"Instead of issues of population explosion or excess-leisure, we may be collectively tackling the greatest challenge ever — survival — at a cosmic scale of time and space." ▸p5

"... it's in deep space that non-biological 'brains' may develop powers that humans can't even imagine." ▸p7

"By creating a Million-Member network of engaged scientists and engineers we can prove the power of collective action." ▸p30

THE NEW YORK ACADEMY OF
# SCIENCES
MAGAZINE • FALL 2017

# *Imagining* THE NEXT 100 YEARS

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*"The beauty of basic research is that we never know where it will lead. If we have the courage to confront its risks, it can lead to great rewards. Thus, in a world facing unprecedented challenges — climate change, threatened food availability, aging demographics — we must continue to prioritize courageous and dedicated basic research. Our lives depend on it."*

– **Elizabeth Blackburn**, *Nobel Laureate (Nobel Prize in Physiology or Medicine, 2009), President of the Salk Institute for Biological Studies*

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# Contents

# Imagining

## THE NEXT 100 YEARS OF SCIENCE AND TECHNOLOGY

As the New York Academy of Sciences approaches its third century, we started thinking about the scientific discoveries that might be made in the next 100 years. Then it occurred to us — the New York Academy of Sciences has the World's Smartest Network™, why not put the question to our Members?

So we invited some of our most extraordinary young and senior scientist Members, to offer their thoughts about what they believe could be the next generation of discoveries or the greatest challenge that science or technology must solve in the decades to come. The following is a selection of the many responses we received. They have been edited to fit space restrictions. All opinions cited are those of the authors named and do not necessarily reflect those of the editorial or scientific staff of the New York Academy of Sciences. We thank all those who contributed content and hope you enjoy reading these "imaginings."

▸ **More can be found on our website at: *www.nyas.org*.**

### *I IMAGINE:* CURES, HOLOGRAMS AND WORLD PEACE

**Sanskar Agrawal**, *Junior Academy student, Hopewell Valley Central High School, Pennington, NJ*

I imagine we will find vaccines to prevent the onset of diseases, allowing us to extend the average human lifespan by at least 20 years. We will be able to reverse global warming and secure the future of the planet. New modes of terrestrial transportation will be invented that will allow us to travel many times the speeds we are currently accustomed to. People and companies will produce their own electricity using reusable energy sources, making power plants and the use of fossil fuels obsolete. Space travel will become a common mode of transport, allowing us to travel to places such as colonies on solar planets, and planetary moons. Quantum computing will make computers so powerful and network connectivity so fast that a small data center will be enough to serve the needs of all humanity. Television and phones will become obsolete and holography will replace them. Sense of touch and smell will further complement this technology, making it as real as the physical world.

### *I IMAGINE:* "LYF-FI"

**Sanghamitra Anand**, *Junior Academy student, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India*

We can't imagine being without "Wi-Fi connectivity" — our need for information, communication and entertainment makes us dependent on the internet and the technology to access it. We also need plants to promote life. Imagine how incredibly accessible and lush our world would be if we could manage to genetically engineer each of the millions of plant species to give off Wi-Fi. The economic and technological advancements would be huge. Regardless of the scientific credibility of this idea, I strongly believe that our future generations will embrace this innovation.

### *I IMAGINE:* A PHYSICAL INTERNET AND THE FIFTH MODE OF TRANSPORT

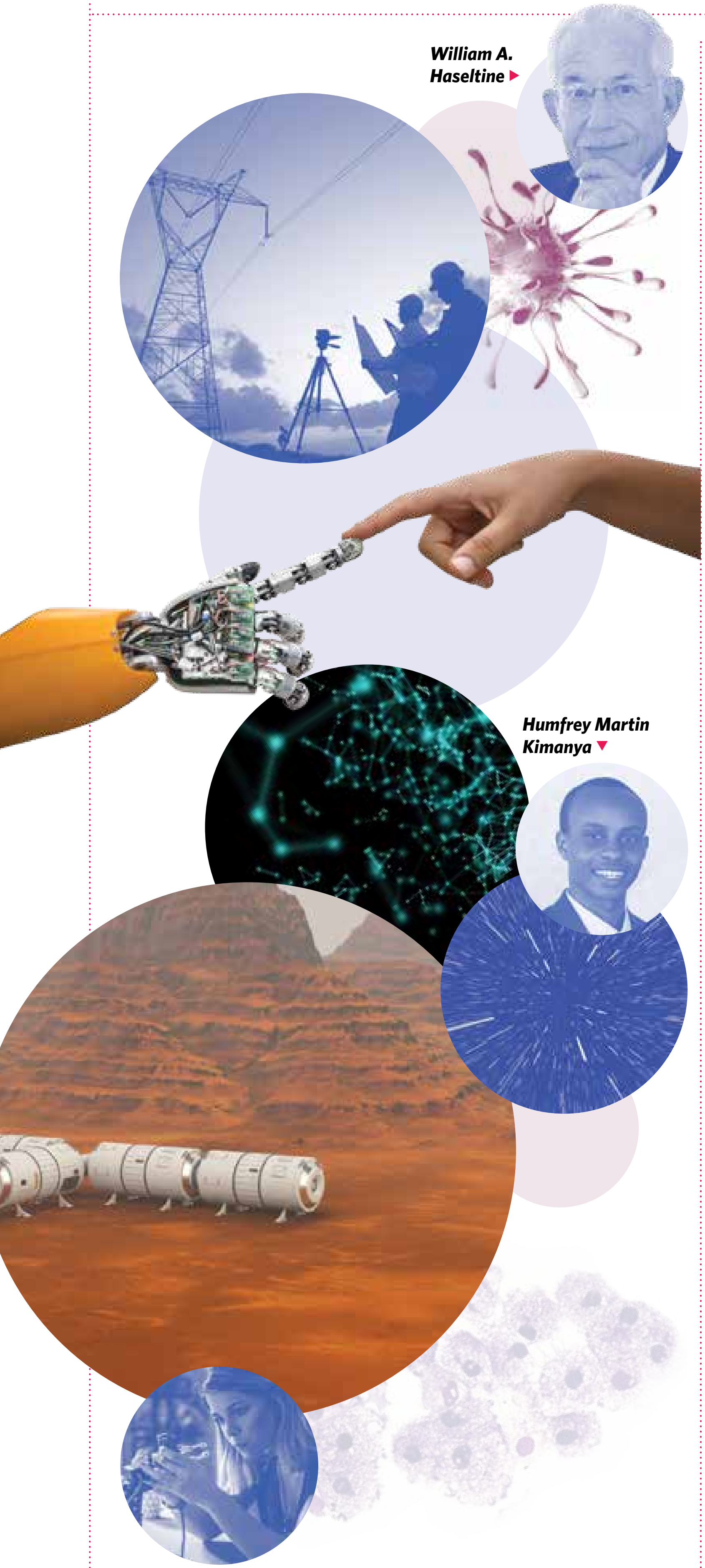
**Professor Franco Cotana**, *Professor, Industrial Technical Applied Physics, Faculty of Engineering, University of Perugia, Italy*

Pipenet is a project started 15 years ago by researchers at CIRIAF-University of Perugia (Italy) proposing an innovative vision of a new transportation system. It consists of a low-cost, environmentally sustainable network of pipes with linear electrical frictionless engines powered by renewable energy sources where encapsulated goods are transported at a velocity >1500 km/h with a transportation capability equal to 1 ton/sec (see ciriaf.it/pipenet). This creates a physical internet consisting of a real network where products can be quickly transported from one location to another in real time. The last km of delivery can be implemented by drones.

### *I IMAGINE:* SEVERAL POSSIBLE FUTURES

***George Church***, *PhD, Founding Core Faculty & Lead, Synthetic Biology, Wyss Institute at Harvard University; Professor of Genetics, Harvard Medical School; Professor of Health Sciences and Technology, Harvard and MIT; Associate Member, Broad Institute of Harvard and MIT, Director, Personal Genome Project*

Humans are possibly the only species that can comprehend events 13.8 billion years ago and 100 trillion years from now — and successfully execute multi-century plans. Since my group works on transformative technologies (genome reading and writing, aging reversal, mirror life, molecular computing, synthetic neurobiology and immunology), we might be able to see possible futures (emphatically plural) a bit earlier than most people — and hence have a responsibility to discuss, far in advance, potential extreme outcomes (mixtures of positive and negative). Next-generation sequencing arrived in six years, not the Moore's law estimate of six decades. If all transtechs above are similarly super-exponential, and if trends toward non-violence and caring continue, then we may see an end to poverty, physical and mental disease and significantly augmented thought and compassion. Like our recently vast spectrum of physical and cultural artifacts, neural diversity may expand — de-pathologized and embraced — far exceeding current imagination. If the universe beyond earth seems uninhabited, we may seek sufficient practical understanding of our divergent goals, dignities and ethics, that we can send these as compact physical packages at relativistic speeds to other star systems (and capable of replication and phoning home). This may be our Darwinian response to existence crises that could destroy all life on earth. We may experiment with small, intentionally isolated and self-sufficient colonies on earth — in stark contrast to our growing economic and cultural interdependence. Instead of issues of population explosion or excess-leisure, we may be collectively tackling the greatest challenge ever — survival — at a cosmic scale of time and space.



***William A. Haseltine*** ▸

***Humfrey Martin Kimanya*** ▾

## *I IMAGINE:* CREATING YOUNGER VERSIONS OF OURSELVES

**William A. Haseltine** (left), *PhD, Chair and President, ACCESS Health International, New York, NY*

Our lives began with the first living form that arose 4 billion years ago, a single celled microorganism that appeared when our planet was still being shaped by bombardment from the heavens. Inheritance is a fundamental characteristic of life. The DNA molecule in that primordial organism has been replicating itself with variation for more than 3.5 billion years. As we look to the future, a central question persists: can we tie the transient existence of our individual lives to the immortality of the DNA molecule that defines us?

The promise of regenerative medicine is developing more slowly than I had hoped 18 years ago when I first coined the term. We know there are substances in a fertilized egg that can turn back the genetic clock. We know how to take newly created embryo like cells and develop them into adult tissues. We are close to producing cells that can restore muscle function to damaged hearts and create neurons that can replace parts of the brain. What we lack is the medical science that allows these fresh cells to be systematically implanted into our tissues. An enormous amount of work remains to be done to understand the signals that direct a specific tissue to become what it is. In this we are underinvested. The most powerful medicine is a younger form of oneself. Any country could become a world leader in this field, with proper investment in the fusion of cell biology and transplantation medicine. Whether it happens in my lifetime, or my children's lifetime, or my grandchildren's lifetime, this is a promise science can fulfill. When it does, it will be a gift to the future of mankind.

## *I IMAGINE:* SPACE ELEVATORS, THOUGHT TO TEXT AND ENERGY-BASED PAINT

**Sharon Lin**, *Junior Academy student, Massachusetts Institute of Technology, Cambridge, MA*

With recent interest in space tourism, I think it's worth speculating about the creation of "space elevators" — structures that will allow rockets to launch at the edge of the atmosphere, rather than from the surface. While the concept may seem far-fetched, rapid developments in space-based civil and mechanical engineering, have sparked numerous innovations.

I'm also excited about brain-computer interfacing, especially noninvasive devices that allow users to accurately detect activity within their brain. Companies like Neurolink and Facebook have been investing in research to enhance the speed of translating thought to text, and while the technology is developing, research is already being done such as OpenBCI's open-sourced toolkit and the Muse headband.

Finally, the development of new renewable energy sources — from paint-on solar cells to microgrids — are soon going to provide a democratization of energy to all corners of the world. It's incredibly exciting to be living in a generation where we'll have the opportunity to contribute to such innovative research!

### *I IMAGINE:* SHAKING HANDS ACROSS A VIRTUAL DIVIDE

**Humfrey Martin Kimanya** (opposite, left), *Junior Academy student, Kibaha Secondary School, Dar es Salaam, Tanzania*

In the next century there will be unimaginable advancements in communication to link people all over the world. For example, video conferences where we can actually communicate tangibly. A person in Tanzania in an online meeting will be able to shake hands with another person in Belgium!

Now, the questions are: "Is it really possible? How does this happen? Won't that violate the laws of physics and nature?" Currently by wearing special gadgets we can simulate the feeling of shaking hands with another person through a computer, much like video game technology.

But in the future, people will be able to put their hands through the computer screen to shake hands with someone. This will mean that the relativity theory of Einstein, and others, will have to be rephrased or at least obeyed in the technological sense. It is also possible that, by then, people will not only physically communicate with each other using computers but also travel in computers! In simple terms, teleportation, a puzzle that researchers can surely solve in this century.

### *I IMAGINE:* GREATER HUMAN COLLABORATION WITH OTHER SPECIES

**Herb Klitzner,** *Researcher, Author: Computers and Cognitive Science, the History of Values and Hidden Stories, and how these fields inform the Future of Personal Technologies*

Forecasting across 100 years becomes more manageable when seen in stages of successive possibilities. I imagine three such stages of development:

**By 2050**: Each person will be able to scientifically understand himself/herself from a unique attribute mix point of view. Individuals will use available analytical tools and personal knowledge, to determine the meaning of their respective combinations of facts. Data used in determining this meaning will include the personal genome (a recent entity), the Myers-Briggs Type Indicator (MBTI, a 100-year-old instrument based on a theory of Carl Jung), and unlimited other measures. People will also sometimes interpret data for their dependents to help make needed decisions in health and other fields.

**By 2085**: This Personal Science-based information and activities opens the door for individuals to begin to understand members of other species in terms of their own defining attributes and to move toward collaborative behavior where appropriate. This will be the Age of Interspecies Personal Encounter and will engender greater compassion toward other species. We don't need aliens arriving or communicating with us in order to experience a interspecies moment.

**By 2120**: This experience will lead researchers to raise a fundamental question — can the chemistry and behavior of animals in the wild be altered so that animals will not eat other animals and yet thrive and reach their Aristotelian actualization? Experiments will be done on a small scale and begin to influence general thinking.

### *I IMAGINE:* EARLY MARS SETTLERS MAY NOT NECESSARILY BE HUMAN

**Sir Martin Rees**, *Astronomer Royal, Fellow of Trinity College, Emeritus Professor of Cosmology and Astrophysics, University of Cambridge*

Robotic and AI advances are eroding the need for humans to venture into space. Nonetheless, I hope people will follow the robots, though it will be as risk-seeking adventurers rather than for practical goals. The most promising developments are spearheaded by private companies: they can tolerate higher risks than a western government could impose on publicly-funded civilian astronauts, at a lower cost than NASA or ESA.

By 2100 thrill-seekers in the mould of (say) Felix Baumgartner, who broke the sound barrier in free fall from a high-altitude balloon, may establish "bases" on Mars, or maybe on asteroids. Elon Musk of Space-X has said he wants to die on Mars, but not on impact. But don't expect a mass emigration from Earth. It's a delusion to think that space offers an escape from Earth's problems. Nowhere in our Solar System offers an environment even as clement as the Antarctic or the top of Everest. There's no "Planet B" for ordinary risk-averse people.

But we (and our terrestrial progeny) should cheer on the brave space adventurers. Precisely because space is an inherently hostile environment for humans, these pioneers will have far more incentive than us on Earth to re-design themselves. They'll harness the super-powerful genetic and cyborg technology that will be developed in coming decades. These techniques will be heavily regulated on Earth, but the Martians will be far beyond the clutches of the regulators.

So it's these robotic spacefarers, not those of us comfortably adapted to life on Earth, who will spearhead the post-human era. Moreover, if post-humans make the transition to fully inorganic intelligences, they won't need an atmosphere. And they may prefer zero g — especially for constructing massive artifacts. So it's in deep space that non-biological "brains" may develop powers that humans can't even imagine.

*Emily Lau* ▲

*Sarah Olson* ▶

## *I IMAGINE:* UNCOVERING THE DEPTHS OF EARTH'S FINAL FRONTIER

**Emily Lau**, *New York Academy of Sciences NEXT Scholars program mentee, Biochemistry and Anthropology major, Hunter College City University of New York, NY*

Humankind has traveled through treacherous currents, the driest deserts, howling winds and precarious storms to explore our world. However, there is one significant portion yet to be fully explored — the deep sea. The oceans house mystically magical organisms: bioluminescent organisms, venomous snails, shocking jellyfish, brilliantly colored fish, large mammals and clever cephalopods to name a few. Organisms in the depths of the ocean are subjected to extreme conditions such as intense pressure and frigid temperatures. Deep sea ecological research explains how organisms have adapted to these extremes and has many implications in the improvement of conservation biology and the understanding of evolutionary biology. Current scientific advancements and production of deep-sea vessels have allowed for limited deep sea exploration. It would be wonderful, in the upcoming years, for both scientists and the public to gain knowledge about the biodiversity housed thousands of meters below the Earth's surface. The advancement of deep sea exploration relays the passion and natural curiosity of humans in the preservation of our wondrous planet.

## *I IMAGINE:* MORE WOMEN IN STEM

**Sarah Olson**, *student, MiraCosta College, San Diego, CA*

At this year's New York Academy of Sciences' Global STEM Alliance Summit 2017, attendees witnessed the future STEM workforce — bright young women working with their peers to engineer solutions for some of the world's biggest problems, including clean water and sustainable energy. These young women are part of the next generation of scientists, who will change the world with their research. Developments in technology are enabling us to make discoveries in previously inaccessible places, from the depths of the ocean to the furthest reaches of space. While we cannot predict that we will find life on other planets or how many species are still left to discover, there is one thing that we do know: that women in STEM will continue to change the world through their research.

## *I IMAGINE:* BROCCOLI BY BACH, MELONS BY MOZART AND APRICOTS BY ABBA

**Debra Swack**, *Fulbright and Education Specialist, SUNY Research Foundation at SUNY Buffalo State, Buffalo, NY*

How and why plants communicate bio-acoustically is not well understood nor documented, however it is known that they do so to relay information about the conditions of their environment (such as drought and predator threat) to each other. My work utilizes the research of evolutionary biologist Monica Gagliano, at the University of Western Australia, who studies their communication and records and analyzes both the sounds they make and their responses to sounds they hear or feel through vibrations. Scientific studies have documented that plants grow and bend specifically toward 220 hz sound, which can also be used in agriculture as a virtual fertilizer. I plan to create a 3D animated interactive art installation incorporating holographic flower imagery, a bio-acoustic soundscape (using a laser doppler vibrometer or acoustic camera) and dancers (who become the flowers and 'vibrate' in tune with each other), with enhanced viewing via Microsoft's wearable holographic headsets. I imagine that this blending of music and the arts with botanical science will enable greater yields of food sources that we will need to feed a hungry world as well as creating a whole new art form!

## *I IMAGINE:* THE COMING REVOLUTION IN SMART ELECTRIC POWER

**Yu Zhang**, *Assistant Professor, Department of Electrical Engineering, University of California, Santa Cruz, CA*

The way we generate and consume electricity in the early 22nd century will look a lot different than the way we do it in the early 21st century. Advanced sensor capabilities and smart internet-capable devices along with high-penetration renewable energy will transform the nation's aging power infrastructure. This is starting to happen with power companies hooking up their networks to the burgeoning "internet of things." But that is just a precursor to a vastly more energy-efficient smart grid, where it will be common to find homes that generate much of their own power. Individual houses will have photovoltaic devices and small storage units so every home becomes an energy "prosumer," producing electricity and selling it back to the grid. Those carbon-free and zero-energy homes will form networked microgrids, which feature a higher level of resilience if there's ever a blackout in the main grid, they'll be unaffected.

Power systems will be interconnected via the internet to allow consumers to optimize their electricity consumption. Dishwashers, refrigerators and electric vehicles will be automatically adjusted to real-time pricing signals. This will not only reduce energy bills, but also will significantly improve the efficiency and reliability of the whole grid. ◀

# **I IMAGINE**: How Technology Will Shape Scientific Research in the Next Century

*By Charles Cooper*

When the New York Academy of Sciences marked its centennial in 1917, just eight percent of homes had landline telephones, and it took a full five days to travel from New York to London.

Albert Einstein would introduce the idea of stimulated radiation emission that year with the publication of *On the Quantum Theory of Radiation*. However, it wasn't until mid-century that researchers were able to apply his insights to build the maser, and then the laser.

In a speech he gave in 1917, inventor and Academy Honorary Member, Alexander Graham Bell offered several prescient predictions about things like industrialization and the prospects for commercial aviation 100 years later. Yet even the most clairvoyant observers at the time would not have foreseen the transformations wrought by science and technology in the world of 2017.

But what about 2117? What can we expect in the coming century given our understanding of the trajectory of scientific and technological advances? We put that question to Academy Members in a number of different disciplines, and here's what they said.

▲ ***Ryan Rose***
*Customer Experience and Product Design Cisco Systems*

## NO KNOWLEDGE EVER GETS LEFT BEHIND AGAIN

A century into the future, predictive analytics and machine learning systems will be in a position to anticipate what human beings need to know, according to **Ryan Rose**, who leads **Customer Experience and Product Design** for a new social learning platform at **Cisco**.

"Right now, we're just trying to leverage data to give us better ideas," said Rose. "But if we project 100 years ahead, computer systems won't just be making recommendations to people, they will make the decisions. Machine learning won't be just about finding a way to get that information to a human. It will make the leap in logic to actually say, 'This customer needs this system to be this way' and then make that happen."

With machines poring through disparate bits of information, systems will be able to connect the dots to register what Rose describes as "instant adaptation."

"That's going to be huge. You will see innovation occurring as quickly as the machine thinks it and asks, 'Why don't we try this?' You can still have all of the human touch points, but the speed at which this happens will be much faster simply because we will not be waiting on someone to say, 'I think that these things are related.'"

Rose also expects a future in which no knowledge gets left behind as information is captured and retained digitally.

"Now, when we want to review knowledge from yesteryear, it's archived in a movie or maybe some type of audio recording that we cannot interact with. But think about a society with access to the great experts or just the everyday experiences of people from any time. We'll have all this information about individuals, their knowledge and expertise, and it will be stored so that someone in the future can 'speak' with any individual. Your descendants will be able to get a better understanding, even if it is just a digital understanding, of what you felt or thought."

"The interaction could be something as simple as a 3D projector or augmented reality, but you'll be able to talk back and forth through natural language processing. I think there is a great future where the wealth of information about humanity is preserved and being able to interact with those moments in perpetuity."

***William K. Schmidt, PhD*** ▲
*President, NorthStar Consulting, LLC*

## IMAGINING A PAIN-FREE WORLD

**William Schmidt**, a pharmacologist and the **President of NorthStar Consulting, LLC**, is optimistic that pain treatments in the next century will no longer carry high risks of addictive side effects.

"Within the next 100 years, we will have additional analgesics to prescribe along with opioids so that we can use lower dosages, replace opioids altogether, or (perhaps) have safer opioid analgesics that are less likely to show an addictive profile," he said.

That would be a welcome development. An epidemic of opioid abuse has led to one of the worst drug crises in American history. Indeed, the Centers for Disease Control estimates that 91 Americans die every day from an opioid overdose.

Schmidt, one of the world's leading researchers into the discovery and development of novel analgesic and narcotic antagonist drugs, also expects developmental breakthroughs in the products that doctors can prescribe to deal with pain.

"I expect we will have analgesic products that are unlikely to cause respiratory depression, either acutely or chronically, were someone to take a higher dose. I also expect we will also have — not only medicines to treat inflammation and pain directly — but genetic mechanisms for controlling some types of pain or pain signaling pathways that we can exploit to reduce the impact of pain within the body," he said. "We are already finding that we are able to treat things like rheumatoid arthritis in ways that are far more effective than what I learned when I was taking pharmacology in medical training."

It also would mark a veritable revolution in pain treatment, a field whose limitations Schmidt learned about through personal experience as a five-year-old when he broke his arm. Back then, doctors were afraid to use opioids to relieve his excruciating pain.

"I now recognize the medication they used hadn't a chance of working because they were afraid to use more effective medications in children," Schmidt recalled. "But that was the best that doctors knew how to do back then." A century from now, Schmidt says, no one may ever have to suffer that sort of trauma.

ABOVE RIGHT: *Department of Environmental Science, Policy & Management, University of California, Berkley. FROM LEFT TO RIGHT:* ***Jan Buellesbach***, ***Maria Tonione***, ***Kelsey Scheckel***, ***John Lau***, ***Elizabeth I. Cash***, ***Rebecca Sandidge***, ***Brian Whyte***, ***Jenna Florio***, ***Neil Tsutsui*** *(Principal Investigator) and* ***Joshua D. Gibson***. *Photo credit: Elizabeth I. Cash.*

## THE COUNTDOWN TO A BIG BIO-ETHICS DEBATE

When evolutionary biologists like **UC Berkeley's Jan Buellesbach** look at the trajectory of recent advances in genetics and molecular biology, they see a future laden with untold scientific potential.

"The field is developing so quickly — especially in genomics," said Buellesbach. "It's unbelievable when you think how expensive and cumbersome it used to be to sequence a genome. Now, they almost come at a rate of a dime a dozen … and we're just scratching the surface."

One example of that new technical prowess is CRISPR, a gene editing technology that scientists are now using to develop treatment therapies for a range of diseases, including cancer. Researchers have already successfully used gene editing to repair a disease-causing mutation in a human embryo.

But access to that kind of capability has also fueled debate about the ethics of using technology to alter human genes. In the world of 2117, Buellesbach expects genomics breakthroughs will give society the theoretical ability to selectively eradicate the genetic conditions that lead to diseases, or any traits that might be considered detrimental. It also means society will need to navigate an ethical minefield where so-called designer babies are no longer a theoretical possibility.

"With computational power getting exponentially faster and cheaper all the time, it's not such a sci-fi scenario anymore," he said. "I think we are likely heading towards a future where there will be research on how to perfect *Homo sapiens* in certain ways, especially if we start to manipulate our own genomes."

Before then, he noted that more cautious naturalists who don't believe we should interfere with human nature are likely to argue that just because science can do something doesn't mean it's wise to put theory into practice.

"What would be considered genetic perfection?" pondered Buellesbach. "I would find that very troubling. Who is to say what trait can be considered universally negative? Even 100 years from now, I don't think we'll have a unified view about that. There's no question that this would entail too much power. We know from history that this … can be very dangerous, and decisions about that shouldn't be left in the hands of the few people in positions of authority.

## GENOMICS WILL REVOLUTIONIZE MEDICINE

Doctors nowadays choose among myriad treatments to help patients suffering from heart disease and other ailments. By the time 2117 rolls around, however, trial-and-error will have been relegated to the history books. Genomics advances will pave the way for the right treatments for the right diseases for the right patients and at the right times, according to **Kent Lloyd**, a professor in the **Department of Surgery at UC Davis**.

In the future, Lloyd says doctors will have the kinds of drugs that don't just target the protein product — the end result of genes gone bad — but actually fixes them without needing to worry about having the drug go after the protein product.

"Also, if we have enough knowledge and can predict with great certainty that someone will develop a disease — why not try to prevent the disease from progressing or even starting?" he said. "That's where the future is — not only more precise treatments for diseases when they happen, but further down the road, more precise preventive measures for individuals you can predict are highly likely to contract the disease," he added.

These breakthroughs are predicated on research now underway to uncover deeper understanding of basic gene functions and how they impact human health.

"When we scan a person's genome, we might find a variant in gene X, another variant in gene Y, and another variant in gene Z. If we didn't know what those genes do, we wouldn't know which of those are more related to the cardiovascular disease that a patient might have," he said.

"We can test therapies in mice with that mutated gene to assess whether that therapy might be good or bad, what the effect might be and whether it might cause other things that we wouldn't want it to cause," Lloyd said. "This new knowledge will greatly catalyze and accelerate the implementation and practice of precision medicine. I think this will have a huge impact on health … around the world."

Lloyd also sees potential in harnessing new genome editing technologies. In the future, he expects doctors to be able to change gene variants that create mutant proteins. The patient's system would then produce the normal protein, potentially reducing symptoms or relieving prospective diseases.

"We definitely need to improve on extant technologies and develop newer and more precise (or targeted) ones than today, no question about that," Lloyd said. "And we have the scientific power to be able to do it. If we put a little bit of effort in now … the return on investment will be enormous."

## ENGINEERING A STRESS-FREE LIFE

Ongoing advances in engineering and computer science are going to transform the global healthcare system, raising the prospect of breakthroughs in various areas of personal health, according to **Subhro Das**, a computer engineering researcher at the **IBM T. J. Watson Research Center.**

"Life expectancy will go beyond what we might imagine," said Das, part of an interdisciplinary team at IBM working on developing new computational approaches for improving health behaviors. "We might be able to find cures for diseases like cancer, and to find more effective ways of preventing things like type 2 diabetes."

That's the long-term view. More short-term, Das also expects intelligent systems will be able to analyze real-time data collected from body sensors and other mobile technologies that trigger commands to other connected devices to address signs of stress, such as elevated blood pressure or cortisol levels.

"For instance, I might be having a hard day at work. But my laptop, my phone, my house thermostat and my car — they are all going to be connected and sharing data among themselves," he said. "My car would get a signal from my laptop and put it in a mode so that when I'm driving home, soothing music would come on. Also, my house thermostat now knows that I was having a bad day at the office, so it will be able to adjust the temperature of my house to make me feel more comfortable."

More broadly, Das said that the continuing improvement in machine learning and data mining will enable more "smart buildings" to be equipped with sensors that can alert medical teams when somebody needs assistance. If there are people living inside who have medical conditions like Alzheimer's disease, or suffer a fall, those sensors are going to be communicating among themselves and will be able to get help quickly.

***Subhro Das, PhD*** ▶
*Research Scientist, Computational Health Behavior and Decision Sciences*
*IBM T. J. Watson Research Center*

RIGHT: *Laboratory technician culturing cell specimens from precision-designed mouse models for experimental analysis at the UC Davis Mouse Biology Program.*

## WINNING THE BATTLE TO BEAT BRAIN PATHOLOGIES

While the study of the brain presents dauntingly complex challenges, **Dr. Marcie Zinn**, a cognitive neuroscientist at **DePaul University** believes medical practitioners will one day be able to reverse the process of brain degeneration.

One hundred years from now, Zinn expects new technologies will transform our understanding of the functioning of the central nervous system. Armed with new tools, future researchers will be equipped to gain new insights into brain pathologies and uncover more effective ways to diagnose, treat, prevent and even cure disorders.

"There has been a lot of excellent research telling us why brain degeneration occurs. Take, for example, ALS (a progressive neurodegenerative disease of the central nervous system.) Currently, there is no cure for ALS. The degeneration takes place rather quickly without impediment. I think the first thing that anyone wants is to figure out how to slow down the process."

The brain poses obvious challenges for cognitive neuroscientists because it is continually changing itself on a millisecond basis. But the study of neurologically impaired people has been aided by recent imaging advances, such as visualization tools, which allow researchers to more accurately understand neural networks.

Looking over the horizon, though, Zinn expects more breakthroughs thanks to the increasing intersection of biochemistry and technology that might lead to new treatments for many neurological impairments, including the regrowth of brain cells.

"Formerly, science thought that new brain cells did not grow or regrow throughout the lifespan," she said, "but we now know that brain cells do regenerate under the right conditions."

## SLOW BUT STEADY: CLOSING IN ON A WORLD WITHOUT CANCER

Roughly $300 billion has been spent since 1971, when President Nixon declared the nation's "war on cancer" but as new technologies give researchers deeper understandings of genes and molecular pathways, it's also possible to imagine a future world free of cancer. Just don't bet on bolt-from-the-blue breakthrough announcements.

To be sure, the history of medicine is replete with serendipitous, sometimes world-changing observations, such as the 1928 discovery of penicillin by bacteriologist Alexander Fleming. That discovery resulted in the development of antibiotics that have saved millions of lives. In contrast, the field of cancer treatment has been marked by steady improvements in technology and better patient care.

Indeed, Academy Members **Ijaz S. Jamall**, a toxicologist and **Principal Scientist** with the biomedical consultancy, **Risk-Based Decisions Inc.**, working in conjunction with **Dr. Björn LDM Brücher**, a surgical oncologist in Germany, noted that while cancer biology "has increased by leaps and bounds during the last 50 years," it's wise not to get too carried away.

"We should try to avoid using terms such as landmark, hallmark, breakthroughs or war against cancer, etc.," he said. "Such terms imply a lot more than can be delivered."

Still, slow but steady advances offer encouragement about the future. Jamall pointed to the deployment of new immunotherapy and nanotechnology techniques that help doctors diagnose and treat cancers earlier than ever before. Also, researchers now benefit from increased computer and data processing power as well as more precise 3D imaging tools. In addition, Jamall said, some vaccines are proving effective in preventing cancers caused by pathogens like HPV (human papillomavirus), HCV (the Hepatitis C virus), and HBV (the Hepatitis B virus), a development that he predicted will influence future therapies worldwide.

Even more progress is possible in the future with the development of nanobots and nano-drug delivery tools that improve the diagnosis and treatment of cancers by targeting features specific to cancer cells or malignant tissue without damaging nearby healthy cells and tissues.

Jamall said that nanotechnology can further improve the earlier detection of cancers by homing in on particular features of early cancers such as inflammation that currently slip below the radar of existing imaging and blood tests (biomarkers) of cancer.

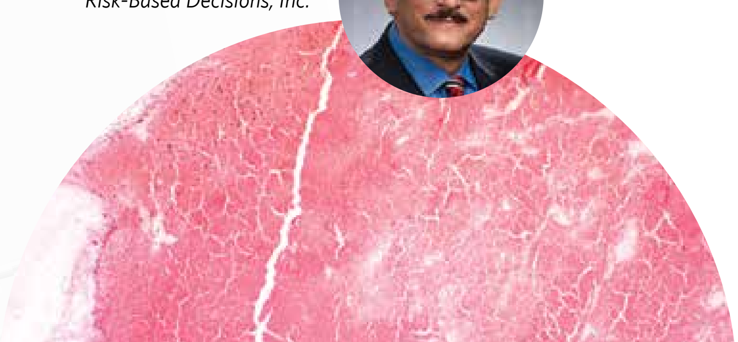
In the meantime, he said, science is on the right path with the development of more effective vaccines and immunotherapies that will become better over time. But just as critical to the future, said Jamall, is a re-thinking of diseases and their treatments with an eye toward developing new and relevant approaches.

"One goal is interdicting the multi-sequence steps leading up to carcinogenesis," he said. "This would be a giant leap forward in cancer prevention." In conjunction with early screening and more effective treatments, he said science would advance closer toward the goal of making the majority of cancers (approximately 80 percent) "diseases of inconvenience" such as diabetes or arthritis. ◀

***Charles Cooper**, is a Silicon Valley based technology writer and former Executive Editor of CNET.*

**Dr. Björn LDM Brücher** ▸
*Professor of Surgery and a Distinguished Fellow New Westminster College, British Columbia*

**Ijaz S. Jamall, PhD, DABT** ▸
*President & Principal Scientist Risk-Based Decisions, Inc.*



# **Gender in the Research Workforce**: New Analytical Report Reveals Uneven Progress Towards Equality

*By Holly J. Falk-Krzesinski and Sacha Boucherie, Elsevier*

What is the future of the global STEM workforce? A recently released report, *Gender in the Global Research Landscape (2017)*, by information analytics company Elsevier, provides unprecedented data-driven insights as to where this might be headed.

On a positive note, the report demonstrates the number of women researchers is increasing, but it also makes clear that progress has been incremental and uneven.

Of the 12 comparator countries/regions analyzed Australia, Brazil, Canada, Chile, France, Denmark, the European Union (E.U.), Japan, Mexico, Portugal, the United Kingdom (U.K.) and the United States (U.S.), the proportion of women was 49 percent in 2011-2015 (up from 38 and 41 percent, respectively, in 1996-2000) in both Brazil and Portugal. However, in Japan, although the proportion of women also increased, it was still only 20 percent in 2011-2015. The country with the largest increase in the proportion of women between the two time periods was Denmark (moving from 29 to 41 percent).

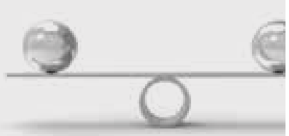
The report findings highlight research areas where improvements are most needed in terms of gender diversity. For example, while health and life sciences have the highest representation of women, still fewer than 25 percent of researchers in physical sciences are women.

### METHODOLOGY

Drawing on data from Elsevier's Scopus database, analytical expertise, and a unique gender disambiguation methodology, the report looks at trends and measures of research performance over a period of 20 years, 12 comparator countries/regions and 27 subject areas. The study analyzes data across two inclusive five-year timeframes: 1996-2000 and 2011-2015. To accurately disambiguate the data by gender, Scopus Author Profiles were combined with data from third-party name data providers: NamSor, Genderize, Wikipedia.

The 12 comparator countries/regions analyzed are: Australia, Brazil, Canada, Chile, France, Denmark, the E.U., Japan, Mexico, Portugal, the U.K. and the U.S.. They were selected based on their representation of major global geographies, having a high total scholarly output, and allowing application of the gender disambiguation methodology.

***Download*** *the full report at: www.elsevier.com/connect/gender-and-science-resource-center*



### COLLABORATION AND MOBILITY

With regards to collaboration, women researchers generally engage less in both international collaboration and academic industry collaboration than men. Moreover, women researchers tend to be less geographically mobile than their male counterparts, although in Japan a disproportionately high number of women researchers were found to leave the country.

### LEADERSHIP

Leadership was analyzed through the proportion of papers on which researchers are first or corresponding authors. In the U.S., women are first or corresponding author on 43 percent of their engineering papers, 20 percentage points less than men. In nursing where women represent more than half of nursing researchers, the reverse is true.

### PATENT APPLICATIONS

Women constitute only a tiny proportion of inventors based on the number of submitted patent applications, though the gap is starting to close. Globally, the percentage of patent applications that include at least one woman among inventors also increased, from 19 percent in 1996-2000 to 28 percent in 2011-2015. In Portugal women now comprise 30 percent of inventors (compared with 14 percent in 1996-2000); while in Mexico women have increased from 7 to 21 percent.

### GENDER AS SUBJECT AREA OF RESEARCH

Finally, gender as a subject area of research seems to be growing in size and complexity, with new topics emerging that include papers on feminism, gender stereotyping, and gender classification and identification. The dominance of the U.S. has declined, as gender research activity in the E.U. has risen and is now more equally split between the U.S. and the E.U. in the period from 2011-2015.

### CONSIDERATIONS FOR THE FUTURE

The data clearly highlights great variability between geographies and across all measures of research performance, so what are the next steps? What are Portugal and Brazil doing different than Japan to give them an almost gender balanced research workforce? What policy changes has Denmark implemented to achieve the greatest percentage increase of women in research among the comparators studied? These critical questions that will impact the future STEM workforce will require input from decision makers from all sectors — academia, corporate, government — to develop solutions. ◀

# The Future of K-12 Education is in **Teacher Training** and **High Standards**

*By New York State Education Commissioner MaryEllen Elia*

The global economy is changing the nature of work and the kinds of careers our children will pursue. Data from the U.S. Bureau of Labor Statistics indicates that the fastest-growing occupations will require highly educated, highly skilled workers. Many of these careers will be in the science, technology, engineering and math (STEM) fields.

It is more important than ever that we provide all students with the knowledge and skills they'll need to succeed in an ever-more competitive global environment. In New York, we continue to take important steps to help ensure that students are prepared for success after high school.

We recently updated our English language arts and mathematics learning standards — that is, what we expect students to know and do in the various subject areas at each grade level. The process was deliberate, transparent and collaborative; expert educators were involved every step of the way. The result will be improved teaching and learning in New York's classrooms, with a greater emphasis on supporting English language learners, students with disabilities and other special populations.

*"...our students need an education that will prepare them to use (and maybe even help develop) the new technologies that will solve the world's ever-more complex problems."*

At the same time, using the nationally-developed Next Generation Science Standards as a starting point, we utilized the expertise of science education stakeholders to draft a rigorous new set of science learning standards. Our vision for the future of science education is now contained in the New York State P-12 Science Learning Standards. These new standards provide endless possibilities for teachers to engage students in science learning experiences that explore, advance and deepen their understanding of natural phenomena.

The process of establishing learning standards cannot be a static one; we must continually review and renew the standards to ensure our children can keep pace with a world that is evolving rapidly and continuously.

Studies show that the quality of a child's teacher is the single most important school-based factor in that student's educational success. So, we have put a great deal of effort into the way we train and support teachers. For the past two years, I have worked closely with my good friend, SUNY Chancellor Nancy Zimpher, on the TeachNY campaign. TeachNY is a movement to lift-up the teaching profession and ensure that New York and the nation will have the high-quality educators needed for the future. This includes updating the curriculum used in schools of education, so that teachers are prepared to deliver the new, more rigorous learning standards.

Teachers — especially those who teach at the elementary level — must be prepared to give our youngest learners a solid base of knowledge in the STEM areas. And we must support and encourage them to engage in "hands-on" teaching, both inside and outside of the classroom. Those kinds of hands-on experiences are often the most meaningful for children, and instill in them an early love for scientific exploration and discovery.

It is sometimes hard to imagine just how quickly and radically technology has changed our lives. Smart phones have been commercially available for only 10 years, but we already take for granted the awesome computing power we now all carry in our pockets. So, our students need an education that will prepare them to use (and maybe even help develop) the new technologies that will solve the world's ever-more complex problems.

Success in the future will also require us to do a much better job of ensuring equity, diversity and integration throughout our educational systems. Research shows that socioeconomic and racial integration leads to better academic outcomes for all students, while at the same time reducing the achievement gap among students of different racial and ethnic backgrounds. As well, we must continue to work to ensure that schools are safe havens where students are free and empowered to learn without fear of discrimination, harassment or intimidation because of their race, ethnicity, religion, immigration status, disability, sexual orientation, gender identity or any other basis. Every school must provide a learning environment where all students feel safe and welcome, and where parents and families are encouraged to take an active role in their children's education.

I believe strongly that education holds the key to our future success. I am encouraged and optimistic that here in New York we are taking the right steps to provide the kinds of educational opportunities that will lift-up our society for generations to come. ◀

# The Future of Higher Education is **Flexibility**

*By Nancy L. Zimpher, Chancellor Emeritus, The State University of New York*

The technological advances of the past few decades have ushered in an era of distance-learning capability that has triggered a conversation about what, exactly, the future of higher education will look like. Speculation ranges across the extremes: On the one hand, that the ability to earn entire credentials online, from certificates to PhDs, will inevitably force the extinction of brick-and-mortar campuses, to the other, in which critics argue that courses taken online are so much less rich than the traditional campus and classroom experience that they are "junk degrees."

The truth, of course, lies somewhere in between. Importantly though, the determination of higher ed's future is not an exercise in theory but rather a practical one with real-world outcomes that affect millions of people. Every university and college leader today must be wide awake to this fact and accept the responsibility eagerly with both hands. In doing so they must do two things simultaneously: they need to know exactly who their students are and never take their eyes off the changing, fast-emerging needs of the world and workforce. With both of these things in sight, heads of colleges and universities need to create institutions or systems that can respond to the needs of students and sectors.

*"...higher ed's future is not an exercise in theory but rather a practical one with real-world outcomes that affect millions of people."*

It will come as no surprise to this publication's readership that today about 65 percent of jobs in the United States require a degree beyond high school.[1] Moreover, the jobs that earn a middle-class living or better almost certainly, increasingly, require advanced education. New York State is even more competitive than average: nearly 70 percent of jobs will soon require a college degree, but right now only 46 percent of adult New Yorkers have one. This wide gap between the current reality and the projected need for educated, skilled citizens has created a fault line upon which we cannot expect to build stable, competitive, thriving economy and communities.

To close the gap we need to know who today's students are. Unlike eras past, in which the picture of the typical college student was a young, white, male student living on campus and attending classes full time, today's student profile is very different.[2] Forty percent of college students are age 25 or older. Fifty-six percent are female. Twenty-eight percent are raising families while they earn their degree. Sixty-three percent of students are enrolled full-time, and 36 percent of students work part-time while taking classes and another 26 percent work full-time. Today, 41 percent of students live on campus. The remainder, owing to their life obligations — juggling jobs, families, and expenses — commute. Fifty-eight percent of college students today are white; 17 percent are Hispanic and 15 percent are black — the fastest growing segments of the U.S. population and also the most underserved.

The world has changed, and higher education needs to not only change with it but stay ahead of the curve, ready to receive the students who come to us. The future of higher education is flexibility.

This means expanding our operations so that we can meet students where they are, on their time. It means providing an array of avenues by which to earn a degree and support to ensure they complete. High-quality online learning opportunities are a critical piece of this.

One out of three New Yorkers who earn a college degree do it at The State University of New York. In the last three years, more than 320,000 of our students have taken online classes, and 8,000 have received a SUNY degree by taking the majority of their classes online. Our online learning platform, launched in 2014, is the largest in the world. But for SUNY it is not enough to be the biggest, we need to be the best. This is our commitment to New York: to prepare students by any and every high-quality means possible to earn a college degree and to build their best life. ◀

***Nancy L. Zimpher*** *served as the twelfth chancellor of The State University of New York from 2009 to 2017, during which time she was also chair of the New York Academy of Sciences Board of Governors from 2011 to 2016. In January 2018 Dr. Zimpher will become a senior fellow at the Rockefeller Institute of Government, where she will also be the founding director of the nation's first Center for Education Pipeline Systems Change.*

*1. A. P. Carnevale, N. Smith, & J. Strohl, Recovery: Job Growth and Education Requirements through 2020. Washington, DC: Georgetown University Center on Education and the Workforce, McCourt School of Public Policy (2103). Retrieved from https://cew.georgetown.edu/cew-reports/recovery-job-growth-and-education-requirements-through-2020/.*

*2. Among many, The Bill & Melinda Gates Foundation has done excellent work compiling college student demographics, including information that can be found at http://postsecondary.gatesfoundation.org/what-were-learning/todays-college-students/.*

# Two New York Startup Companies Envision a **Waste-Free Future**

*By Hallie Kapner*

Small companies throughout New York State are bringing bold, transformative technologies from the lab into the world thanks to support from the New York State Energy Research and Development Authority (NYSERDA). Together with the New York Academy of Sciences, NYSERDA is supporting visionary early-stage startups through proof-of-concept centers that foster the growth and development of clean tech businesses. The two centers, PowerBridgeNY and Nexus-NY, have provided critical financial support, mentorship, and guidance for dozens of startups that are shaping the future of clean energy. Two companies, Allied Microbiota and Dimensional Energy, are tackling waste remediation and reuse with novel techniques that are being tested and proven today.

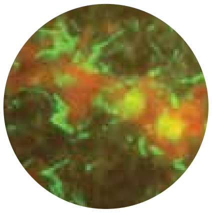
## Tackling Toxic Waste with **Nature's Warriors**

Amid some of the most expensive real estate in the world, on the waterfronts of Manhattan and Brooklyn, lay the remnants of disaster. The waters of the East River, Newtown Creek and the Gowanus Canal are among the local sites where benzene and oil residues mingle with persistent pollutants, such as polychlorinated biphenyls (PCBs), to form a stubbornly toxic soup that resists remediation. For environmental microbiologist Ray Sambrotto, Lamont Associate Professor at the Lamont-Doherty Earth Observatory at Columbia University, the solution for cleaning up such sites may be as simple as a common soil bacterium isolated from a compost pile in the 1990s.

Allied Microbiota, the company Sambrotto and a cohort of Columbia colleagues founded in 2017, is commercializing the use of this bacterial strain, aiming to reclaim polluted areas by simply allowing the microbes to do what they do best: break down environmental contaminants. The scientific community has long been aware that common microbes can degrade some pollutants — indeed, dozens of bacterial species are credited with dispatching of much of the oil dumped into the Gulf of Mexico during the Deepwater Horizon explosion. The class of contaminants that includes PCBs, polyaromatic hydrocarbons and dioxins are less susceptible to natural attenuation, however, and these so-called recalcitrant pollutants require expensive, logistically challenging remediation techniques. "The idea of using bacteria for bioremediation of recalcitrant pollutants isn't a new one," said Sambrotto, noting that research interest has waxed and waned over several decades. As advances in biotechnology have moved into the environmental field, the notion of deploying nature's soldiers against a decidedly unnatural group of pollutants has gained momentum.

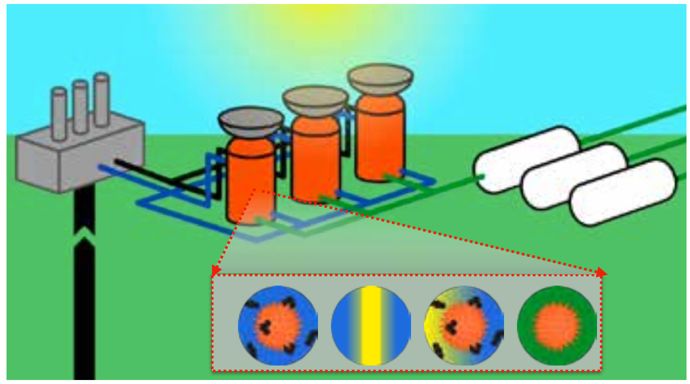
Sambrotto and his Allied Microbiota co-founder Frana James describe their approach as "augmentation," as it uses specialized bacteria to amplify the work of native microbes, a process they believe can be done safely and at low cost. "Our bacteria are thermophiles, and they only reproduce when conditions are ideal," Sambrotto said, adding that if temperatures drop below 40 degrees Celsius, the bacteria enter a dormant state. When active, they are powerhouses of bioremediation, eliminating recalcitrant pollutants at breakneck speeds relative to other bacterial breakdown methods. Sambrotto credits this speed to the fact that the microbes are aerobic, rather than anaerobic, like most strains used in remediation. "Aerobic enzymes have much more rapid degradation rates," he said. "Oxygen is just a better hammer to hit these things with."

With support from PowerBridgeNY, a proof-of-concept center that commercializes cleantech spinning out of universities, Sambrotto and James are pilot testing their technique on polluted soil and sediment samples from the Hudson River and other sites. "People are more than happy to send us samples, and they're especially interested in hearing about the speed of remediation, as that's what drives costs," he said. Experiments on samples containing a mix of PCBs and chlorobenzene reveal breakdown rates of 25-40 percent per day under opti-



mal conditions, versus 1 percent with anaerobic bioremediation. "When we hit that sweet spot to maintain optimum growth of the organism, breakdown rates are orders of magnitude faster than anything we've seen," said Sambrotto.

While more pilot tests are needed — and the company is on the lookout for such projects — the promising early results have inspired the team to think about the future. Sambrotto described his vision of eliminating the financial barriers to remediating desirable but toxic spots along the Hudson River and restoring their utility. "Hopefully, we can bring the cost down enough to address these areas," he said. "Rather than digging up sediments and moving them elsewhere for treatment, I can envision a portable system that allows us to bring bacteria to the site and treat it right there. It's incredible to think that we could reclaim properties that have been fallow for decades." ◀



OPPOSITE: *Epifluorescent photomicrograph of bacteria (green rods) on soil (orange-red particles). Particles were stained with a fluorescent dye.*

ABOVE: *The Dimensional Energy technology is "plug-in" compatible with established carbon capture systems. The schematic illustrates how waveguide and catalyst concepts are integrated to enhance light exposure to the surface of nanostructured catalysts.*

# Turning Carbon Dioxide Emissions into **Tomorrow's Fuels**

Most people don't often think about combustion — the fundamental chemical reaction that converts a fuel source into energy, leaving water and carbon dioxide as waste products. Jason Salfi is the opposite. As CEO and co-founder of Dimensional Energy, along with David Erickson, Tobias Hanrath and Clayton Poppe, he spends his days talking about ways to reverse combustion, which may sound like a tall order, "but it's what plants do all the time," Salfi said, describing the process his company is working to commercialize: a form of artificial photosynthesis that uses sunlight, water and waste carbon dioxide to create fuel.

Dimensional Energy was born from serendipity, when Erickson and Hanrath, two faculty scientists from Cornell University, unknowingly submitted complimentary applications to NEXUS-NY, a clean energy business accelerator for which Salfi serves as an advisor. Noting the ties between the professors' technologies, which tapped sunlight and catalytic materials to convert waste carbon dioxide ($CO_2$) into hydrocarbon fuels, the NEXUS-NY team played matchmaker, suggesting the two join forces with Salfi to form a company.

Since 2016, the team has refined their core technology and begun laying plans for an industrial partnership to test their capabilities at increasingly larger scales. Although the technology is still in its early stages, the team envisions a scalable reactor that uses sunlight as an energy source, along with novel nanocatalysts and fiber optic waveguides developed in Hanrath and Erickson's labs, to convert waste $CO_2$ into methanol or syngas for use in a broad range of industrial processes. "We're not just sequestering carbon dioxide, we're creating something useful," said Erickson.

As a semi-finalist in the Carbon X-PRIZE, a $20 million competition accelerating the development of carbon conversion technologies, the Dimensional Energy team is testing the feasibility of situating their reactor at point sources of $CO_2$ emissions, such as natural gas or coal-fired power plants, although Salfi says such co-location isn't crucial for the system to be successful at scale. "Ultimately, it's up to the industrial customer whether we capture the carbon on site or use sequestered carbon," he said. "For now, we're just aiming to create a reactor that fits within the current industrial infrastructure, with a few novel modifications."

This level of attention to design schemes that work well in industrial settings is a distinguishing factor of Dimensional Energy's approach to tackling what is, by all measures, a challenging end goal. Carbon conversion technologies are viewed as a critical component of efforts to rebalance the carbon landscape, but the field is still relatively new and most technologies are early-stage. At present, the cost of sequestering and transporting $CO_2$ makes many potential applications cost-prohibitive at scale, and new sequestration technologies, including those that capture $CO_2$ directly from the air, are not fully commercialized. Erickson believes the company's pragmatic approach to design and functionality will ease the process toward scalability. "We're pursuing traditional methods of building small prototypes and learning how to optimize and grow," said Erickson, "But since day one we have looked at major chemical plants to understand what works in that setting, and we've modeled our reactors on proven designs that we know can scale."

Salfi and his team are realistic about the timeline for carbon conversion to have a measurable impact — easily 30 years by many estimates — but they, like most others working in the renewable energy field, are undeterred by the long time horizon. "This is hard work, and I can tell you that there are easier ways to make money," Salfi said. "But there are so many pioneers and passionate people excited to build businesses around these technologies, and our mission to make a difference drives what we're doing and how we approach the challenges we face." ◀

# **One Eye on the Future**: Looking Ahead with the 2017 Blavatnik National Laureates

*By Hallie Kapner*

Physicist Niels Bohr (among others) said "prediction is very difficult, especially if it's about the future." Just ten years ago, it would have been a stretch for even the most optimistic prognosticator to predict that the iPhone, then a newborn technology, would be in one billion hands or that the human genome could be sequenced affordably in 24 hours. These examples of the dizzying pace of progress are good reminders that while attempts to peer into the future of science and technology are essential for growth and inspiration, reality sometimes exceeds the wildest visions.

The 2017 winners of the Blavatnik National Awards for Young Scientists, materials scientist Yi Cui, chemist Melanie Sanford, and bioengineer Feng Zhang, are no strangers to vision. Chosen from a pool of more than 300 nominees from universities around the country, this year's Laureates exemplify the kind of fearless thinking that upends norms and breaks boundaries, ultimately bringing revolutionary ideas and advances into reality. Asking any of them to discuss their day-to-day research would provide a fascinating peek into some of the most cutting-edge work in their respective fields, yet just as intriguing are their thoughts on the future. When asked to fast-forward ten or twenty years to discuss what's next in their fields, each readily dove headlong into the world to come, shedding light on achievements that are both probable and possible, then reaching further to describe potential advances that seem far-fetched today, but may be the ultimate achievements of tomorrow.

*"Ten or twenty years from now, the only constraint will be our imaginations..."*

## DELETING DISEASE

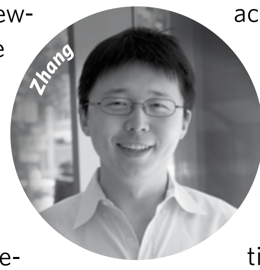
Ten years is a long time for Feng Zhang, as he recalls that the technology he helped pioneer, CRISPR-Cas9, didn't exist a decade ago. As Zhang, a Core Member of the Broad Institute at MIT and Harvard, talks excitedly about the rapid pace of advancement in the field of genome editing, he highlights that there's still plenty of room for growth. Zhang was among the first to conceive of using CRISPR, an adaptive immune function native to bacteria, as a DNA-editing tool, a breakthrough that has turned the ability to quickly, cheaply, and precisely edit the genomes of plants and animals from science-fiction into an everyday occurrence. From Zhang's point of view, developing the tools was just the beginning — the work of the future is in refining and applying those tools to alleviate suffering and disease.

The advent of rapid, affordable genome sequencing has allowed researchers to identify many of the mutations that cause disease, which fall into two categories: monogenetic diseases, such as Huntington's, caused by a single mutation, and polygenetic diseases, which comprise the majority of illnesses, wherein multiple mutations are implicated. Today, most of the work being done with CRISPR targets monogenetic diseases. Even in those cases, a fix is far more complex than simply cutting and replacing. "The major issue is that we don't know how to repair the mutation efficiently, nor what exactly needs to be done to have a therapeutic consequence," said Zhang. "I think we'll develop techniques for delivering gene therapy to the right tissues, which is still a big challenge." Zhang also projects a future where CRISPR technologies can be adapted to treat patients with diseases so rare that they are often overlooked by the therapeutic pipeline. "The economics don't work for drug companies to focus on rare diseases, but as gene editing becomes more mature, we could feasibly create individualized therapies that would circumvent the typical drug development process," he explained.

But the ultimate CRISPR application — editing multiple genes to treat complex polygenetic diseases — remains the stuff of fantasy. Two decades from now, Zhang expects we'll be much closer. "Even if we have the technology to make multiple genetic changes, we don't know enough about how multiple genes interact in disease at this point," he said, noting that the interplay of different gene variations can produce effects we don't fully understand. "There are variations known to protect people from HIV, but they increase susceptibility to West Nile Virus," he said. "That's just one example — we need a much better understanding of these connections in order to achieve these bigger goals."

## BIG IDEAS FROM THE SMALLEST STRUCTURES

For Yi Cui, professor of materials science and engineering at Stanford University, the buzzword of the future is energy. Specifically, inexpensive, widely-available clean energy, along with new battery technologies that will transform cars and other consumer products as well as the electrical grid itself. Cui, whose research focuses on using nanoscale materials to tackle environmental and energy issues, has several breakthrough technologies to his credit — including a water filtration technology that uses electrified silver nanostructures to puncture viral and bacterial membranes, purifying water faster and more cheaply than chemical treatments, and designs for ultra-long life, low-cost batteries that may pave the way for what Cui sees as the major potential achievement of the next two decades: grid-scale energy storage.






Solar cells have become more efficient and renewable energy costs are dropping, yet energy storage remains the major hurdle for scientists, who recognize both the economic and environmental advantages of a future dominated by clean power. Continual improvements in the energy density of today's batteries will yield rewards in the relatively near term, says Cui, who sides with experts who predict mass adoption of electric vehicles over the next 10-15 years. "I wouldn't be surprised if we're seeing cars that can run 400 miles on a single charge," he said, but the greatest gains in clean energy won't be achieved until batteries can store enough energy to allow for the integration of solar, wind and other renewable power sources into the mainstream electrical grid. "Energy storage is the missing link," Cui said, "and if we can solve that, it will be the most extraordinary achievement we can hope to have in this field in the next 20 or 30 years."

The potential for nanomaterials to help mitigate the impacts of environmental pollution also looms large for Cui. As the global population grows and resource needs increase, he predicts a starring role for nanoscale structures in efforts to purify water and remediate soil pollution, and is developing a nano-driven "desalination battery," which removes salt from seawater using less energy than reverse-osmosis, as well as air and water purification technologies that use nanostructures to capture particulates and pollutants with remarkable speed and efficiency.

## THE BEST MOLECULE FOR THE JOB

In a future envisioned by Melanie Sanford, there will be no compromise to designing molecules for some of the most important chemical tasks in the world, namely medical imaging, drug development, energy production and fields where the characteristics of a chemical reaction, or the process by which a molecule is made or utilized, can mean the difference between mediocre performance and excellence.

Sanford is making this vision a reality, developing customized approaches for the goals of various industries. "Depending on the target for the reaction we're developing, the dreams for the future are different," she said. The pharmaceutical and medical industries are two areas where Sanford believes that astonishing advances will be realized in the coming decade. Among them, the ability to customize the tracer molecules that are crucial to obtaining quality images in positron emission tomography, or PET, scans used in cancer, cardiac and brain diagnostics. "Right now, the tracers used aren't the best or the most appropriate, they're the ones we can make with the limited set of reactions we have for adding a radioactive tag to a molecule," said Sanford. "Ten or twenty years from now, the only constraint will be our imaginations — the reactions and catalysts in development now will allow us to ask, 'What molecule do I want to make to get the best result for this application?' and then be able to make it."

Customization plays an equally important role in another field Sanford sees poised for transformation through the design of novel reactions — agricultural chemicals. Using reactions that yield the desired result, but do so using readily available materials with minimal energy consumption or waste production, would represent significant improvement and a major sustainability overhaul of some of the largest-scale chemical processing activities on earth. "These syntheses are being performed at such a massive scale that waste really matters," said Sanford.

The ability to make the best molecule for the job will be key to making Cui's grid-scale energy storage a reality through new battery technologies. Sanford animatedly described the potential for developing new molecules to store energy, as well as tools for understanding and predicting the behavior and characteristics of those molecules. "It's going to be very exciting to both develop molecules with huge storage capability, but also to be able to use them to balance various needs and parameters — high storage capacity with high solubility — so we can really understand how to modify structures to yield the best performance for an application," she said.

Zhang, Cui and Sanford harbor no delusions of ease when it comes to the dreams they've set forth. Rather, they greet the challenges ahead with equal measures of determination and hope. "We have an enormous amount of work to do in the coming decades," said Cui. "But everything we're working towards is so important for the sustainable growth of the world and for the health and future of our children. I'm confident we can do it." ◀

# Driving Innovation in **Immunity**

*Winner of the 2017 Ross Prize in Molecular Medicine is breaking new ground in immune responses through Fc receptors.*

*By Kari Fischer, PhD, NYAS Staff*

Jeffrey V. Ravetch, MD, PhD, Theresa and Eugene M. Lang Professor and head of the Leonard Wagner Laboratory of Molecular Genetics and Immunology at The Rockefeller University, received the 2017 Ross Prize in Molecular Medicine — established in conjunction with the Feinstein Institute for Medical Research and *Molecular Medicine* — for his discovery of how antibodies generate a wide range of immune responses: through Fc receptors.

The path to this accolade was a hard won fight. Ravetch's work challenged a dogma of immunology, and consequently he spent his first 20 years as an independent investigator in relative isolation. When asked how he would encourage other researchers to drive through such a period, his response was emblematic of his career, "I think the point of science is that you never stop learning. You have to continually push yourself to be uncomfortable in a new field, and potentially get up there and say something that's wrong."

Raised in the age of *Sputnik*, a young Ravetch elected scientists instead of sportsman as his heroes — absorbing the biographies of Louis Pasteur and Albert Einstein. Recounting his first experiments in his high school basement, without any guidance, Ravetch laughed, "It's remarkable how naïve I was." He studied the embryonic development of zebrafish, using a homemade frame to collect the embryos and a borrowed microscope.

Transitioning into more formative research, Ravetch delved into the biophysics of RNA folding as an undergraduate. He subsequently earned an MD so he could apply his findings to human disease, a PhD in bacterial genetics and a postdoc employing molecular biology to study antibody recombination. Ravetch had no one love in science, except for science itself.

When first pursuing antibody receptors that may mediate inflammatory responses, he encountered either indifference or bewilderment as the mechanism for this process already existed: through the complement system. But Ravetch had the benefit of not yet being an immunologist — he lacked the tunnel vision that can form when studying one field — and instead was driven by a basic interest in the structure and function of Fc receptors. His group eventually demonstrated that the Fc region of antibodies can either induce or suppress an immune response by binding to the activating or inhibitory versions of Fc receptors on immune cells — without complement. This was groundbreaking, and opened many questions on how antibodies can fine tune immune activation or suppression.

Ravetch found one answer through a bit of serendipity: he was invited to the right conference. Knowing little about intravenous gamma globulin (IVIG) therapy, he flew to California to attend a clinical meeting on the topic. IVIG is the administration of antibodies isolated from donated blood, and is given as an anti-inflammatory. How IVIG worked was unknown, and Ravetch heard an abundance of theories at the conference. None were satisfying, and Ravetch had a new question to chase.

He returned to the lab, and found that IVIG's therapeutic effects occurred through the inhibitory Fc receptor. Moreover, the antibodies' ability to induce an inhibitory response, and dampen inflammation, resulted from the presence of specific carbohydrates attached to their Fc region. The presence and structure of those carbohydrates dictates the type of Fc receptor with which they can bind. Reigniting his undergraduate training on intricate molecular relationships, Ravetch went back to "school." "Nothing prepared us for this kind of interaction, and it was fascinating. It was one of those wonderful Christmas vacations where, for two weeks, I just sat and read up on carbohydrates."

Beyond scholarly pursuits, these discoveries influence therapy. Ravetch's findings on Fc receptors had not yet gained traction at the advent of therapeutic antibodies, and pharmaceutical companies focused on the antigen-binding variable region, not the Fc. This carried into the pioneering field of cancer immunotherapy, where many promising agents were successful in mice, but then failed in the clinic. There, Ravetch cites a lack of attention to the Fc, and he now collaborates with companies to share his expertise and develop better therapeutic antibodies for the treatment of cancer, inflammation and infectious diseases.

Lately, Ravetch is branching into a new area with vaccines, exploring how antibodies offer protection upon vaccination, and how that knowledge could improve vaccine design — perhaps yielding a universal flu vaccine. Beyond that, Ravetch does not have a plan, but this is true to his style: "I don't really know what's going to happen in the next weeks or months. There's a certain expectation based on what you're doing, but if you don't see unexpected observations, the fun is gone … I'm looking forward to the unknowns."

FROM LEFT TO RIGHT: ***Kevin J. Tracey**, **MD**, President and CEO, The Feinstein Institute for Medical Research; **Jeffrey V. Ravetch**, **MD**, **PhD**, Theresa and Eugene M. Lang Professor, The Rockefeller University; **Robin Ross**, Board of Directors, The Feinstein Institute for Medical Research; **Klass Kärre**, **MD**, **PhD**, Professor, Karolinska Institutet.*

# Brightest International Young Scientists **Reach for the Stars**

*By Hallie Kapner*

When Japanese physicist Kumiko Hayashi of Tohoku University and neuroscientist Ephraim Trakhtenberg of the University of Connecticut met at the New York Academy of Sciences this year, the synergies between their work weren't immediately obvious. The two scientists were paired together as part of the *Interstellar Initiative*, a joint project of the Academy and the Japan Agency for Medical Research and Development (AMED), which grouped 50 early-career scientists from around the world for interdisciplinary research projects. "The biggest global challenges, whether in health, the environment, or energy, require scientists with different expertise to work together," said Academy President & CEO Ellis Rubinstein. "The *Interstellar Initiative* brings together brilliant young scientists who would likely never cross paths, and supports them as they develop solutions to major health issues."

Hayashi and Trakhtenberg are devising new therapies to restore neuronal function following injury. As human cells mature, their ability to replicate is severely reduced. This phenomenon is especially prevalent in the brain, where the creation of new neurons exists only at very low levels in adulthood, and Trakhtenberg's work suggests that motor proteins may be involved in this loss. "If we can understand the dynamics of these proteins, we may be able to reverse the process," he said. Over the past several years, Hayashi developed novel algorithms that can be applied to motor protein measurement and analysis. "I don't know much about neuroscience," she said, "but it turns out that my algorithms can illuminate some mechanisms of the brain."

This teamwork is precisely what AMED president Makoto Suematsu envisioned creating through the *Interstellar Initiative*, part of a broader strategy to bring international partnerships and new funding streams to Japan's R & D pipeline. As technological advances that enable data sharing and ease remote collaboration have become ubiquitous, Suematsu believes it is crucial for Japanese researchers to join global research efforts. "International collaboration is critical in many fields," Suematsu said. "From infectious disease outbreaks to cancer treatment and drug development, we can accomplish much more when we reach out, shake hands and collaborate."

Another *Interstellar Initiative* team, comprised of NYU biologist Carlos Carmona-Fontaine, oncologist Valerie Chew of Singapore Health Services and physicist Shuichi Shimma of Osaka University, is juggling large time differences and global transport of perishable patient samples as they pursue their project. Blending Chew's expertise in oncology with Carmona-Fontaine's efforts to understand the role of metabolites in cancer cells and Shimma's imaging techniques, the group is uncovering the interplay of metabolite activity and immune changes in tumor cells. Noting that the *Interstellar Initiative* breaks down barriers that inhibit cross-disciplinary partnerships, Carmona-Fontaine commented that scientists "usually stick to our own communities, and there's often a disconnect between scientists from different parts of the world — yet there are many advantages to learning different ways to look at a similar problem." Chew was thrilled to be paired with teammates who brought both new expertise and new technologies. "If you're working in your own zone, you'll do what's familiar," she said. "But bringing together different disciplines and technologies creates a novel, creative environment for solving problems."

Proposals devised by *Interstellar Initiative* teams will be submitted to international funding agencies. For physician and biologist Deepak Lamba and biologist Akira Satoh, such funding may help them realize applications for their research. Lamba, who is developing methods for using stem cells to repair retinal tissue, is working with Satoh, whose research is illuminating the regenerative pathways of amphibians. They are probing the factors that influence regenerative capabilities in mammalian and amphibious cells, with the hope of developing methods of repairing and regenerating damaged tissue. "[Stem cell research is] moving so quickly that I think we'll start seeing applications in the not-so-distant future," Lamba said. Satoh noted that stem cell research is less popular among Japanese scientists, while Lamba added that few labs in the US are using amphibians to study regenerative pathways. "We would never have done this on our own — it's a unique challenge for us to do together."

Rubinstein is quick to highlight that this is just the beginning for the *Interstellar Initiative*. "This is only our first cohort, and there's so much exciting research in the works already," he said.

FROM LEFT TO RIGHT: ***President Suematsu****, Japan Agency for Medical Research and Development (AMED), recognizes the collaborative work of Japanese physicist* ***Kumiko Hayashi****, Tohoku University and neuroscientist* ***Ephraim Trakhtenberg****, University of Connecticut, along with* ***Ellis Rubinstein****, President and CEO, New York Academy of Sciences at the recent* Interstellar Initiative *workshop presented by AMED and the Academy.*

# Celebrating the Inaugural Honorees of the **Innovators in Science Award**

*Adria Martig, PhD, NYAS Staff*

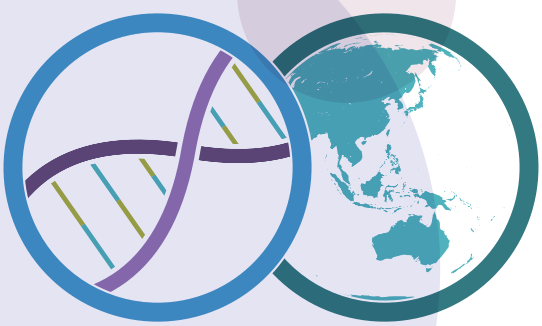
In November 2016, Takeda Pharmaceutical Company Limited and the New York Academy of Sciences launched a new award program to recognize and celebrate disruptive and transformative research conducted by promising Early-Career Scientists and outstanding Senior Scientists across the globe working in the areas of neuroscience, gastroenterology, oncology and regenerative medicine. Two prizes of $200,000 will be awarded each year, one to an Early-Career Scientist and the other to a Senior Scientist who have distinguished themselves for the creative thinking and impact of their research. All Award Winners and Finalists will receive a medal and will be invited to present their work as Distinguished Speakers at a symposium featuring their accomplishments.

Following are the first Winners and Finalists of this extraordinary prize.  They were selected from 170 nominations from 114 research institutions across 28 countries. Takeda Pharmaceutical Company and the New York Academy of Sciences salute these exceptional scientists whose exemplary work will be recognized at an Award Ceremony and Symposium to be held at the Academy in November, 2017.

## SENIOR SCIENTIST WINNER ★

***Shigetada Nakanishi****, MD, PhD, Director, Suntory Foundation for Life Sciences Bioorganic Research Institute, Kyoto, Japan*

Dr. Nakanishi devoted his career to the molecular analysis of cellular messenger systems and their role in regulating neural networks. Using DNA technology, electrophysiological tools and Xenopus oocyte expression systems, Dr. Nakanishi identified the molecular structure and function of G-protein coupled, NMDA and glutamate receptors. This fundamental work accelerated the identification of novel membrane receptors and paved the way for development of elegant methods to understand how receptors contribute to synaptic function.



## SENIOR SCIENTIST FINALISTS

***Ben Barres****, MD, PhD, Professor of Neurobiology, Stanford University School of Medicine, Stanford, CA, USA*

Dr. Barres pioneered the field of neuron-glia interactions and made seminal contributions to understanding the role of microglia and astrocytes in synaptic pruning and synapse formation in the brain. In addition, he developed widely used methods to purify and culture neuronal cells and established principles of CNS myelination. In more recent work, Dr. Barres investigated the role of reactive astrocytes in CNS injury and disease, providing new insights into potential therapeutic interventions for neurodegeneration.

***David Julius****, PhD, Professor of Physiology, University of California, San Francisco, USA*

Dr. Julius is recognized for his research on molecular mechanisms underlying somatosensation and pain. Using cutting edge genetic and molecular tools, he identified ion channels responsible for peripheral thermosensation. Dr. Julius found that these channels respond not only to heat and cold but to chemical signals as well, acting as molecular integrators of diverse modalities that regulate sensory neuron excitability under normal and pathophysiological conditions. In addition, he identified ion channel isoforms that contribute to unique sensory modalities such as infrared sensation and electroreception.


## EARLY-CAREER SCIENTIST WINNER

***Viviana Gradinaru**, PhD, Assistant Professor of Biology and Biological Engineering, California Institute of Technology, Pasadena, CA, USA*

Dr. Gradinaru is recognized for developing innovative tools to investigate neural circuits underlying locomotion, reward and sleep. Her early work defined subcellular and transcellular trafficking principles that resulted in production of potent and safe optogenetic tools. More recently Dr. Gradinaru developed whole-body tissue clearing techniques, a fundamental approach to visualizing central and peripheral nervous system interactions with target organs and skeletal systems. Dr. Gradinaru applied these techniques to advance the efficacy of deep brain stimulation, a powerful therapeutic option for people suffering from movement and affective disorders.

## EARLY-CAREER SCIENTIST FINALISTS

***Michael Halassa**, MD, PhD, Assistant Professor of Neuroscience, New York University, New York, NY, USA*

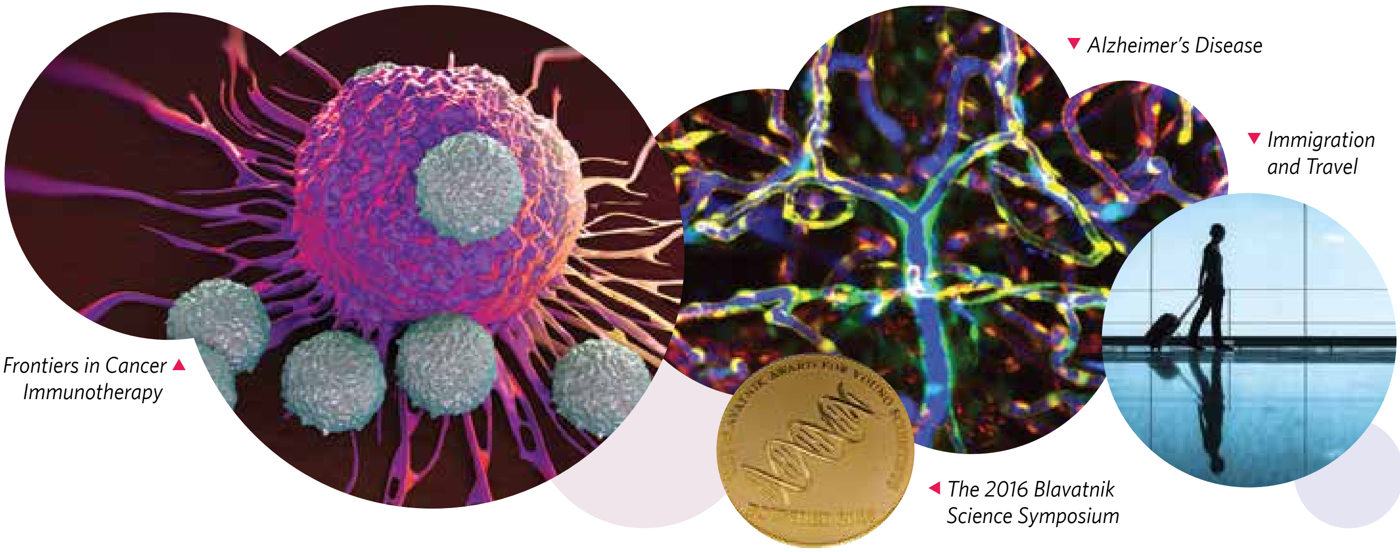
Dr. Halassa is recognized for developing neuro-computational frameworks that define cognitive processes like attention and executive function. His research describes thalamic control of functional connectivity within and across cortical regions in cognition, challenging the field's classical understanding of the thalamus as a sensory relay center of categorical information. Using a combination of genetic, optical, electrophysiological and computational approaches, Dr. Halassa has defined a new theoretical model of thalamo-cortical function that has important implications for disorders such as schizophrenia, autism and ADHD.

***Kay Tye**, PhD, Whitehead Career Development Assistant Professor of Neuroscience, Massachusetts Institute of Technology, Cambridge, MA, USA*

Dr. Tye is recognized for her circuit-based approaches that study neural networks involved in emotion and social behaviors. Using optogenetics to enable precise spatial and temporal manipulation of neural activity, she reformed the field's understanding of neural circuits that underlie motivation and reward. Her elegant approaches revealed that positive and negative emotional values are encoded by distinct neural circuits that intermingle within a single brain region, challenging the paradigm of thinking about the brain's functional units as separate anatomical elements. Dr. Tye's research has important implications for disorders of motivation and emotion including anxiety, depression and addiction. ◀

# Academy eBriefings

*eBriefings are online multimedia reports documenting recent Academy events. Find new and noteworthy ones here and more at* ***www.nyas.org/eBriefings****.*



▼ *Alzheimer's Disease*

▼ *Immigration and Travel*

*Frontiers in Cancer Immunotherapy* ▲

◀ *The 2016 Blavatnik Science Symposium*

## Frontiers in Cancer Immunotherapy

Cancer immunotherapy's ability to harness the body's own immune system to target and kill tumor cells has proven to be clinically formidable. Now that checkpoint blockades have been developed to squelch the immune system's own negative regulatory mechanisms and release cytotoxic T cells from suppression, researchers and clinicians are finding tumor antigens to use as targets and synthesizing optimized receptors to target them. On February 27 and 28, 2017, scientists and physicians convened at the New York Academy of Sciences for Frontiers in Cancer Immunotherapy, a symposium focused on toxicities induced by these therapies, and methods for dealing with the resistance that develops in some populations.

Cancer cells express and display novel antigens that can be recognized and attacked by the immune system. This insight could not be exploited therapeutically, however, until researchers realized that the tumor microenvironment actively suppresses the immune system, in the same manner as successful pathogens. As a result, immune checkpoint blockades — antibodies targeting and neutralizing PD-1, PD-L1 and CTLA-4 — have now been used to release cytotoxic T cells from this immunosuppresssion and successfully treat patients with melanoma and leukemia.

But as is often the case with promising new treatments, once the initial euphoria of success fades, issues of toxicity and resistance arise. Various technologies are showing promise to combat these factors, as well as methods for extending the utility of immune checkpoint blockades to solid tumors, which have traditionally been more recalcitrant. The way forward likely includes identifying new antigens in tumors, both those that have never been targeted by immune checkpoint blockade and those that have escaped through antigen loss; optimizing recombinant and synthetic immune molecules like CARs; and finding biomarkers to better identify patients who might most benefit from immunologically based therapies as well as patients who might most suffer toxic effects from them. But current limitations in the field, notably its reliance on animal models of questionable applicability, must first be overcome.

Speakers tackled these topics from a variety of angles. **Padmanee Sharma's** keynote address focused on MD Anderson's "reverse translation" approach, which links clinical trials and laboratory research. Instead of starting with a hypothesis and developing therapies for patients, they use what works in patients to generate hypotheses to test in the lab and identify biomarkers; in this way the responses of patients treated with ipilimumab informed experiments that led them to identify the role of the ICOS pathway in CTLA-4 blockade therapy.

Other speakers looked at the role of the tumor microenvironment, what researchers might learn from graft versus host disease, advancements in both epigenetic drugs and therapeutic and personalized vaccinations, as well as promising new insights for harnessing the microbiome, among many other topics. ◀

***Full eBriefing by Diana Gitig:***
***www.nyas.org/immunotherapy2017-eb***

# Alzheimer's Disease as a Neurovascular Inflammatory Disorder

For the past several decades Alzheimer's disease has been framed as a neurological disorder, and therapeutic efforts — all, to date, unsuccessful — have largely focused on interfering with the accumulation of amyloid beta protein deposits. However, the appreciation and understanding of how vascular dysfunction contributes to disease pathology is growing, and inflammatory contributors are also under intense investigation. On December 6, 2016, the Academy brought together researchers currently investigating a variety of vascular and inflammatory mechanisms that could contribute to the disease to share insights and promising therapeutic targets. Topics included ongoing research on the roles of different cell types in the vasculature, defining the intersection between vascular and inflammatory factors, and proposed mechanisms through which these pathways could contribute to Alzheimer's disease pathology. ◀

***Full eBriefing by Alla Katsnelson:***
***www.nyas.org/ebriefings/alzheimers-disease-as-a-neurovascular-inflammatory-disorder/***

# What International Scientists Should Know about Immigration and Travel

Changes are likely to occur to the U.S. immigration system, in the wake of the White House's executive order on immigration and pending court rulings.

In 2013, a National Science Foundation report found that one in six U.S. scientists and engineers is an immigrant — either a naturalized U.S. citizen, permanent resident, or temporary visa holder — meaning any such policy changes could have significant ramifications for the scientific community.

In response, the New York Academy of Sciences brought together experts to discuss the executive order's implications for international graduate students, postdocs and early-career scientists currently residing in the U.S., as well as those who wish to apply for graduate programs or jobs in the country. This information is applicable not only to scientists from the six countries specifically listed in the executive order, but to any international scientist concerned about overseas travel in the near future. ◀

***Full eBriefing:***
***www.nyas.org/ebriefings/what-international-scientists-should-know-about-immigration-and-travel/***

# The 2016 Blavatnik Science Symposium

On July 18–19, 2016, the New York Academy of Sciences hosted the third annual Blavatnik Science Symposium, a gathering of 54 laureates, finalists and alumnae of the Blavatnik Awards for Young Scientists. What began in 2007 as a regional program granting unrestricted funds to a small cohort of extraordinary young scientists has grown into a robust community nearly 200 strong.

The Blavatnik Science Symposium has become a vital component of the Blavatnik Awards community, bringing winners and finalists together for two days of research updates, panel discussions and networking among this interdisciplinary group of scientists, who are on the forefront of where science is headed next. Speakers presented new insights into gravitational waves, nanotechnology, combating infectious diseases and other hot topics. ◀

***Full eBriefing by Hallie Kapner:***
***www.nyas.org/ebriefings/the-2016-blavatnik-science-symposium/***

# *Annals* Highlights

*Annals of the New York Academy of Sciences* is the premier publication of the Academy, offering review articles in topical areas and proceedings of conferences. Learn more and order copies at **www.nyas.org/annals**.

## Unlocking the Unconscious

Another fruitful collaboration between the Nour Foundation and *Annals of the New York Academy of Sciences* has produced the forthcoming special issue *Unlocking the Unconscious: Exploring the Undiscovered Self*. Collected in the issue are transcripts of three panel discussions, moderated by *To the Best of Our Knowledge* producer Steve Paulson, that unpack the intricacies of the unconscious, followed by perspective articles by six of the panelists, each expanding in greater detail on some of the topics from the discussions.

In the first panel, "Delving within: the new science of the unconscious," a definition of the unconscious is discussed, as well as questions about the nature of consciousness, the dividing line between consciousness and the unconscious, and the importance of making the unconscious conscious. While acknowledging Freud's contributions, Paulson reminded us that we now reap the benefits of neuroscience. Efrat Ginot stated that there are ~450 different psychotherapeutic techniques, and Heather Berlin listed the strengths of several therapies. Several points of view regarding psychoanalysis were aired, and why some people benefit more than others from therapy. George Makari pointed out that psychoanalysis has given people a language to name things and to consider whether those things are important.

The second panel, "Dreaming: a gateway to the unconscious?" began with a discussion by Deirdre Barrett of Allan Hobson's research on rapid eye movement (REM) sleep. Although some scientists view dreaming as little more than noise, Kelly Bulkeley defined dreaming as imaginative play in sleep. Rubin Naiman summarized REM sleep as "consolidation of memory and the processing of emotions," and that we might consider waking a kind of dreaming, not dreaming a subset of waking. Bulkeley explained weirdness in dreams by thinking of it as "going beyond what *is*, to imagine *what might be*." Barrett's comments on lucid dreaming went on to discuss *dream incubation* — a request or suggestion to oneself for dream topics.

The third panel, "The deeper self: an expanded view of consciousness," revisited questions about the unconscious. Mark Solms, a Freud specialist, defined the unconscious as "an intentional agent that's part of you, that's making decisions, driving your volitional activities without your awareness" but that also "resists self-knowledge." Siri Hustvedt presented a brief history of the concept of the unconscious, beginning with Ptolemy, also mentioning one of her favorites, Sir William Hamilton. Differences and similarities between Freud and Jung were noted. Sonu Shamdasani, a Jung expert, suggested alternatives to the concept of an unconscious, having himself decided to "opt out" of having one — preferring to "travel light." Using her unique perspective as both psychologist and writer, Hustvedt discussed how the unconscious relates to writing. She briefly noted a new model of the unconscious — neuropsychoanalysis.

Six perspectives followed. In "Dreams and creative problem-solving" Deirdre Barrett gave an overview of her definition of dreaming: our brain thinking in a very different neurophysiologic state. Next, Kelly Bulkeley described three frontiers of investigation in dream research in "The future of dream science." Efrat Ginot integrated neuropsychology with psychoanalytic thinking and experience in her perspective, "The enacted unconscious: a neuropsychological model of unconscious processes." Rubin Naiman, in "Dreamless: the silent epidemic of REM sleep loss," described the unrecognized public health hazards of REM sleep loss — weight gain, concentration difficulties, irritability, anxiety, tension, delusions, and hallucinations. In "Questioning the unconscious," Sonu Shamdasani gave a brief history of the development of concepts of the unconscious and then presented ways of bringing understanding to various sides of the discussion. And in "What is 'the unconscious,' and where is it located in the brain? — a neuropsychoanalytic perspective," Mark Solms postulated that psychoanalysis and the neuroscientific disciplines have much to learn from each other.◀

**Special Issue: Unlocking the Unconscious**
***Ann NY Acad Sci* • October 2017**

## Keeping it Tight (Or Not) Between Cells

Tight junctions are protein complexes found in vertebrates that join the membranes of adjacent cells, forming tight, virtually impermeable, barriers. These critical complexes are formed as networks of *sealing strands* comprising transmembrane proteins. More than 30 different proteins have been identified in mammals that contribute to the formation of tight junction strands and determine leakiness or tightness between cells. Tight junction proteins bind to other tight junction proteins within the *same* membrane, to form tight junction strands; at the same time, tight junction proteins in the plasma membranes of separate but neighboring cells bind to each other, physically linking the cells (green balls in picture).

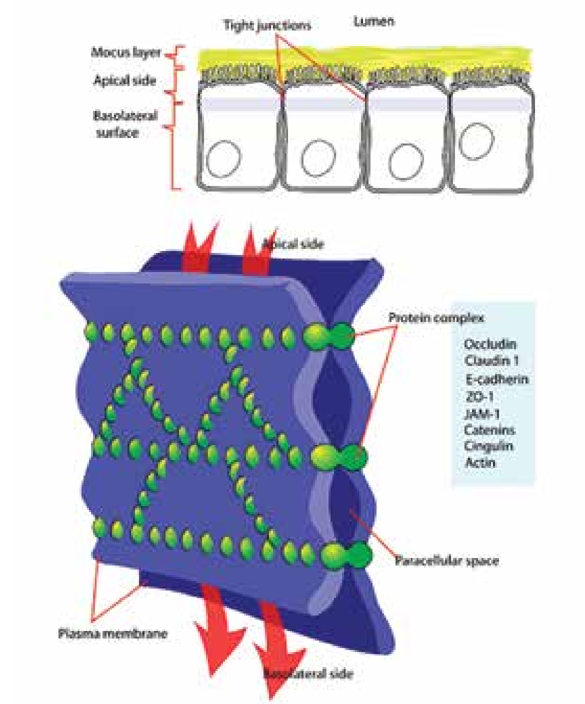
*Tight Junctions and Their Proteins I*, the first of two special *Annals* issues exploring tight junctions, presented a combination of review articles and original research papers that discuss the current understanding of the molecular constituents and mechanisms underlying tight junctions.

The review articles span a range of topics related to junctional protein complexes and their components. These scholarly overviews include recent findings on the X-ray three dimensional crystal structures of claudins and discussed the insights provided into the intermolecular interactions that underlie how the proteins, assembled in the junction complex, provide barrier function. Another review discussed the mechanisms at the transcriptional level (when DNA is transcribed into RNA) that result in the coordinated assembly of tight junction complexes during the differentiation and development of epithelial sheets. Other reviews explored a number of further topics, including the degradation and recycling of tight junction proteins; the diverse roles of a tight junction protein called "zonulin 2"; the unique paracellular water pathway established by the protein "claudin-2"; and junctional structures in arthropod cells called "septate junctions," which are analogous to vertebrate tight junctions.

In the second half of *Tight Junctions and Their Proteins I*, several authors presented new, original research findings. For example, two papers discussed structural properties of tight junction proteins and their interactions; one explored the functional roles of specific amino acids in claudins during tight junction formation, while the other presented computer *in silico* modeling of the formation of pores (as opposed to barrier function) that form between cells. Three papers explored *tricellular* tight junctions, which are junctions, composed of the proteins "tricellulin" and "lipolysis-stimulated lipoprotein receptor", that seal at the intersections of three individual cells. One of the papers explored the contribution of tricellular tight junctions to paracellular permeability, finding that tricellular tight junctions have different functions in different types of epithelial sheets — providing permeability in some but not others. Another paper presented data showing that tricellulin can be removed from cells by a process of targeted degradation through activity of another protein in cells called "Itch" (a ubiquitin ligase). The third paper demonstrated how the tensile force (the force between cells pulling them apart) across tight junction complexes determined the distribution of contact proteins between bicellular and tricellular junctions, depending on cell density. Finally, two somewhat more technical articles explored, in one, the use of a protein fragment from the *Clostridium perfringens* enterotoxin as a claudin-sensitive cancer biosensor and, in the other, use of a protein-based mimetic (based on a protein fragment of the claudin-5 protein) to modulate the permeability of the blood–brain barrier to improve drug delivery to the brain.

A second volume exploring further intricacies of tight junction proteins will be published by the end of the calendar year.◀

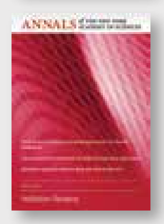
**Special Issue: Tight Junctions and Their Proteins I**
***Ann NY Acad Sci 1397 • September 2016***




ABOVE: *Image in the public domain is from Wikipedia.*

## ADDITIONAL RECENT *ANNALS* VOLUMES

Special Issue:
**The Year in Diabetes and Obesity**
*Ann NY Acad Sci* 1391: 1–100.
March 2017



Special Issue:
**Addiction Reviews**
*Ann NY Acad Sci* 1394: 1–127.
April 2017

Special Issue:
**The Year in Cognitive Neuroscience**
*Ann NY Acad Sci* 1396: 1–236.
May 2017

Special Issue:
**The Year in Ecology and Conservation Biology**
*Ann NY Acad Sci* 1399: 1–115.
July 2017

## THE LAST WORD

# **The Third Century**: A Vision for the New York Academy of Sciences

As befits a Bicentennial Year, the New York Academy of Sciences, staff, Board of Governors and Membership have spent the months since our 200th birthday last January 29, celebrating our distinguished past along with our relatively recent renaissance. But what's in store for us as we enter our Third Century? Can we do justice to the past and present commitments of the incredible network of supporters we have developed over the decades? Think of Darwin, Pasteur, Thomas Jefferson, Bell and Edison, Margaret Meade, Lord Kelvin, Louis Pasteur and Barbara McClintock. Or think of the 100-plus Nobel Laureates; the scores of industry, academic and government leaders; and the generous philanthropists and over 1000 institutional partners who have supported us. What could they expect of us in the next 10 decades?

The previous pages are a mosaic of the hopes and dreams of Academy Members contemplating where science and technology can take our planet and how to improve education in the decades to come. But what about the future of our Academy itself? In this essay, I will propose an aspirational vision — one that I hope you will find to be not only inspiring but achievable. And all of it hinges on two principles.

*"Much of what is possible will be built on the foundation of what can be achieved in the next two decades."*

First, that social networking is increasing the potential of global collaborations exponentially by complementing the traditional methods of face-to-face interaction. And that means that we can now build upon the incredible network we have already developed and fashion a Million Member, globally active social network that will employ science and technology to address the greatest challenges facing our planet and its citizens.

And, second, that the impact of this network will prove exponentially more effective at solving problems because it will enable collective action on a heretofore unimagined scale.

### A GLOBAL VISION

Much of what is possible will be built on the foundation of what can be achieved in the next two decades. So I will focus on the Academy's potential in the year 2030.

2030 has become an iconic year. Based on a consensus of 193 nations, 17 "Sustainable Development Goals" (SDGs) will be pursued over the next dozen years and, by 2030, we hope the world as we know it will be transformed for the better.

Extreme poverty will be banished from the earth, except perhaps in remaining conflict zones or pariah states. Hunger and malnutrition will largely be scourges of the past thanks to a doubling of agriculture achieved through sustainable uses of energy, water and so forth. And with regard to health and wellness, epidemics won't become pandemics, and there will be dramatic reductions in maternal and infant mortality. And that's just for starters. (Read the full SDG list at: http://www.un.org/sustainabledevelopment.)

Now, even if you haven't been following this ambitious playbook closely, I think you will agree that these 17 SDGs embody the most ambitious detailed vision of a better planet ever proposed by humankind. And perhaps for that reason you may feel some skepticism concerning the likelihood that these ideals can be achieved. But perhaps you haven't noticed the extraordinary progress made over the last two decades through the power of **collective action**:

- Extreme poverty was cut in half empowering a billion people to join the world economy.
- Deaths from malaria were reduced by up to 70 percent.
- Maternal mortality was reduced by almost 50 percent.
- And millions more children — especially girls — are graduating from primary schools with the next target being universal graduation from secondary schools.

How did all this happen? Visionary macro-economic planning, improved policy adoption, savvy investments, public-private partnerships in extraordinary numbers and — particularly warming to our hearts — innovations in science and technology.

In a world where the daily news is often horrific, the Sustainable Development Goals are expanding on the surprising success of their precursors, the Millennium Development Goals. And nothing is more inspiring than the stories of the institutions and individuals who are coming together to help achieve these goals through collective action.

## AN ACADEMY VISION

So, collective action has become the key to my vision of what the New York Academy of Sciences can achieve in its Third Century. Without fanfare — perhaps even without notice — collective action has been at the heart of many of the Academy's greatest and most promising new initiatives during the last decade.

To cite some examples, our Science Alliance for Graduate Students and Postdocs in the New York area overcame what had been previously nearly a zero-sum-game ethos among competing academic institutions. Today, young scientists from across the New York Tri-State region come together on a regular basis for career mentoring and special frontiers-of-science inspiration and collaborative opportunities. Because of the Science Alliance programs, tens of thousands of young scientists are engaging in collective action.

The synergistic effect of that landmark project in New York was soon recognized by the world-class universities of London — King's, Imperial and University College, London (UCL). They commissioned the Academy to help them overcome natural competitiveness, and after we organized and held three landmark conferences on cutting-edge topics — combining the best of King's, Imperial and UCL and demonstrating the power of working together — a sea change took place in cooperation among not only the London-based universities, but even among long-time archrivals Oxford and Cambridge.

Gradually, world political and business leaders, seeing concrete results from such activities, began to take notice. The Academy was invited to develop collective-action-*fostering* initiatives in Mexico City, Russia, Qatar and Malaysia. PepsiCo, realizing the potential of the Academy's neutrality to innovate, invited us to develop a public-private partnership that, with the crucial collaboration of the Mortimer D. Sackler Foundation, enabled the World Health Organization to create its first-ever prioritized road map of interventions desperately needed by 2 billion under- and over-nourished people on our planet — an unprecedented public-private partnership.

From that success, Johnson & Johnson and Pfizer asked the Academy to organize an international Alzheimer's initiative. This led to a landmark summit that brought together, for the first time, Alzheimer's governmental policy leaders from the United States, Canada, the European Union and Japan. Among other things, the summit provided critical precursors of transformational activities now being funded by the G7 that are advancing Alzheimer's research.

All of these extraordinary efforts by the individual and institutional Members of your Academy resulted in perhaps its greatest honor and challenge. In January 2016, UN Secretary General Ban Ki-moon asked the Academy to catalyze the private sector in innovative partnerships to help the UN agencies achieve the Sustainable Development Goals by 2030.

No wonder that the New York Academy of Sciences has become devoted to the notion of collective action in the sciences and technology. For its first 190 years, the Academy was primarily a convener and a disseminator of knowledge discussed at scientific conferences. Among the thousands of conferences and tens of thousands of scientists who have participated in our convenings and publications over the last 200 years, we can be particularly proud of holding the first-ever meetings on antibiotics, asbestos hazards, women in science, AIDS and SARS, to name a few. Indeed, much scientific progress has emerged from Academy ventures through serendipitous collisions of outstanding talents at our many meetings and conferences, and insights gleaned from papers published in *Annals of the New York Academy of Sciences*.

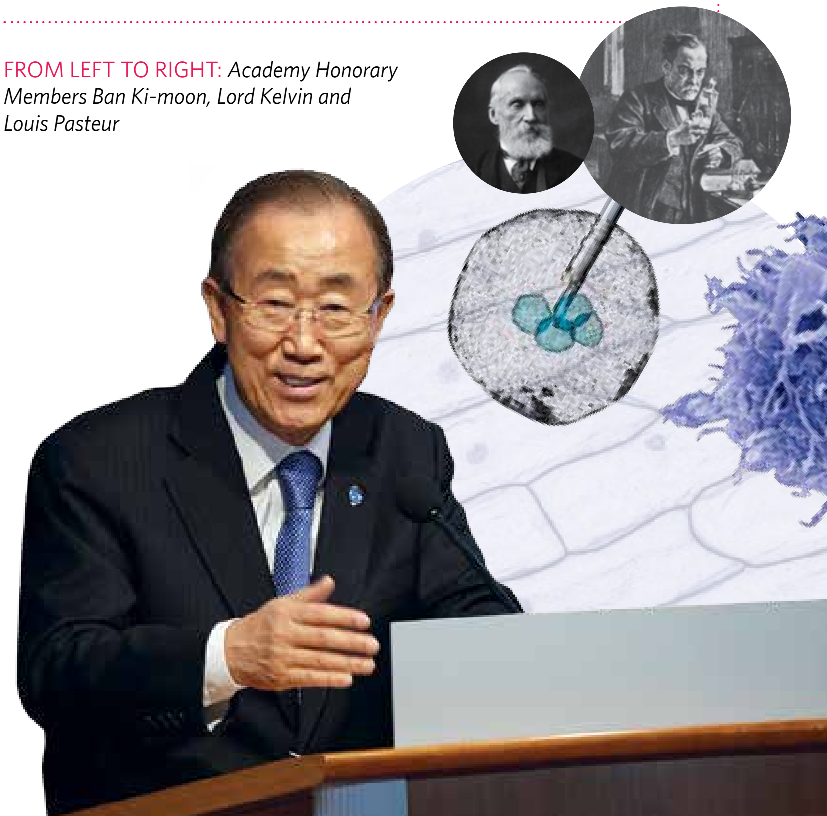
Those accomplishments notwithstanding, in the last decade, the Academy's Board, staff and Membership have begun to realize an even grander vision: to catalyze change by incentivizing competing institutions and individuals — as well as those normally unknown to one another because of the silos in our society — to work together in unparalleled collective efforts.

The immediate impact has been twofold: First, we can take great pride in driving significant social change. Second, we have discovered that the participants involved in these collective action initiatives are finding inspiration and a sense of fulfillment in **volunteering to make a difference**.

Once upon a time, professionals joined organizations (like ours) to improve their career prospects or, even, to get discounts on services! Today's professionals, in contrast, seem to want to spend their spare time volunteering for NGOs that give them opportunities to make a real difference.

So imagine the attraction of the Sackler Institute for Nutrition Science, or the Academy's work in early childhood development, or our newest initiative to enable the private sector to engage in the grand challenges of the planet. Young scientists and engineers — and especially secondary school students — are expressing a passion for the Academy and what it can accomplish.

FROM LEFT TO RIGHT: *Academy Honorary Members Ban Ki-moon, Lord Kelvin and Louis Pasteur*



## SCALING TO A MILLION

What can the Academy hope for as its Third Century initiatives develop? When I left the editorship of *Science* to take the leadership helm of the Academy in November 2002, there were about 200 Student Members, and the majority of Members were well past their early careers. Today, roughly 40 percent of our 20,000 Members are post-docs, Ph.D. students and gifted high school students. They are the Academy's future, and the planet's lifeline.

Thanks to the generosity of the Blavatnik Family Foundation — and more recently the Takeda Foundation and Japan's relatively new Agency for Medical Research and Development (AMED) — we are now developing a pipeline of the world's most promising young scientists and engineers, who will not only be the innovators of the future but serve as role models and mentors, inspiring the generations behind them.

I have already alluded to our 8,000-strong network of post-graduates. But for the science and technology students coming up behind them — the undergraduates of promise who desperately need mentoring — we have initiated the Next Scholars Program. This initiative matches collegiate woman with a female mentor from academia or industry to support the development of professional skills that will position them for future leadership roles.

As the Next Scholars kicks off recruitment, and our population reaches 600 self-identified female undergraduates and their mentors, by 2030, we see undergraduate women from other global regions as well as students with STEM majors from other historically underrepresented groups joining the program. At scale, we'll have created a continuous pipeline of mentoring to our most engaged STEM students from their early high school years through their graduate school and career.

And taking one more step back into the pipeline of tomorrow's innovators, I arrive at what could prove to be the most significant initiative developed by the New York Academy of Sciences: the Global STEM Alliance.

You no doubt have read about it before, so I will only summarize the highlights of this extraordinary opportunity to make a meaningful difference in the world by noting first that the GSA was inspired by inspirational Nobel Laureate and previous Academy President Joshua Lederberg. As a junior in high school with extraordinary science potential, Josh had been honored by the Academy by being inducted into the Junior Academy. In conversation with me, he claimed that this early honor confirmed his lifelong mission to use science to make a difference.

The Junior Academy provides uniquely inspiring experiences for the world's most gifted students who meet on a social network we created called LaunchPad. They quickly get to know one another across geographies — children from every continent interacting with one another around scientific topics. And they gain access to hundreds of experts willing to act as their advisors and mentors.

This unprecedented social network encourages the students to self-assemble into multinational teams to tackle an SDG related challenge and attempt to create a commercially feasible solution. To get a sense of the inspirational power of this activity, consider these two examples:

- **AquaeVitae Team**
  *(four students from the U.S., Macedonia, U.K. and India):*
  By combining nanotechnology and other water filtering methods, AquaeVitae aims to distribute its filters worldwide to people lacking access to potable water.
- **Go-Deck Team**
  *(four students from the U.S., Singapore and Tanzania):*
  Go-Deck, an off-the-grid cooling solution made from landfill bound materials, provides a reduction in temperature and humidity control during the transportation and storage of produce via the use of evaporation technology.

Considering the uniqueness, power and potential scale of the Junior Academy, it will come as no surprise that over 300 corporate and academic partners in 100 countries now support it with scores more joining annually.

## SO WHAT DOES ALL THIS MEAN FOR THE THIRD CENTURY OF THE NEW YORK ACADEMY OF SCIENCES?

Because there is no practical limit to the number of professional scientists and engineers who would gladly serve as experts and mentors, and because the costs of expanding the social network are hundreds of times less than what would have traditionally been required through the sponsorship of face-to-face meetings — not to mention ongoing collaborations — the true power of the Junior Academy initiative will be established when we have shown that 1 million of our Junior Academy Students mature into the innovators of tomorrow and, importantly, remain with us as Members of the Academy.

All of this would not be possible if it were not for the Academy's incredibly talented staff who develop and manage our awards programs, scores of great conferences, seminars and workshops, and *Annals* (the longest continuously published scientific journal in the United States), not to mention the relatively new team building the Global STEM Alliance and special after-school programs that inspire middle school children in underserved schools around the world. By creating a Million-Member network of **engaged** scientists and engineers we can prove the power of collective action.

I hope you find this vision worthy of continued support and — in particular — **participation**. And as our Third Century gets underway, if you haven't already been engaged in our current activities — or if you have ideas about new initiatives — please write me an email. Tell me your passions and become another crucial Member of the Million Member Club a.k.a. "the World's Smartest Network™." ◀

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# THE NEW YORK ACADEMY OF SCIENCES AND JOHN WILEY & SONS ANNOUNCE A JOINT BOOK SERIES

Academy Members are invited to submit proposals for scholarly book projects in any field of the life and physical sciences.

**Proposals should include:**

- A detailed outline of the book
- An estimated length and timeframe for completion
- Author(s) curriculum(s) vitae

**Proposals and/or questions should be submitted to annals@nyas.org**

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