THE KAVLI PRIZE

Science Prizes for the Future

press release

Research in observational X-ray astronomy, inventions of aberration-corrected lenses in electron microscopes, and the discovery of sensory receptors for temperature and pressure win USD 3 million Kavli Prizes

Seven scientists from five countries honoured for breakthrough discoveries in astrophysics, nanoscience and neuroscience

May 27, 2020 (OSLO) — The Norwegian Academy of Science and Letters today announced the 2020 Kavli Prize Laureates in the fields of astrophysics, nanoscience and neuroscience. This year's Kavli Prize honours scientists whose research has transformed our understanding of the very big, the very small and the very complex. The laureates in each field will share 1 million USD.

This year's Kavli Prize Laureates are:

- **Kavli Prize in Astrophysics:** Andrew Fabian (UK)
- **Kavli Prize in Nanoscience:** Harald Rose (Germany), Maximilian Haider (Austria), Knut Urban (Germany) and Ondrej L L Krivanek (UK and Czech Republic)
- **Kavli Prize in Neuroscience:** David Julius (US) and Ardem Patapoutian (US)

"The 2020 Kavli Prize Laureates represent truly pioneering science, the kind of science which will benefit humanity in a profound way, inspiring both current and future generations," says Hans Petter Graver, president of The Norwegian Academy of Science and Letters.

The 2020 Kavli Prize Laureates

Understanding the role of black holes in the 'ecosystem' of galaxies

The Kavli Prize in Astrophysics is awarded to astronomer and astrophysicist ***Andrew Fabian*** for his pioneering research and persistence in pursuing the mystery of how black holes influence their surrounding galaxies on both large and small scales. For decades, researchers have pondered the mechanics and physical processes of galaxies, and many have made discoveries that point to aspects of their inner workings; yet none has the unique vantage point of Fabian: to take a multi-scale understanding and systematically know where to look to put the pieces of the puzzle together and create the bigger picture of this vast ecosystem.

In the current cosmological paradigm, the universe is a 'living' system, in which the flows of gas into galaxies and black holes at their centres, and the subsequent release of energy back into the galaxies and their surroundings, all play vital roles. As the darkest objects in the universe, black holes are observed as their gravity attracts surrounding gas, dust and stars, which swirl into them at high velocities, creating intense radiation, much of it X-rays. Observational X-ray astronomy opened up access to view these and other extremely hot and energetic components of the universe, providing stunning evidence for these processes at work, unveiling how the major constituents of the universe can profoundly influence its overall evolution.

Fabian, a professor at the University of Cambridge, employs X-ray astronomy to explore the physics of the universe. His body of work – from understanding large-scale galactic evolution to the physics of black holes at the centres of galaxies – enabled him to make connections between local conditions around supermassive black holes and the larger gas flows within and between galaxies. This research provided evidence that supermassive black holes at the heart of galaxies are the engines that drive the flow of hot gas out of the galaxy, redistributing energy through the universe and providing the building blocks for future galaxy formation.

"Andrew Fabian is one of the most prolific and influential astronomers of our time," said Viggo Hansteen, chair of the Kavli Prize Committee in Astrophysics. "His research, breadth of knowledge and insights into the universe provided the essential physical understanding of how disparate phenomena in this ecosystem are interconnected."

More details available at the Kavli Prize website: www.kavliprize.org

Enabling scientists to see what was once impossible

The Kavli Prize in Nanoscience is awarded to four scientists for their research and inventions of aberration-corrected lenses in electron microscopes that have created the ability for researchers worldwide to see the structure and chemical composition of materials in three dimensions on unprecedentedly short-length scales: ***Harald Rose*** of the Universität Ulm and Technical University of Darmstadt, ***Maximilian Haider*** of CEOS GmbH, ***Knut Urban*** of the Forschungszentrum Jülich, and ***Ondrej L Krivanek*** of Nion Co.

A major goal of nanoscience is to create materials and devices assembled with atomic scale precision to obtain novel functionalities. The size of an atom is around one ångström (0.1 nanometer), so imaging and analysis of materials and devices at the sub-ångström scale is crucial to illuminate the details of the nanoscale world. The resolution of a classical microscope is limited by the wavelength of the probe used for imaging. Because visible light has a wavelength around 5000 times larger than an atom, optical lenses simply cannot image atoms.

In the early part of the 20th century beams of electrons with atomic-scale wavelength became available, leading to the invention of the transmission electron microscope in 1931. With this type of microscopy, a beam of electrons is transmitted through a thin material, forming an image based on the electrons' interaction with it. The image is then magnified and focused onto an imaging device. But the resulting images were distorted and blurry because making ideal lenses to focus beams of electrons turned out to be a big theoretical and experimental hurdle. The problem persisted for over 60 years as both theorists and experimentalists struggled to find a solution. Thanks to their insights, skills and the increase in computational power in the 1990s, these researchers were able to construct aberration-corrected lenses relying on electromagnetic fields to focus beams of electrons, making sub-ångström imaging (less than one ten-billionth of a metre) and chemical analysis in three dimensions a standard characterization method.

The 1 million USD Kavli Prize is shared by:

- *Harald Rose*, for proposing a novel lens design, the Rose corrector, enabling aberration correction in transmission electron microscopy that can be applied to both conventional and scanning transmission electron microscopes.
- *Maximilian Haider*, for the realization of the first sextupole corrector, based on Rose's design, and for his role in the implementation of the first aberration-corrected conventional transmission electron microscope.
- *Knut Urban*, for his role in the implementation of the first aberration-corrected conventional transmission electron microscope.
- *Ondrej L Krivanek*, for the realization of the first aberration-corrected scanning transmission electron microscope (a type of transmission electron microscope in which the electron beam is focused on a small spot) with sub-ångström resolution, well suited for spatially resolved chemical analysis; obtained using a quadrupole-octuple corrector.

"Their work is a beautiful example of scientific ingenuity, dedication and persistence. They have enabled humanity to see where we could not see before," said Bodil Holst, chair of the Kavli Prize Committee in Nanoscience. "Honouring these scientists and sharing with the world who they are and how they have transformed research, technology, industries and our lives is more important than ever."

More details available at the Kavli Prize website: www.kavliprize.org

Discovering sensory receptors for temperature and pressure

The Kavli Prize in Neuroscience is awarded to ***David Julius*** and ***Ardem Patapoutian*** for their independent discoveries of sensory receptors for temperature and pressure, respectively. While the mechanisms for smell and vision have long been described, a specific molecular understanding for how physical properties like temperature and pressure are detected and encoded into electrical signals the brain can process had been lacking. Over the past two decades, Julius and Patapoutian have independently described the molecular mechanisms that underpin sensitivities to temperature and pressure, as well as pain, and provided new insights into human physiology and disease.

David Julius, a physiologist and professor at University of California, San Francisco used an elegant approach to discover how the body detects high and low temperatures by exploiting the fact that there are chemicals that mimic different temperatures – such as the heat of pungent chili peppers and the coolness of mint. Julius and his team began by employing capsaicin, the compound in chili pepper that elicits the sensation of heat, to identify the gene encoding the first known temperature-sensitive sensor, the ion channel named TRPV1. Julius further discovered that the TRPV1 channel is also activated by high concentrations of protons and chemical compounds generated during the inflammatory response, providing a molecular basis for the pain hypersensitivity observed in damaged and inflamed tissue. This ion channel is a molecular integrator for both temperature sensing and inflammatory signals. Hotness – whether the burn from a spicy chili pepper or the burn from piping hot coffee – is encoded by the same sensor.

Genetic experiments conducted by Julius then showed that mutant mice deficient for TRPV1 have reduced heat sensitivity and a marked reduction in inflammatory and cancer pain. This discovery led to the identification of a family of channels involved in sensing specific ranges of warm and cold temperatures as well as irritants and inflammatory processes that may result in debilitating pain. In other experiments, Julius and collaborators identified these channels as infra-red heat sensors in vampire bats and snakes, and as targets of spider and scorpion toxins, further validating their roles in temperature and pain sensation throughout the animal world. The newly discovered TRPV1 and related channels are now areas for development of new pain-relieving drugs.

Ardem Patapoutian, a professor at Scripps Research and an investigator at the Howard Hughes Medical Institute, discovered a family of pressure-sensitive ion channels, the PIEZOs, with deep evolutionary roots, as they are present in many distantly related species.

Patapoutian and colleagues employed cells from a neuroblastoma cell line, which can be grown in a dish in a laboratory setting. These cells respond to pressure changes from a light touch by generating an electrical signal. With a curated list of over 300 suspected genes (out of the more than 20,000 that exist in our DNA) that might encode for a pressure-sensitive channel, they grew cultures of cells missing one gene at a time. Patapoutian's lab then tested the samples one by one, looking for the gene that, when missing, resulted in cells without pressure-sensing abilities. Candidate gene #72 on the list turned out to be the one.

PIEZOs were soon confirmed by Patapoutian to be essential for pressure sensing in mammals. His work showed that PIEZOs form ion channels and that they are directly responsible for pressure-sensing by Merkel cells and touch sensory terminals in the skin, and by proprioceptors (sensory receptors with endings in the muscle that respond to the body's position and movement in space).

PIEZOs also sense pressure by nerve terminals in blood vessels and in the lungs and affect red blood cell volume, vascular physiology and underlie a broad range of human genetic disorders. The discovery of the PIEZOs opened the door to understanding mechanobiology, an emerging field of science that intersects biology, engineering and physics, and focuses on how physical forces and changes in the mechanical properties of cells and tissues contribute to health and disease.

"The individual discoveries of David Julius and Ardem Patapoutian have given the scientific community the molecular and neural basis for thermosensation and mechanosensation that is revolutionizing our understanding of sensory detection and will have a profound impact on addressing health and disease worldwide," said Kristine B. Walhovd, chair of the Kavli Prize Committee in Neuroscience.

More details available at the Kavli Prize website: www.kavliprize.org

Kavli Prize Committees

Astrophysics
Viggo Hansteen (Chair), *University of Oslo, Norway*
Alessandra Buonanno, *Max Planck Institute for Gravitational Physics, Germany*
Andrea Ghez, *University of California Los Angeles, US*
Robert C. Kennicutt, Jr, *University of Arizona, US*
Irwin I. Shapiro, *Harvard University, US*

Nanoscience
Bodil Holst (Chair), *University of Bergen, Norway*
Gabriel Aeppli, *Paul Scherrer Institut, Switzerland*
Susan Coppersmith, *University of New South Wales, Australia*
Shuit-Tong Lee, *Soochow University, China*
Joachim Spatz, *Max Planck Institute for Medical Research, Germany*

Neuroscience
Kristine B. Walhovd (Chair), *University of Oslo, Norway*
Alexander Borst, *Max Planck Institute of Neurobiology, Germany*
Catherine Dulac, *Harvard University, US*
Mary E. Hatten, *The Rockefeller University, US*
Denis Le Bihan, *NeuroSpin, CEA, France*

About The Kavli Prize

The Kavli Prize is a partnership between The Norwegian Academy of Science and Letters, the Norwegian Ministry of Education and Research and The Kavli Foundation (US). The Kavli Prize honours scientists for breakthroughs in astrophysics, nanoscience and neuroscience that transform our understanding of the very big, the very small and the very complex. Three million-dollar prizes are awarded every other year in each of the three fields. The Norwegian Academy of Science and Letters selects the laureates based on recommendations from three prize committees whose members are nominated by The Chinese Academy of Sciences, The French Academy of Sciences, The Max Planck Society of Germany, The U.S. National Academy of Sciences and The UK's Royal Society. First awarded in 2008, The Kavli Prize has honoured 54 scientists from 13 countries – Austria, Czech Republic, France, Germany, Japan, Lithuania, The Netherlands, Norway, Russia, Sweden, Switzerland, the United Kingdom and the United States.

For more detailed information on The Kavli Prize, the 2020 laureates and their work, visit www.kavliprize.org.

The Kavli Prize Laureates are typically celebrated in Oslo, Norway, in a ceremony presided over by His Majesty King Harald followed by a banquet at the Oslo City Hall, the venue of the Nobel Peace Prize. Due to the COVID-19 pandemic, this year's award ceremony is postponed and will be held together with the 2022 award ceremony in September 2022.

For more information, please contact:

Marina Tofting (Norway)
The Norwegian Academy of Science and Letters
+ 47 938 66 312
marina.tofting@dnva.no

Stacey Bailey (United States)
The Kavli Foundation
+ 310 739 2859
sbailey@kavlifoundation.org