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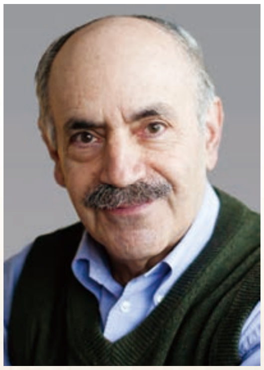
Japan Prize News
No. 64 Feb. 2021

JAPAN PRIZE

2021 Japan Prize Laureates Announced

Prof. Martin Andrew Green
Professor, University of New South Wales (UNSW Sydney)
Australia

Prof. Bert Vogelstein
Professor, Johns Hopkins University School of Medicine
USA



Dr. Robert A. Weinberg
Member, Whitehead Institute for Biomedical Research
Professor, Massachusetts Institute of Technology (MIT)
USA

Fields Eligible for the Award:
Resources, Energy, Environment, Social Infrastructure

Development of High-Efficiency Silicon Photovoltaic Devices

Prof. Martin Green has pioneered the development of high-efficiency silicon photovoltaic devices and contributed significantly to the realization of solar power that is now cheaper than fossil fuel power.

Especially, he made great achievements in increasing power conversion efficiency dramatically from around 17% to 25% by innovating advanced technologies and integrating them into practical devices that now make the transition to a low-carbon society realistic.

He has also trained the researchers and entrepreneurs who have played key roles in industrial development and in reducing the price of silicon photovoltaic devices.

Fields Eligible for the Award:
Medical Science, Medicinal Science

For their pioneering work in conceptualizing a model of multi-step carcinogenesis and its application and impact on improving cancer diagnosis and therapeutics

In spite of improved survival rates, the grim fate of most diagnosed patients is to succumb to the disease or one of its associated comorbidities. Improved survival rates over the last several decades are, in part, the result of discovery of novel anti-cancer agents. The medical advancements underpinning discovery of novel therapeutics and improvements in access to care, and early detection were predicated on innumerable basic and clinical research findings that have elucidated the inner workings of cancer development and survival mechanisms. Understood as a general principle, cancer arises through the accumulation of genetic and epigenetic mutations and alterations that are favorable to the survival and expansion of the tumor cells. This concept has been termed “multi-step carcinogenesis model” and has served as a reliable and accepted foundation for subsequent oncological research. Many of the seminal studies underpinning the multi-step carcinogenesis model were the research discoveries made by Drs. Robert Weinberg and Bert Vogelstein.

JAPAN PRIZE

The creation of the Japan Prize was motivated by the Japanese government’s desire to “contribute to the development of science and technology worldwide by establishing a prestigious international award”. Supported by numerous private donations, the Japan Prize was established in 1983 with a cabinet endorsement.

This award honors scientists and researchers worldwide who are recognized for having contributed signifi cantly to the peace and prosperity of humankind through their original and outstanding achievements that have greatly advanced the progress of science and technology.

The eligible fields of this award cover all fields of science and technology. Every year, two fields for the award presentation are chosen by considering the developments in science and technology.

As a general rule, one award is given for each field and each laureate receives a certificate of merit, a prize medal and a cash prize.

The Presentation Ceremony is held annually in the presence of Their Majesties the Emperor and Empress of Japan and is also attended by the Speaker of the House of Representatives, the President of House of Councilors, the Chief Justice of the Supreme Court, and various ministers as well as eminent figures from various circles.

"Resources, Energy, Environment, Social Infrastructure" Field

Achievement : developing high-efficiency silicon photovoltaic devices

Prof. Martin Andrew Green (Australia)
Born: July 20, 1948 (Age: 72)
Professor, University of New South Wales (UNSW Sydney)

Predicted Growth of Solar Power

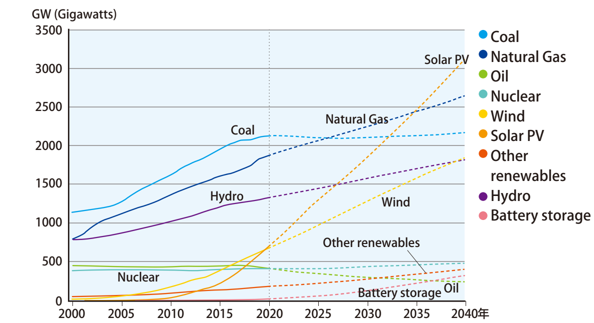
In order to realize our dreams of achieving a decarbonized society, there needs to be a shift towards the use of electrical power generated by renewable sources that do not emit carbon dioxide, a contributing factor to global warming. Renewables include solar, wind, and geothermal power, but in the past, introducing such sources was difficult due to the increased costs when compared to fossil fuel-fired plants and hydroelectric power.

In the mid-2010s, solar power costs dropped below those of fossil fuel power, and thus began the era of solar power plants being able to be built cheaper than fossil fuel plants. Solar power generation is expected to undergo rapid expansion in the future (see below graph). Behind this paradigm shift is the ability of photovoltaic devices (commonly known as solar cells) to convert solar energy to electric power at high rates of efficiency, and the reduction in power generation costs that have allowed for the construction of large-scale solar power plants. Prof. Green has been working on improving conversion efficiency of crystalline silicon photovoltaic devices since the 1970s, and he has achieved many successes over that time.

The mechanisms behind solar photovoltaic devices and solar power generation

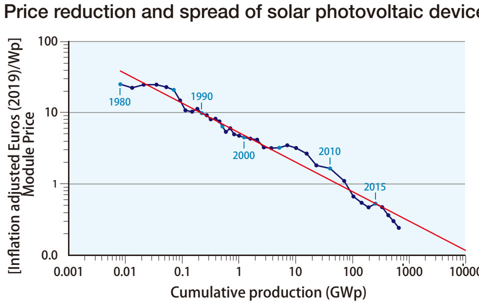
There are many types of devices that generate power from sunlight, but crystalline silicon (a type of semiconductor) is said to be found in approximately 95% of photovoltaic devices in use around the world. The

Installed power generation capacity by source in the State Policies Scenario, 2000-2040



Source: IEA World Energy Outlook 2019

Price reduction and spread of solar photovoltaic devices



Up until 2000, improvements in conversion efficiency were a major factor in the reduced cost of solar photovoltaic devices, but in the 2000s, the increased size of power plants also began to contribute to lower prices. Prof. Green has contributed to both, having been involved in both technological development and the cultivation of individuals who are involved in the evolution and expansion of solar power generation. (Source: Photovoltaics Report, Fraunhofer Institute for Solar Energy Systems, ISE with support of PSE Projects GmbH, 16 September 2020)

majority of those are p-n junction solar cells, which have p-type silicon is placed adjacent to n-type silicon. When struck by photons from the sun, the energy causes the release of a negatively-charged electron and a positively-charged "hole," whereby the electron moves into the n-type silicon and the hole moves into the p-type silicon. That charge then flows out the electrodes (or contacts) as electrical power.

A high power conversion efficiency can be obtained if every electron-hole pair that is generated can be extracted as power, but in practice, energy is lost when the electrons and holes recombine. (see below figure.)

PERC solar cells and Prof. Green's role in improving solar cell efficiency

The first efficient p-n-junction crystalline silicon solar cell was demonstrated by Daryl. M. Chapin, Calvin S. Fuller, and Gerald L. Pearson at Bell Labs in 1954. From 1972 to 1974, Joseph Lindmayer, James F. Allison, Joseph G. Haynos and colleagues at COMSAT Laboratories improved power conversion efficiency to nearly 17%. However, there were no further improvements in power conversion efficiency for nearly a decade.

In 1975, Prof. Green then provided fresh insight into the processes determining the recombination of electrons and holes excited by sunlight and suggested much higher conversion efficiency of 25% was experimentally feasible. In 1983, he and his team realized a record efficiency of 18%. This was the first in a series of 18 certified efficiency records by his team, achieving 24.7% efficiency in 1999 (reaching his target of 25.0% by recalibration in 2008).

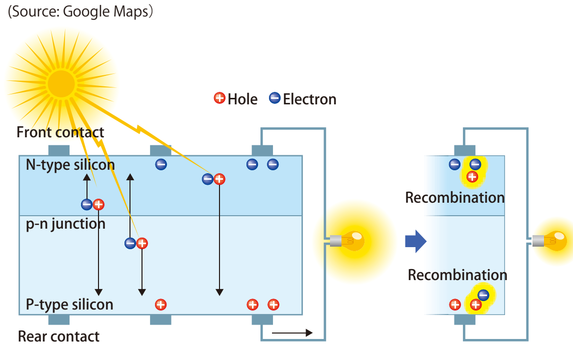
The PERC cell that he invented included measures for not only reducing recombination along the top region of the cell (the "emitter") but also along the rear of the cell as well. This PERC structure now dominates the photovoltaic device market.

Building a more secure society with solar power generation

The decades-old notion, that renewable energy is important for global environmental protection but is too expensive, has completely changed, as the society-wide adoption of photovoltaics has made solar power cheaper than fossil fuel power. This change is encouraging companies to enter the sustainable energy market and is driving a policy push for renewable energy,

Source : Google Earth

Noor Abu Dhabi PV Power Plant, a gigawatt-level solar power plant in Abu Dhabi. This power plant is installed with the p-n junction crystalline silicon PERC cells invented by Prof. Green. PERC devices are considered environmentally friendly because they can generate between 10 and 30 times the amount of energy required to produce the devices, depending on location and technologies used. (Source: Google Maps)

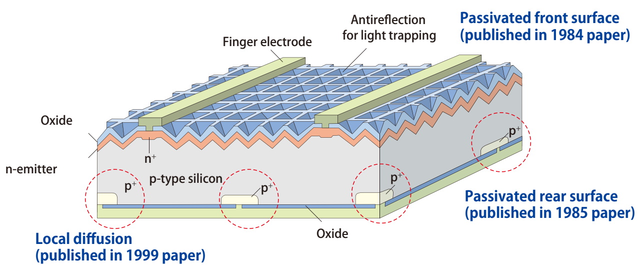


which in turn is accelerating the global movement towards a low-carbon/decarbonized economy. Nowadays, solar cells are recognized as a major solution to the challenges of sustainable energy and global warming, and various types of new solar cells are being actively researched and developed. Against this background, the time has come to recognize the achievements of Prof. Green, who developed a high-efficiency silicon solar cell that has provided an actual solution to global issues, along the way fostering many engineers and entrepreneurs who have transformed the industry.

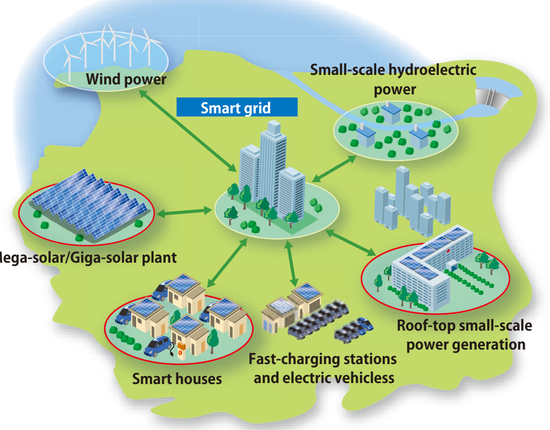
Solar power is a clean energy source not only because it emits no carbon dioxide when producing power, but also because solar power produces more energy than the energy used to manufacture and dispose of solar cells. Moreover, solar power can be flexibly adapted to meet various needs, from large-scale megawatt and gigawatt level power plants to small-scale residential generation using roof-top solar arrays. Distributed electric power generation through small-scale facilities can help reduce the severity and scale of damage caused during natural disasters. When solar power and other renewables become the backbone of our electric power generation infrastructure, we will have attained the ability to produce electricity in a more sustainable way.

History of improvements in power generation efficiency

1954	Bell Labs invents the first efficient crystalline silicon solar cell
1973	COMSAT Labs achieves 17% efficiency, an achievement that remains unbroken for nearly a decade
1975	Prof. Green proposes new concept suggesting potential 1.5 times increase in efficiency using advanced recombination suppression
1983	Prof. Green achieves 18% efficiency, which is achieved through passivation of the silicon-electrode interface and current extraction through the local tunnel junction
1983	Prof. Green invents PERC, which harnesses passivation on front and rear surfaces
1999	Prof. Green achieves 24.7% efficiency
2008	Prof. Green's solar cells certified at 25.0% efficiency



Prof. Green's high efficiency solar photovoltaic device (based on diagram in his 1999 paper) is now the mainstream device in the Si-PV market. The blue text denotes technologies developed by Prof. Green.



Large and small-scale solar power plants can be distributed throughout a region and can be tailored to match the natural and urban environments of the area. Other types of renewable energy power plants can also be constructed, and if the entire system is connected by a smart grid, it can redistribute power as needed and ensure continued power supply in the case of disaster .

"Medical Science, Medicinal Science" field

Achievement : For their pioneering work in conceptualizing a model of multi-step carcinogenesis and its application and impact on improving cancer diagnosis and therapeutics

Prof. Bert Vogelstein (USA)
Born: June 2, 1949 (Age: 71)
Professor, Johns Hopkins University School of Medicine

Dr. Robert A. Weinberg (USA)
Born: November 11, 1942 (Age: 78)
Member, Whitehead Institute for Biomedical Research
Professor, Massachusetts Institute of Technology (MIT)

Summary: Discoveries of oncogenes and tumor suppressor genes and proposal/verification of the multi-step carcinogenesis model.

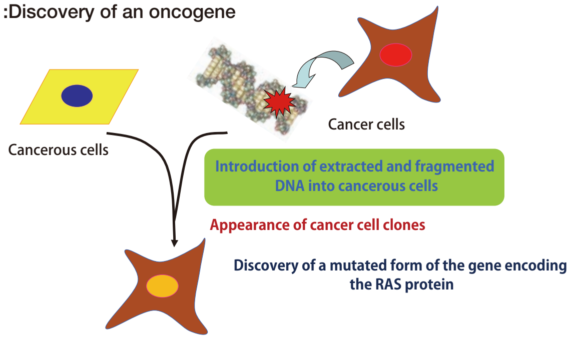
Dr. Weinberg discovered the presence of cellular genes, called proto-oncogenes, which can be converted to cancer-causing oncogenes by a mutation(s). He also contributed in the discovery of a gene, now called a tumor suppressor gene, that is required for the protection of cells to become cancer cells. Dr. Vogelstein independently searched for actual mutated genes in human cancer cells and discovered numerous new genes that are critical to the development of cancer. On the basis of these achievements, the concept of "multi-step carcinogenesis model" was established. Although many other investigators contributed to this field, Drs. Weinberg and Vogelstein stand out in that they continued their innovative research as the pioneers and leaders in corroborating this concept. In fact, Dr. Weinberg experimentally demonstrated the requirement of multiple oncogenes to convert normal cells into cancer cells, while Dr. Vogelstein verified the concept by molecular genetics combined with histopathology of large intestinal lesions, from which human colorectal cancers arise, to show the association of a series of mutations in cancer-associated genes. Thus, they revealed pivotal roles for certain human oncogenes and tumor suppressor genes in the propagation and suppression of numerous common human cancers. Their discoveries have also led to the opening of the field of cancer genomics, now an especially powerful force in discerning and developing mechanism-based human cancer diagnostics and therapeutics.

Dr. Weinberg's achievements

Dr. Weinberg helped launch this new era of human cancer genes. In elegant and original research, he introduced extracted and fragmented DNA from cancer cells and then introduced the fragmented DNA into cancerous cells and found an appearance of cancer cell clones (Fig. 1). When he then analyzed the cancer cell-derived genes in these cells, he discovered a mutated form of the *RAS* gene. Normal *RAS* gene product is important for the promotion of cell growth and it is transiently activated by cell growth signals and then converted into an inactive state to prevent excessive cell growth. On the other hand, the product of the mutated RAS continues to remain in the active form; in analogy to car driving, the driver keeps stepping on the accelerator (Fig. 2).

This "oncogene" was simultaneously discovered by other groups, but Dr. Weinberg further advanced his study using primary cultured cells, which cannot be transformed by the mutant *RAS* gene alone. He then demonstrated that these primary cells become cancer cells by introducing multiple oncogenes. During this research, Dr. Weinberg also assumed the presence of genes the products of which suppress cancer cell development and greatly contributed to the discovery of *RB* gene, the first of so-called "tumor suppressor genes"; in analogy to car driving, the driver puts on the brakes. Thus, these studies lead to the establishment of a paradigm that cancer will arise by the appearance of oncogenes and disappearance of tumor suppressor genes (Fig. 3).

Figure 1:Discovery of an oncogene



Dr. Vogelstein's achievements

Dr. Vogelstein took a different approach, using methods of molecular genetics combined with histopathology of large intestinal lesions to show that a series of mutations in cancer-associated genes (*i.e.*, *APC*, *RAS*, *TP53*, and others) were associated with the progression from benign adenomas to increasingly aggressive colon adenocarcinomas, establishing a foundation of multi-step carcinogenesis model (Fig.5). In fact, Dr. Vogelstein was among the first to demonstrate that *TP53*, which was originally considered as an oncogene, is a tumor suppressor gene. His discoveries, in parallel with those of Dr. Weinberg, have also led to the opening of the field of cancer genomics, now an especially powerful force in discerning and developing mechanism-based human cancer diagnosis and therapeutics. On the basis of the series of discoveries, Dr. Vogelstein has authored conceptual cornerstone of modern cancer research, namely, the *Vogelgram*.

Figure 2:Functional difference between the normal and mutated RAS proteins

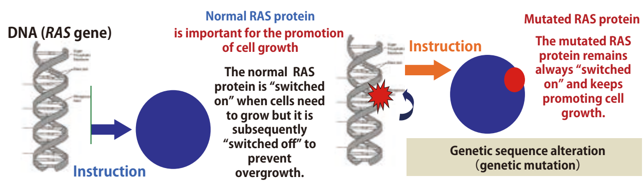


Figure 3:Development of cancer cell ; Outline

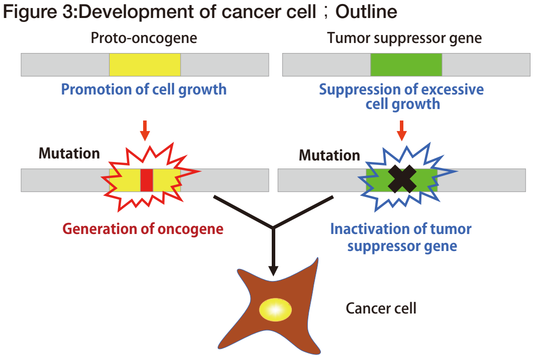
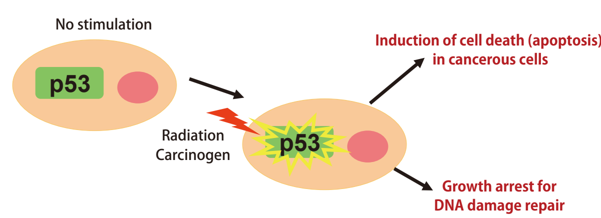


Figure 4:Action of normal tumor suppressor p53 (*TP53* gene product)

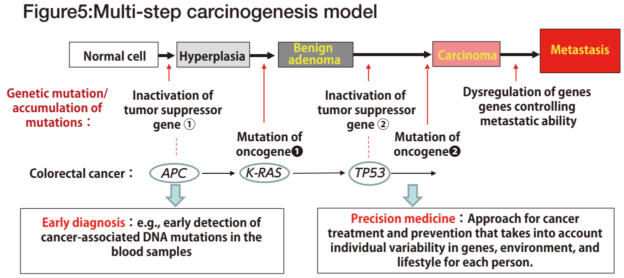


The ripple effects of the achievements by Drs. Weinberg and Vogelstein

The scientific and social contribution of the work by Drs. Weinberg and Vogelstein has been immeasurable to the cancer field. Their efforts have provided a paradigm of cancer progression that has shaped our view up through today. While this has produced important changes in how cancer is diagnosed and treated, the complexity of cancer evolution has proven much greater than any could have imagined. Drs. Weinberg and Vogelstein have published influential conceptual cornerstones articles of modern cancer research, namely, *Hallmarks of Cancer* by Dr. Weinberg, together with Dr. Douglas Hanahan (Fig. 6), and *Vogelgram* by Dr. Vogelstein (Fig. 5).

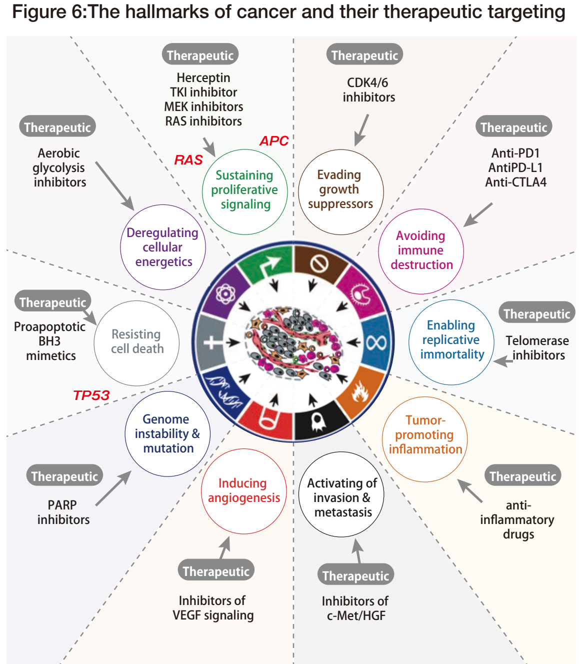
Overall, the paradigm set out by these two investigators has established principles that have enabled an understanding of the complexity of cancer, especially in providing a strong rationale for early cancer detection and intervention. Their accomplishments have served as the basis for many of the contemporary developments of targeted cancer therapies. Indeed, the notion of "precision medicine" in oncology has been synthesized from many of their ideas. Overall, their work has not only advanced basic cancer research, but also created the transformative field of cancer drug development that is improving the lives of many cancer patients.

Figure5:Multi-step carcinogenesis model



"Vogelgram" (modified from the original article of Fearon ER and Vogelstein B in Cell 61, 759-767, 1990)

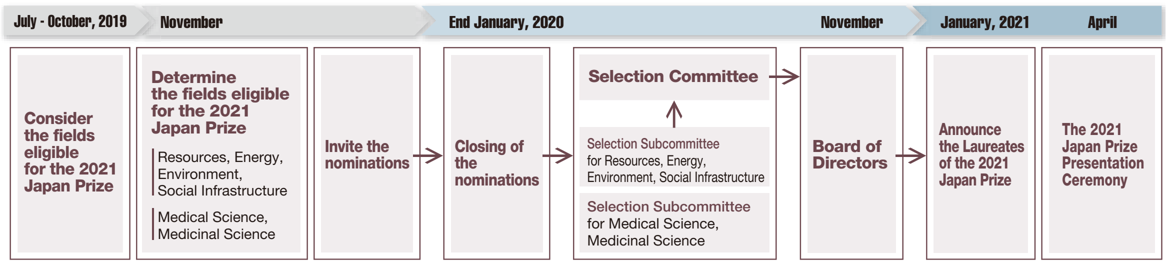
Figure 6:The hallmarks of cancer and their therapeutic targeting



"Hallmarks of cancer" (modified from the original in Hanahan D and Weinberg RA, Cell 144, 646-674, 2011)

Nomination and Selection Process

- Every November, the Field Selection Committee of The Japan Prize Foundation designates and announces two fields in which the Japan Prize will be awarded two years hence. At the same time, the Foundation calls for over 14,000 nominators, strictly comprised of prominent scientists and researchers from around the world invited by the Foundation, to nominate the candidates through the web by Web System. The deadline for nominations is the end of January of the following year.
- For each field, a Selection Subcommittee conducts a rigorous evaluation of the candidates' academic achievements. The conclusions are then forwarded to the Selection Committee, which conducts evaluations of candidates' achievements from a wider perspective, including contributions to the progress of science and technology, and significant advancement towards the cause of world peace and prosperity, and finally the selected candidates are recommended for the Prize.
- The recommendations are then sent to the Foundation's Board of Directors, which makes the final decision on the winners.
- The nomination and selection process takes almost two years from the time that the fields are decided. Every January, the winners of that year's Japan Prize are announced. The Presentation Ceremony is held in April in Tokyo.



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  Research Professor, Academic Advisor, Teikyo University
  Academic Advisor, Japan Society for the Promotion of Science
  Professor Emeritus, The University of Tokyo

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  TMDU Advanced Research Institute
  Tokyo Medical and Dental University
- **Yoshihiro Hayashi**
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  National Museum of Nature and Science
- **Hiroto Ishida**
  Director
  The Japan Prize Foundation
- **Kazunori Kataoka**
  Professor Emeritus/Project Professor, The University of Tokyo
  Vice Chairperson/Director-General of Innovation Center of NanoMedicine (iCONM), Kawasaki Institute of Industrial Promotion
- **Yoichiro Matsumoto**
  President
  Tokyo University of Science
- **Masayuki Matsushita**
  Director
  The Japan Prize Foundation
- **Shojiro Nishio**
  President
  Osaka University
- **Tadatsugu Taniguchi**
  Professor Emeritus, Advisor to the Office of President
  The University of Tokyo

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  President
  Tokyo University of Science

Deputy Chairman

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  Professor
  Organization for the Strategic Coordination of Research and Intellectual Properties

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  Research Institute for Value-Added-Information Generation
  Japan Agency for Marine-Earth Science and Technology
- **Yuya Kajikawa**
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  Tokyo Institute of Technology
- **Norichika Kanie**
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  Graduate School of Media and Governance, Keio University
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  The University of Tokyo
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  Faculty of Science and Engineering, Waseda University
- **Taikan Oki**
  Professor
  Graduate School of Engineering, The University of Tokyo
- **Nobuko Saigusa**
  Director, Center for Global Environmental Research
  National Institute for Environmental Studies
- **Chiharu Tokoro**
  Professor
  Faculty of Science and Engineering
  Waseda University

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  Professor Emeritus
  Advisor to the Office of President
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  Graduate School of Medicine
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  Executive Vice President, The University of Tokyo
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  Institute of Industrial Science, The University of Tokyo
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  Team Leader, Laboratory for Organismal Patterning
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- **Midori Kamimura**
  Distinguished research scientist
  TEIJIN PHARMA LIMITED
- **Hideki Katagiri**
  Vice Dean
  Tohoku University School of Medicine
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- **Junko Takita**
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- **Kazuhiko Yamamoto**
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  RIKEN Center for Integrative Medical Sciences
- **Motoko Yanagita**
  Professor
  Graduate Schools Medicine, Kyoto University
- **Yoshihiro Yoneda**
  Director General
  National Institutes of Biomedical Innovation, Health and Nutrition

(alphabetical order, titles as of January, 2021)

Eligible Fields for the 2022 Japan Prize

Areas of Physics, Chemistry, Informatics, and Engineering

Materials and Production

Background and Rationale:

The discovery and development of new materials with non-conventional properties and the development of advanced production technologies have brought about numerous innovations, thereby contributing greatly to the sustainable development of our society and to the improvement of safety in social infrastructure. We have designed and synthesized artificial materials, such as semiconductors, polymers, nanomaterials, catalysts, magnetic materials, and new types of structural materials, and have seen notable progress in materials design for responsible consumption and production. We have also developed new industrial technologies, such as design and manufacturing technologies supported by computational and data science, high-resolution/highprecision measurement technologies, robotics, and precise nanostructure control process.

In order to make effective use of finite resources and build a sustainable society for the future, we are in need of epoch-making innovations in the development of new functional materials and structural materials, as well as in industrial design and production & operation technologies.

Eligible Achievements:

The 2022 Japan Prize in the fields of Materials and Production will be awarded to an individual or individuals who have made momentous scientific and technological breakthroughs that contribute significantly to the sustainable development of society or to its potential for great advances in the future. Such achievements will include the development of materials with new functions, development of new structural materials that support social infrastructure or improvement of technologies for industrial design and production & operation, which enable the creation of new products, services and industries that improve the quality and safety of people's lives.

Areas of Life Science, Agriculture, and Medicine

Biological Production, Ecology/Environment

Background and Rationale:

The existence of humankind is completely dependent on the sustainable and diverse use of Earth’s biological resources. However, the global expansion of human activities coupled with the increase in population is decimating the natural environment and biodiversity forcing humanity to reconsider how biological resources are used.

In order to improve the situation, it is necessary to perceive biological production, the environment, and ecological integrity from a unified viewpoint. This requires advancements in fundamental science that enable us to conserve the invaluable environment and ecosystems, protect biodiversity, and sustainably use ecosystem services, and the creation of scientific and technological innovations, including earth observation and ecosystem modeling. For the sustainable use of biological productivity, we require new developments including the creation of new breeds through genome editing, the application of ICT, AI and robotics for advanced production, the realization of environmentally friendly biological production, the harnessing of useful substances from organisms, the enhancement of food functionality, and the reduction of food loss and waste.

Eligible Achievements :

The 2022 Japan Prize in the fields of Biological Production, Ecology/Environment will be awarded to an individual or individuals who have significantly contributed to the creation, development, and dissemination of scientific and technological breakthroughs that enable the sustainable development of human society in harmony with the ecosystem, or to its potential for great advances in the future. This year's Prize places emphasis on contributions to the advancement of basic science in ecology and the environment, and progress in biological production technologies.

Fields Selection Committee for the 2022 Japan Prize

Chairman

- **Michiharu Nakamura**
  Counselor to the President
  Japan Science and Technology Agency
  Director, The Japan Prize Foundation

Vice Chairman

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  National Institute for Materials Science
- **Kohei Miyazono**
  Professor
  Department of Molecular Pathology
  Graduate School of Medicine, The University of Tokyo

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  President, Josai University
  Professor Emeritus, The University of Tokyo
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  Professor, Graduate School of Science and Engineering, Soka University
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- **Eiichi Nakamura**
  University Professor
  Department of Chemistry
  Graduate School of Science, The University of Tokyo
- **Yuichi Sugiyama**
  Head
  Sugiyama Laboratory, RIKEN Baton Zone Program
- **Mariko Takahashi**
  The Science Coordinator
  The Asahi Shimbun
- **Masayuki Yamamoto**
  Professor Emeritus, The University of Tokyo
  Professor Emeritus, National Institute for Basic Biology

(alphabetical order, titles as of November, 2020)

Schedule (2022-2024)

The eligible fields for the Japan Prize (2022 to 2024) have been decided for the two research areas, respectively.

These fields rotate every year in a three year cycle.

Every year the Fields Selection Committee announces the eligible fields for the next three years.

Areas of Physics, Chemistry, Informatics, and Engineering

Year	Eligible Fields
2022	Materials and Production
2023	Electronics, Information, and Communication
2024	Resources, Energy, Environment, and Social Infrastructure

Areas of Life Science, Agriculture, and Medicine

Year	Eligible Fields
2022	Biological Production, Ecology/ Environment
2023	Life Science
2024	Medical Science and Medicinal Science