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Japan Prize News
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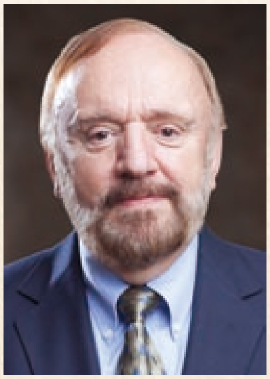
JAPAN PRIZE

2013 Japan Prize Laureates Announced

Prof. C. Grant Willson and Prof. Jean M. J. Fréchet for development of chemically amplified resist polymer materials for innovative semiconductor manufacturing process
Dr. John Frederick Grassle for contribution to marine environmental conservation through research on ecology and biodiversity of deep-sea organisms

"Materials and Production" field

Prof. C. Grant Willson
Professor of Chemistry and Chemical Engineering
The University of Texas at Austin
USA



Prof. Jean M. J. Fréchet
Vice- President for Research
King Abdullah University of Science and Technology
USA

"Biological Production and Biological Environment" field

Dr. John Frederick Grassle
Professor Emeritus,
Rutgers, The State University of New Jersey
USA

The Japan Prize Foundation has decided to award the 2013 Japan Prizes to Prof. C. Grant Willson, Professor of Chemistry and Chemical Engineering, Rashid Engineering Regent Chair, The University of Texas at Austin; Prof. Jean M. J. Fréchet, Vice-President for Research, King Abdullah University of Science and Technology in the Kingdom of Saudi Arabia; and Dr. John Frederick Grassle, Professor Emeritus, Rutgers, The State University of New Jersey.

Prof. Willson and Prof. Fréchet will be awarded in the field of "Materials and Production" for the development of chemically amplified resist polymer materials for innovative semiconductor manufacturing process.

In the field of "Biological Production and Biological Environment" Dr. Grassle will be awarded for the contribution to the marine environmental conservation through researches on ecology and biodiversity of deep-sea organisms.

The Laureates will be formally honored at the Presentation Ceremony to be held in Tokyo on April 24, 2013.

JAPAN PRIZE

The Japan Prize is awarded to scientists throughout the world who have been credited with original and outstanding achievements and have made major contributions to the advancement of science and technology, thereby manifestly furthering the cause of peace and prosperity of mankind.

While the prize encompasses all categories of science and technology, two fields of study are designated for the prize each year in consideration of developments in science and technology.

Each Japan Prize laureate receives a certificate of merit and a prize medal. A cash prize of 50 million yen is also awarded to each prize field.

"Materials and Production" field

Achievement : Development of chemically amplified resist polymer materials for innovative semiconductor manufacturing process

Prof. C. Grant Willson
Born : March 30, 1939 (Age 73)
Professor of Chemistry and Chemical Engineering
The University of Texas at Austin

Prof. Jean M. J. Fréchet
Born : August 18, 1944 (Age 68)
Vice-President for Research
King Abdullah University of Science and Technology

Summary

The most important key technology which has been the driving force for innovation in semiconductor technology over the past half a century is lithography, which engraves fine circuits in semiconductors. Dr. Grant Willson and Dr. Jean Fréchet, along with the late Dr. Hiroshi Itoh, embarked on the development of the resist to be used for lithography in the early 1980's, and succeeded in developing a new key technology known as a chemically amplified resist. Through the use of resist developed jointly by the three doctors, a lithography using a short wavelength deep ultraviolet (deep UV; wavelength 254nm) was achieved. By improving this chemically amplified resist, an era of the next generation integrated circuit with a minimum semiconductor circuit width of under 250nm was opened up. The chemically amplified resist is an important technology for the extreme ultraviolet lithography (EUV; wavelength 1-10nm), a present leading edge technology, as well as for electron lithography, and is a key technology in creating new types of electronics.

Advancements in photolithography has supported the development of semiconductor integrated circuits

Progress in semiconductor integrated circuits (IC) which were developed in the 1960's has been made by improvements in the device density. According to "Moore's Law" which has become well-known as a result of the paper published in 1965 by Gordon Moore, a co-founder of Intel Corporation, it was estimated that "the number of transistors of integrated circuits will double every 24 months." This has become a reality, giving birth to an advanced information society.

The greatest contribution made to the advancement of integrated circuits is this most important key technology called lithography, which is a microfabrication technology. "Litho" means stone, and "graphy" means to write; thus, it can be said that semiconductor lithography is a technology in which fine electronic circuits are written on silicon wafers.

Diagram 1 shows the lithography process in the manufacture of semiconductors. First of all, a polymer film called resist is applied to the silicon wafer to be processed through spin coating. A photochemical reaction occurs within the resist when exposed to light. There are two types of resist materials, one being easy to dissolve in a solvent called the developer and the other is not.

Thus, when the resist is exposed and developed through a photomask in which a circuit pattern is written, a resist pattern corresponding to the mask pattern is written. Furthermore, the process using chemicals or plasma to process the area not covered by the resist is called etching. Last of all, after the resist is removed through polishing, a silicon wafer configured to the desired design is attained. There are positive type and negative type resists; the positive type is the one in which the exposed area dissolves in the developer, and the negative type is the one in which the exposed area remains.

The properties of the resist play an extremely important part in increasing the device density of the integrated circuit. In the early days, known polymers with photochemical reactions were used on the resist. However, gradually new types of resist materials have been pursued with higher exposure sensitivity, higher resolution in order to write finer circuits, and with superior etching resistance.

Catalysts formed through chemical reactions create a chain reaction

In the latter 1970's at the IBM Research Laboratory located in San Jose, a central Silicon Valley city in California, U.S.A., the development of new resist materials was underway. At that time, Dr. Grant Willson was the head of the resist development.

One way to improve the resolution of the semiconductor lithography is to shorten the wavelength of the ultraviolet rays used for resist exposure. However, when the wavelength was shortened, a problem arose in that the resist exposure sensitivity was significantly reduced, making it difficult to write a circuit. Lithography using light was approaching its limit, so an electron lithography was proposed. Due to cost problems, however, efforts were made to stretch the potential of the conventional lithography to the limit.

At the time, Dr. Willson's goal was the resist development to attain a lithography using the deep UV of a conventional high-pressure mercury lamp with the shortest wavelength of 254nm. In order to achieve that goal, in 1979, Dr. Jean Fréchet, an associate professor at the University of Ottawa in Canada who was engaged in the function study of polymers, made use of the sabbatical system (a long-term paid leave given to a university teacher over a certain period of time in order for him to dedicate himself to research) and joined in the development. Thereafter, he became a partner in resist development. In the following year, the late Dr. Hiroshi Itoh (~2009), who was studying polysaccharide synthesis at the State University of New York, came to work under Dr. Willson as a postdoctoral fellow.

The research team headed by Dr. Willson, Dr. Fréchet and the late Dr. Itoh paid particular attention to chemically amplified resist as a method to improve the resist sensitivity. With chemically amplified resist, a catalyst known as the active species is first created within the resist through light exposure. It was thought that by merely causing the catalyst to create a chain of chemical reactions within the resist, the polymer properties of the resist can be changed at once by a slightest exposure to light. Among the researchers were some who pointed

Diagram 1 : Principles of photolithography

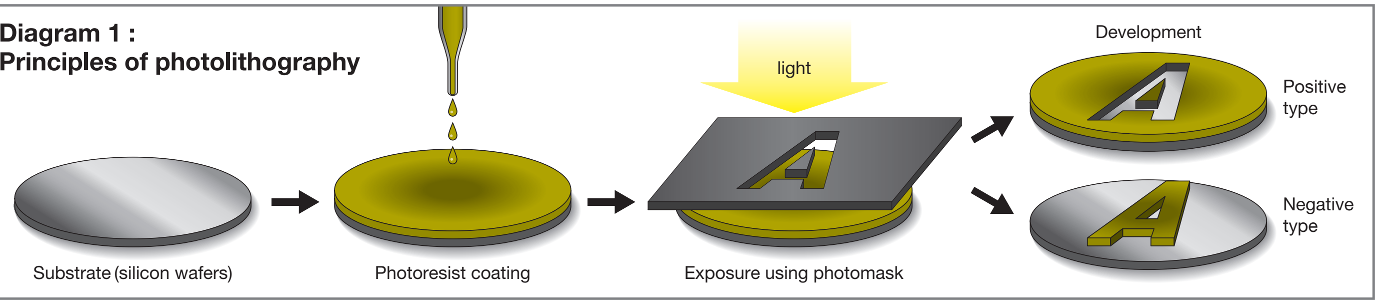
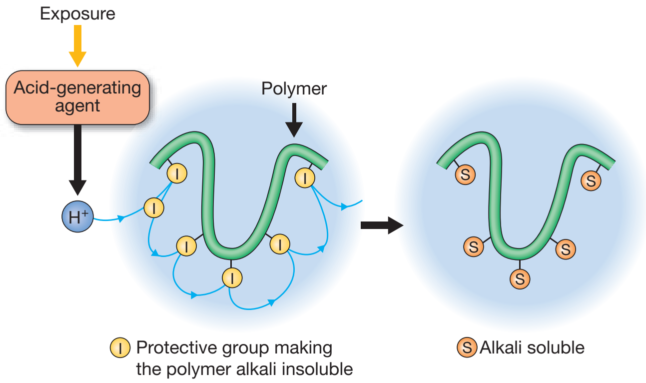


Diagram 2 : Chemically amplified resist concept



When the chemically amplified resist is exposed, the compounds within the resist generate acid. The acid changes the protective group, changing the resist from alkali insoluble to a soluble group, and due to the generated acid, a chain reaction results.

out that due to unregulated chain reactions that occur in chemically amplified resist, the resolution may conversely deteriorate even if the exposure sensitivity improves. However, they decided to undertake the challenge.

While repeating the trial and error process, in 1980, the research team succeeded in developing a resist material which creates an extremely stable reaction during resist synthesis even under light exposure. According to the paper published in 1982, a chemically amplified resist was proposed (diagram 2) in which acid is generated as active species, and the resultant acid successively changes the protective groups which protect the polymers from the alkali solvent used in exposure. Such a resist was actually synthesized, and the first chemically amplified resist used for semiconductor manufacture was a polymer in which t-butoxycarbonyl (tBOC) was removed with acid, producing polyhydroxystyrene (PHS) (deprotection reaction).

A chemically amplified resist overcame obstacles the semiconductor technology was facing

The resist developed at this time became the prototype for the later positive-type resist, and various chemically amplified resists were subsequently developed. At IBM, a chemically amplified resist was used in a 1 megabit DRAM production with a minimum integrated circuit width of 1µm. However, in general, it came to be widely used in what was called the next generation DRAM in lithography with a minimum width of 250nm. Dr. Willson, Dr. Fréchet and the late Dr. Itoh continued their joint research thereafter on chemically amplified resists, and contributed to the development of semiconductor lithography. Dr. Willson and Dr. Fréchet have expanded their research field to include studies on various polymer functions.

Chemically amplified resists have proved useful in lithography using the krF excimer laser with a wavelength of 248nm, which plays a key role in the present semiconductor exposure device. Additionally, chemically amplified resists are playing an important part in extreme ultraviolet (EUV) lithography and electron lithography which are receiving widespread attention as the next generation semiconductor technology, and continue to serve as key technology in paving the way for new electronics technology to this day.

What became the driving force to overcome the limitations of the semiconductor lithography in the 1970's was the chemically amplified resist developed by three scientists. Through the emergence of the chemically amplified resist, it can be said that the electronics industry has been able to follow the development as predicted by "Moore's Law."

"Biological Production and Biological Environment" field

Achievement : Contribution to marine environmental conservation through research on ecology and biodiversity of deep-sea organisms

Dr. John Frederick Grassle

Born : July 14, 1939 (Age 73)
Professor Emeritus,
Rutgers, The State University of New Jersey

Summary

It has been thought for many years that only a limited number of living organisms exist in the deep sea exceeding a depth of 200m, due to the fact that hardly any sunlight, needed for photosynthesis, reaches there. However, in 1977, a hydrothermal vent called a black smoker was discovered at the bottom of the Pacific Ocean, and the existence of a wide variety of organisms was recorded. Marine Biologist Dr. Johon Frederick Grassle organized an ecological survey mission using a manned research submersible, and clarified the existence of a chemosynthetic ecosystem in the deep ocean which utilizes not sunlight, but chemical substances supplied from the earth's interior.

Through his studies in the 1980's and the 1990's, Dr. Frederick Grassle proved that an abundant biodiversity exists in the deep sea comparable to that of the tropical rainforest. Furthermore, in 2000, a 10-year project which endeavors to shed light on the diversity, distribution and population of all marine life called "CoML: Census of Marine Life" was founded. The research findings thereof are greatly contributing to the preservation of the marine ecosystem which has rapidly been lost since the 20th Century.

Dream to become a marine biologist came true through the ecosystem study of coral reef benthos

Dr. Frederick Grassle, who is now acclaimed as a world-class marine biologist, was actually born in Ohio which does not have a coast. However, nearby was Lake Erie. During his junior high school days, Dr. Grassle developed a fondness for the underwater world, having read books written by Jacques Yves Cousteau, an inventor of the underwater breathing apparatus.

The opportunity for Dr. Grassle to become involved in oceanographic studies came when he was studying zoology at Yale University. His instructor encouraged him to participate in studies being carried out by the Woods Hole Oceanographic Institute in Cape Cod, Massachusetts. While continuing to gather marine species there, he cultivated a strong desire to become an oceanographer.

After earning a Ph.D. at Duke University in 1967, Dr. Grassle obtained the Fulbright-Hays scholarship and engaged in the study of the ecosystem of organisms living in the coral reefs of Australia. Coral reefs are known to have one of the most abundant biodiversities of all marine environments. In particular, Dr. Grassle focused on sandworms which live in the sediments on the ocean floor, and clarified the role which benthos play in the coral reef ecosystem that attracted little attention. Dr. Grassle even improved by himself the scientific instruments used in gathering life from sediments and cast a spotlight on a new dimension of the coral reef ecosystem.

Discovery of unique and abundant ecosystem in the deep sea floor which was previously believed to be a wasteland

Dr. Grassle, given recognition on research findings on coral reefs, was recruited as a member of the Woods Hole Oceanographic Institute in 1969. In the 1970's, it was the exploration of the deep ocean this institute embarked on. At the time, the plate tectonics theory was in its development period, and it was thought that many undersea volcanoes and hydrothermal vents like fountains on land existed in the area on the ocean floor where a new crust was formed (diverging plate boundaries), which many sought to discover. Thereafter in 1977, by means of the survey conducted by geologists on the "DSV (deep submergence vehicle) Alvin," a manned research submersible, water eruption of nearly 20℃ was discovered in the deep ocean floor of approximately 2500 m, near the Galapagos Islands. It was confirmed that a massive number of living creatures, unlike anyone had ever seen before, existed there.

Dr. Grassle, who came to know of this report, conducted his own survey on the DSV Alvin in 1979. The survey team on this expedition succeeded in obtaining some amazing footage. There was a chimney-shaped vent erupting hot water exceeding 300℃, which came to be called a black smoker chimney. The hot water contained such toxic compounds as hydrogen sulfide, and based on the common knowledge of the times, such was an environment unfit for life. Yet, near the hot water vent right in front of Dr. Grassle's eyes existed tubeworms which poked their red "plume" out of their protective tube, as well as bivalves, growing in clusters.

Up to that point in time, life was thought to be dependent mainly on sunlight as its main energy source, and the greater part of the ecosystem on earth was supported by organic substances synthesized by photosynthetic organisms. In other words, the deep sea where light does not reach was thought to be a desert-like place where only a limited number of organisms which are supported by organic substances precipitated from the shallow waters could exist. However, it was verified that in reality, the deep sea has an abundant ecosystem beyond our expectations. At that time, Dr. Grassle confirmed, "These organic matters must be obtaining their energy source not from sunlight, but from methane, hydrogen sulfide and other substances which are supplied from the earth's interior."

Dr. Grassle's idea was backed up by many studies thereafter, and the ecosystem using chemical substances came to be called the "chemosynthetic" ecosystem, a word used as a counterpart for "photosynthesis." Such microorganisms as sulfur-oxidizing bacteria support the chemosynthetic ecosystem. The microorganisms oxidize the chemical substances found in hot water such as hydrogen sulfide and hydrogen, and use the energy obtained to synthesize organic substances from carbon dioxide. Such large organisms as tubeworms exist by taking in such microorganisms into their bodies and "coexisting" with them (Diagram 1).

The discovery of the chemosynthetic ecosystem exerted a great influence in a wide range of biological fields. The research on the origin of life is one of them. For example, it came to be believed by many scientists that if there are volcanic activities, there is a possibility of life even in planets and satellites in the space where hardly any sunlight reaches and most of the water exists in the form of ice.

The founding of the CoML Project sheds light on marine biodiversity

During the 1980's and 1990's, Dr. Grassle enthusiastically carried out studies on the biodiversity of marine life in the deep sea. Dr. Grassle took notice of the fact that there are areas on the ocean floor in the eastern part of United States at a depth of 1500 m to 2500 m where there is an abundance of biodiversity. He divided the area into small sections and surveyed the types and numbers of marine life found. As a result, he clarified that the patch-mosaic dynamics can be applied as a mechanism for supporting biodiversity even in the deep sea. In other words, even in a seemingly uniform deep sea environment, there is a complex adaptive system in which a diverse environment exists on a minute scale called patches. Ever-changing patches spread like mosaics, resulting in a wide variety of life. From a quantitative study of such deep sea ecosystem, Dr. Grassle could conclude that "an abundant biodiversity exists in the deep sea comparable to that of the tropical rainforest."

Diagram 1 : Chemosynthetic ecosystem in deep sea

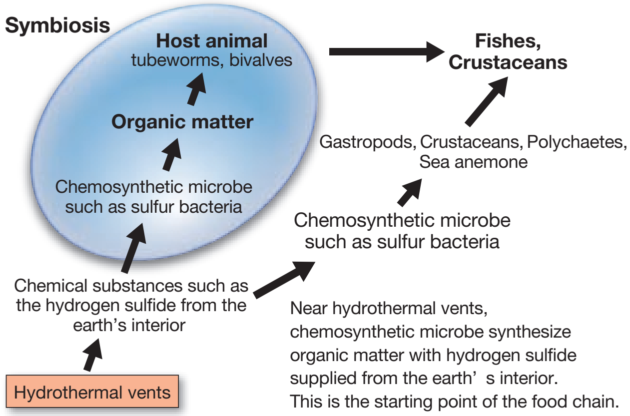
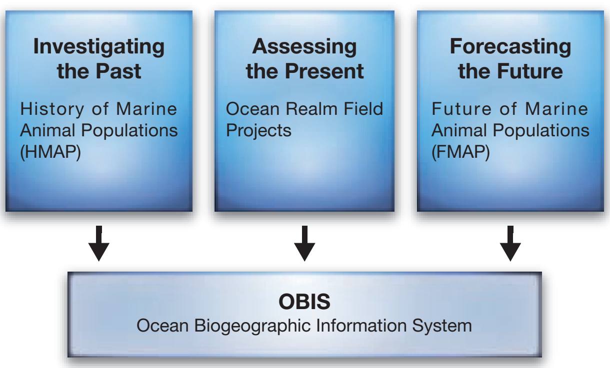


Diagram 2 : Scientific Framework of CoML



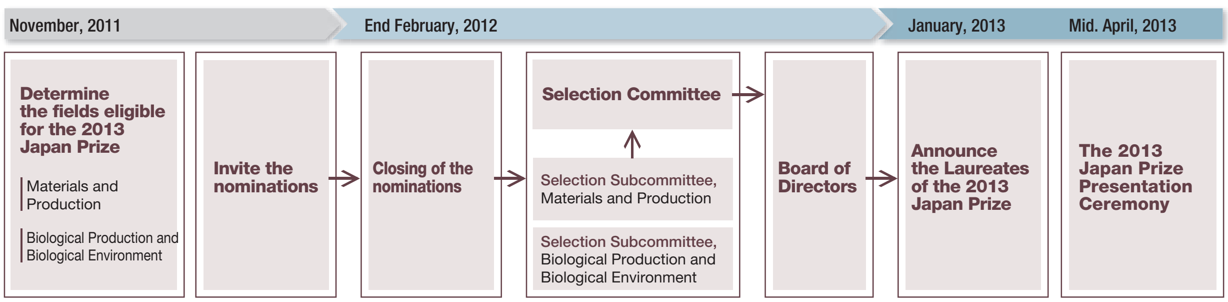
With this study as a motivational force, Dr. Grassle aimed to clarify on the diversity of all marine creatures and embarked on developing a worldwide network. In 1989, the base of operation was moved to the Institute of Marine and Coastal Sciences at Rutgers University in New Jersey where various research projects have been carried out, including the most well-known CoML, of which Dr. Grassle is a co-founder. CoML is a global marine life research network with researchers now from over 80 countries. In a 10-year project from 2000 to 2010, diversity, distribution and population of marine life have been surveyed and analyzed. In addition, Dr. Grassle has had a strong interest in environmental preservation and has held a conviction that reliable scientific data is indispensable for environmental preservation. To that end, he has devoted his energy to make available the research results of CoML in the form of an Ocean Biogeographic Information System (OBIS) database (Diagram 2). The summary of the CoML findings released in 2010 revealed that 90% of the thousands of new species and marine life consist of microorganisms.

At present, marine diversity is rapidly decreasing, and a major contributing factor is the depletion of fishing resources. By means of the CoML survey, not only has the marine region needing the most preservation been highlighted, but it has also contributed in the setting of standards with respect to evaluating future changes from climate change and overexploitation due to fishing. In addition, OBIS is presently being managed by UNESCO/ IOC, and is being used worldwide in drafting preservation policies regarding marine life.

How should we continue to preserve the marine biodiversity clarified by Dr. Grassle through his deep sea research? That is one of our major challenges for the 21st Century.

Nominations 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 13,000 nominators, strictly comprised of prominent scientists and researchers from around the world invited by the Foundation, to nominate the candidates through the web by JPNS (Japan Prize Nomination System). The deadline for nominations is the end of February 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 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 one year from the time that the field are decided. Every January, the winners of that year's Japan Prize are announced. The Presentation Ceremony is held in mid-April in Tokyo.



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Vice Chairman
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Member Makoto Misono — Professor Emeritus, The University of Tokyo

Member Hideo Miyahara — President, National Institute of Information and Communications Technology

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Deputy Chairman
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Member Takashi Nakamura — Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University

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Member Takakazu Yumoto — Professor, Primate Research Institute, Kyoto University

(alphabetical order, titles as of December, 2012)

Fields Eligible for the 2014 Japan Prize Selected

Areas of Physics, Chemistry and Engineering

Electronics, Information and Communication

Background and rationale:

Today, our world is in the midst of rapidly developing information and knowledge-based society. The advancement of essential technologies in electronics, information and communication have brought about dramatic improvement in productivity and have also revolutionized the speed, efficiency and the scope of information exchange, thereby contributing significantly to the evolution of human society through creation of new cultures and lifestyles. In addition, these advancements are also playing a significant role in the field of energy management by responding to the ever-increasing energy consumption.

Amid such changes, it is anticipated that further advancement of these technologies will not only improve its reliability and security but will also enable us to respond to new social issues, thereby contributing greatly to the sustainable development of human society.

Achievement eligible:

The 2014 Japan Prize in the field of "Electronics, Information and Communication" is awarded to individual(s) who has made significant contributions to society by achieving scientific and technological breakthroughs in creating new industries and improving productivity, developing essential technologies and systems that contribute to the realization of information and knowledge-based society, and developing fundamental science and technologies that have high potential to promote further advancement of our society.

Areas of Life Science, Agriculture and Medicine

Life Science

Background and rationale:

In recent years, the drastic progress of life science has contributed significantly in understanding the complex functions of biological life including us human beings. Most notably, with revolutionary advancement in life science research technologies, things which were once considered technologically impossible, such as the mapping of genetic blueprints, are now becoming possible one after another. As a result, we are now making new discoveries that will significantly change our concept of life in the levels of molecules, cells, tissues, organs and whole body.

It is anticipated that such progress in understanding of life science will contribute towards the welfare of mankind by unlocking new possibilities in life forms including us human beings and help lead the way for the creation and promotion of future medicine.

Achievement eligible:

The 2014 Japan Prize in the field of "Life Science" is awarded to individual(s) who has made significant contributions to society by achieving scientific and technological breakthroughs of discovering new life phenomena, elucidating vital functions, developing revolutionary analysis technologies, and creating future medicine.

Fields Selection Committee for the 2014 Japan Prize

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Director, Institute of Microbial Chemistry

Member **Atsuko Tsuji**
Editorial Writer, The Asahi Shimbun

(alphabetical order, titles as of December, 2012)

Schedule (2013-2015)

The fields eligible for the Japan Prize (2013 to 2015) have been decided for the two research areas, respectively.
These fields rotate every three years, basically.
Every year the Fields Selection Committee announces the eligible fields for the next three years.

Areas of Physics, Chemistry and Engineering

Year	Eligible Fields
2013	Materials, Production
2014	Electronics, Information, Communication
2015	Resources, Energy, Social Infrastructure

Areas of Life Science, Agriculture and Medicine

Year	Eligible Fields
2013	Biological Production, Biological Environment
2014	Life Science
2015	Medical Science, Medicinal Science