALPH** (2012–13), and Visitor **MICHÉLE LAMONT** (1997), a cultural and comparative sociologist and author or coauthor of a dozen books.

At IAS, Abu-Lughod worked on a project titled "Acknowledgments: Making an Anthropologist." Generally, she is interested in anthropology and gender politics in and of the Arab and Muslim world. She has focused on questions of representation and ethics; the cultural politics of poetry, media, and museums; and the international circulation of rights discourses.

During her time at the Institute, McGrath researched Lady Mungo, the oldest human remains found in Australia, specifically how the complex aftermath of her 1968 "discovery" unearthed new conceptualizations of the history discipline. Ralph worked on a manuscript combining African-American studies, disability studies, and critical medical anthropology. In 2014, he published his first book *Renegade Dreams: Living through Injury in Gangland Chicago*.

In the School of Natural Sciences, Members **MIRJAM CVETIC** (1995–96, 2002–03) and **STEPHEN WOLFRAM** (1983–86) have also joined the class. Cvetic studies elementary particle physics ranging from the study of basic interactions to experimental tests of fundamental theories, and Wolfram is the founder and CEO of software company Wolfram Research, in addition to his academic work as an adjunct professor at the University of Illinois Department of Computer Science.

KAREN VOGTMANN, Member (1980–81) in the School of Mathematics, who works on geometric group theory, has joined the academy. Finally, **LINDA COLLEY**, Visitor (2010) in the School of Historical Studies, an expert on British, imperial, and global history since 1700, was appointed as well. ■

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