Welcome to The Franklin Institute Awards, the oldest comprehensive science and technology awards program in the United States. Each year, the Institute recognizes extraordinary individuals who are shaping our world through their groundbreaking achievements in science, engineering, and business. We celebrate them as modern day exemplars of our namesake, Benjamin Franklin, whose impact as a scientist, inventor, and statesman remains unmatched in American history. Along with our laureates, we honor Franklin’s legacy, which has inspired the Institute’s mission since its inception in 1824.

From shedding light on the mechanisms of human memory to sparking a revolution in machine learning, from sounding the alarm about an environmental crisis to making manufacturing greener, from unlocking the mysteries of cancer to developing revolutionary medical technologies, and from making the world better connected to steering an industry giant with purpose, this year’s Franklin Institute laureates each reflect Ben Franklin’s trailblazing spirit.

The Franklin Institute presents, as part of its Awards Week celebration of science, a series of learning programs, open to the public, so that its internationally distinguished laureates can share their discoveries, experiences, and perspectives with the Greater Philadelphia community. These events offer a unique insider’s view on research activities in a range of disciplines. The week culminates in a grand medaling ceremony, befitting the distinction of this historic awards program.

In this convocation book, you will find a schedule of these events and biographies of our 2019 laureates. We invite you to read about each one and to attend the events to learn even more. Unless noted otherwise, all events are free and open to the public and located in Philadelphia, Pennsylvania.

We hope this year’s remarkable class of laureates sparks your curiosity as much as they have ours. We look forward to seeing you during The Franklin Institute Awards Week.

FOR MORE INFORMATION, CONTACT:
Beth Scheraga, Director of the Awards Program
215.448.1329
bscheraga@fi.edu
www.fi.edu/awards
THE FRANKLIN INSTITUTE AWARDS

The long, distinguished history of The Franklin Institute Awards dates back to 1824, when the Institute was founded by a group of leading Philadelphians to train artisans and mechanics. Philadelphia, then the largest city in the United States, was the nation’s innovation and manufacturing center. The same year, the Institute arranged the first of what became a series of regular exhibitions of manufactured goods. With the exhibitions came the presentation of awards—first certificates and later endowed medals—for technical achievement.

Since 1875, recipients have been selected by the Institute’s Committee on Science and the Arts (CS&A), formerly known as the Committee on Inventions. This all-volunteer committee still selects recipients of the Benjamin Franklin Medals, dedicated to their charge of recognizing the most impactful advances in science and engineering.

In 1998, the Institute’s long-standing endowed Awards Program was reorganized under the umbrella of the Benjamin Franklin Medals, now presented in seven areas of science and engineering. The Bower Award for Business Leadership and the Bower Award and Prize for Achievement in Science are made possible by a bequest in 1988 from Philadelphia chemical manufacturer and philanthropist Henry Bower, the grandson of a 19th century Franklin Institute laureate. The Bower Science Award is presented in a different, predetermined field each year and includes a cash prize of $250,000. All medalists receive 14-karat gold medals.

Through its Awards Program, The Franklin Institute seeks to provide public recognition and encouragement of excellence in science and technology. The list of Franklin Institute laureates virtually charts their advancement through the past two centuries—from the development of the typewriter to the dawn of quantum computing. The honor roll of more than 2,000 Franklin Institute Awards medalists includes Nikola Tesla, Marie and Pierre Curie, Rudolf Diesel, Orville Wright, Thomas Edison, Max Planck, Albert Einstein, Frank Lloyd Wright, Stephen Hawking, Gordon Moore, Jane Goodall, Elizabeth Blackburn, Steven Squyres, Bill Gates, Dean Kamen, Subra Suresh, and Cornelia Bargmann—to name but a few.

Celebrating outstanding achievements in science and technology from around the world is an important way The Franklin Institute preserves Benjamin Franklin’s legacy.

The Franklin Institute

In the spirit of inquiry and discovery embodied by Benjamin Franklin, the mission of The Franklin Institute is to inspire a passion for learning about science and technology.

As the most visited museum in the Commonwealth of Pennsylvania, The Franklin Institute is one of the country’s leading science centers. Science and technology have the potential to solve some of the most critical issues of our time, to improve our lives, and to inspire our curiosity about the world around us. Every day, The Franklin Institute provides resources that help people connect with science and technology in creative ways that resonate with learners of all ages and backgrounds. The Institute directly reaches more than 1 million people each year with informal learning experiences that engage students, adults, and families. Reaching beyond the central learning space of its historic museum, the Institute has evolved to provide people with educational resources in their own neighborhoods through hands-on activities in classrooms, workshops in libraries, community centers, and other settings, and online engagement. The Franklin Institute is committed to making these resources available to as many people as possible throughout the Mid-Atlantic region and beyond.
The Franklin Institute congratulates the 2019 Franklin Institute laureates, pioneers in their fields whose work has benefitted humanity and deepened our understanding of the universe and its inhabitants.

Frances H. Arnold, Ph.D., FREng
Bower Award and Prize for Achievement in Science

Indra K. Nooyi
Bower Award for Business Leadership

Marcia K. Johnson, Ph.D.
Benjamin Franklin Medal in Computer and Cognitive Science

Gene E. Likens, Ph.D.
Benjamin Franklin Medal in Earth and Environmental Science

Eli Yablonovitch, Ph.D.
Benjamin Franklin Medal in Electrical Engineering

James P. Allison, Ph.D.
Benjamin Franklin Medal in Life Science

John A. Rogers, Ph.D.
Benjamin Franklin Medal in Materials Engineering

John J. Hopfield, Ph.D.
Benjamin Franklin Medal in Physics
AWARDS WEEK SCHEDULE

MONDAY, APRIL 8, 2019

10:00–11:00 AM
**Bioresorbable Electronic Medicines**
Laureate address by John Rogers, 2019 Benjamin Franklin Medal in Materials Engineering

*Featuring:*
John A. Rogers, Ph.D., Laureate
Northwestern University

*Location:*
Pennsylvania State University
Millennium Science Complex Café, Third Floor
University Park, Pennsylvania
www.psu.edu

*Contact:*
Melissa Fink, mff3@psu.edu | 814.863.7966

Sponsored by The Franklin Institute and the Pennsylvania State University

TUESDAY, APRIL 9, 2019

11:00 AM–12:45 PM
**Laureates’ Laboratory**
Meet 2019 Franklin Institute laureates and participate in interactive demonstrations to learn more about the concepts behind their work. Registration is not required for this event.

*Location:*
The Franklin Institute
Second Floor
www.fi.edu

*Contact:*
Beth Scheraga, bscheraga@fi.edu

WEDNESDAY, APRIL 10, 2019

9:00 AM–12:00 PM
**Soft, Body-Integrated Microsystems Technologies**
Symposium honoring John Rogers, 2019 Benjamin Franklin Medal in Materials Engineering

*Featuring:*
John A. Rogers, Ph.D., Laureate
Northwestern University
Canan Dagdeviren, Ph.D
MIT Media Lab
Roozbeh Ghaffari, Ph.D
Northwestern University
Nanshu Lu, Ph.D.
University of Texas at Austin

*Location:*
Temple University
Walk Auditorium, Ritter Hall
1301 Cecil B. Moore Avenue
www.temple.edu

*Register:*
https://events.temple.edu/the-2019-franklin-institute-laureate-symposium

*Contact:*
Dr. Fei Ren, fei.ren@temple.edu | 215.204.9593

Sponsored by The Franklin Institute, Robert M. and Mary Haythornthwaite Foundation, Temple University College of Engineering, and Temple University Department of Mechanical Engineering

Please note: Times listed are seated program start times. Many programs offer refreshments and a registration period prior to the listed time. For more details on each event, please consult www.fi.edu/awards-week.
WEDNESDAY, APRIL 10, 2019 (continued)

9:00 AM–12:30 PM
Novel Photonic and Electromagnetic Bandgap Engineering
Symposium honoring Eli Yablonovitch,
2019 Benjamin Franklin Medal in Electrical Engineering

Featuring:
Eli Yablonovitch, Ph.D., Laureate
University of California, Berkeley
Alfredo de Rossi, Ph.D.
Thales Research & Technology - France
Nader Engheta, Ph.D.
University of Pennsylvania
Vidya Ganapati, Ph.D.
Swarthmore College
Kamal Sarabandi, Ph.D.
University of Michigan

Location: Drexel University
George D. Behrakis Grand Hall
Creese Student Center
3210 Chestnut Street
www.drexel.edu

Register: https://drexel.edu/engineering/news-events/events/franklin-medal-in-electrical-engineering/

Contact: Prof. Afshin Daryoush, daryousa@drexel.edu

Sponsored by The Franklin Institute, Villanova University, IEEE Philadelphia Section, and Drexel University

11:00 AM–12:00 PM
Immune Checkpoint Blockade in Cancer Therapy:
New Insights, Opportunities, and Prospects for Cures
Laureate address by James Allison, 2019 Benjamin Franklin Medal in Life Science

Featuring:
James P. Allison, Ph.D., Laureate
University of Texas MD Anderson Cancer Center

Location: Drexel University College of Medicine
New College Building, Geary A Auditorium
245 North 15th Street
www.drexel.edu

Contact: Dr. Noreen Robertson, nmr26@drexel.edu

Sponsored by The Franklin Institute and Drexel University College of Medicine

11:00 AM–12:30 PM
Memory & Reality
Laureate address by Marcia Johnson, 2019 Benjamin Franklin Medal in Computer and Cognitive Science

Featuring:
Marcia K. Johnson, Ph.D., Laureate
Yale University

Location: University of Pennsylvania
Biomedical Research Building (BRB)
14th Floor Lounge
421 Curie Boulevard
www.upenn.edu

Contact: Dr. Helene Intraub, intraub@udel.edu

Sponsored by The Franklin Institute, MindCORE at the University of Pennsylvania, and the University of Delaware

9:00 AM–2:30 PM
Science Communication:
How We Do It, How We Can Improve
Symposium honoring Gene Likens, 2019 Benjamin Franklin Medal in Earth and Environmental Science

Featuring:
Gene E. Likens, Ph.D., Laureate
Cary Institute of Ecosystem Studies and University of Connecticut
James Galloway, Ph.D.
University of Virginia
Sujay Kaushal, Ph.D.
University of Maryland
Chris Mooney
The Washington Post

Location: Temple University
Mitten Hall
1913 North Broad Street
www.temple.edu

Register: https://cst.temple.edu/franklin-symposium

Contact: Dr. Laura Toran, ltoran@temple.edu

Sponsored by The Franklin Institute and Temple University College of Science and Technology and Office of Research
THURSDAY, APRIL 11, 2019

8:15 AM–12:30 PM
Directed Evolution of Biocatalysts and Green Technologies
Symposium honoring Frances Arnold, 2019 Bower Award and Prize for Achievement in Science

Featuring:
Frances H. Arnold, Ph.D., FREng, Laureate
California Institute of Technology

Jared Lewis, Ph.D.
Indiana University

Bruce Lipshutz, Ph.D.
University of California, Santa Barbara

Jeffrey Moore, Ph.D.
Merck & Co., Inc.

Location: University of Pennsylvania
John M. Smolen, Jr. Auditorium
Department of Chemistry, Room 102
34th and Spruce Streets
www.penn.edu

Contact: Dr. Roger Grey, wcgrey@verizon.net

Sponsored by The Franklin Institute and the University of Pennsylvania Department of Chemistry

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THURSDAY, APRIL 11, 2019

5:30 PM  Cocktail Reception
7:00 PM  Awards Ceremony and Medals Presentation
8:30 PM  Dinner
9:30 PM  Dessert and Live Music

Valet Parking on 20th Street
Black Tie

Presented by Bank of America

2019 Corporate Committee
Christopher Franklin, Chair
2019 Friends Committee
Linda J. Hauptfuhrer, Chair

To purchase tickets, visit www.fi.edu/awardsdinner.

For more information, contact Marci Generose, director of donor relations, at 215.448.1352.

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Please note: Times listed are seated program start times. Many programs offer refreshments and a registration period prior to the listed time. For more details on each event, please consult www.fi.edu/awards-week.
Frances Arnold loves enzymes. These marvelously complex protein molecules convert sunlight, sugar, and carbon dioxide into life. In nature, enzymes have been optimized to work in different environments over millions of years of evolution. Appreciating their importance in daily life—enzymes are used in everything from laundry detergents and beer to pharmaceuticals and fuel—Arnold has committed herself to developing new enzymes that are specifically intended for human use. Her scientific achievements are based on a wild premise: that humans can use the same principles of biological evolution, but in a practical time frame, to design sophisticated tools for industrial chemistry.

Enzymes are notoriously difficult to produce and manage in the laboratory setting, often causing delays in the development of new products. But the idea that enzymes could be made to fit the laboratory environment rather than tailoring the lab to accommodate each enzyme was entirely new—and not readily accepted. Some argued that what does not exist in nature simply can’t exist at all. Others targeted Arnold’s credentials—she earned degrees in mechanical and aerospace engineering at Princeton before earning a Ph.D. in chemical engineering from the University of California, Berkeley—and accused her of “practicing chemistry without a license.”

But Arnold was undaunted. Overcoming odds had long been par for the course: Arnold grew up in Pittsburgh, the daughter of a nuclear physicist and a homemaker, and the only girl among four rowdy brothers. Though she was not a stand-out student in high school, while living on her own and working nights as a waitress, Arnold was admitted to Princeton University. Not many women attended Princeton at that time, and almost none enrolled to study mechanical and aerospace engineering. Going against the flow has long been part of Arnold’s process.

Over the last three decades, Arnold doubled down on her hypotheses, and the resulting body of work has contributed to a major paradigm shift in biological design philosophy. She is a pioneer in directed evolution methods to engineer biocatalysts for the use of living, biological systems or their parts to speed up chemical reactions and impart the desired very high chemical specificity characteristic of natural enzymes. All of this is based on the premise that artificial selection can be used in the lab setting to optimize biological function.

Directed evolution technology demonstrated that artificial selection, as practiced by breeders of plants and animals for thousands of years, could be mimicked in the lab to make new proteins. Introducing random mutations into the DNA encoding an enzyme and forcing bacteria to make the mutated enzymes, Arnold then selected those having the traits she wanted. Repeating the process on DNA extracted from the bacteria with the best enzymes, Arnold was able to “breed” enzymes that, while perhaps irrelevant in nature, are essential to human use.

For example, naturally occurring enzymes often lack features necessary for commercial applications, such as the ability to
stay active in the presence of organic solvents and in relatively high concentrations. By generating many variants and selecting the best ones, Arnold directs the evolution of viable enzymes, opening the door to a world of products that were previously difficult or impossible to produce.

Another significant example of the capabilities of Arnold’s technologies is her creation of a large set of new cytochrome P450 enzymes. The flexible structure of these enzymes gives them a wide range of functions in nature; in humans, cytochrome P450 enzymes are involved in the metabolism of hormones, vitamins, and toxins. Using directed evolution, Arnold has built on this flexible backbone to create novel catalysts that perform transformations unknown in the biological world, but important for a variety of chemical and pharmaceutical purposes. In addition to these applications, Arnold’s work gives scientists a fundamental understanding of how proteins evolve and function in nature.

Importantly, Arnold’s technologies provide a means of replacing traditional catalytic chemistries with processes that are more environmentally friendly. Though synthetic chemistry makes possible many of the products we rely on every day, these chemical processes are often derived from petrochemicals, depend on rare or toxic compounds, or generate large amounts of waste. Arnold sees her experiments with biological evolution as a source of cleaner, better chemicals. Of note, Arnold and two of her students founded the company Gevo in 2005; it is now a publicly-traded company producing isobutanol, a leading candidate biofuel that could serve as a replacement for or an additive to fossil fuels. Isobutanol will undoubtedly be of increasing interest as the search for renewable resources to replace fossil fuels becomes ever more urgent.

These days, Arnold’s critics have little to say. Her groundbreaking advancements have led to many honors, including her recognition as one of a small handful of researchers elected to all three branches of the U.S. National Academies (Science, Engineering, and Medicine). In 2018, she became only the fifth woman—and the first American woman—to receive the Nobel Prize in Chemistry. Arnold is a singular talent. Her insight, intuition, and tireless work have provided unique and powerful contributions to the chemical industry, shaping a new responsibility for preserving the sustained health of our planet.

LAUREATE SPONSOR:
Roger A. Grey, Ph.D.
Chair, 2019 Bower Science Award Pre-Selection Committee
Chair, Committee on Science and the Arts Chemistry Cluster
Consultant, Owner
RAG Chem Consulting, LLC
West Chester, Pennsylvania
Member of Committee of Science and the Arts since 1998

Prior to 1997, awards were designated by the year of nomination. Subsequently, awards were identified by the year of presentation.

Learn more about Dr. Arnold and her work at “From Inspiration to Impact—Science That Engineers Innovation” on April 8 at The Franklin Institute and “Directed Evolution of Biocatalysts and Green Technologies” on April 11 at the University of Pennsylvania. — See pages 4 and 6 for details.
For the past 12 years, Indra Nooyi has called the shots as chairman and CEO of PepsiCo—one of the most recognized brands in the world. Nooyi stepped down from the company in early 2019, but during her tenure, sales increased by 80% and PepsiCo’s philanthropic and community initiatives expanded, leaving the company vastly more successful than when she joined.

Since its inception in 1965, PepsiCo has prided itself in its ability to evolve as tastes, trends, and lifestyles change across more than 200 countries and territories. Although she grew up in a conservative South Indian family in Madras, India, Nooyi embodies the same instinct for innovation. From a young age, Nooyi was a powerhouse. She climbed trees, played cricket, and rocked out on her guitar in local halls as her parents watched from the front row.

Nooyi was not a typical Madras woman: at the time, women were discouraged from taking active roles in sports, entertainment, and business. Respecting your elders, studying hard to get good grades, and marrying at age 18 were widely thought to be women’s main duties. Hard work and courteousness came naturally to Nooyi, but the expectation to do without professional success was tougher to swallow. Inspired by her older sister, who was the first to leave home for college, Nooyi fought for a spot at Madras Christian College, one of India’s highly competitive schools. Her acceptance—one of five women admitted to a science program—was an exceptional achievement.

“...Nooyi has been consistently ranked as one of the most powerful and effective women in business.”

The business management bug bit Nooyi partway through her undergraduate program and, after completing her first master’s degree at the Indian Institute of Management in Calcutta, she accepted a position at Johnson & Johnson in India. She was responsible for launching a new line of feminine hygiene products—which could not be advertised or even sold in public. The campaign was a hard-fought success and, in many ways, prepared Nooyi for obstacles she would face when she moved to the U.S. in 1978 to pursue a second master’s degree at Yale.

Coming to the U.S. was tougher financially than Nooyi had expected. She took part-time jobs and worked night shifts, but was unable to afford a decent suit for job interviews. Desperate, Nooyi purchased an ill-fitting outfit and, though the pants were too short and the jacket several sizes too big, she wore it to her first major interview. The experience was mortifying but serendipitous: An employee in career development saw her leaving the interview upset and asked what Nooyi normally wore to interviews in India. The conversation gave Nooyi the confidence she needed. In the future, she would wear a sari to interviews at high-powered U.S. firms. If a company did not want to hire her based on who she was, she thought, they did not deserve her.

Nooyi’s tenacity and talent caught the eye of both General Electric and PepsiCo and soon the two were vying to take her on board. Joining PepsiCo in 1994 was an incredible achievement—at the time no foreign-born person or woman was on the executive floor—but came with fresh challenges. Many colleagues...
questioned why Nooyi had been hired to a senior-level position given what they perceived to be her limited experience. Some felt she was too outspoken, challenging division presidents too often. But Nooyi wasn’t concerned. She was hired to do a job and was focused on doing it better than anybody else.

With visionary foresight, Nooyi prepared the company for a changing consumer base—one that was seeking healthier products and lifestyles. Discussion about rising rates of obesity and the risks of sedentary lifestyles were becoming more commonplace. It was stylish to “go organic” and purchase natural products. Nooyi recognized the need to build PepsiCo’s portfolio around good-for-you products.

Nooyi was the motivating force behind the divesture of PepsiCo’s fast food brands. She transformed the snacks, beverages, and restaurant divisions, which included KFC, Taco Bell, Pizza Hut, and California Pizza Kitchen, by orchestrating the acquisition of popular brands like Tropicana, Quaker Oats, Gatorade, and Naked. Wanting to give consumers a whole range of products, Nooyi’s updated portfolio included “fun” (less healthy) and “better-for-you” (more healthy) products that were widely available and priced affordably.

Since taking the top spot at PepsiCo, Nooyi has been consistently ranked as one of the most powerful and effective women in business. In addition to launching new product lines, she has helped transform the company’s corporate culture—the business provides a wide variety of products at different price points to expand the consumer base, and increasingly focuses on environmental sustainability and work/life balance for employees. PepsiCo has worked toward empowering women and minorities by hiring diverse personnel to senior-level positions. The company now offers on-site services, such as daycare, to support employees with families.

PepsiCo has always been a company with a soul, Nooyi says, but it has now come out in a phenomenal way. Nooyi helped lead the PepsiCo Foundation’s efforts to address issues of global concern, like racial and gender equality. Nooyi’s legacy will live on well past her departure. PepsiCo aims to invest $100 million in initiatives to support 12.5 million women and girls worldwide in their pursuit of higher education and workforce readiness by 2025. The next generation of women leaders will be well prepared due to Nooyi’s seemingly superhuman influence.
What is the relation of our perceptions, memories, and beliefs to reality? Marcia Johnson confronted this question during her freshman year of college when she recounted to friends an event from her early childhood when the family car had a flat tire on a trip during a California drought. She described her father taking the tire to be repaired and her sister going to a farmhouse for water while she waited with her mother and brother in the car. She vividly remembered the farmhouse and the woman in the kitchen who provided the water. She also remembered the guilt she felt when the family didn’t save any water for her father. Her parents verified the flat tire story but, to her surprise, said that after her father left, the rest of the family never left the car. Imagining a way to get a drink of water as a child was experienced by Johnson as a detailed, accurate memory when she described the event years later.

Marcia K. Johnson, Ph.D.
Sterling Professor Emeritus of Psychology
Yale University
New Haven, Connecticut

CITATION:
For developing innovative models of human memory with applications in psychology, brain science, human development, and our understanding of the malleability of memory in real-world settings.

The disparity between her memory and reality prompted many questions that would later form the basis of Johnson’s career and establish her as a world-renowned authority on the cognitive processes underlying memory and thought. As her career unfolded, Johnson first devised creative behavioral tasks to track down these elusive processes, and then became an early advocate of brain imaging as a means to further expand knowledge in cognitive science. The resulting research and theory from Johnson’s lab advanced our understanding of mind and brain, providing insight into fundamental issues in cognitive psychology, neuroscience, clinical science, social psychology, developmental psychology, and the changes in cognition that occur with normal aging.

“What is the relation of our perceptions, memories, and beliefs to reality?”

A native of California, Johnson was educated by the state’s public schools and colleges. She earned her B.A. and Ph.D. in psychology at the University of California, Berkeley and joined the faculty at Stony Brook University (1970–1985), Princeton (1985–2000), and Yale (2000–2016). When she entered the field, prominent models depicted memory as an information processing system in which what we see or hear is first briefly stored in a short-term memory and then, depending on a number of factors, may be transferred to a relatively permanent long-term memory, or may be lost. Although these models could account for many aspects of memory, they did not address the role of imagination and interpretation. They did not provide traction for asking why, as in Johnson’s own false memory experience, people sometimes mistake what they imagined as something that had actually happened.

At Stony Brook, Johnson and another new assistant professor, John Bransford, investigated the role of interpretation in memory. In one study, when people heard a story that included the sentence, “The spy threw the secret document into the fireplace just in time since 30 seconds longer would have been too late,” they sometimes falsely remembered hearing, “the spy burned the secret document.” They had inferred that the spy intended to destroy the document when the spy may have intended to hide it in a cold fireplace. Inferences based on the listener’s prior knowledge of fireplaces and beliefs about spies’ intentions affected their memory. Other studies showed the critical role that prior knowledge plays not only in how information is interpreted, but whether it is remembered at all.
Johnson then focused on a fundamental dilemma. How can we explain why we sometimes accurately distinguish the source of a memory (correctly recognizing an event as having been experienced or having been imagined) and sometimes fail to do so? How do we distinguish the source of any mental experience, like a dream from waking events, whether we did something or only intended to, or if we read something or heard about it? Johnson’s empirical studies and theoretical developments, especially with collaborators Carol Raye of Barnard College, Shahin Hashtroudi of George Washington University, and Stephen Lindsay of the University of Victoria, led to the Source Monitoring Framework. A key idea is that we make judgments about our experiences based on differences in the profiles of features that different sources such as vision, audition, dreams, or imagination have. For example, although perception usually yields more visual and contextual details than imagination, their profiles overlap, sometimes resulting in mistakenly thinking an imagination was a perception, as in Johnson’s flat tire memory.

In a second model, the Multiple Entry, Modular memory system (MEM), Johnson proposed a general model consisting of component processes underlying cognition and memory. Research prompted by MEM and the Source Monitoring Framework has, for example, compared the patterns of brain activity arising from perception and imagination, identifying where they overlap, and how patterns of brain activity relate to subjective vividness. Other critical issues addressed with brain imaging include how features of events become associated, how context and goals affect what features are activated, and identifying the brain regions involved in evaluating the sources of memories.

Findings based on Johnson’s work provide the backdrop for better understanding a wide range of issues, including potential memory contamination in legal and therapy contexts, how stereotypes and self-interest may affect our memory about others, the relation between memory and emotion, changes in cognition during development and aging, and disruptions in cognition in brain damaged or clinical patients.
Gene E. Likens, Ph.D.
Founding Director and President Emeritus, Distinguished Senior Scientist Emeritus
Cary Institute of Ecosystem Studies
Millbrook, New York

Distinguished Research Professor and Special Advisor to the UConn President on Environmental Affairs
University of Connecticut
Storrs, Connecticut

CITATION:
For his pioneering long-term studies of forest, stream, and lake ecosystems, and for his efforts to educate the public and the U.S. government about acid rain and other environmental issues.

Gene Likens was born in Indiana during the Great Depression. His family lived in a log cabin on a small farm owned by his grandparents and, though they struggled financially, he enjoyed a happy childhood. Likens spent as much time outdoors as possible and, he says, that early exposure sparked a lifelong fascination with the natural sciences. At first, science was a secondary passion. Likens wanted to become a professional baseball player and played in the rookie leagues in Kansas, even making the All-Star team. At Manchester College, he intended to become a high school basketball coach. He only took the graduate record exam to appease a persistent teacher adamant that he pursue a graduate degree in the sciences. Likens performed so well on the exam that he decided to attend graduate school. Ecosystems caught his attention as a graduate student at the University of Wisconsin, Madison, not only because of his love of nature, but also because he enjoyed exploring the complexity of the natural world.

For over 50 years, Likens has advanced our understanding of the processes that support life on Earth and how humans alter these processes at local and global scales. In 1963, while teaching aquatic ecology at Dartmouth College, Likens and three colleagues founded the Hubbard Brook Ecosystem Study at the Hubbard Brook Experimental Forest (HBEF) in New Hampshire and pioneered the use of watersheds—land areas that form the basin supplying water to rivers or lakes—as a method of studying the health and function of an ecosystem. In a watershed, plant life, animals, soil, air, and water interact, creating a complex puzzle. Likens applied a medical metaphor to his work: Physicians use blood chemistry to examine patient health. Could stream water chemistry be used to diagnose watershed health? If the chemistry of water flowing from a watershed were different than expected, the soils, roots, trees, and microbes could be analyzed to figure out why. Conditions within a watershed affect not only life in that area, but all future locations through which the passing water will flow. Ultimately, all ecosystems (watersheds) are connected.

Likens found that precipitation in the Hubbard Brook Valley was unusually acidic—at least 100 times more acidic than expected. Was the high level of acidity specific to the area? Where did the acidity come from and what effect did it have? These questions spawned a series of studies. Likens and his team installed precipitation collection stations all over the world and found that the rain and snow at Hubbard Brook was up to 1,000 times more acidic than the water in remote areas untouched by industrialization.

As Likens’s research progressed, scientists abroad were also documenting increased acidity in European watersheds. Their studies suggested that air pollution was falling on the landscape as acidified rain and snow. Likens suspected something similar was happening in North America. Always up for a challenge, he and his team set out on a small plane and chased plumes of power plant emissions over the Midwest, collecting samples out the window.

In 1969, Likens joined the faculty at Cornell University. He set up precipitation collectors around the Finger Lakes in New York and found the rain and snow there were also acidic. These findings indicated that acidic precipitation was not limited to Hubbard Brook. In a seminal 1974 study, Likens and co-author Herb Bormann identified fossil fuel combustion as the primary cause of acid rain. The
effects were visible in natural and laboratory studies, from corroding infrastructure, to freshwater fishkills, to stunted forest growth.

As the data came in, Likens recognized that only an informed public could help affect change, so he limited scientific jargon when publishing his findings. His 1972 and 1974 papers made waves almost immediately and were soon picked up by newspapers and television, featuring images of buildings and headstones bearing the telltale scars of acid rain. As documentation of acid rain impacts grew, so too did pushback from industry representatives. Likens rose to the challenge: he argued for better regulation, led a small team of scientific colleagues to brief President Reagan and the full Cabinet on the issue, and founded the Institute of Ecosystem Studies (now the Cary Institute of Ecosystem Studies), one of the world’s leading independent environmental research organizations, in 1983. Committed to researching disease ecology, forest and freshwater ecosystem complexity and health, climate change, urban ecology, and invasive species, Cary Institute scientists have been instrumental in informing environmental management practices throughout the world.

Likens’s and his colleagues’ tireless advocacy paid off when, in 1990, the Clean Air Act was amended to drastically curb the impact of acid rain in the U.S. Likens had made a career of advancing scientific evidence into policy and improving communication between scientists, policy makers, the media, and the public. A primary goal now is to improve efforts to communicate with the public and provide information in a way that they can better use in their daily lives.

It is difficult to overstate the role Likens’s research played in exposing the ecological consequences of acid rain in the U.S. Thanks largely to his work, the government now sponsors 28 long-term ecological sites, all modeled on HBEF. Continuously funded since 1963, the Hubbard Brook Ecosystem Study employs about 50 senior scientists and 70 students from 25 institutions who continue to conduct research there. The results of this research will continue to benefit delicate ecosystems for generations.

LAUREATE SPONSORS:
Robert W. Sanders, Ph.D.
Professor of Biology
Temple University
Philadelphia, Pennsylvania
Member of Committee on Science and the Arts since 2014

Laura E. Toran, Ph.D.
Professor, Department of Earth and Environmental Science
Temple University
Philadelphia, Pennsylvania
Member of Committee on Science and the Arts since 2014

Gene Likens’s Laureate Legacy

The laureate legacy recognizes previous laureates connected to the current laureates by a shared intellectual thread.

1912  E. LATHROP AND O. SHREINER
1913  J.A. BIZZELL AND T.L. LYON
1946  KARL TERZAGHI
1970  RUTH PATRICK
1974  ARIE JAN HAAGEN-SMIT
1981  MARION KING HUBBERT
1999  RALPH J. CICERONE
2000  EVILLE GORHAM
2003  NORMAN A. PHILLIPS AND JOSEPH SMAGORINSKY
2006  LUNA B. LEOPOLD AND M. GORDON WOLMAN
2008  WALLACE S. BROECKER
2010  W. RICHARD PELTIER
2011  JILLIAN F. BANFIELD
2013  ROBERT A. BERNER
2015  SYUKURO MANABE
2017  CLAUDE LORIUS

Please note that the laureate legacy does not represent a comprehensive list of all Franklin Institute medalists.

Learn more about Dr. Likens and his work at “Science Communication: How We Do It, How We Can Improve” on April 10 at Temple University. — See page 5 for details.
The 2019 Franklin Institute Laureates

Benjamin Franklin Medal in Electrical Engineering

Eli Yablonovitch, Ph.D.
James & Katherine Lau Engineering Chair
Professor, Electrical Engineering and Computer Sciences Department
University of California, Berkeley
Berkeley, California

Citation:
For widely-used scientific improvements to radio- and light-based technologies in wireless communications and solar energy applications.

Eli Yablonovitch was 10 years old when he decided to become a scientist. The Soviet Union had just successfully launched into space Sputnik I, the world’s first artificial satellite, ushering in the start of the modern space age. While the adults worried about the launch and its implications, the young Yablonovitch felt the first definitive stirrings of his awe and reverence for science. He began taking science seriously. He performed his first rudimentary science experiments by testing the reaction to flooding on termites, which were gorging on a rotted fence post in the backyard of his home in Montreal. The adults’ reaction to Sputnik further motivated Yablonovitch.

Some may have considered Yablonovitch a “cerebral” or “scholastic” child. At the age of five, a neighbor told him that radios could speak because there were little people inside. Yablonovitch recalls crawling behind the radio and taking a look inside. Feeling the warm glow of the vacuum tubes, Yablonovitch knew the neighbor had humored him. He was determined to stop being patronized and to become as smart as the adults. He became an avid reader of Scientific American and Popular Electronics.

Practical results were his end goal. Yablonovitch preferred to roll up his sleeves and engage in experimental work. He aspired to become an inventor, like Thomas Edison, and went on to build his first circuits, amplifiers, and chemical analysis equipment.

Yablonovitch wanted to invent something that, like Edison’s inventions, would become a part of people’s everyday lives.

While an undergraduate at McGill University, Yablonovitch watched a stunning high power laser demonstration at an RCA lab in Montreal. He realized that lasers had enormous potential for practical, daily applications. Light, he recognized, was something we experience every day, everywhere around us. It was a resource to explore and manipulate. As he earned advanced degrees at Harvard, Yablonovitch honed his interest in light.

By the 1990s, he led the solid-state physics research program at Bell Communications. Yablonovitch suggested that all semiconductor lasers should be strained—a strategy that enhances conductivity. Today his idea is employed for almost all optical telecommunications, for DVD players, and in the ubiquitous red laser pointers. In virtually every human interaction with the internet, optical telecommunication occurs by strained semiconductor lasers.

Subsequently, at Bell, he established himself as a pioneer in the photonic bandgap, electromagnetic bandgap, and photonic crystal concepts, structures that have become belatedly recognized for providing color throughout the animal kingdom, but that also improve the flow of light for optical communications in data centers.

As complex as each of these discoveries may be, we can all appreciate their applications in our daily lives. Nearly all photovoltaic solar panels use the “Yablonovitch Limit” for trapping sunlight. He is the co-founder of Luxtera Corporation, the company that pioneered...
silicon photonics. At data centers, millions of such optical microchips exploit an internal photonic crystal for optical polarization splitting, and billions of users connect to these data centers every day. Luxtera was recently acquired by Cisco.

Yablonovitch pursued another challenge in cellphone communications. Only a few decades ago, cellphones were bulky bricks with extendable antennas and frequent dropped calls. Yablonovitch observed that conventional cellphone antennas were highly inefficient. He co-Founded Ethertronics Inc., a company that developed efficient, slim, cellphone antennas. Consider the brisk transformation of the telecommunications industry. Today, we can slip our phones easily into a pocket and make calls from even the remotest areas. Ethertronics’ impact has been global: headquartered in San Diego, with an international network of world-class design centers in China, Korea, Denmark, and Taiwan. Ethertronics Inc. shipped more than 2 billion cellphone antennas to name brand manufacturers worldwide. A good fraction of the human race carries his technology next to their bodies every day.

Yablonovitch’s work transformed the field of optical physics and led to many new technological advances—but, surely, his biggest achievement is that he has helped make the world smaller and better connected.

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Villanova University
Villanova, Pennsylvania
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Eli Yablonovitch’s Laureate Legacy

The laureate legacy recognizes previous laureates connected to the current laureate by a shared intellectual thread.

1906  FREDERIC E. IYES
1918  GUGLIELMO MARCONI
1923  ALBERT W. HULL
1930  WILLIAM HENRY BRAGG
1932  JOHN B. WHITEHEAD
1938  JOHN S. HALL
1941  CHANDRASEKHARA VENKATA RAMAN
1949  SERGI A. SCHELKUNOFF
1953  WILLIAM F. MEGGERS
1959  GEORGE W. MOREY
1966  JACK S. KILBY AND ROBERT N. NOYCE
1968  POL EDGARD DUWEZ
1971  JOHN HASBROUCK VAN VLECK
1972  DANIEL EARL NOBLE
1977  CHARLES KUEN KAO AND STEWART E. MILLER
1997  FEDERICO CAPASSO

Please note that the laureate legacy does not represent a comprehensive list of all Franklin Institute medalists.

Learn more about Dr. Yablonovitch and his work at “From Inspiration to Impact—Science That Engineers Innovation” on April 8 at The Franklin Institute and “Novel Photonic and Electromagnetic Band Gap Engineering” on April 10 at Drexel University — See pages 4 and 5 for details.
Sharon Belvin was diagnosed with melanoma just weeks before her wedding. She had more than 30 metastatic tumors in her lungs, brain, and skin. Standard drugs had failed and, hospice-bound, she enrolled in a clinical trial led by Jim Allison in a final effort to save her life. Six months after her initial treatment, the tumors were gone. A decade later, now a fitness instructor and mother of two, Sharon is still cancer-free. It is for patients like Sharon that Immunologist Jim Allison persists in searching for cures for cancer. He is one of the first scientists to observe the role of the immune system in fighting cancer and to prove that blocking the body’s normal “stop signals” to an immune response could shrink or even eradicate tumors.

Allison’s brilliance was inspired by his upbringing in the small town of Alice, Texas. He spent his days with his chemistry set and joined his father, a country doctor, on house calls. He likes to say his father was the first immunologist he knew—he has childhood memories of being exposed to chicken pox to build his immune system. But Allison’s childhood memories were not all positive. He also observed how the radiation treatments and chemotherapy used to treat his mother’s lymphoma ravaged her body. As a result, Allison has a special understanding of cancer and a powerful drive to find a cure.

Allison attended the University of Texas, Austin with an eye towards medical school, but found bench science a better fit. He earned his Ph.D. in biological sciences from UT in 1973. His interest in the mechanisms of the immune system intensified. In particular, he hoped to better understand the function of immune system cells called T cells. At the time, it was known that T cells circulated throughout the body, searching for and killing invading bacteria and viruses without damaging normal cells. But questions remained: How do T cells recognize invaders? How are they activated and inactivated?

This initial phase of Allison’s research led to important discoveries. He and his colleagues identified a T-cell antigen receptor—a molecule found on the surface of T cells—responsible for recognizing invaders and triggering an immunological response. Their experiments led to the breakthrough realization that the T cell requires two signals for full activation: one from the antigen receptor and another ‘confirmatory’ signal to authenticate the response. Allison likens them to the ignition switch and the gas pedal. In 1992, his lab identified that confirmatory signal, a protein called CD28 on the T-cell surface.

In the mid-1980s, while at the University of California, Berkeley, Allison, with Jeff Bluestone, then at the University of Chicago, discovered that another T-cell receptor (CTLA-4) had an unexpected function; it actually stops the T-cell immune response. This landmark finding revealed that a stop signal is a critical checkpoint in the process: after the immune system is activated, CTLA-4 appears a few days later to inhibit the activation of the T cells. If cancer cells were still around at this time, they could become virtually invisible to the T cells. These discoveries inspired in Allison the dream that manipulating signaling pathways could one day cure cancer. Cancer cells routinely arise in the human body, but most are neutralized before they turn into tumors. Allison theorized that a medication that blocks CTLA-4 from ‘putting on the brakes,’ allowing the immune system to continue working, could successfully fight tumors able to evade the initial
response. Scientists had been searching for a cure for cancer for decades and even the best medications available were highly toxic to patients—Allison’s idea of an “immune checkpoint blockade” could change the field forever.

To prove his theory, Allison developed a molecule that uniquely and specifically bound to CTLA-4, blocking its function. Preclinical trials of this drug in mice demonstrated that tumors could be effectively eliminated by the immune system. Allison’s research directly led to the development of ipilimumab, the first therapy ever to demonstrate improved overall survival in a randomized clinical trial in patients with metastatic melanoma. Ipilimumab was an unprecedented success, curing several common cancers even at end stages. Allison’s work broke ground for the rapid advancement of novel immunotherapeutic drugs. New therapies continue to extend his work to target other immune system “braking” molecules and are now being used to successfully treat melanoma, non-small cell lung cancers, kidney cancer, bladder cancer, head and neck cancers, and Hodgkin’s lymphoma. Allison’s innovative discoveries and their successful translation into new therapies have saved the lives of countless patients with advanced cancers.

Perhaps Allison’s disposition makes him an ideal scientist. He is unafraid to fail. David Raulet, a former colleague at UC Berkeley, has commented that Allison always “had a steady eye towards how to apply fundamental knowledge for treating diseases and was quick to strike when such opportunities arose.” This description is apt as it is unexpected: Allison is mellow. Now back in Texas, he plays harmonica and still gets star struck by country music legend Willie Nelson, even though he has soloed with him in front of tens of thousands at the Austin City Limits music festival.

Allison is widely recognized for transforming contemporary thinking about cancer and its interaction with the immune system, and for inspiring a paradigm shift in the treatment of patients with debilitating and fatal disease. Further confirmed by his receipt of the Nobel Prize in Physiology or Medicine in 2018, Allison’s work has truly marked the dawn of a new era in cancer treatment.

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Chair, Committee on Science and the Arts Life Science Cluster
Professor, Department of Biochemistry and Molecular Biology
Drexel University College of Medicine
Philadelphia, Pennsylvania
Member of Committee on Science and the Arts since 1998

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James Allison’s Laureate Legacy

The laureate legacy recognizes previous laureates connected to the current laureate by a shared intellectual thread.

1909  MARIE CURIE AND PIERRE CURIE
1968  MARSHALL WARREN NIKENBERG
1982  CESAR MILSTEIN
1987  STANLEY COHEN
1997  MARIO CAPECCHI
2005  ELIZABETH H. BLACKBURN
2008  VICTOR AMBROS, DAVID BAULCOMBE, AND GARY RUVKUN
2010  PETER C. NOWELL
2013  RUDOLF JAENISCH
2016  ROBERT S. LANGER

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Learn more about Dr. Allison and his work at “Immune Checkpoint Blockade in Cancer Therapy: New Insights, Opportunities, and Prospects for Cures” on April 10 at Drexel University College of Medicine.
— See page 5 for details.
When John Rogers is faced with a problem, he locks on until he finds a solution. His career, which crosses fields as diverse as materials science, neurological surgery, computer engineering, and chemistry, is all-consuming. But Rogers wouldn’t have it any other way: tirelessly ambitious, his top priority is to develop patient-friendly technologies that can provide insight into our health, extend our lifespans, and enhance understanding of how the human body works.

The results of his efforts speak for themselves. Rogers, director of the Center for Bio-Integrated Electronics at Northwestern University, has developed wireless systems used by medical professionals to assess, diagnose, and treat heart and brain diseases. He has created ultra-miniaturized implants that can be injected into patients to study brain function and provide electrotherapy to treat neurological disorders. Some of his implants can even deliver drugs directly to a targeted organ and then absorb safely into the body, with no additional surgery needed.

All of these inventions are incredible—but it is the development of wearable technologies called “epidermal electronic systems” (EES) that have the greatest immediate potential to transform medical care forever. During his 13-year tenure at the University of Illinois, Rogers perfected his EES devices. They can wirelessly extract, monitor, process, and communicate information from inside the body without requiring surgical implants. They adhere easily to the skin, like a temporary tattoo, and are so flexible that the natural bending, stretching, and twisting of patients’ skin do not cause any damage to the electronics. Data is collected and transmitted wirelessly to a smartphone or tablet.

Conventional electronic medical monitoring devices tether patients to their beds with bulky cords and require the use of sticky, skin-irritating electrodes and obtrusive fluid ports. Such monitors are uncomfortable and cumbersome for adults and, for certain patients, can present heightened risks. For example, nearly 300,000 babies are born prematurely in the United States each year and require monitoring in the Intensive Care Unit that can last for months. Because premature newborns’ skin is often underdeveloped, typical adhesives can cause injuries and scarring. The cords restrict movement and natural interactions between the baby and mother, which may delay bonding and emotional development. Rogers’s neonatal heart monitor has the potential to change all of this: a thin, skin-like membrane just bigger than a postage stamp is placed on the baby’s chest using no adhesives at all. The monitor requires no on-board power source—so there are no cumbersome power cords—and wirelessly communicates clinical-quality information. The device is so gentle that it has been used successfully on babies as young as 26 weeks gestational age—the most fragile preemies.

But Rogers doesn’t stop with laboratory research. He wants his devices out in the real world, where they can have an authentic impact on our daily lives. His team secured funding from the Gates Foundation and the Save the Children Foundation to distribute 20,000 neonatal heart monitors to underdeveloped areas of India, Pakistan, and Zambia where no monitoring capability for premature babies exists.
Blending science and technology has been a motivator since Rogers’s early days at Bell Laboratories. Renowned for its innovation and advances in fundamental physics, materials science, and development of new technologies, Rogers credits Bell Labs for his commitment to economically sustainable manufacturing practices and marketing of his technologies. In fact, he has translated his scientific breakthroughs through the commercialization of more than 100 patents, by co-founding eight companies, and by collaborating with major players like Medtronic, Reebok, and L’Oreal.

Take Rogers’s battery-free UV-radiation meter, which has been lauded by dermatologists as groundbreaking. As rates of melanoma skin cancer is increasing, Rogers says, it is important to have a device that can provide UV information so people can make healthier choices about sun exposure. Importantly, the device must be easy to use—which is why the UV device is so small that it’s worn on a fingernail and is durable enough to withstand a run through the washing machine.

Other new technologies will be on shelves soon, including a device that can measure both biophysical (heart rate, breathing, muscle tone) characteristics and biochemical assessments. In a major partnership with Gatorade, this new device will monitor the impact of hydration on athletic performance by measuring electrolyte, lactic acid, and glucose concentrations contained within sweat. An exciting potential exists for this technology’s use in clinical applications: if glucose levels can be measured accurately with sweat, patients with diabetes could one day self-monitor without a finger prick.

Rogers’s tremendous accomplishments have only just begun. From the most delicate infants to star athletes, users of all kinds are poised to benefit from Rogers’s revolutionary innovations.

John Rogers’s Laureate Legacy

The laureate legacy recognizes previous laureates connected to the current laureate by a shared intellectual thread.

1962 THEODORE H. MAIMAN
1966 JACK S. KILBY AND ROBERT N. NOYCE
1971 PAUL JOHN FLORY
1975 FREDERICK P. HERMAN, STEVEN R. HOFSTEIN AND FRANK R. WANLASS
1877 ALBERT V. CREWE
1989 CHARLES W. OATLEY
1996 RICHARD E. SMALLEY
2004 ROBERT NEWNHAM
2009 GEORGE M. WHITESIDES
2012 LOUIS E. BRUS
2012 ZVI HASHIN
2017 MILDRED S. DRESSELHAUS

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Learn more about Dr. Rogers and his work at “Bioresorbable Electronic Medicines” on April 8 at Penn State University, “From Inspiration to Impact—Science That Engineers Innovation” on April 8 at The Franklin Institute, and “Soft, Body-Integrated Microsystems Technologies” on April 10 at Temple University. — See pages 4 and 5 for details.
The 2019 Franklin Institute Laureates

BENJAMIN FRANKLIN MEDAL IN PHYSICS

John J. Hopfield, Ph.D.
Howard A. Prior Professor of Molecular Biology, Emeritus
Princeton University
Princeton, New Jersey

CITATION:
For applying concepts of theoretical physics to provide new insights on important biological questions in a variety of areas, including neuroscience and genetics, with significant impact on machine learning, an area of computer science.

John Hopfield, professor of molecular biology at Princeton University, began his career as a solid-state physicist. Over nearly six decades, he has used his knowledge and experience to cross borders between scientific disciplines, for example, to illuminate physical concepts underlying biological and biochemical processes. A true adventurer, Hopfield is not focused on disciplinary constraints; he cares more about asking questions, tackling potential solutions, and moving on once the problem yields.

Born to two physicists, as a child, Hopfield built model airplanes and crystal set radios. He enjoyed blanket permission to dismantle whatever he wished in the house—as long as everything was returned to its original condition. Becoming a scientist or engineer was never a question: Hopfield’s primary motivation had always been to understand how things work. Whether pertaining to cosmology, biology, the transistor, or the human brain, the physics of our world has been a constant inspiration.

Hopfield earned his undergraduate degree in physics from Swarthmore College in 1954 and completed his Ph.D. at Cornell University in 1958. His career as a solid-state physicist (using quantum mechanics, crystallography, electromagnetism, and metallurgy to study solid matter) began in earnest in 1958 after he joined the prestigious Bell Laboratories as a member of the technical staff. He attributes his tireless work ethic to the experts he encountered at Bell Labs and the quality of their research, and to the high standards he had to meet there.

While at Bell Labs, Hopfield learned that his talent was often best expressed in finding simple answers to complex problems. But the more he learned about a topic, the deeper his questions probed and the more difficult it became to limit his inquiries to the field of solid state physics. His scientific contributions began to intersect with many fields, and would inspire not only fellow physicists, but, also biologists, engineers, computer scientists, and psychologists.

A major contribution to the field of genetics came in 1974, when Hopfield demonstrated that the high degree of accuracy present in genetic expression could be explained by coupled chemical reactions called “kinetic proofreading.” Hopfield described kinetic proofreading as a mechanism for error correction in biological reactions, such as protein synthesis. It is essential in all steps of gene expression and in the immune system’s ability to identify foreign substances.

But Hopfield was not one to linger on any particular question for too long. He describes himself as the type of person who will try most anything but prefers to move on once his understanding reaches an acceptable level. It is why, he says, he is a poor piano player, sailor, skier, tennis player, and golfer—but it also provokes him to ask more complex questions of the world around him. In the
1980s, Hopfield boldly focused his attentions to the most complex and elusive system in the Universe: the human brain—whose mysteries he continues to pursue today, nearly 40 years later.

In 1982, Hopfield developed a model of neural networks to explain how memories are recalled by the brain. The Hopfield model explains how systems of neurons interact to produce stable memories and, further, how neuronal systems apply simple processes to complete whole memories based on partial information. This neural network approach to memory further emboldened a new generation of physicists to look with fresh eyes at other complex interacting systems and to branch out into other areas of science.

The contemporary impact of the Hopfield model is evident in fields as diverse as physics, biology, and computer science. By constructing an artificial neural network capable of modeling certain functions of the human brain, machines can now use these processes to store “memories.” This technological advance unleashed a tide of deep learning technologies in which machines learn from the external world: Smartphones recognize our faces or fingerprints to unlock. Self-driving cars learn to drive by watching us behind the wheel. Our machines now observe, learn, and remember on their own. Hopfield’s work expanded the horizons of physics, making it clear how local computations could give rise to global outcomes.

John Hopfield’s Laureate Legacy

The laureate legacy recognizes previous laureates connected to the current laureate by a shared intellectual thread.

1926  NIELS BOHR
1972  BRIAN D. JOSEPHSON
1982  KENNETH G. WILSON
1986  BENOIT MANDELBROT
1986  LEO KADANOFF
1989  EDWARD LORENZ
1990  HUGH E. HUXLEY
1992  ROLF LANDAUER
2011  JOHN R. ANDERSON
2012  VLADIMIR VAPNIK
2017  MICHAEL I. POSNER

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*Member, The Franklin Institute Committee on Science and the Arts
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The mission of The Franklin Institute’s Committee on Science and the Arts is to sustain the scientific character of The Franklin Institute through the investigation of worldwide scientific and technological achievements and its recommendations for the awarding of Benjamin Franklin Medals and the Bower Award and Prize for Achievement in Science. The Committee maintains high standards for awarding the medals using the following selection criteria:

- The committee carefully selects candidates using a thorough case investigation process to recognize those scientists and engineers who lead their fields, expand knowledge, and serve humanity.
- Individuals must be nominated for an invention, discovery, technological development, or a body of such work reflecting uncommon insight, skill, or creativity on the part of the candidate.
- The work must have significant scientific value or proven utility. It must have provided significant direction for future research, solved an important problem, or provided great benefit to the public.
- Candidates for the award must be living persons.
- The Committee considers individuals from all over the world.

Committee members who become case sponsors represent their nomination cases before the full committee for review and action. Following two successful case presentations, including a review of letters of evaluation solicited from preeminent experts in the field of the case, the nomination is forwarded to the Institute’s Board of Trustees for final review and approval. During the following spring, medalists are brought together at The Franklin Institute for the annual Awards Ceremony and Dinner and Awards Week celebration of science.

The all-volunteer Committee on Science and the Arts is composed of scientists and engineers from academia and industry. Meeting regularly throughout the year, it has a reputation for diligence and integrity. The committee’s work reflects the mission of The Franklin Institute and provides a valuable service to the public and to the scientific community.

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