SUPPORTING EXCELLENCE IN SCIENCE

An evaluation of the
World Premier International Research Center Initiative
from 2007 to 2021

Digital Vision / Getty Images

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PUBLISHER'S INFORMATION

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Cover image: Yuichiro Chino / Getty Images

AN OVERVIEW OF THE WPI PROGRAMME

David Swinbanks, founder of Nature Index, looks at the WPI's 15-year history, and its bright future.

The World Premier International Research Center Initiative (WPI) was established in 2007 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to create globally influential Japanese research centres, producing work with major scientific and societal impacts.

David Swinbanks was based in Tokyo when the first WPI centres were launched, and has followed the programme with great interest, both in his former position as CEO of NPG Nature Asia-Pacific, and current roles as the founder of the Nature Index and senior advisor to Digital Science.

"I am a great believer in the importance of basic research which, in the long run, can be of huge benefit to society," he says. "The WPIs in a relatively short time have done an excellent job of carrying out high quality inter-disciplinary basic research and they have developed very strong international collaborative links with leading researchers around the world."

The initial four pillars of the WPI programme were: leading edge research, fusion research, globalization, and system reform.

The WPI's leading-edge research is evident through its scholarly output. "The institutes publish large numbers of high-quality research articles in top journals as indicated by their large per capita output in the 82 top quality journals of Nature Index," says Swinbanks. "But, evaluation of the success of the WPI programme requires looking at a broad mix of measures and, critically important, also needs to draw on the opinions of key opinion leaders in the field to determine the extent to which WPIs have realized fusion research, globalization, and system reform."

> **The WPIs have done an excellent job of carrying out high quality inter-disciplinary basic research.**

To that end, the Japan Society for the Promotion of Science (JSPS) commissioned a scientometric impact report by Digital Science and a reputation survey by Research Consulting, to evaluate the success of the WPI programme.

This booklet reviews the findings of the two reports. The discussion has been broken up into five sections - scientific impact, fusion, internationalization, system reform, and societal impact. To conclude, parts of the WPI programme that could be improved are identified and solutions recommended.

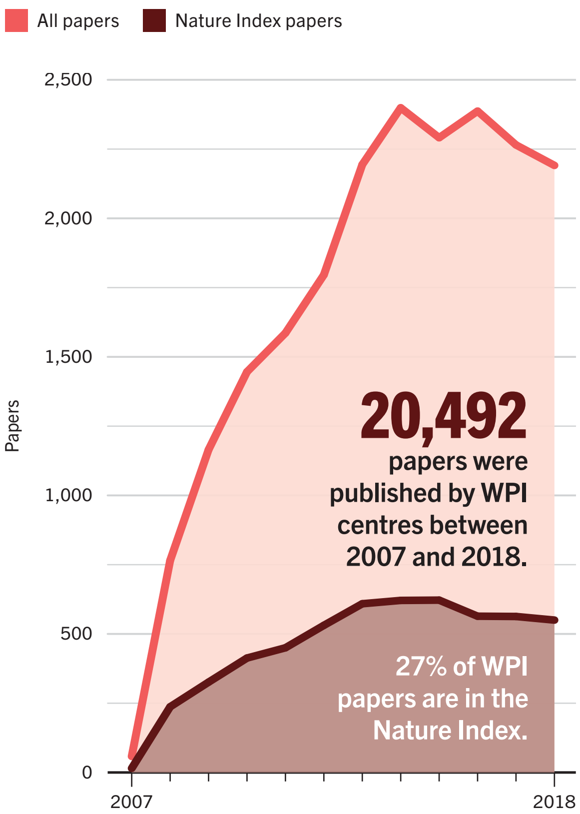
David Swinbanks

David Swinbanks joined Nature in 1986 and has spent a large part of his career in Japan, with a five-year stint in London where he launched a series of Nature-branded physical science journals. He moved to Australia in 2013 and set up the Sydney office for Nature Portfolio expanding on an existing presence in Melbourne. He is chairman of Springer Nature in Australia and New Zealand, founder of Nature Index and senior advisor for Digital Science.

WPI BY THE NUMBERS

A snapshot of the research performance of the World Premier International Research Center Initiative.

PAPERS



NUMBER BREAKDOWN

¥700 mil.

The amount granted by MEXT per fiscal year to each centre for a period of 10 years.

9,357

The number of news stories that have mentioned WPI research.

54%

The average percentage of WPI publications mentioned online.

4,631

The number of patents filed that cite WPI research.

Sources: Digital Science, *The scientific and societal impact of the World Premier International Research Center Initiative* (2021); WPI Secretariat, *10 Year Commemoration of the WPI Program: Circulating World's Best Brains*, 2nd printing (2018); Digital Science. (2018-) Dimensions [Software] available from https://app.dimensions.ai. Accessed on (25 January 2021), under licence agreement.

A TIMELINE OF THE WPI PROGRAMME

2007
Five centres join the WPI programme
- **AIMR**, Tohoku University
- **IPMU**, The University of Tokyo
- **iCeMS**, Kyoto University
- **IFReC**, Osaka University
- **MANA**, National Institute for Materials Science

2010
I^2CNER at Kyushu University joins the WPI programme

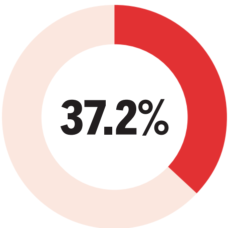
2012
Shinya Yamanaka (**iCeMS**) wins the 2012 Nobel Prize in Physiology or Medicine

2012
Three centres join the WPI programme
- **IIIS**, University of Tsukuba
- **ELSI**, Tokyo Institute of Technology
- **ITbM**, Nagoya University

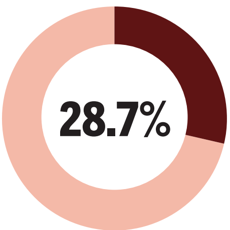
The **IPMU** at the University of Tokyo becomes a Kavli Institute – **Kavli IPMU**

FOREIGN RESEARCHERS

Almost every WPI centre has achieved its goal of 30% foreign researchers and 20% foreign primary investigators (PIs) by 2021.



The average percentage of foreign researchers at each of the 13 WPI centres in 2019.



The average percentage of foreign PIs at each of the 13 WPI centres in 2019.

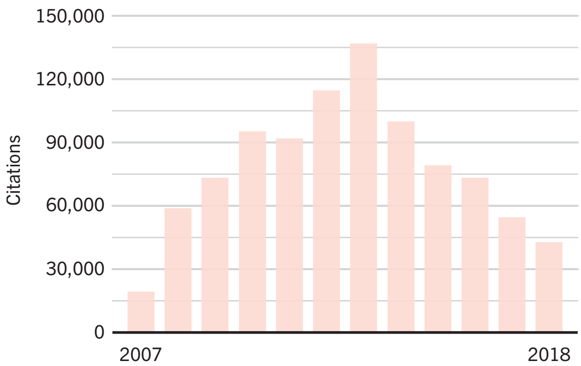
Note: The publisher remains neutral with regards to jurisdictional claims in published maps and institutional affiliations.

INTERNATIONAL COLLABORATION

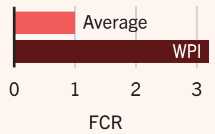
1 in 4 collaborative papers included international co-authors from 92 locations.

1. United States	2. China	3. United Kingdom	4. Germany	5. France
3,536 co-authors	2,128	1,205	1,196	815

CITATIONS



The WPI's Field Citation Ratio (FCR) is 3.2 times higher than the average.



2015
Takaaki Kajita (**Kavli IPMU**) wins the 2015 Nobel Prize in Physics

The **ELSI Origins Network (EON)** is formed, with support from the John Templeton Foundation

2016
A comprehensive collaboration agreement signed between Osaka University and Chugai Pharmaceutical Co., Ltd., to fund **IFReC** for 10 years

2017
Two centres join the WPI programme
- **IRCN**, The University of Tokyo
- **NanoLSI**, Kanazawa University

WPI Academy established. **AIMR, Kavli IPMU, iCeMS, IFReC, MANA** enter the academy

2018
Two centres join the WPI programme
- **ICReDD**, Hokkaido University
- **ASHBi**, Kyoto University

2020
I^{2}CNER enters WPI academy

New WPI missions, 'Values for the Future', released

2021
Benjamin List **(ICReDD)** wins the 2021 Nobel Prize in Chemistry

Milosz_G / Getty Images

PRIORITIZING BASIC SCIENCE

The scientific impact of the World Premier International Research Center Initiative.

Basic research is defined by the OECD as "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view."

While basic research is curiosity-driven, without an immediate application, it sows the seeds for future progress and innovations. Some notable examples include the 1960 invention of the laser, the foundation of which can be found in a 1917 theoretical paper by Albert Einstein and a 1960s mathematical theory describing packet switching leading to the invention of the internet.

The WPI programme has recognized the long-term importance of basic research to society and made it the cornerstone of the programme. The primary objective of the programme, stated in the initial application for centres in 2007, was to "enhance the level of science and technology in Japan and continuously trigger innovation that serves as an engine for future growth, it will be necessary to boost the nation's basic research capabilities while strengthening its global competitiveness."

Some notable examples of WPI basic research from the first 10 years of the programme include:

- 2013: An iCeMS team successfully controlled neural stem cell fate using light technology. Results were published in *Science*.
- 2013: An AIMR paper published in *Science* solved the 50-year mystery of the structure of metallic glass.
- 2014: A team, including an ITbM researcher, demonstrated that control of the opening/closing of stomata is essential for plant growth.
- 2014: An IFReC-led team revealed how *Toxoplasma* uses an organism's immune response to spread infection throughout the body.
- 2015: An international team, including Kavli IPMU researchers, published a paper in *Physical Review Letters* suggesting that dark matter behaves like the Yukawa particle.
- 2016: An IIIS-led team discovered the gene regulating the sleep/wake network, and published their results in *Nature*.
- 2016: An ELSI-led team refined the giant impact hypothesis that explains how the moon formed.

The programme's focus on basic research has been reaffirmed by Michinari Hamaguchi, the chair of the WPI programme committee in the 2021 programme booklet:

"It will be necessary for the nation to generate cutting-edge research results through the advancement of basic research — results that contribute to ground-breaking technological innovation and to the

RESEARCH HIGHLIGHT

Growing a backbone happens like clockwork

The genetic clock that determines when an embryo's spine should grow has been modelled in a dish, enabling insights into hereditary spinal disorders.

Embryonic vertebrate growth is driven by a group of 'segmentation clock' genes, so-named because their expression oscillates, with gene activity rising and falling at regular intervals. Each oscillation generates another somite — a cluster of cells that can develop into vertebrae and ribs. Errors in this genetic clock can lead to skeletal disorders, but for ethical reasons the mechanisms cannot be directly studied in human embryos.

A team including researchers from the WPI Institute for the Advanced Study of Human Biology (ASHBi) at Kyoto University generated stem cells in the lab that transform into presomitic mesoderm (PSM), a tissue that gives rise to somites. They engineered the stem cells to simultaneously activate fluorescent molecules so they could visualize gene activity, and found that the oscillations occur every five hours.

The researchers then generated PSM using stem cells from patients with spondylocostal dysostosis, a rare skeletal growth disorder. Mutations in two key segmentation clock genes disrupted the synchronized oscillations between cells, which led to abnormal growth. Synchronization was restored by correcting the mutation using CRISPR-Cas9 gene editing.

In depth studies of the segmentation clock, such as this, could help reveal more of the genetic mutations that drive spinal disorders.

REFERENCE:
Nature **580**, 124-129 (2020).
doi: 10.1038/s41586-020-2144-9

RESEARCH HIGHLIGHT

Leaf-like fossils may be earliest animal life forms

Ancient frond-like life forms found in the coastal waters and deep seas around half a billion years ago may represent the earliest animals.

The enigmatic organisms of the Ediacaran period – which covers 635 to 541 million years ago – have long proved a challenge to classify because the fossil evidence of their existence was mostly limited to impressions of their soft bodies.

A researcher from the WPI Earth Life Sciences Institute (ELSI) at the Tokyo Institute of Technology has led a study of 206 beautifully preserved fossils of *Stromatoveris psygmoglena*, a leaf-life creature consisting of a single large frond and a stem that anchored it to the sea floor.

Based on the complex branching and petal-like elements in its body shape, the researchers concluded that the organism had enough similar features to other known early animals for it to also be classed as an animal.

The research team also examined fossils of seven other species of 'petalonamids' from the Ediacaran period. Given the similarities in structure and function between them and *Stromatoveris*, they proposed that the phylum Petalonamae be included in the category of animal.

This would push the date for the earliest animal life forms on Earth back to approximately 571 million years ago.

REFERENCE:
Palaeontology **61**, 813-823 (2018).
doi: 10.1111/pala.12393

discovery and elucidation of new phenomena shared by the whole of humankind."

Supporting basic research is at the heart of the WPI's initial four missions: leading-edge research, fusion research, globalization, and system reform.

The rest of this section will introduce the two reports commissioned by JSPS to evaluate the success of the WPI programmes at addressing these missions, focusing on the scientific impact of the programme.

SCIENTOMETRIC IMPACT REPORT: OVERVIEW

Subsidiary companies of Digital Science, Dimensions and Altmetric, ran a scientometric analysis on more than 20,000 publications produced by nine WPI institutes between 2007 and 2018:

- Advanced Institute for Materials Research (AIMR)
- Earth-Life Science Institute (ELSI)
- Immunology Frontier Research Center (IFReC)
- International Center for Materials Nanoarchitectonics (MANA)
- International Institute for Carbon-Neutral Energy Research (I^{2}CNER)
- International Institute for Integrative Sleep Medicine (IIIS)
- Institute for Integrated Cell-Material Sciences (iCeMS)
- Institute of Transformative Bio-Molecules (ITbM)
- Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU)

The 2021 Digital Science Research productivity report ('The scientific and societal impact of the World Premier International Research Center Initiative') found the citation impact of WPI institutes is typically triple that of similar disciplinary research. Since 2007 WPI research from the nine centres was collectively cited almost one million times.

REPUTATION SURVEY: OVERVIEW

For the second impact measure, a Reputation Survey ('The impact and reach of the World Premier International Research Center Initiative: Results from a global reputation survey') of all 13 WPI centres was conducted by Research Consulting. Out of the 683 stakeholders identified, all of non-Japanese origin, 66 agreed to undertake a semi-structured qualitative interview with a member of the Research Consulting team. Of the 66 stakeholders, 55 were academics, three were editors, and eight were policymakers and funders from a wide range of countries and institutions.

The nature of the interview questions meant all participants had previous experience with the WPI centres, which suggests the findings of this report should be considered in conjunction with the Impact Report for a more accurate assessment of the WPI programme's reach.

The Reputation Survey included four more WPI centres in addition to the nine centres above. They were:

- Institute for the Advanced Study of Human Biology (ASHBi)
- International Research Center for Neurointelligence (IRCN)
- Nano Life Science Institute (NanoLSI)
- Institute for Chemical Reaction Design and Discovery (ICReDD)

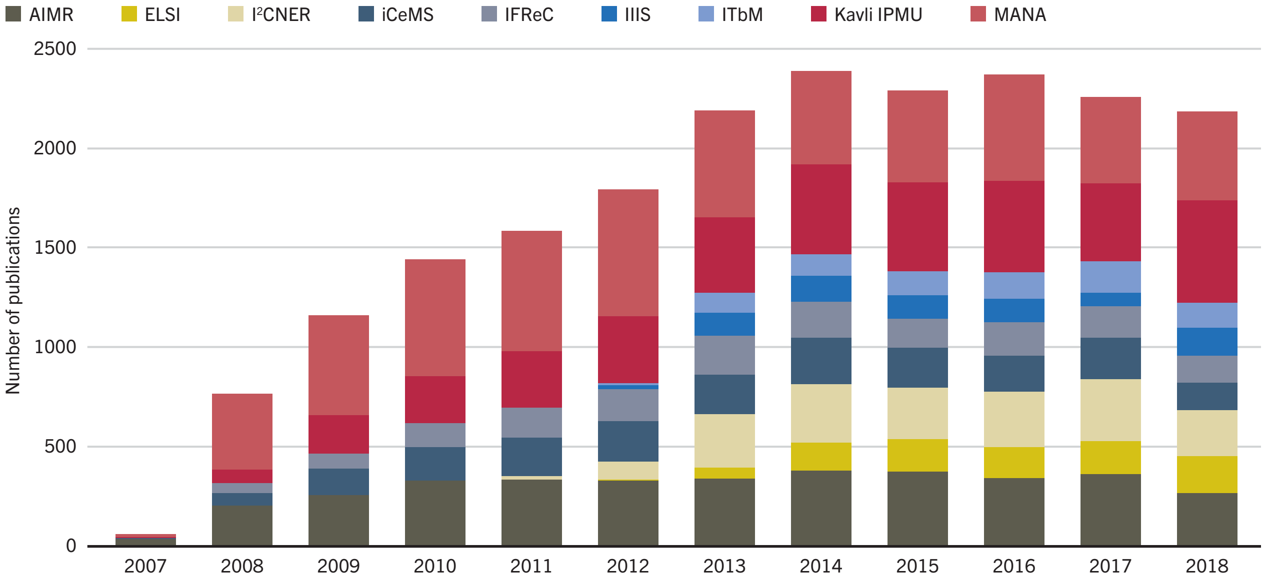
The Reputation Survey found that while academics worldwide considered the science at individual WPI centres to be excellent, recognition was generally attached to the centre closest to the discipline of the surveyed academic rather than the WPI brand.

Centre reputations came from three main sources: personal relationships, conferences and events and academic literature published by WPI centres.

MARK GARLICK / SCIENCE PHOTO LIBRARY / Getty Images

Total publication count per institution, 2007–2018

Digital Science used the Dimensions database to analyse 20,492 publications with a DOI produced by WPI centres, with citations and relationships recorded up to March 8, 2021.



While funders, policymakers and editors had positive views of the quality of science produced by individual WPI centres, recognizing them for having strong staff and for working in key areas of science, they had low awareness of the WPI programme overall.

COMPARATIVE REPUTATION OF WPI SCIENCE

The Reputation Survey found that the quality of the science carried out at WPI centres was undisputed, with eight interviewees commenting that WPI centres equal institutes at the highest level.

"I definitely believe the science that comes out of these labs is on par with worldwide science. This is world-class science and the names of their PIs are clearly recognized," one interviewee reported.

WPI centres were recognized for impacting scientific discourse in two main ways:

- Leading scientific discoveries through publishing in high-impact journals, developing cutting-edge tools and techniques, and sharing knowledge and expertise through collaboration, and
- Building international connections by hosting conferences and events, supporting young scientists from around the world and by making Japanese academia more accessible to the global community.

UNIQUENESS OF WPI SCIENTIFIC RESEARCH

Reputation Survey respondents noted that WPI centres share a reputation for the rare combination of significant funding and a focus on fundamental research. As a result, individual WPI centres' global reputations have risen rapidly.

Six interviewees described the focus of WPI centres as "curiosity-driven research," while another 18 pointed out the importance of the significant and long-term funding behind this.

"At I²CNER, we were able to follow our instincts and do really curiosity-driven research. This was a really productive period for me, and we made some fundamental steps in understanding some of the materials we were focusing on," one respondent said.

"They are doing fundamental research, but they have surprisingly clear longer term translational goals… This is a very healthy way of thinking – you need to know the fundamental science before moving to the applied one," said another respondent, about ASHBi.

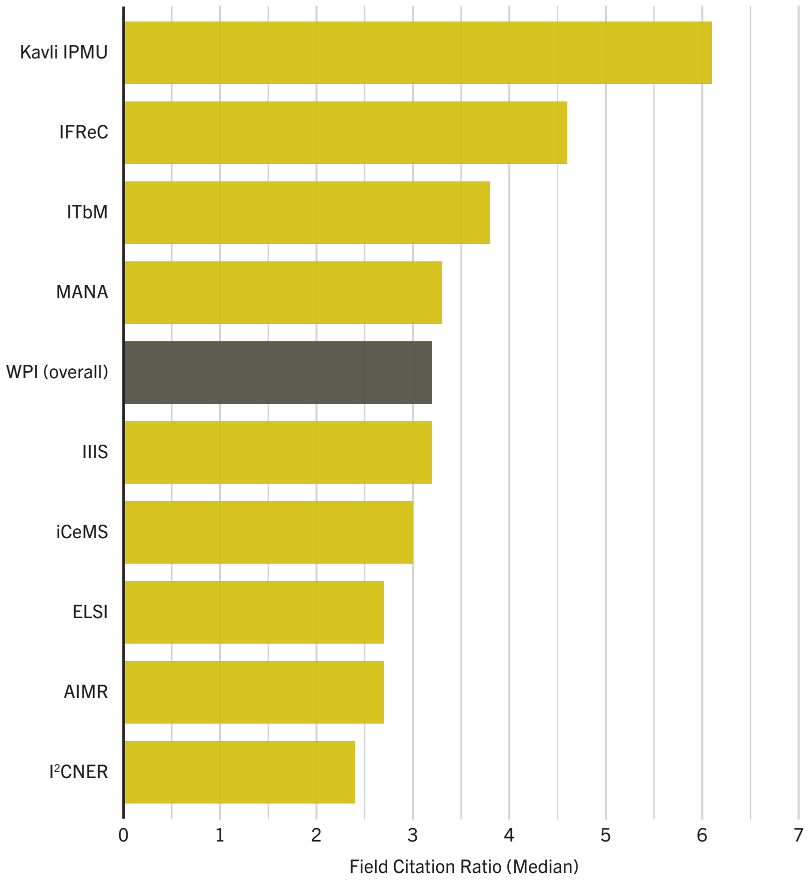
The focus on open, fundamental research was perceived by respondents as key to helping WPI centres remain at the forefront of science and compete with leading institutes.

Some WPI centres have developed leading tools and techniques, which in certain cases have then become references in a field. Interviewees mentioned an atomic force microscopy technique pioneered at NanoLSI and nanosheet fabrication techniques developed at MANA as examples.

"They are of course having an impact. For example, the work on nanosheets is fundamental research which will have a big impact on the academic community but also on in-

Relative disciplinary citation impact

Field Citation Ratios (FCRs) allow for comparison of citation rates in different scientific fields.



dustry. This research is really pioneering and well known worldwide," one respondent said.

Another positive impact cited by interviewees was the tendency for Japanese academia to work closely with industry. This collaboration is viewed as a way to translate fundamental research into real-world socioeconomic impact.

Twelve interviewees noted important interactions between WPI centres and Japanese industry, pointing out that that these can help magnify the impact and reach of the centres.

One interviewee cited the work of I^2CNER and said that the Institute's clear research focus on climate change and carbon neutrality has direct real-world application, making relationships and collaborations with industry more significant than it may be in other WPI centres.

IMPACT REPORT: SCIENTOMETRIC OUTPUT USING FIELD-WEIGHTED CITATION RATIOS

Overall global research output (as measured by the number of papers, proceedings, and preprints published each year) has nearly doubled over the past decade, rising at a constant rate from 2.8 million items in 2010 to just under six million in 2020.

The Scientometric Impact Report showed that the WPI centres started publishing quickly after their launch and steadily in subsequent years. MANA was the most productive institute in terms of total number of publications.

Field Citation Ratios (FCRs) measure the scientific influence of a citation, when compared to other research published in similar fields. The FCR is assessed on articles that are at least two years old.

The FCR benchmarks each WPI centre. It uses the ratio of the citations for publications produced by each centre, compared with the global average citations in the same year and field of research. A value of 1.0 represents the average number of citations of articles published within the same disciplinary area, so any value greater than 1.0 shows above-average impact.

The Scientometric Impact Report found that all WPI publications were highly cited compared to other research published in similar fields, with median FCRs ranging from 2.4 to 6.1.

Since 2007, Japanese research was dominated by medicine, with engineering consistently in second place. Japanese research in the physical, chemical and materials sciences is also very strong, with FCRs substantially higher than the global mean.

Kavli IPMU has the highest relative citation impact of all institutes, with high FCRs indicating that each institutes' publications were cited at higher rates than the typical publication in the same discipline during each institute's active years.

The Scientometric Impact Report found that WPI institutes' publications were collectively cited 937,955 times throughout the duration of the study.

The Scientometric Impact Report also delivered a detailed analysis of the Altmetric Attention Score (AAS) for the top five articles from each centre during the study period and found that Kavli IPMU publications achieved exceptionally high interest. The AAS shows web-driven scholarly interactions as a complementary measure to traditional citation-based metrics. ■

RESEARCH HIGHLIGHT

Gas reservoirs fuel underwater volcanoes in the Okinawa Trough

An immense gas reservoir beneath the Okinawa Trough could be the mystery source of carbon dioxide and methane emerging from underwater volcanoes.

The Okinawa Trough is an ocean basin next to Japan's Ryukyu archipelago on the Pacific Ring of Fire. Seafloor spreading, caused by the thinning of the Eurasian crust as it overrides the sinking Philippine plate, has created a field of hydrothermal vents that are disgorging methane and carbon dioxide. However, the source of these gases is unknown.

A team including researchers from the WPI International Institute for Carbon-Neutral Energy Research (I^{2}CNER) at Kyushu University used the velocities of seismic pressure waves generated from airgun surveys around the Iheya North Knoll in the mid-Okinawa Trough to model the subsea geology. They identified several very low-velocity zones more than 250 metres beneath the sea floor that reveal several large gas reservoirs.

Marius Hepp / EyeEm / Getty Images

Underwater gas reservoirs could be important sources of greenhouse gases.

The researchers suggest that the gas is trapped beneath a methane rich layer formed under great pressure. As seawater flows down through faults in the seafloor and under this impermeable layer, it is heated by magma or rocks, accumulating methane that has been produced by microbes in the organic sediment, and carbon dioxide released by ascending magma, before erupting back out of hydrothermal vents.

Such reservoirs could be important sources of both natural and greenhouse gases and should be considered when calculating carbon flux under the sea.

REFERENCE:
Geophysical Research Letters **46**, 9583-9590 (2019).
doi: 10.1029/2019GL083065

Mastering the ABCs of three-layer graphene

Two different forms of three-layer graphene have been produced for the first time, which could lead to the development of new photoelectric nanodevices such as light sensors.

Because of its remarkable properties, graphene, a one-atom-thick layer of carbon atoms arranged in a honeycomb structure, has attracted great interest since it was first isolated in 2004. Material scientists have been interested in discovering how these properties change when multiple layers of graphene are stacked on top of each other.

For three-layer graphene, the layers can all be slightly shifted relative to each other (called ABC graphene) or they can form a sandwich, with just the second layer displaced relative to the other two layers (ABA graphene). These two structures were predicted to have different electronic properties, but until now no-one had succeeded in selectively producing them.

Now, a team led by researchers at the WPI Advanced Institute for Materials Research (AIMR) at Tohoku University have demonstrated that these two forms of three-layer graphene can be selectively fabricated by simply varying temperature and pressure during growth. They also confirmed that their electronic properties are indeed different as predicted: ABA graphene was an excellent conductor of electricity, whereas ABC graphene had semiconductor-like electrical properties.

This raises the possibility of tailoring the properties of graphene-based nano-electronic devices by varying the number of graphene layers and their stacking sequence, the researchers note.

REFERENCE:
NPG Asia Materials **10**, e466 (2018).
10.1038/am.2017.238

VladNikon / Getty Images

STRONGER TOGETHER

How WPI built a research fusion strategy from the ground up.

WPI centres are constructed from the ground up to address complex and multi-faceted research challenges faced by our global and interconnected societies. These challenges do not generally fit into siloed scholarly disciplines.

In response, WPI adopted 'fusion' as a core strategy, with each WPI centre tasked to create interdisciplinary domains as one of their four key missions.

The purpose of fusion is to build infrastructure, events and processes that encourage collaboration across different disciplines, groups and projects. Gathering researchers from varied disciplines and backgrounds encourages sharing of ideas, techniques and information, and breakthrough curiosity-driven research follows.

This can prompt rapid, transformational progress in knowledge generation and accelerate discoveries as scholars learn from each other.

Research Consulting's 2021 WPI reputation survey found wide recognition of WPI centres' implementation of fusion, via specific individuals or groups within WPI centres.

"They started to implement fusion in 2007, and now everyone is doing this; so they had the vision well in advance and they were successful," stated one respondent.

One example is the WPI International Institute for Integrative Sleep Medicine (IIIS) at the University of Tsukuba. At IIIS, chemical research from the Nagase laboratories combines with expertise from biological programmes such as the Yanagisawa/Funato laboratory, which in turn merges with clinical studies and device development within the centre.

Another example is the WPI Nano Life Science Institute (NanoLSI) at Kanazawa University, where researchers from four distinct fields—computational science, nanometrology, life science and supramolecular chemistry—work together to establish the foundations of the new discipline of nanoprobe life science.

IMPLEMENTING FUSION ON A LARGE SCALE

WPI centres embed fusion into building design and include open spaces designed for cross-disciplinary collaboration and research laboratories set up to serve multiple groups.

"Such an approach to fusion is significantly different from the average, as fusion is most often achieved via virtual rather than physical centres: these are not equally conducive to serendipitous conversations and discoveries, including because of the difficulty of communicating across countries and time zones," notes the authors of Research Consulting's 2021 WPI Reputation Survey.

Fusion is now a key strategic priority adopted by leading research centres across the world and is expected to play a role in most cutting-edge research fields, according to 25 respondents to the reputation survey.

But a distinguishing factor in the WPI programme is its magnitude, with 15 interviewees noting the unique scale of WPI's fusion efforts.

"Having a whole institute focusing on fusion is quite unique – it's usually smaller teams," one interviewee notes.

"The fact that buildings for WPI centres were designed with fusion in

RESEARCH HIGHLIGHT

Powering sensors day and night

A thermoelectric device that generates a current flowing in the same direction day and night is ideal for powering sensors without batteries.

Sensors are used to monitor everything from traffic volume to outdoor temperature. Sensors that can draw energy from their environment are desirable because they don't require batteries and can be set up anywhere.

Thermoelectric devices are promising for powering sensors because they generate electric currents whenever there is a temperature difference across them. Unlike solar cells, they can operate at night and thus do not require batteries to store electricity. However, when the temperature gradient across the device flips as day turns to night, the generated current reverses direction, temporarily dropping to zero in the process.

Now, three researchers at the WPI International Center for Materials Nanoarchitectonics (MANA), at the National Institute for Materials Science in Japan, have found a way around this problem by crowning their thermoelectric device with a wavelength-selective emitter. In contrast to a broadband emitter, theirs continually cools the device by radiating heat to the environment. This ensures that the device's surface is always cooler than its base — even during the heat of the day.

The trio showed that this strategy guarantees that the current generated by the thermoelectric device never drops to zero.

REFERENCE:

Applied Physics Letters **117**, 013901 (2020). doi: 10.1063/5.0010190

mind is significant: physical spaces enable and encourage the circulation of ideas, for example including communal areas, desk arrangements and the layout of lab benches," the report authors note.

Take the WPI International Research Center for Neurointelligence (IRCN) at the University of Tokyo: IRCN conducts interdisciplinary scientific studies across clinical, computational, human, life and social sciences, at the interface of human and machine intelligence.

IRCN has remodelled its laboratories and offices to include lounges and scientific interaction spaces that facilitate team science, and its five core research facilities (Imaging, ES Mouse/Virus, Data Science, Human fMRI, and Science Writing) are set up to enable cross-disciplinary collaborations.

FROM INTERNATIONAL TO INTERNAL: EVENTS ENCOURAGE SERENDIPITOUS DISCOVERIES

WPI centres provide physical infrastructure that supports fusion research, and they also support the continuous exchange of ideas and cultures. This combination of factors makes WPI centres attractive, according to 23 respondents in the Reputation Survey.

Funders, policymakers and editors noted that WPI centres employ more international staff compared with other Japanese organizations and are seen as being more internationally open, with the WPI centres' use of English perceived as "highly valuable," mirroring the view of academic interviewees.

If an academic comes to present at a WPI centre event, they not only meet other presenters, but also researchers working at that WPI centre.

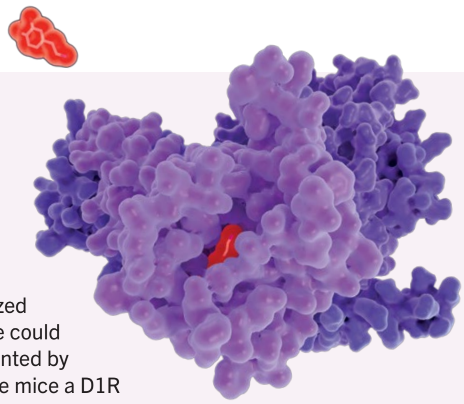
"WPI centres and the events they organize can act as a melting pot to form new international collaborations and exchange ideas regardless of nationality," note the authors.

"WPI centres are designed and built to enable intellectual exchange," note the report authors. "This strongly supports fusion and is also an important element contributing to the attractiveness of the centres: academics from all over the world value the opportunity to visit WPI centres, because they can have valuable interactions with other leading scholars."

For example, the Earth-Life Science Institute (ELSI) addresses the challenging puzzle of the origins of life. It was established as an adaptive organization where novel evolutionary innovations are catalysed by the fusion of ideas from multiple fields, hosting theorists and experimentalists from astrophysics, cosmochemistry, biology, geology, and beyond.

Within ELSI, fusion research is boosted by hands-on tutorials, strategy meetings and interdisciplinary courses along with interdisciplinary study groups to help researchers learn the best strategies to communicate and collaborate across boundaries. ELSI also funds international interdisciplinary research, such as the ELSI Origins Network and Aquaplanetology projects.

Vibrant intellectual exchanges, partly arising from the focus on fusion, show that WPI centres have the potential to drive change in Japanese academia. ■



JUAN GAERTNER / SCIENCE PHOTO LIBRARY

RESEARCH HIGHLIGHT

Learning reward receptors examined

Dips in dopamine concentration serve as a cue to refine generalization during learning, according to new research. Understanding the biology of discriminative learning may provide insight into neuropsychiatric conditions with impaired discrimination, such as psychosis or schizophrenia.

Dopamine is known to be involved in learning, with bursts of dopamine that reward correct predictions being detected by the dopamine D1 receptors (D1R). The new study showed that discrimination is added to this generalized learning via the activity of another receptor, D2R.

Researchers at the WPI International Research Center for Neurointelligence (IRCN) at the University of Tokyo trained mice to associate a specific tone with the reward of a sugary drink. The mice generalized this pattern, licking at the water spout even in response to tones of a different frequency, but this generalized response could be prevented by giving the mice a D1R blocker.

The team then trained mice with reward tone and a tone of a different frequency that wasn't linked with a reward. The mice learned to discriminate between the two, and the absence of an expected reward was accompanied by a dip in dopamine concentration.

Further experiments using optical manipulation of neurons and combinations of stimulators and agonists clarified the molecular mechanisms involved.

REFERENCE:
Nature **579**, 555-560 (2020).
doi: 10.1038/s41586-020-2115-1

RESEARCH HIGHLIGHT

Hibernation trigger found in the hypothalamus

A group of neurons in the hypothalamus region of the brain may hold the key to inducing a hibernation-like state that could have medical applications.

Some mammals, such as bears, go into long periods of hibernation, where they can lower their body temperature and oxygen needs while still keeping their metabolism active. Mice also show a similar, much shorter low-metabolism state known as torpor.

A team of researchers, including scientists from the WPI International Institute for Integrative Sleep Medicine (IIIS) at the University of Tsukuba, have identified a group of neurons that express the gene for a neurologically-active protein called QRFP, which is known to be involved in regulating metabolism.

Michel VIARD / Getty Images

Some mammals, such as the Hazel Dormouse (pictured), go into a low-metabolism state called torpor.

When these neurons, found in the hypothalamus, are chemically triggered, it induces a long-lasting, safe state of hibernation in mice. The animals showed slower heart rate and breathing, and their body temperature fell, but they were able to recover from this state without needing any outside interference.

The mechanism of this hibernation circuit appears to be similar to that seen in squirrels, and suggests it may be a common feature across mammals. This raises the possibility that this circuit could be activated in humans to slow the metabolism and reduce the risk of tissue damage after a stroke or heart attack.

REFERENCE:
Nature **583**, 109-114 (2020).
doi: 10.1038/s41586-020-2163-6

Gut cells control serotonin production in mice

Specialized gut cells detect extracellular RNA from microbes and boost the production of serotonin in response, leading to changes in bone growth and gut peristalsis, involuntary muscular contractions in the digestive tract.

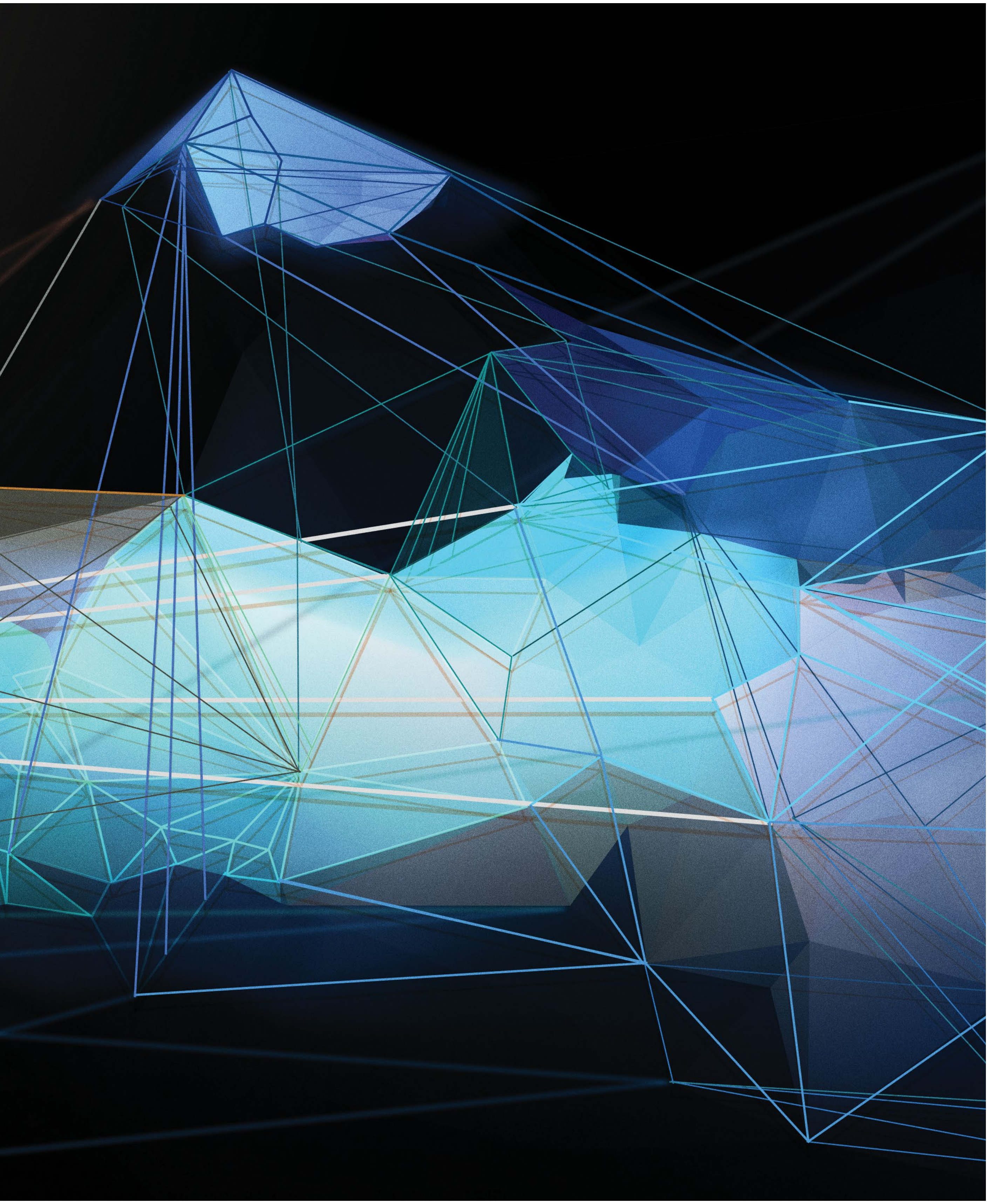
Most of the body's serotonin is produced by enterochromatin cells in the gut, but the molecular mechanisms controlling the production of this important hormone were unknown. Researchers investigating the role of the recently discovered mechanosensing gene *Piezo1* in these processes discovered that it affects them by regulating serotonin synthesis.

The team led by researchers at the WPI Immunology Frontier Research Center (IFReC) at Osaka University, engineered mice lacking *Piezo1* expression in their gut. The mice had an increase in bone mass and disturbed peristalsis. Further investigation revealed lower serotonin levels in their blood plasma.

Piezo1-mediated serotonin production wasn't driven by mechanical stimulation, but rather by the presence of microbial RNA. Using antibiotics to knock out the mice's microbiome caused changes similar to the deletion of *Piezo1*. Treating gut cell cultures with RNA extracted from faecal matter activated *Piezo1*, but there was no response to faecal DNA or proteins. Stimulating the gut of live mice with faecal RNA led to increased serotonin production, but not in mice lacking *Piezo1*.

Given the link with processes in the gut and bone, identifying and understanding the RNA-*Piezo1*-serotonin axis may lead to new therapeutic approaches for diseases such as osteoporosis and colitis.

REFERENCE:
Cell **182**, 609-624 (2020).
doi: 10.1016/j.cell.2020.06.022



Mina De La O / Getty Images

A GLOBAL OUTLOOK

Achieving internationalization in WPI centres.

International reputation and influence are key goals for the WPI Initiative, which aims to establish vibrant environments that attract the highest calibre of researchers from around the world. In 2018, 41% of researchers at WPI centres came from outside Japan, compared to 7.8% at Japan's national universities in 2017.

The Reputation Survey found that WPI centres have established a growing global reputation despite their relatively recent formation.

Survey respondents noted that it usually takes decades for research centres to become established and forge a lasting reputation. While WPI centres have bucked this trend through rapid growth and by building international profiles in a limited amount of time, there was consensus that they remain relatively young and need more time to cement their presence globally.

"The best thing about IRCN is that they bring together some obvious things and some very new ones. Of course, it's a very new centre, so their international reputation is developing," one respondent said.

International collaboration delivers an additional benefit to the universities that host WPI centres through increased citation impact. These collaborations can also share the cost and the benefits of resource-intensive research infrastructures across universities, and sometimes even nations.

WPI centres may also clear pathways for other international centres and organizations to collaborate through initiatives such as joint posts, student enrolments, visits and exchange programmes.

INTERNATIONAL COLLABORATIONS

WPI researchers were regarded as attractive international collaborators by 35 interviewees, and the centres were viewed as proactively reaching out to seek links beyond Japan. As noted previously, however, one of the report's limitations is that all interviewees had previous experience with the WPI programme, which may have influenced their responses.

Collaborations often develop between WPI staff and foreign academics as a result of existing ties or prior connections, as highlighted by 16 interviewees.

This indicates there are further opportunities for WPI centres to reach out to new partners and build new networks.

"It should be recognized that an element of serendipity typically underpins the most impactful and transformational breakthroughs," said the Reputation Survey authors.

The Scientometric Impact Report used scientific co-authorship patterns to measure international collaboration.

The report shows that WPI centre researchers were involved in global collaborations spanning 92 countries and territories (on six continents) across the duration of the study.

Collaborations with researchers from the United States of America (3,536 co-authors) and China (2,128 co-authors) were particularly productive. Within Europe, co-authorships with researchers based in the

RESEARCH HIGHLIGHT

Self-growing synthetics inspired by strength training

A material that mimics muscles to heal and grow could lead to prosthetics that perform better over time.

When a weight lifter pushes their physical limits, their muscle fibres break down, enabling new, stronger ones to grow. Unlike muscles, which enjoy a constant supply of new building material from the bloodstream, synthetic materials cannot regrow when they break. This has made designing durable prosthetics extremely challenging.

A team including researchers from the WPI Institute for Chemical Reaction Design and Discovery (ICReDD) at Hokkaido University created a hydrogel using two intertwined polymers — one rigid and brittle, the other soft and stretchable. The researchers submerged their hydrogel in a solution containing monomers — base molecules that can join up into polymers — and stretched it.

While the stretchy polymer kept the hydrogel intact, some of the brittle polymer chains broke, generating reactive molecules called mechanoradicals at the end of the exposed strands. These radicals attracted floating monomers that had been absorbed by the hydrogel, like a muscle absorbs amino acids from the blood, and bound them into a new, stronger polymer network. After repeated stretching and release, the hydrogel grew in strength and size, as muscles do after regular exercise, and was able to lift a weight progressively higher as the gel stiffened.

Self-growing gels could be used to incorporate artificial muscles into soft-robotics and improve the performance of prosthetic limbs.

REFERENCE:
Science **363**, 504–508 (2019).
doi: 10.1126/science.aau9533

> **It's a very welcoming culture for international people. That is a very positive thing for international teams and groups.**

United Kingdom (1,205), Germany (1,196) and France (815) were the most prominent.

Astronomy and physics are fields known for strong international collaboration, so it is unsurprising that Kavli IPMU had the highest number of WPI centre international co-authorships.

All of the WPI centres in the scientometric impact report were found to collaborate with international partners at rates exceeding global and domestic baselines, with one in four WPI programme publications, on average, co-authored with international collaborators.

OPENNESS AND OPPORTUNITIES TO INTERACT

The Reputation Survey found that WPI centres were viewed as being more internationally open than other Japanese institutions. WPI centres were described as being very welcoming of international academics by 21 interviewees.

The high representation of international staff was noted by 15 interviewees, while 11 pointed out the importance of operating in English.

Staff at WPI centres were commended for assisting visitors navigate daily life, which some found challenging due to the lack of English spoken in Japanese society.

"They will help you get established, feel yourself at home in many different ways, it's a very welcoming culture for international people. That is a very large, positive thing for international teams and groups," one respondent said.

WPI centres are designed and built to facilitate intellectual exchange, which makes centres more attractive to international researchers. They recognize the potential that the centres provide for valuable interactions with other leading scholars when they attend conferences or events, or work at a centre on a short or long-term basis.

The Reputation Survey analysis suggests that WPI centres and the events they organize can act as a catalyst to form new international collaborations and exchange ideas, regardless of nationality. ■

RESEARCH HIGHLIGHT

'Fibre on fibre' artificial matrix improves human stem cell culture

A matrix of gelatin nanofibres layered on cellulose and biodegradable plastic microfibres can act as a three-dimensional scaffold upon which to culture human stem cells.

Human pluripotent stem cells have an enormous range of applications in medical research and development, from regenerative medicine to drug design. One challenge for scientists working with these pluripotent stem cells is culturing them in large quantities while preserving their essential qualities and features.

A team led by researchers from the WPI Institute for Integrated Cell-Material Sciences (iCeMS) at Kyoto University has developed an artificial material designed to mimic the structure of the matrix in which pluripotent stem cells are found in the body.

The material consists of a base of microfibres made from cellulose – which is the main component of plant cell walls – and a biodegradable polymer, which is then layered with gelatin nanofibres. The structure offers stability for the growing stem cell cultures, to avoid exposing them to mechanical stress, while also allowing nutrients to circulate around the stem cells.

In experiments, researchers showed the structure supported the healthy growth of the pluripotent stem cells over two months without any change to their function.

REFERENCE:
Biomaterials **124**, 47-54 (2017). doi: 10.1016/j.biomaterials.2017.01.039

Science Photo Library - STEVE GSCHMEISSNER / Getty Images

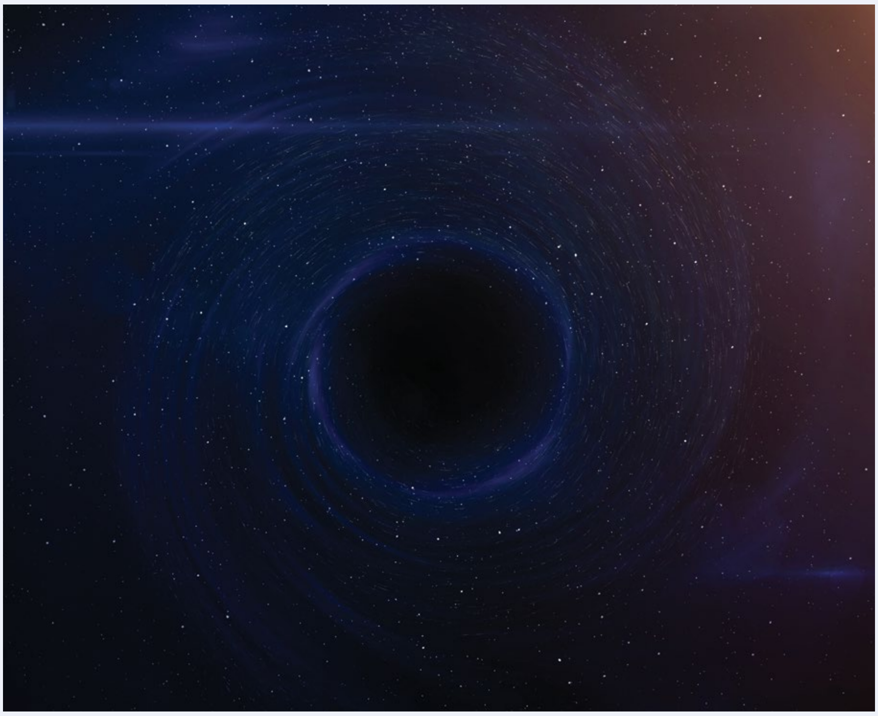
RESEARCH HIGHLIGHT

Primordial black holes ruled out as prime dark matter source

Black holes born at the beginning of time can make, at most, a minuscule contribution to the mysterious dark matter that makes up about 85% of the Universe's total mass.

Cosmologists know that dark matter is out there because they can see its gravitational effects in galaxies, but they are having a hard time tracking down its source. The most likely candidates have been new elementary particles, but back in 1974 physicist Stephen Hawking proposed a very different possibility — tiny black holes created within the first second or so of the Universe's existence.

Now, a team led by researchers at the WPI Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) at the University of Tokyo has shown that this scenario is highly improbable.



buradaki / Getty Images

Unlike conventional black holes (artist depiction above), primordial black holes do not have visible halos.

Unlike conventional black holes, primordial black holes are not expected to have visible halos of gas and debris around them. But they give away their presence when they pass in front of a supernova and act as massive lenses, bending the light from the supernova by their gravity.

The team looked for such gravitational lenses between Earth and the nearby Andromeda galaxy but were only able to find one event that fell in the mass range of black holes they were looking for. Based on this, they calculated that primordial black holes in that mass range can make up 0.1% at most of dark matter mass.

REFERENCE:
Nature Astronomy **3**, 524–534 (2019).
doi: 10.1038/s41550-019-0723-1

Ordering disordered proteins

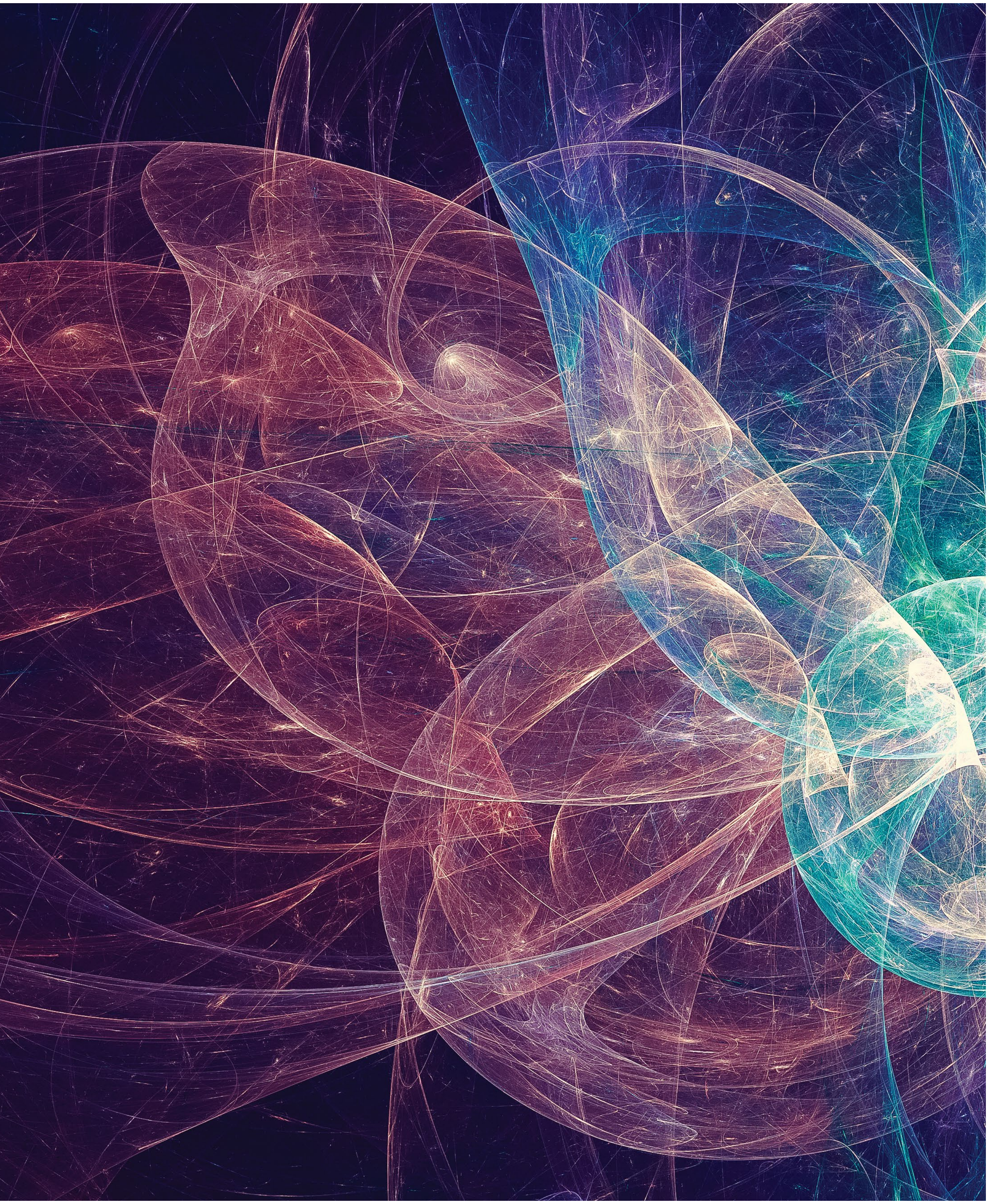
New research shows how high-speed atomic force microscopy can be used to characterize proteins with complex, dynamic structures that are challenging to analyse using other methods.

Many proteins have intrinsically disordered regions which do not have a fixed structure. This makes them difficult to analyse with techniques such as crystallography or electron microscopy. Intrinsically disordered proteins play a significant role in many biological processes, so characterizing their structure is an important goal.

Researchers at the WPI Nano Life Science Institute (NanoLSI) at Kanazawa University led a team that used high-speed atomic force microscopy to analyse the structure and dynamics of a set of intrinsically disordered proteins. They placed the proteins on mica and took roughly 13-24 images of them every second.

With this approach, they were able to distinguish the fully disordered, partially disordered, and fully ordered regions of the proteins, as well as the disorder-to-order transition. The technique also detects the size of the disordered region and provides information on the nature of the transiently folded structures, such as the shapes they take and their transition dynamics. Combining this with information from other approaches can give a realistic, dynamic picture.

REFERENCE:
Nature Nanotechnology **16**, 181-189 (2021).
doi: 10.1038/s41565-020-00798-9



oxygen / Getty Images

CULTURAL CHANGE

Can the WPI programme lead to system reform in Japan?

The funders, policymakers and editors surveyed as part of Research Consulting's report held positive views on the quality of the science, the strength of key staff, and the importance of the fields of research produced within the WPI programme, despite having a low awareness of the WPI programme itself. These respondents were mostly influenced by their knowledge of individual institutes within the programme.

Respondents commended WPI's relatively high proportion of international staff compared to other Japanese institutions, noting the centres' international openness, compared to their counterparts, had the potential to drive long-term change in Japanese academia. In this context, one policymaker said that the research and administration approaches taken at WPI centres are "shaking the Japanese research system".

OPENING PATHWAYS

Funders and policymakers felt that opportunities for international collaboration had the potential to be better leveraged, as current pathways to engaging with the WPI programme were mainly limited to events, exchanges and visits.

The WPI programme was viewed as having the potential to enable strategically important developments, such as mechanisms for substantive joint funding and other broader interactions with foreign policymakers and funders.

However, respondents raised concerns about the current duration of WPI centres' funding, with 23 interviewees stating that long-term funding is key to success.

Long-term funding of research centres is important to achieve high visibility, with some respondents stating that a 10-year timeframe is too short to establish and embed world-leading institutes. Policymakers and funders pointed out that ambitious research programmes need secure and ongoing funding to be able to take risks, and some programs comparable to WPI have permanent funding lines as a result.

"Setting up a new institute, bringing people together who haven't worked together before does take time. After this sort of 'activation time', things take off – and that's why losing the funding after ten years is such a pity," one respondent said.

> **My experience as a young researcher was intense. Japanese work ethics live up to their reputation.**

Respondents also identified the potential to boost future collaboration opportunities through clearer communication, noting that the WPI website was difficult to navigate and the process for engaging in a collaboration or exchange programme was not clear.

"The feeling I have is that the WPI website is a mixture that doesn't really know which target to go for. It's not sloppy, but it's not as engaging for a researcher, while as a bystander it's too cumbersome," one respondent said.

Another limitation of the WPI programme identified by the Reputation Survey was the lack of opportunities for start-up and spin-out companies. One academic interviewee noted that these opportunities could be a good means of showing the potential for fundamental research to have application to society.

CULTURAL BARRIERS

Reputation Survey respondents did note certain cultural barriers to international collaboration.

While WPI centres have greater gender and national diversity than typical Japanese institutions, some respondents note this is still limited, particularly at the PI level. "[The idea of] being there with the pioneers of these techniques was very attractive. But personally I am not sure I'd go, because of the gender imbalance," one respondent said.

Many international staff see WPI centres as a stepping-stone, with only a minority considering a long-term future in Japan. Interviewees also noted that language barriers and challenges to integrate with the Japanese culture mean visiting academics can struggle to shape a career in Japan.

These cultural barriers were seen to potentially also reduce the extent to which some Japanese researchers choose to work abroad, concerned by associated risks for their career.

The Japanese academic culture was also seen as an obstacle for visitors, with 19 interviewees commenting that Japan's hierarchical social structures and work culture meant that staff (particularly the most junior) are expected to work late on a daily basis, having to remain in their office until their superiors leave.

"My personal experience there as a young researcher was really intense: Japanese work ethics do live up to their reputation," one respondent said. However, five interviewees noted that WPI centres are less hierarchical than many Japanese universities. ■

SEAN GLADWELL / Getty Images

THE SOCIETAL IMPACT OF WPI CENTRES

Does supporting basic research lead to wider benefits to society?

In 2020, Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) announced that a new WPI Mission, Values for the Future, will also evaluate centres according to the societal value of basic research in social and natural sciences.

FINDINGS FROM THE REPUTATION SURVEY

Research Consulting's Reputation Survey respondents focused on the importance and impact of WPI centres and on the wider significance of fostering fundamental research in the long term.

Key points included 16 interviewees who noted that fundamental research has the potential to lead to major breakthroughs and important industry applications. A further 13 interviewees noted that funding for fundamental research is essential for continuous innovation, and that WPI centres can enable curiosity-driven scientific endeavours. Finally, 23 interviewees warned that the societal impact of fundamental research can only be understood in the long term.

Reputation Survey respondents outlined a range of ways in which WPI centres impact society, both within and beyond academia. For example, engagement in local communities via symposia and public lectures communicates Japan's scientific ambitions and may inspire new generations to take up fundamental research.

Respondents noted that WPI centres are helping to raise the profile of Japanese scientists on the global stage, in some cases this is closely related to industry collaborations.

"People are actively talking about their work on the global stage and communicate well with the international community. And their outlook is very much a global outlook," one respondent said.

By promoting collaborations and intellectual exchanges with a global audience, WPI centres actively support the internationalization of Japanese academia, including in their host institutions. However, interviewees point out that this often involves culture change.

FINDINGS FROM THE SCIENTOMETRIC IMPACT REPORT

Digital Science's Scientometric Impact Report assessed the societal influence of the WPI centres via three methods.

- assessing the promotion of scientific literacy via global social media engagement and news coverage of WPI research
- calculating the economic and public policy impacts of WPI research via industry collaboration and research commercialization, and
- analysing published research relevant to the UN Sustainable Development Goals

Global public engagement

Altmetrics data is used to assess the extent of global public engagement with research. This assesses the ar-

RESEARCH HIGHLIGHT

Tweaking a single gene boosts rice productivity

Boosting the expression of a single gene is enough to make rice better at taking up ammonium and more efficient at photosynthesis, leading to an increase in grain yield.

Work in the model plant Arabidopsis had shown that increasing the expression of a gene encoding a plasma membrane transporter enhanced the opening of pores in the leaves known as stomata, which are crucial for gas exchange during photosynthesis. This resulted in greater photosynthesis, but it was unclear whether the findings would hold in crop plants.

To find out, a team led by researchers at the WPI Institute of Transformative Bio-Molecules (ITbM) at Nagoya University overexpressed a similar plasma transporter in rice, the OSA1 gene. Plants with increased *OSA1* had greater dry weight than normal plants, and knocking out the gene had the opposite effect.

Measurements revealed increased ammonium uptake, stomatal opening, and photosynthesis in plants with *OSA1* overexpression. RNA sequencing analysis of these plants and plants with the gene knocked out found altered expression of a suite of genes involved in photosynthesis, ammonium assimilation, and other processes. Finally, field experiments with *OSA1*-overexpressing rice showed increased yield and greater nitrogen use efficiency across a wide range of conditions.

REFERENCE:
Nature Communications **12**, 735 (2021).
doi: 10.1038/s41467-021-20964-4

Publications related to select UN Sustainable Development Goals

The majority of WPI research related to the UN SDGs were in the areas of energy, climate action, and health.

894 papers related to at least one SDG were published by WPI centres between 2007 and 2018.

	SDG7 Affordable and clean energy	SDG13 Climate action	SDG3 Good health and well being	SDG6 Clean water and sanitation	SDG11 Sustainable cities and communities
WPI programme (total)	709	108	77	7	6
AIMR	130	5	-	-	-
ELSI	19	20	1	1	2
I²CNER	159	57	1	2	-
iCeMS	37	9	2	1	2
IFReC	1	-	61	-	-
IIIS	7	-	10	-	-
ITbM	10	-	1	-	1
MANA	346	17	1	3	1

ticles that are shared, recommended and discussed online. The nature of Altmetric data can make it imprecise, but it is an indicative measure of impact.

The analysis found that one out of every two WPI programme articles was shared online, and on average 54% of publications from WPI centres were mentioned online. All the WPI research publications in the study far exceeded the typical expected engagement rates for publications in similar disciplines and time frames; some doubled and tripled the rate of similar research. This demonstrates that a high proportion of WPI research receives public interest in comparison with similar research in the same disciplines. It is also possible that this greater online engagement is partly due to WPI programme requirements to engage in science communication.

Global media engagement

Though mainstream media coverage is not a direct measure of societal impact, researchers have linked media coverage of research to both public scientific literacy and influence on public policy.

Overall, WPI programme research has received greater-than-expected rates of mainstream media coverage. During the study period, 9,357 news stories were published by 1,020 unique news outlets in 61 countries. This contributes to the WPI goal of societal impact through public and international engagement with WPI research in the mainstream media.

Around half of all WPI programme publications have featured in at least one high-profile news outlet. WPI's public engagement has been global, especially throughout the Americas, Europe and Asia-Pacific region, and in the scientific press.

The Scientometric Impact Report notes that WPI's strong international collaborations could be leveraged to generate broader coverage; non-English speaking researchers could be supported to translate press releases and lay abstracts into their own languages.

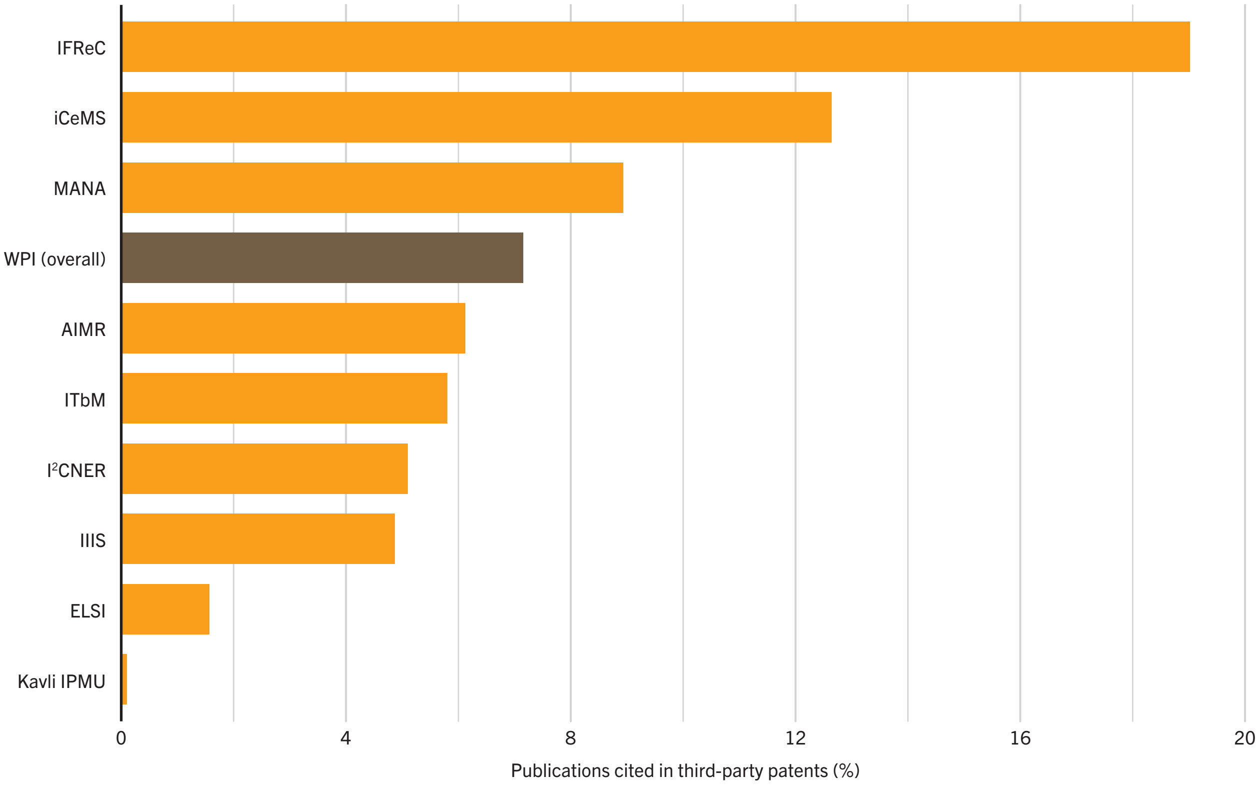
Industry-research collaboration

Collaboration between researchers in academia and the private sector can prompt regional innovation, advances in technology and stimulation of economic growth, according to the authors of the Digital Science report.

WPI programme research fostered 230 industry collaborations between 2007 and 2019, which led to 645 co-authored publications with private sector global leaders. On average, approximately 3.3% of WPI programme

Third-party commercialization rate

The percentage of WPI centre research cited in global patents. The figure for the WPI programme overall is shown in brown.



publications were co-authored with industry.

Domestic industry partnerships with the greatest number of published papers involved Hitachi (36 co-authored publications), NEC (32), JEOL (21), Denso (20), and Toyota Motor Corporation (18).

International industry partnerships with the greatest number of published papers involved Samsung in Korea (14 co-authored publications), Roche in the US (6), Veeco in the US (4), Air Liquide in France (3) and Nestlé in Switzerland (3).

Research commercialization

Patents that cite scholarly works give insights into the impact of research upon technology commercialization, as basic research often prompts breakthroughs in technological innovation and regional economic growth.

This analysis found that research from the WPI centres had a greater impact on the creation of intellectual property via patent citations than was expected for the relevant subject areas, with 1,473 publications out of 20,464 total WPI programme publications (7.2%) found to have been collectively cited 6,346 times in 4,631 global patents.

Patent citation analysis showed the areas of excellence in research commercialization were:

- materials engineering
- physical chemistry
- biochemistry and cell biology
- immunology, and
- macromolecular and materials chemistry.

The analysis found that AIMR, ELSI, iCeMS, IFReC, ITbM, and MANA had exceptional rates of influence on research commercialization.

Research relevant to UN Sustainable Development Goals

The 17 UN Sustainable Development Goals (SDGs) tackle the climate crisis and environmental degradation, together with economic and gender inequality and other major societal challenges.

WPI centres produced 894 publications associated with at least one UN SDG, contributing most frequently to the goal of Affordable and Clean Energy (709 publications) followed by Climate Action (108) and Good Health and Wellbeing (77).

The WPI International Center for Materials Nanoarchitectonics (MANA) accounted for more than one-third of all WPI research addressing UN SDGs. ■

RECOGNITION AND REWARD: HOW WPI CAN IMPROVE ITS STATUS

Recommendations are presented to address the weak points of the WPI programme.

While the science conducted at individual WPI centres is very well regarded by academics worldwide, the reputation survey conducted by Research Consulting found that the WPI brand is not widely recognized, with 30 respondents not identifying WPI centres as being part of an overarching network.

There are a number of reasons for this, most prominently that researchers often give their affiliation by stating the individual institute and university, i.e AIMR, Tohoku University, rather than including WPI in the name, i.e. WPI-AIMR.

"This means that outside Japan there is very little recognition that the WPIs are a collection or network of excellent institutions," observes David Swinbanks, founder of the Nature Index and senior advisor to Digital Science. "Instead they tend to be viewed as excellent, but small, independent specialist institutes of top universities in Japan."

To address this issue, WPI needs to work on its branding, to build the reputation and awareness of the WPI brand as a whole, not just of individual centres. This can be done on a few levels:

1. Conduct a global awareness and visibility promotional campaign targeted at the scientific community
2. Revamp the WPI programme website, which is currently just a subpage of the JSPS website. The interface is very dated, its brand identity is weak, and it is difficult to find via search engines without adding qualifying terms after WPI. The WPI programme needs its own unique domain and an updated search engine optimized website.
3. Requiring that WPI be prominently attached to every centre name in research article affiliations, promotional materials, email signatures, and business cards.

Swinbanks, and a number of survey participants also singled out the 10-year funding term as a problem. "Just as the WPIs are beginning to establish themselves, they lose their funding or have to rely on their host university for ongoing support? That is a fundamental flaw," says Swinbanks.

> **Outside Japan there is very little recognition that the WPIs are a network of excellent institutions.**

While some centres that have graduated to the WPI Academy obtained continuing funding either through their university, such as AIMR and Tohoku University, or via a combination of university and industry sources, such as I²CNER, that tends to have drawbacks. This can manifest as a reduction in the number of foreign scientists, and reversion to a more traditional Japanese academic model, or an increased focus on industrial projects, instead of the basic research that forms the core of WPI missions.

Extending the funding of the centres beyond the 10-year period would help WPI centres retain their unique characteristics and priorities, as well as addressing another identified flaw — the long-term retention of foreign staff. The WPI has been acknowledged as a good step for early career foreign researchers, but the lack of long-term career opportunities means that many regard it as a stepping stone.

There is an adage in STEM, that you can't be what you can't see. To address this, Swinbanks suggests having a requirement for a minimum proportion of foreign PIs at WPIs, and appointing some non-Japanese as heads of the WPIs. By increasing the length of time the centres are funded, encouraging quotas, and providing a defined career trajectory, the WPI centres may retain both their unique characteristics and foreign staff.

A similar issue raised by survey respondents was the dearth of women in top positions, such as principal investigators and directors. This is also something that WPI needs to address, both for Japanese and foreign women.

The science at WPI is strong, with some modifications, the culture and long-term career opportunities for its staff will be as well. ■

APPENDIX: METHODOLOGY

THE SCIENTIFIC AND SOCIAL IMPACT REPORT

Scientometric analysis was performed based on the Dimensions and Altmetric databases by Digital Science.

The Japanese Society for Promotion of Science (JSPS) provided a list of 20,928 publications for analysis. 20,550 of these publications were assigned DOIs, unique identifiers crucial to searching Dimensions and Altmetric for the purposes of this analysis. 20,464 disambiguated DOIs were then analysed. When reporting trends observed at the institute-level, all relevant publications with DOIs that are assigned to each institute (N=20,550) were considered, of which there is a limited degree of overlap between institutes that have co-authored the same articles (N=86).

Dimensions uses advanced text mining techniques to discover connections between documents and entities. These include links between funders and publications, links between researchers and grants, citations from clinical trials to publications, citations from policy documents to publications, as well as 1.4 billion citations between research publications. There are more than 260 million records in Dimensions, with over 4 billion connections between them.

Of the 20,550 WPI institute publications assigned a DOI, 20,492 publications could be linked to a Dimensions publication ID. Publications with a Dimensions publication ID were used as the basis of some or all of the analyses. All bibliometric data from Dimensions reflects citations and relationships recorded up to March 8, 2021.

Altmetric tracks and analyses the online activity around scholarly literature. Altmetric collates what people are saying about published research outputs in scholarly and non-scholarly forums like the mainstream media, policy documents, social networks, and blogs to provide a more robust picture of the influence and reach of research. Altmetric has tracked over 164 million discussions around 17 million research outputs across a range of online sources.

Of the 20,464 unique WPI programme publications assigned a DOI, 11,740 are included in Altmetric Explorer, which indexes only those publications mentioned online in a source that Altmetric tracks. Altmetric data was used as the basis of some or all of the analyses. The scientific and social impact report reflects the Altmetric attention recorded up to March 30, 2021 for all data except for Altmetric Attention Score percentiles, which were retrieved May 17, 2021.

REPUTATION SURVEY

The reputation survey was conducted by Research Consulting. It was based on semi-structured qualitative interviews, using an interview questionnaire co-developed with JSPS and Springer Nature. Project contributors were identified and recruited in close collaboration with Springer Nature, and the findings arising from the interviews were analysed via thematic coding, using the NVivo software.

Interviewees included 66 stakeholders, comprising 55 academics, three editors and eight policymakers and funders, contributed to the reputation survey. Interviewees covered a wide range of countries and institutions. It should be noted that all academics involved had some previous experience with WPI centres, and were from countries outside Japan, and non-Japanese nationals. ■