20th Annual Meeting

STS *forum* 2023

Summary

October 1, 2 and 3, 2023
Kyoto, Japan

20th Anniversary

Science and Technology in Society *forum*

Summary of STS *forum* 2023

STS *forum* 2023 - 20th Annual Meeting

October 1-3, 2023

Plenary Sessions | Concurrent Sessions | By Invitation Only

September 30, 2023 (Saturday)

10:00-18:30	Registration [The Prince Kyoto Takaragaike] (for all STS *forum* participants)	09:30-18:00	Regional Action on Climate Change (RACC15) [Room A]
		11:00-12:30	AA-STS Board Meeting
		12:00-12:50	Young Leaders Network
		12:50-15:30	Dialogue between Young Leaders and Nobel Laureates
		12:00-15:30	Young Leaders Alumni Meeting
		13:00-15:00	Board Meeting
		14:00-16:40	Kyoto Symposium
		14:00-17:00	12th Global Summit of Research Institute Leaders
		16:00-18:00	Forum for Unity, Science, and Empowerment (FUSE)
18:00-20:00	Networking Plaza [Gold Room (B2F), The Prince Kyoto Takaragaike]		

October 1, 2023 (Sunday)

08:30		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			
10:00-10:50 50 min.	100	**Opening: The World in 2023 — What do we need from S&T? [Main Hall]**			
10:50-12:10 80 min.	101	**Koji Omi Memorial Plenary: Lights and Shadows of AI [Main Hall]**			
12:10-13:50 100 min.		Lunch and Networking Time [Sakura]			12:10-13:30 CEO Meeting 12:10-13:30 CTO Meeting 12:10-13:30 University Presidents' Meeting 12:10-13:30 Heads of Private Foundations Meeting 12:10-14:50 S&T Ministers' Roundtable
13:50-15:50 120 min.	102	Energy	Climate Change	Earth and Commons	Life Sciences
		Action for Net-Zero Emission [Room B-1]	**Adaptation to Climate Change [Room B-2]**	**Agriculture, Food and Water Security [Room K]**	**AI in Health [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		Revolutionary Materials and Devices [Room C-1]	**Science and Technology as a Driver for Development [Room C-2]**	**Fostering New Generations of Scientists with Inclusion and Diversity [Room H]**	**Trust of Information in Digital Age [Room A]**
15:50-16:00		Coffee Break			
16:00-17:00 60 min.	103	**Koji Omi Memorial Lecture: Conversation with Prof. Dr. Svante Pääbo [Main Hall]**			
17:10-18:10 60 min.	104	**Path to Sustainability [Main Hall]**			
18:10		Move to the venue (Shuttle bus provided from ICC Kyoto to site)			
19:00-21:00	105	Special Buffet Dinner at Ninna-ji Temple			

October 2, 2023 (Monday)

07:30		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			08:00-08:45 General Meeting
09:00-10:10 70 min.	200	**200A: Lights and Shadows of Human Activity in Space [Main Hall]**		**200B: Global Health — What the world needs to prepare for the next pandemic [Room A]**	
10:10-10:40		Coffee Break			
10:40-12:40 120 min.	201	Energy	Climate Change	Earth and Commons	Life Sciences
		New Technologies for Low Emission Transportation [Room B-1]	**Sustainable and Resilient Urban Environments [Room B-2]**	**Biodiversity and Ecosystem Services [Room K]**	**New Frontiers in Biotechnology [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		Quantum Science and Technologies [Room C-1]	**Collaboration among Academia, Industry and Government [Room C-2]**	**AI in Education [Room H]**	**Quest for Digital Equity [Room E]**
12:40-14:20 90 min.		Lunch and Networking Time [Sakura]			12:50-14:10 Academy of Science Presidents' Meeting 12:50-14:10 Academy of Engineering Presidents' Meeting 12:50-14:10 Funding Agency Presidents' Meeting
14:20-16:20 120 min.	202	Energy	Climate Change	Earth and Commons	Life Sciences
		Fusion Energy [Room B-1]	**Green Technologies [Room B-2]**	**Deep-sea Exploration and Exploitation [Room K]**	**Healthy Aging [Room D]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		AI & Hyper Automation [Room C-1]	**Nurturing Innovation-based Startups [Room C-2]**	**Trust in Science [Room H]**	**Data in AI [Room E]**
16:20-16:50		Coffee Break			
16:50-18:00 70 min.	203	**203A: Basic Science, Innovation and Policy [Main Hall]**		**203B: Science and Technology for Business [Room A]**	
18:00-21:00	204	Cocktails and Official Dinner [Event Hall] Special Concert: The Multifaceted Pianistic Artistry of Hayato Sumino			20:30-22:00 Council Meeting

October 3, 2023 (Tuesday)

08:00		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)
09:00-11:00 120 min.	300	**Key Messages from Concurrent Sessions [Main Hall]**
11:00-11:40		Coffee Break
11:40-12:30 50 min.	301	**Closing: Science and Technology for the Future of Humankind [Main Hall]**
12:30-13:30	302	Farewell Buffet Lunch [Swan]

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Plenary Sessions

Opening Plenary Session: The World in 2023 -- What do we need from S&T?

[Chair]

Komiyama, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., Japan

[Speakers]

Kishida, Fumio, Prime Minister, Government of Japan, Japan

McNutt, Marcia, President, National Academy of Sciences, U.S.A.

Belhocine, Mohamed, Commissioner, Education, Science, Technology and Innovation, African Union Commission (AUC)

Tokura, Masakazu, Chairman, KEIDANREN; Chairman of the Board, Sumitomo Chemical Co., Ltd., Japan

Opening Remarks

Prof. Hiroshi Komiyama, Chairman, Science and Technology in Society *forum* (STS *forum*); Chairman, Mitsubishi Research Institute, Inc., opened the 20th Annual Meeting of STS *forum* and thanked the participants for their attendance. Prof. Komiyama also expressed his gratitude to sponsors, members, and contributing organizations for their support. He then reminded the participants that STS *forum* was founded to discuss the lights and shadows of science and technology from a long-term perspective and pointed out that its significance has only grown.

Komiyama, Hiroshi

Humankind has spread throughout the globe, establishing civilizations, and making improvements to people's quality of life. The progress experienced by humankind, such as the more than doubling of the average life expectancy, has always been supported by science and technology. On the other hand, science and technology have also brought about dark shadows. Human activities, propelled by science and technology, have grown enormously in scale and have had a great impact on the substance of the earth and of the air. Whether humanity will continue to prosper or fall into decline is dependent on humans' own efforts.

There are, however, reasons for hope. One is the great potential of solar energy. Another is saturation. Once saturation is reached, manmade objects can be recycled, making it no longer necessary to dig up underground resources, enabling the achievement of a circular society. Furthermore, it will be possible to recycle materials by solar energy, enabling the achievement of a sustainable circular society.

Nevertheless, to realize a positive future, humankind must tackle social and political issues such as food and water shortages, disparities, social divides, and war. We must act now, while we still can. Knowledge is key to addressing these issues. The various forms of knowledge can be likened to a porcupine fish. Each spine of the porcupine fish is like an area of knowledge developed in isolation. If these could be converged, there is no challenge humans could not overcome.

There is huge potential for generative AI to facilitate such a convergence. On the other hand, generative AI also raises concerns, such as human society becoming overly reliant on AI leading to a decline in cognitive abilities, the monopolization of the technology by a select few, and human bodies and brains falling behind the speed and magnitude of changes in technology and the natural environment. Leaders from politics, business, and academia have a collective responsibility to maximize the vast potential of generative AI, while countering its negative impacts. It is hoped that STS *forum* will spearhead the path forward on generative AI.

No single country or field alone can ensure a prosperous future for humanity. Instead, it is necessary to leverage our collective wisdom beyond our respective silos. One Japanese initiative that seeks to do this is the Platinum Society, which aims to realize a sustainable

Kishida, Fumio

world and a prosperous social model in which all can achieve self-actualization. After 15 years of this initiative, there are early signs of transformation in Japanese society. It is hoped that, if all STS *forum* participants take action, a transformation for a brighter future for all of humankind can similarly be achieved.

Mr. Fumio Kishida, Prime Minister, Government of Japan, opened his remarks by noting that in the two decades since the founding of STS *forum*, science and technology have enabled significant advances to human life and society. He hoped that future progress in science and technology would continue to yield benefits for all.

For example, developments in generative AI can have positive impacts in a wide range of fields, including industry, education, and healthcare. Such advances in science and technology will hopefully continue to bring greater benefits to the public. However, concerns and issues have also been raised, such as disinformation, privacy, and copyright protection, which must be addressed. To this end, at the G7 Hiroshima Summit, leaders agreed on a vision for trustworthy AI and launched the Hiroshima AI Process. Japan is taking the lead on ensuring good governance and transparency in AI.

This dual nature, with positive and negative aspects, is not limited to generative AI but applies to all fields of science and technology. To ensure a brighter future for humankind, it is imperative to keep driving innovation forward, while earnestly addressing the potential negative impacts on society and ethical issues. International cooperation and human resource development will be key to overcoming such issues. At the G7 Hiroshima Summit, leaders agreed to promote international talent mobility and circulation. The promotion of brain circulation, which was stalled by COVID-19, is more important than ever and Japan will take the lead in such efforts.

STS *forum* brings together opinion leaders from around the world to engage in constructive discussions and networking, and it is hoped that its circle of collaboration will continue to expand. On the 20th anniversary of STS *forum*, it is vital to reemphasize the importance of

peaceful uses of science and collaboration. At the G7 Hiroshima Summit, leaders visited the Hiroshima Peace Memorial Museum and reaffirmed the importance of peace and human life.

The venue of STS *forum* is also highly significant, having hosted historical events such as a Pugwash Symposium in 1975, which was the first to be held in Japan and which brought together scientists to discuss how to achieve a world without nuclear weapons, and also the adoption of the Kyoto Protocol in 1997, which marked the start of concerted global efforts to tackle climate change. Now, through STS *forum*, it serves as the backdrop to discussions on key topics of science and technology. Mr. Kishida closed his remarks by posing two questions, “What kind of future do you wish to create?” and “How should we develop and use science and technology to create such a future?”

Dr. Marcia McNutt, President, National Academy of Sciences, U.S.A., began by posing the question that was the theme of the session: What do we need from science and technology? She suggested that science and technology are in fact the easy part. The hard part is people and ensuring the trust of the people. Scientists and engineers need to do more to connect with societies and show the public that they share their values. Unless scientists and engineers build trust with people who are not science-literate, progress in science and

McNutt, Marcia

technology will go to waste. A good example could be seen during the COVID-19 pandemic, whereby vaccines against the virus were very rapidly developed and manufactured, and yet there was strong resistance among some parts of the public to being vaccinated.

Another field where efforts to foster public trust will be needed is gene-editing. Gene-editing is poised to enable a major breakthrough in achieving more sustainable agriculture, but if people do not trust gene-editing, they will not eat the food produced using this technology. Similarly, in the United States, potable water is used to flush toilets, which is extremely wasteful. Scientists should work with architects and local building code mangers to develop better plumbing and water conservation solutions. Scientists could also work with social scientists to, for example, ensure the public's recycling efforts are as effective as possible. Meanwhile, in the area of AI, which has been making waves of late, AI developers should work with ethicists and others to ensure it is accessible and ethical, that it does not exacerbate existing issues, and that it feels beneficial to regular people.

Belhocine, Mohamed

Prof. Mohamed Belhocine, Commissioner, Education, Science, Technology and Innovation, African Union Commission, spoke about advances in science and technology and the associated challenges in the context of Africa. There is no limit to what science and technology can do to resolve social problems and to foster prosperous and inclusive societies. With that in mind and with the hope for an integrated, prosperous, and peaceful continent, Africa formulated Agenda 2063, a 50-year development plan, and placed science and technology at the heart of the implementation of its Seven Aspirations through the Science, Technology and Innovation Strategy for Africa.

Science and technology are also essential to the integration process of Africa. Collaboration in knowledge production, sharing, and archiving is fundamental to science and technology. Across the continent, scientists, researchers, and students are working together on issues such as improving access to energy and clean drinking water, protecting and conserving biodiversity, enhancing climate resilience, reducing poverty and hunger, and disaster prevention and mitigation.

Science and technology also contribute greatly to making economies more competitive. At the same time, data can be used to provide evidence-based solutions for preventing or resolving conflicts. Science and technology need to be supported with investment in education. Furthermore, science-based and science-driven policies are essential. Africa is also endeavoring to implement regulatory frameworks to ensure that developments in AI benefit the countries and peoples of Africa and that the potential downsides are minimized. The Commissioner also emphasized how we can deploy science and technology in generating, processing, and communicating data towards evidence-based conflict prevention and management, and public health (diseases, pandemic) improvement. This can bring about attitudinal change for peace building and preservation processes as well as for creating healthy communities.

Mr. Masakazu Tokura, Chairman, KEIDANREN; Chairman of the Board, Sumitomo Chemical Co., Ltd., pointed out that the world has faced two broad challenges in recent years. The first is ecological collapse as a result of climate change. The second is the expansion, entrenchment, and reproduction of disparities. These challenges are interacting, creating even more complex crises. Underlying these crises is excessive capitalism and it is time to pause and rethink it. KEIDANREN believes in the importance of incorporating social points of view into the market economy.

Tokura, Masakazu

Technologies such as generative AI and gene-editing have huge potential to bring about positive impacts on society. However, they also undeniably have negative aspects that cannot be left unchecked. What should be done? It is clear that simply imposing strict regulation is not the answer. Rather, it is necessary, while incorporating ethics and values, to explore what those technologies should be used

for and how, in order to benefit humanity in the best ways. We need to unlock the vast potential of science and technology, while also managing the associated risks. Advances in science and technology hold the key to solving social issues while simultaneously achieving sustainable economic growth.

At the same time, natural sciences can only go so far. "Integrated knowledge," or "So-Go-Chi" in Japanese, is required, with the need to bring together not only natural sciences, but also liberal arts and social sciences. Similarly, no single country or sector has all the answers. STS *forum* is an excellent opportunity for key leaders in science, politics, and business to jointly discuss science and technology issues and foster multilateral collaboration. Furthermore, STS *forum* can show how science and technology can overcome the challenges of our time and pave the way for a brighter and more prosperous future.

Koji Omi Memorial Plenary: Lights and Shadows of AI

[Chair]

Kleiner, Matthias, Professor, Technical University of Dortmund, Germany; Scientific Advisory Board Member, Representative, Werner Siemens Stiftung, Switzerland

[Speakers]

Nishimura, Yasutoshi, Minister of Economy, Trade and Industry, Ministry of Economy, Trade and Industry; Member, House of Representatives, Japan

McLean, Angela, Government Chief Scientific Adviser, Department for Science, Innovation and Technology, Government Office for Science, U.K.

Norvig, Peter, Distinguished Education Fellow, Human-Centered Artificial Intelligence, Stanford University; Research Director, Google Research, Google Incorporated, U.S.A.

Matsuo, Yutaka, Professor, Graduate School of Engineering, The University of Tokyo, Japan

Yeh, Mike, Regional Vice President, Corporate External and Legal Affairs, Microsoft Asia, Microsoft, Singapore

Samiei, Saba, Founder and CEO, MACSO Technologies; Founder and CEO, Comfort.AI, New Zealand

Opening Remarks

The session was opened by Prof. Matthias Kleiner, who noted that STS *forum* has recognized and discussed the importance of AI to human society for many years. No technology has had as profound an impact in so short a time as the development of AI, from defeating the most skillful humans at the most advanced games of strategy, to helping industry in its ability to optimize complex networks and supply chains, and revolutionizing scientific research in a wide range of fields. The new GPT chatbot programs have particularly captured the imagination of the public all over the world.

Kleiner, Matthias

However, as promising as the new technology seems to be, it learns from the unlimited amount of the human inputs on the internet and thus may reflect, incorporate, and entrench the human biases in the material it was learning from. It also raises fears of job displacement, including knowledge workers,

has enormous capability for spreading misinformation and deep fakes, and can distort conceptions of the democratic process. Furthermore, its neural net algorithms are opaque, leading to its occasional strange replies. There is a rising alarm about our societal rush to embrace that technology without due concern for its shadows.

Mr. Yasutoshi Nishimura shared his perspectives on the lights and shadows of AI. AI has the potential for economic transformation, but there are also downsides and potential issues. To create innovative economic growth, it is necessary not only to leverage but to further develop AI, and Japanese businesses will do just that. Japan will also secure computing and data resources, which are essential to these efforts. Furthermore, the Japanese government will ensure excellent human resources from academia and industry will be able to freely contribute to national AI initiatives.

At the same time, it is necessary to acknowledge and deal with the risks in generative AI. Generative AI is in its infancy and many issues have been pointed out, such as hallucinations, leaks of private information, and copyright infringements. However, excessive regulation will hinder innovation. To maximize the contribution of disruptive innovations, Japan will promote social implementation while managing risk in a balanced manner. As AI technologies become more sophisticated, it will become essential to utilize the expertise of the private sector.

The G7 Digital and Tech Ministers' Meeting compiled five principles for agile governance for emerging technologies, including AI. Japan will integrate this and other guidelines that exist

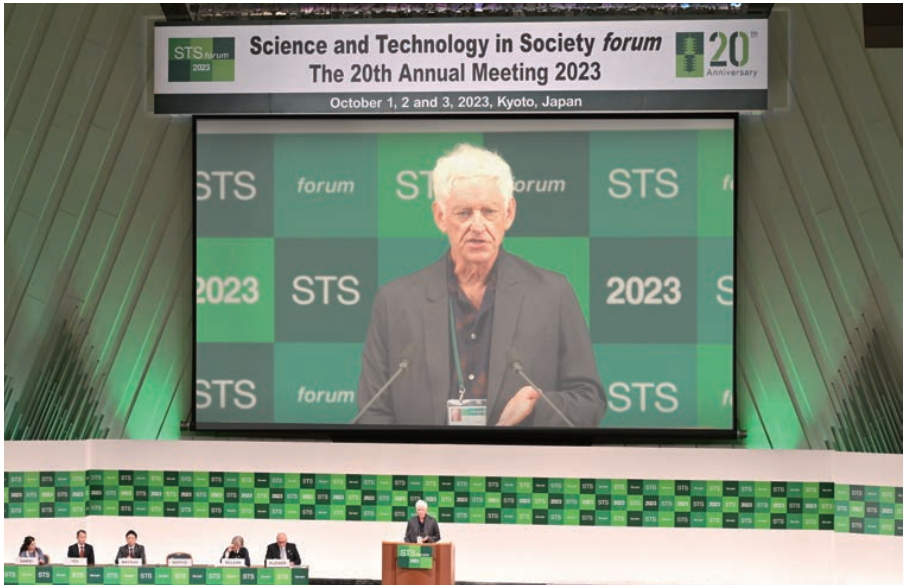
on AI and make them easier to understand for different stakeholders. It will also encourage businesses to implement voluntary risk-based initiatives, as well as collaboration on the development of rules for generative AI. Japan will also work to ensure interoperability in AI governance. In addition, Japan is promoting the Rapidus project to secure the necessary industrial base for semiconductors domestically, while also working with like-minded countries to strengthen supply chains.

Prof. Dame Angela McLean explained that AI has been the most prominent issue she has been working on as the Chief Scientific Adviser to the UK Government. She also explained that she is instinctively a technology optimist, recognizing the potential of frontier AI to deliver positive changes to society, such as medical advances, better public and cheaper services, more sustainable agriculture, and the chance to abandon menial tasks for more creative work. However, she acknowledged that there are also related risks that must be managed.

Around the world, it is necessary to reassure the public that a framework for managing AI risks that is responsive, proportionate, and future-proof will be put in place as soon as possible. International collaboration will be essential to such discussions on governance. Such global efforts are ongoing, and the UK will similarly host the AI Safety Summit, with the aim of demonstrating a shared understanding of the risks associated with frontier AI, international plans to address them, and agreed areas of collaboration. Most importantly, it will be important to communicate how AI can and will be used as a force for good. By doing so, it is hoped that the dominant narrative around AI will become positive rather than negative.

Dr. Peter Norvig started by outlining the changes in the discussions and narrative around AI. At first, discussions focused on the algorithms. Then, they moved to big data. Today, the key challenge is getting the objective right. AI is now dealing with much more difficult issues with more conflicting factors and trade-offs. AI systems cannot make the right choices until humans tell them what they should do. More important than decision support is objective support, which entails understanding and accurately describing to the AI systems what it is that the user actually wants.

In addition, it is not enough, now, to train the AI to focus only on what the user wants. Other stakeholders must also be considered. For example, in the case of driverless cars, the system needs to account for not only the passenger, but also pedestrians, cyclists, and others driving. At a larger level, it is necessary to consider societal implications, such



as urban sprawl or unemployment of drivers. Human-centered AI means understanding all these levels, having AI tools that augment humans rather than replaces them, and determining the appropriate level of automation.

One of the greatest areas of potential for AI is education. AI could enable the provision of a personalized tutor and educational experience to every student. Generative AI could also democratize the writing of code, which is a powerful tool but inaccessible to many. Overall, the most exciting aspect of AI is the potential to develop human-centered tools that empower people and make their lives better.

Prof. Yutaka Matsuo remarked on how generative AI has been the subject of much public attention over the past year. He also noted the importance of leaders gaining hands-on experience and understanding generative AI. Prof. Matsuo then shared AI-related developments in the Japanese context, where efforts are being made to enhance productivity while actively addressing risks. The application of AI is crucial, but there are several technical challenges that must be tackled, including hallucinations and reinforcement of biases. Fortunately, there are also potential technical solutions to these issues.

Beyond technical challenges, there are also issues such as potential copyright infringements and what data should be used to train AI models. Furthermore, misinformation, cyberattacks, and defense-related applications must also be considered. Japan aims to take a leading role in global discussion on these subjects. Historically, humans have learned to harness new tools to do more good than harm. It is hoped that STS *forum* and other similar initiatives will contribute to that.

Mr. Mike Yeh shared the example of Microsoft Copilot, which aims to integrate generative AI into Microsoft Office functions. For example, Copilot can produce a 100-word summary of long email threads in Outlook. In this way, generative AI could enable huge productivity enhancements, which could in turn feed into creativity gains. It is also hoped that such changes will create more time for industry experts to think through the tough societal challenges that AI could address, to bring broad benefits to society.

When the bullet train was first developed, there was a realization that to go fast and far, a priority needed to be placed on safety. Microsoft takes the same approach to AI. Microsoft is building tools and filters to prevent copyright infringements, which has resulted in a commitment to indemnify its customers who use Copilot. Microsoft is also participating in national and international initiatives on regulating governance AI and Mr. Yeh highlighted four innovative approaches that it has agreed to as part of the US White House Voluntary Commitments. The first is having red teaming that is dedicated to pressure-testing the technology. The second is provenance, which entails understanding and labeling AI content, and explaining it to consumers. Third is know your customer, similar to the concept used in the financial industry. Fourth is ensuring not only industry and government but also academia

has access to the latest AI tools, so academics can provide a counter-perspective and ensure AI is developed for the benefit of all.

Ms. Saba Samiei opened by stating that AI is no longer a new technology, but an old technology that is bringing new ways of impact. However, the field has left many questions unanswered. Firstly, AI's power sits in its rare ability to create customization at scale. However, AI is built on the concept of intelligence, something for which there is no universally agreed definition. That raises the question of how it is possible to replicate and scale a concept that is not fully understood or defined. AI also raises many other questions: Why do more advancements result in more criticism? Why, despite the huge amounts of data being generated, is there still a lack of quality data to train good models without bias? Why, despite AI being so ingrained into our daily lives, is there still a lack of knowledge among the public of what this technology is and what it can do for or to us?

AI can be hugely positive. For example, it has enabled livestock monitoring that has significantly reduced livestock death rates or the identification of pollutant sources responsible for the deaths of millions of people. On the other hand, not enough is being done globally to put in place policies fast enough to ensure that this technology is safe for future generations.

Q&A

Following the opening remarks, a Q&A session was held. The first question concerned how to regulate the various concerns raised by AI, such as privacy intrusions or undermining of elections by misinformation and disinformation, without stifling further development.

Prof. McLean agreed that misinformation and disinformation are huge sources of concern, but pointed out that these are not new issues. Societies have experience of effective methods for tackling them, such as prewarning people of the types of misinformation or disinformation they may be subjected to.

Ms. Samiei agreed that educational efforts would be useful. She also pointed out that there are technological solutions for identifying deepfakes, but did not think they were developing fast enough.

Another member of the audience noted that discussions about risk mitigation are always premised on humans being in control, but not enough is being said about how risk mitigation can be done when humans are not in control, as is the case with generative AI.

Mr. Yeh believed that accountability is key to how to set up these systems. For example, doctors are constantly getting access to more and more powerful diagnostic tools, but ultimately it is still the doctor that is held accountable. Likewise, it is the individual or organization using the AI that should be held accountable.

Ms. Samiei pointed out that there is more to what makes us human than just intelligence and opposed giving any level of control to machines until such a time when all aspects of humanity, including empathy, consciousness, and so on, can be replicated by them.

Prof. Matsuo noted that there are multiple stakeholders and each has their own responsibility.

It was pointed out by an audience member that it is impossible for any evidence-based regulation to keep pace with technological change. There is a real possibility of the extinction of human agency, and consequently a compromising of our humanity. Should a moratorium on further AI development therefore not be considered?

Dr. Norvig responded that many people and organizations have developed principles for responsible AI. They have considered the benefits and risks, and have concluded that, on balance, in light of the huge potential benefits, it is not appropriate to stop development. Of course, it is important that every company involved takes this very seriously, and that is what has been occurring.

Prof. McLean agreed and pointed out that the United Kingdom does indeed take this very seriously and is collaborating with other stakeholders around the world.

A question was then raised about how to ensure AI is narrowing rather than widening gaps between developing and developed countries.

Ms. Samiei answered that one of the biggest issues when developing any AI model is the dataset and that it is possible to create statistics that show where the gaps in the data are.

She suggested that more companies should create such statistics, make them public, and take action to close these gaps.

Mr. Yeh highlighted the value of developing an intentional data strategy to ensure different cultures and perspectives are properly reflected in AI.

Closing Remarks

Prof. Kleiner concluded the session by noting that for new products and technologies, recognized technical rules, legal regulations and, under the industry's own direction, independent monitoring institutions have always been established. This successfully ensures safe design, safe operation and reliable monitoring. One only has to think back to the introduction of the steam engine or electricity, where technical monitoring institutions such as Underwriters Laboratories in the USA or the Technische Überwachungsverein in Germany came into being.

Koji Omi Memorial Lecture: Conversation with Prof. Dr. Svante Pääbo

[Chair]
Hamburg, Margaret A., Co-President, InterAcademy Partnership (IAP), U.S.A.

[Speaker]
Pääbo, Svante, Director, Max Planck Institute for Evolutionary Anthropology, Germany; Adjunct Professor, Human Evolutionary Genomics Unit, Okinawa Institute of Science and Technology (OIST), Japan [Nobel Laureate 2022 (Physiology or Medicine)]

Opening Remarks

To open the session, Dr. Margaret Hamburg explained the purpose of the Koji Omi Memorial Lecture, a series which honors the legacy and vision of the late Mr. Koji Omi, and introduced Prof. Dr. Svante Pääbo's career in human genomics, through which he has contributed to our understanding of human evolution and developed methods to extract DNA from archeological and paleontological remains of ancient and extinct organisms.

Keynote lecture

Prof. Dr. Svante Pääbo began by briefly explaining the origin of modern humans in Africa 200,000 to 300,000 years ago, and early humanity's movement across the world within the past 100,000 years, featuring evidence of Neandertals across Asia from over 40,000 years ago and clues to the movements of our common evolutionary ancestors. To study this from the biological perspective, DNA which is 40,000 to 50,000 years old needs to be retrieved. This is usually degraded, chemically modified and present largely as excess DNA of microorganisms. Dr. Pääbo sequenced Neandertal DNA by extracting and locating large numbers of short sequences, which were then mapped to the human genome. He noted that 1-2% of the DNA in present-day humans with roots outside of sub-Saharan Africa is of Neandertal origin, and that 40-50% of the Neandertal genome still exists today within modern human populations.

Hamburg, Margaret A.

Pääbo, Svante

Dr. Pääbo then described how the genome sequence extracted from a bone fragment was used to identify Denisovans: a different form of early humans. By identifying a common ancestor between modern humans and neandertals, modern human's evolution from this common ancestor and level of mixing with neandertals could be measured. Genome analysis can be used to identify genetic contributions from Neandertals to modern humans, which can have effects today, for example protection against miscarriages, or effects on how ibuprofen or warfarin is metabolized in the body, or the severity of COVID-19 infection.

Dr. Pääbo explained that he is especially interested in how genetic changes unique to modern humans may affect brain development, function and behavior.

Discussion

Dr. Hamburg thanked Dr. Pääbo for the introduction to his work, and commented on his unique career and research path, and how his study into human immune response led to work on deriving ancient DNA, commending his striking synthetic approach across disciplines, countries and time periods, and his development of new methods to take big questions about humanity and pull these together into hypotheses.

Dr. Pääbo explained that he had always had an interest in archeology but moved into medicine due to a mismatch in his expectations and the reality of the discipline. This made it easy for him to apply and develop molecular genetic techniques to study ancient remains. Dr. Pääbo stressed that these larger goals are achieved in smaller steps. He commented that the combination of different disciplines was key for the new methods he developed.

Dr. Hamburg commented that while Dr. Pääbo developed several new methods, recognizing emerging technologies such as PCR, which is vital for extracting ancient DNA, was also a key aspect of his research. She asked if limitations in technological advancement were a difficult hurdle to overcome.

Dr. Pääbo replied that scientific research is driven by technology, so adapting new technologies is key to answering new questions. He stressed that some aspects of his work were also down to luck and being in the right place at the right time. Dr. Pääbo explained some setbacks during his research, referring to the first paper he published, which detailed a demonstration that DNA could survive in ancient Egyptian mummies. The paper had two sets of evidence, one being that DNA was able to be cloned from a mummy. However, it became clear afterwards that what had been cloned was actually some kind of contamination.

Dr. Hamburg commended Dr. Pääbo's acknowledgment of the errors within his research and commitment to methodological improvements following this. Then, referring back to Dr. Pääbo's keynote speech, Dr. Hamburg asked for further elaboration into the key aspects that make modern-day humans unique.

Dr. Pääbo explained that other early humans have existed for longer periods in the past, but never became as numerous, or developed technology that changed very rapidly. This may not necessarily be based on increased intelligence, but could instead be due to humans living in larger groups that help the spread of innovations. While researchers can list the genetic changes between Neandertal and modern human DNA, it is extremely difficult to

infer its function. Dr. Pääbo and other researchers in Okinawa are focusing for example on changes which may impact cell divisions in early brain development and study such DNA changes in mouse brains and in human organ cells. The large amount of data available from different people around the world today has allowed researchers to identify and study some effects of Neandertal DNA.

Dr. Hamburg enquired as to the definition of a species within biological anthropology, which is based on the ability for members of species to interbreed and produce fertile offspring. Neandertals have not traditionally been considered part of the human species. She also commented on his innovative method of identifying a new hominin through gene sequencing as opposed to study of fossil remains.

Dr. Pääbo stated that this is generally the case, but groups evolve differences slowly, with mixing along the way. As an example, he described how polar bears and grizzly bears can interbreed and have fertile offspring, but they live in different habitats and are adapted to different environments. He also emphasized that many closely related groups or species mix.

Dr. Hamburg asked about applications of new genomic tools and understandings to try and recreate extinct species or raise the population of endangered species, for example the work of George Church, who aims to reintroduce the wooly mammoth to certain ecosystems.

Dr. Pääbo considered it impossible to recreate a species in a true sense if all its members are dead. He emphasized that the DNA that can be retrieved is degraded, and repetitive parts of the genome, which also effect genetic expression, cannot be reconstructed. So while for example an elephant with some mammoth features could one day perhaps be created, this would not be a recreation of mammoths as a species.

Dr. Hamburg enquired how Dr. Pääbo's work influenced his view of humanity's place in the world, commenting on humanity's disruptions and overuse of complex ecosystems and the threats of climate change.

Dr. Pääbo expressed his personal perspective that climate change and biodiversity loss are enormous challenges, and that overcoming these will take massive social and political efforts. However, he does not think that humans will become extinct due to this, considering that humanity has survived large climatic fluctuations such as ice ages in the past.

Q&A

A member of the audience asked more about the Neandertal contribution to DNA, and whether this interbreeding was more driven by males or female members of the species.

Dr. Pääbo explained that there is less Neandertal DNA on the X chromosome than would be statistically expected, which could suggest male Neandertals contributed more than female Neandertals. However, this could also be due to other reasons.

A member of the audience commented that it is not unusual for species to become extinct, asking whether any aspects of human technological development would have an effect of the likelihood of human extinction.

Dr. Pääbo noted that any complete extinction of humans seems very unlikely to him in any foreseeable future.

A member of the audience asked about the prospect of extracting DNA from existing remains for hominins, and whether there is a necessity to find better preserved remains.

Dr. Pääbo remained optimistic about scientific approaches to excavation, identifying, and extracting DNA from smaller and older specimens in the future.

Path to Sustainability

[Chair]
Petit, Antoine, Chairman and CEO, National Center for Scientific Research (CNRS), France

[Speakers]
Drake, Michael V., President, University of California, U.S.A.
Fujii, Teruo, President, The University of Tokyo, Japan
Moriyama, Masahito, Minister, Ministry of Education, Culture, Sports, Science and Technology(MEXT), Japan
Semeria, Marie-Noëlle, Chief Technology Officer, TotalEnergies, France

Opening Remarks

Prof. Antoine Petit began the session by highlighting that the world knows that people must reduce their carbon footprint at every level, as well as the theory to do so, but the reality is that very little progress has been made. He indicated that this session would look at pragmatic measures to be considered collectively towards moving down the right path.

As scientists, the primary contribution of the participants is to provide knowledge for people to better understand what is happening and what is going to happen. In addition, they must consider cutting edge research that will lead to innovation. They must bring all sciences together, including human sciences, which will be essential to achieve social acceptance of new technologies. Prof. Petit stated his conviction that even if research cannot provide *the* solution to sustainability, it will provide some potential solutions.

Petit, Antoine

He then introduced the initiatives being undertaken by the National Center for Scientific Research (CNRS) in France towards sustainability. He concluded by emphasizing that scientists and institutions needs to share knowledge, expertise, and best practices, so as not to divide the planet but to work together.

Prof. Michael V. Drake explained that humanity has faced many challenges over the years, and the pandemic showed how fragmented the species is. However, it also showed how people can work together to save lives. Now, all nations are facing the consequences of climate change, and that is why research institutions must continue to work together with counterparts across the planet to give humanity hope for a brighter future.

Prof. Drake then explained the initiatives at the University of California, adding that funding from the government is fueling research to increase resilience of state power and water, etc., as well as the activities of research teams in the university. The university is also working on sustainability in daily activities, including climate protection policies, to create an environment where ideas and individuals can develop and encourage cross collaborations.

Prof. Teruo Fujii echoed Prof. Petit's comment that while the world widely recognizes the importance of sustainability, little has been done to achieve it. He then explained the activities of the University of Tokyo towards green transformation (GX), which are based on three different levels: the global scale, national scale, and university scale. On the global scale, the university has proposed frameworks of measures to address climate change based on various fields. At the national level, it organizes industry academia alliances to consider the

pathway to net zero in collaboration. At the university level, the university has implemented renewable energy systems in its campus and promoting GX in the areas of carbon neutrality, circular economy, and nature positivity, in order to transform society as a whole. Prof. Fujii concluded by stating that universities have an important role to provide a platform for different sectors to realize collective actions to tackle global issues.

Dr. Masahito Moriyama commented that global warming and energy and environmental problems are global scale challenges that must be solved to achieve a sustainable society. Extreme weather events are occurring around the world. A major cause is the change in the global environment, beginning with global warming. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been actively working based on the government's goal of achieving carbon neutrality by 2050. One such effort is GX, which aims to realize a balance between reduction of greenhouse gas (GHG) emissions and economic growth. Dr. Moriyama then introduced more details on the various initiatives of MEXT, including developing human resources and supporting the free circulation of ideas among academia.

He commented that a sustainable society cannot be achieved by one country alone, but by all countries. MEXT believes it is important to create new values and transform people's actions, which will lead to solutions at community levels. Moreover, MEXT is working to

implement various initiatives towards achieving a sustainable human society in cooperation with various stakeholders.

Dr. Marie-Noëlle Semeria began by stating that the world still relies on fossil fuels, and so it is essential to create a new energy system for sustainability, taking into account the strengths and weaknesses of each region across the world, while also setting common rules of good practices and unique frameworks across nations, because climate change is a world-wide challenge, that requires global and local solutions.

She stated that the role of research and development is threefold. First is to develop disruptive technical solutions in order to prevent climate change. Second is to advise policy makers and regulatory bodies to give them the right data to set up sustainable frameworks. Third is to educate people and present facts to society in a transparent way. She then stated that the key to system innovation is transparency with society and building trust in the path to sustainability.

Q&A

Questions were then invited from the audience. An audience member asked Dr. Semeria how the transition to sustainability can be made smooth, affordable, and just, especially for countries of the Global South.

Dr. Semeria responded that it is important to observe that different technologies are contributing to sustainability. Industry must focus on major technologies with lower costs, and upscale this technology from pilot scales to social implementation. In the meantime, at the research level, national research labs have to prepare the second generation of technology, and there is plenty of room for innovation, meaning institutions must manage the global roadmap, accelerate what can be accelerated, and anticipate the next generation and focus research efforts across the world. Regulatory framework will also be important.

Another audience member asked the panelists for their views on the role of nuclear energy.

Dr. Moriyama explained that, after the Fukushima accident, it is difficult to operate nuclear energy in Japan. Recently, the Prime Minister agreed that the goal is to eventually diminish the use of nuclear energy, but it is still necessary to reach emission reduction goals. A balance will be necessary in the long term, while overcoming problems and gaining consensus from the populace. Breakthroughs in nuclear power and innovation in technology will be required.

Prof. Fujii commented that Japan is also looking into fusion technology, and there are many start-ups addressing it, so it may become another option in the future.

Prof. Drake added that the University of California is also looking into fusion technology, but there are major challenges to it.

Prof. Petit then asked the panelists how they could educate younger people, for whom climate change is a more serious issue.

Dr. Moriyama responded that, in Japan, there was conflict between economic and academia sectors, but now the situation has changed as more people are aware of the threat of global warming. This was especially seen from the heat wave of the summer, and most people realized that global warming must be stopped. Policy systems will need to be implemented and breakthrough technologies will need to be invented in order to make progress.

Dr. Semeria explained training programs being implemented in TotalEnergies to explain the different energies contributing to sustainability, which also include having employees

examine their own activities and consider how they can reduce their individual carbon footprints. She stated that more people are joining the programs because young people understand the need to transform the energy sector from within.

Prof. Fujii stated that sustainability is an interdisciplinary issue, and economic incentives will be needed. He then explained a program at the University of Tokyo to educate students on GX, in order to help them consider the common issue, while taking advantage of their individual specialties.

Prof. Drake then commented that it is important for people to consider practices in their daily activities. The University of California also makes efforts to make it more energy efficient, such as using multiple programs on daily practices, switching to using electric vehicles for university vehicles, and using organic foods in campus meals. All of these activities are working towards making the world more sustainable.

Lights and Shadows of Human Activity in Space

[Chair]

Zuber, Maria T., Vice President for Research, E. A. Griswold Professor of Geophysics, Massachusetts Institute of Technology (MIT), U.S.A.

[Speakers]

Fujimoto, Masaki, Deputy Director General, Institute for Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA), Japan

Barnawi, Rayyanah, First Saudi Female Astronaut, Saudi Space Agency, Saudi Arabia

Arai, Motoyuki, Founder & CEO, Synspective Inc., Japan

Wörner, Johann-Dietrich, President, National Academy of Science and Engineering (acatech), Germany

Opening Remarks

Prof. Maria T. Zuber began the session by looking at the history of space exploration, leading up to the modern world in which nations have committed to explore space, as well as new players such as commercial entities and NGOs. She then highlighted a series of recent developments in space, including the successful space launches of India and Japan. There have been increased capabilities among many players, and the space domain has become a contested area. There is also a proliferation of small satellites with increased capabilities, and new start-ups coming into the field.

Zuber, Maria T.

Prof. Zuber then commented that the UN Space Treaty was not conceived to handle all the issues that are arising today. There are many new challenges to face. While there are many lights associated with global accessibility of space, such as cooperation, technological innovation, and scientific advancement, there are also shadows such as challenges to governance, ethical developments, and global militarization of space. It will be necessary to protect certain environments, and to manage resource limitation and space traffic. Collaboration, cooperation, and planning will

be needed to establish norms and regulations that promote peaceful and equitable use of space.

Prof. Masaki Fujimoto spoke about the success of the Hayabusa 2 mission, which successfully took samples from the Ryugu asteroid and returned them to earth. While the mission was a success, it faced many challenges, such as not knowing the details of the asteroid before arrival and how the recovery activities had to be conducted amid the COVID-19 pandemic. Prof. Fujimoto explained that asteroids are storytellers of the early days of the solar system, and the samples from the Ryugu asteroid would be used for research into the origins of the habitability of our planet, including through collaborative sample analysis research with a similar mission by NASA.

Prof. Fujimoto highlighted how JAXA and NASA are collaborating in three small body sample return missions in a row, which demonstrates one of the ideal shapes of international collaboration in space. The question becomes what more can be done. JAXA would be able to provide a platform to have multiple small assets onboard that would encourage newcomers to join deep space explorations. In this line of thinking, international cooperation may not necessarily be the way to make missions happen, but it is a part of the goal of space science missions.

Ms. Rayyanah Barnawi began by explaining her history as an astronaut, including her mission to the International Space Station (ISS). Her mission achieved three goals: increase education and awareness of space sciences and technology, learn new ways and conduct experiments that would help protect Earth, and demonstrate international collaboration and the importance of communication.

From an educational standpoint, Ms. Barnawi's mission raised awareness and outreach programs for children around the world. Experiments were conducted with collaborations from government and academia, and communication was increased between the three space agencies involved in the mission. The experiments were aimed at developing technologies that would improve the future of space exploration, as well as overcoming issues on earth such as desertification.

Dr. Motoyuki Arai then explained his career path, and used it to highlight the importance of data driven management on sustainable development, including data provided from satellites. Satellite data could be used in various fields, such as helping governments determine the best locations for renewable energy facilities, monitoring damage from natural disasters, and mapping of remote villages.

Recently, the global situation has changed, and many governments have shifted from using satellites for research to using them for other purposes. All space relevant companies are now focusing on the defense market because of the economics for scalability with costly space craft. Despite this, Dr. Arai hopes to focus more on using satellites for sustainable development.

Prof. Johann-Dietrich Wörner stated that there are a large variety of global challenges, such as resources and conflicts, and space is contributing to solving them. Space is where science is being conducted, and 50% of climate change variables can be monitored from space. Solutions to other fields can also be developed through use of space, such as navigation and international cooperation. However, currently there is more competition over cooperation. Space also remains a privileged space only available to astronauts, and

even so the dangers of space travel remain high. Pollution from space exploration, both in space and on Earth, will also need to be addressed.

Prof. Wörner also commented that it was incorrect to consider space exploration to find an alternate planet to Earth. It is more important to use innovations in space for the benefits of the planet.

Q&A

Questions were then invited from the audience. One audience member asked about the prospects of international colonization in space.

Prof. Wörner responded that rather than colonization, it would be better to consider using locations like the moon and mars for research purposes. He added that there may be potential for multiple partnerships where people work together to use spaces like the moon.

Prof. Zuber commented that the Moon Village concept is popular and collaborating explorations have made progress, but places like Antarctica also remain available as research sites.

Prof. Wörner also commented that, unlike Antarctica, if an incident were to occur at a research facility on the moon or mars, help would not be readily available.

An audience member then asked Ms. Barnawi to comment on being the first female astronaut from Saudi Arabia.

Ms. Barnawi stated that her experience fulfilled her desire for exploration, and she had no hesitancies in signing up for the mission. She commented that it was an exciting experience to be able to conduct experiments on the ISS that would be useful for earth.

Prof. Zuber commented that the ISS welcomes visitors from all countries, and so could be seen as a success in international collaboration.

Prof. Wörner added that the ISS also welcomes Russian scientists, explaining that even in times of conflict, it is important not to cut ties with Russian scientists and that space can deliver cooperation across national borders.

Prof. Zuber agreed with the comment, adding that Russia has been a great partner in space exploration.

A question was then raised about exploring the universe beyond the solar system in the context of international cooperation.

Prof. Wörner commented that deep space missions are not necessarily needed as space can be explored using other means, such as telescopes.

Prof. Fujimoto responded that an exo solar system research program at his institution was not available until recently, because there was no drive until now to propel exploration beyond the solar system.

Prof. Zuber added that early studies of exo solar system planets were done with sensors, but with modern technology, those planets can be studied in more detail.

An audience member then asked about medical and biological research conducted in space.

Ms. Barnawi responded that her space mission was very science oriented, and she conducted experiments related to growth of cells in space. This helped build knowledge on Earth. She also used microgravity in space to consider technology to help cure patients on Earth and help them to live better and longer lives. Space is a green and good environment for trying to understand how to benefit humanity.

Prof. Zuber extended the question to include human wellness and quality of life for people in a business sense.

Dr. Arai responded that technology development, especially in space, is led by the accumulation of necessities aligned with the expansion of humankind's activity in space. The first technology deployment will be led by new medicine or health care systems for people on Earth.

An audience member then asked how data can be regulated to benefit mankind, and who would control the impact of data, including potential geopolitical effects of open data.

Dr. Arai responded that there are different categories of data: high-frequency real-time data and historical data. The historical data could probably be openly shared, whereas businesses would want to keep high-frequency real-time data proprietary. Data is a sensitive issue, so discussion of regulations for what constitutes open data will be needed.

Prof. Wörner added that in the EU, a full open data policy had been set, and under this policy, data was open, but the products businesses made using data were proprietary. However, now, data from small satellites presents a new situation, as space data will be important for everything being undertaken on Earth and has its own commercial value.

A comment was also raised against Prof. Wörner's remark about not seeking a planet B through colonization, noting the importance of having a backup like with data.

Prof. Wörner defended his position, stating it is more important to consider what space can deliver for Earth, and that humanity should try to save the planet, not create a backup.

The last question asked what more scientists can do to convince governments of the benefits of space.

Prof. Zuber commented on the need to send more people like Ms. Barnawi to space.

Prof. Wörner responded that curiosity-based research is a driver of value and that a poll of people in the EU showed that they were willing to spend much more on space research than is currently the case.

Closing Remarks

In closing, Prof. Zuber stated that the space frontier is finally opening, and humanity is at the forefront of becoming a truly space-faring species. Many opportunities have arisen, and on the coming wave of exploration, scientists must think actively about how to promote cooperation and collaboration, and use this opportunity for human benefit.

Global Health — What the world needs to prepare for the next pandemic

[Chair]

Nurse, Paul, Director and Chief Executive, The Francis Crick Institute, U.K. [Nobel Laureate 2001 (Physiology or Medicine)]

[Speakers]

Cole, Stewart, President, Institut Pasteur, France

Hamaguchi, Michinari, Director General, Strategic Center of Biomedical Advanced Vaccine Research and Development for Preparedness and Response:SCARDA, Japan Agency for Medical Research and Development (AMED); Counsellor to the President, Japan Science and Technology Agency (JST), Japan

Colwell, Rita R., Distinguished University Professor, University of Maryland Institute for Advanced Computer Studies, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health, U.S.A.

Cueni, Thomas, Director General, International Federation of Pharmaceutical Manufacturers & Associations (IFPMA), Switzerland

Opening Remarks

Opening the session, chair Sir Paul Nurse explained that there will be pandemics in the future where the vector, timeframe, or location are unknown, with the potential to be even more disruptive than COVID-19, which has already demonstrated the worldwide lack of pandemic preparation even from nations leading biochemical and medical research. He highlighted four main issues, firstly addressing monitoring and surveillance, as zoonotic disease spillover will further increase alongside climate change, making it critical to monitor disease in wild and domesticated animals as well as in humans.

Nurse, Paul

Secondly, modelling can assist in predicting likely future areas of transmission. Open and transparent monitoring and surveillance should be implemented from the moment a problem arises and supported by

international commitment, with testing, tracing, and containment serving as the first line of defense for new and unknown disease vectors. Initially, COVID-19 testing capabilities were overwhelmed, with asymptomatic testing ignored and public laboratories underutilized. Plans should be made to better utilize laboratories and institutes in future, considering the logistics of integration with healthcare facilities. Tracing and containment require interdisciplinary approaches to understand population response to testing, confinement, and vaccine rollout.

Thirdly, vaccines need to be developed more rapidly through data sharing and improvements to techniques using messenger RNA (mRNA). New protocols and infrastructures must be introduced that can be rapidly mobilized without running constantly, and regulatory procedures must be streamlined. International coherence is essential and protectionism must not get in the way of vaccine utilization, with vaccines distributed equitably and at a controlled affordable cost, and limits applied to private sector profits.

Lastly, new treatments based on increased knowledge regarding vectors should be distributed and trialed worldwide, and communication must address false information. National level points for developing policy include singular accountability, prior determination of clear objectives and identification of experts, private-public collaboration, permeability across sectors, and resilience.

Discussion

Prof. Stewart Cole introduced the perspective of the Institut Pasteur, which conducts biomedical research into the identification and isolation of viruses, and was also active in COVID-19 research, epidemiological modelling, and therapeutic strategy development including antibody-based approaches. The institute intervenes to detect pathogens worldwide, using both classical and digital methods, focusing on outbreak investigation in collaboration with international reference centers and the World Health Organization (WHO).

In anticipation of future pandemics due to climate change, the institute is constructing a Center for Research of Vector Borne Diseases, to study pathogen, vector and host interaction, and is also establishing a Centre for Vaccinology and Immunotherapy to develop new interventions through immunoscience. The Pasteur network conducts research and training into public health and epidemic countermeasures, including investigation of climate change related health risks, surveillance technology development for limited resource environments, and vaccine, diagnostic and therapeutic manufacturing initiatives. Prof. Cole stressed that

further cooperation is needed between academia, NGOs and industry to accelerate the innovation continuum from discovery to intervention.

With COVID-19 largely settled down, Dr. Michinari Hamaguchi expressed his thanks to the scientists who worked on mRNA breakthroughs, noting that many issues needed to be overcome during the pandemic, and policies for vaccine application often differed by region. For example, Japan faced difficulties preparing effectively at the outset of the pandemic and established its Strategic Center of Biomedical Advanced Vaccine Research and Development for Preparedness and Response (SCARDA) last year to build pandemic preparedness through funding of vaccine research and development, with strong encouragement for collaboration between academia and private companies.

Dr. Hamaguchi emphasized the need for transparent and accurate international collaboration based on trust and shared goals. Japan is still far from meeting the goals of the Coalition for Epidemic Preparedness Innovations' 100 day mission, which aims to compress vaccine development timelines to 100 days, and must improve the speed of its production and delivery of vaccines while ensuring safety and efficacy. Dr. Hamaguchi also considered the applications of AI, noting legal barriers that affect transport and research of dangerous pathogens, and highlighted the necessity for sensitive, accurate and affordable methods to diagnose healthy carriers of a variety of pathogens, and comprehensive development utilizing engineering, biochemistry and other scientific detection methods.

Prof. Rita Colwell introduced the concept of remote sensing, describing environmental drivers of disease that can be assessed and included in epidemiological parameters to create a powerful tool when combined with computational modelling and AI. By incorporating environmental monitoring, researchers are now able to monitor cholera epidemic risk and predict outbreak intensity with high accuracy, allowing medical personnel, supplies, and other aid to be dispatched quickly and effectively.

Prof. Colwell expressed her concerns regarding the emergence and spread of bacteria closely related to cholera along coastal waters due to raised ocean temperatures. Increased infection risks due to climate change emphasize the relationship between environment and disease, and tools to monitor these changes have enormous potential to empower global public health.

Mr. Thomas Cueni laid out the setbacks and funding limitations in early mRNA research, which started decades ago, and highlighted the struggles of Katalin Kariko in finding even a space in an academic lab, let alone, securing proper funding for her research. He also noted that only two of the 23 mRNA COVID-19 projects succeeded, being Pfizer/BioNtech and from Moderna. Preserving the innovation ecosystem that allowed such a rapid response to the COVID-19 pandemic (e.g. 326 days) will be vital for future pandemics and must not be compromised. Surveillance of and fast access to pathogens, as was the case during this pandemic, is also essential. Referring to the Pandemic Accord under discussion and Nagoya Protocol of the Convention on Biodiversity, Mr. Cueni argued that genetic sequences of pathogens must be quickly shared internationally to allow collaborative research and partnership to develop tests, vaccines and treatments. This sharing must not be hindered, and regulators must work to enable streamlined collaboration as they did during COVID-19.

Mr. Cueni expressed apprehension about the suggestion that companies should commit to not-for-profit sales of vaccines given that the reward for success is a major incentive for investing in risky R&D. In fact, price gouging seen in some countries with masks, personal protective equipment, and other essential items was not seen for vaccines or therapeutics. Furthermore, all companies offered substantial discounts for poorer countries and COVAX. He reflected on the successes and failures of COVAX, the COVID-19 Vaccines Global Access program, on the one hand the success of almost 2bn vaccine doses delivered to developing countries in 2021, on the other hand Africa being left behind for more than half a year

due to the export ban from India Prime Minister Modi imposed in April 2021. The Berlin Declaration was the biopharmaceutical industry response, providing a vision for equitable access in future pandemics, with the industry committing to improving equitable access to vaccines in a next pandemic. However, this will only succeed if governments sign up to a social contract and the trade restrictions that we saw hamper equitable access to COVID-19 vaccines and treatments, are not repeated. He emphasized that more geographic diversity of manufacturing is needed, especially in Africa, but this will take time and can draw on the many voluntary partnerships developed during COVID-19.

Q&A Session

An audience member asked about physical measurements used in remote sensing, and whether there are specific physical variables associated with specific pathogens.

Prof. Colwell answered that researchers can correlate communities of variables associated with specific pathogens, including temperature, salinity, and population movement, measured using satellites, and input these into models to make predictions at around 95% accuracy, also extending this basic model to other diseases.

A member of the audience asked about how to optimize polymerase chain reaction (PCR) testing capability, explaining that PCR testing machines within Japan were not utilized during COVID-19 due to insufficient personnel trained to safely handle infectious materials, and enquired regarding training programs to increase these personnel.

Prof. Cole shared about Pasteur network initiatives in Africa to share standardized operating protocols, stressing the importance of quick and flexible action that avoids protectionism and open sharing of procedures.

Sir Paul highlighted a UK initiative that trained local people within two weeks to set up a testing facility within a single month, by utilizing a containment facility with PCR machines, which at one point implemented 20% of UK testing.

A member of the audience considered funding for epidemics, asking if society is currently in a “honeymoon phase” after which funding will drop off, and commenting on the need to build clinical research capacity in developing countries to ensure equitable access.

Dr. Hamaguchi highlighted Japan’s collaboration between academia and private companies as a way to ensure local and sustainable funding, explaining that Japan also sustainably funds research through the Japan Science and Technology Agency.

Prof. Colwell added that it is critical that laboratories are established in Africa, to provide the ground data necessary for accurate epidemiological predictions.

An audience member asked whether analysis of the most likely future pandemic scenarios should be implemented.

Mr. Cueni answered that many pharmaceutical companies have already increased collaboration and involvement with CEPI, putting frameworks in place to respond to future pathogens. Consortiums between pharmaceutical companies are also working on prototype antiviral treatments, but we should not forget that non-pharmaceutical interventions such as wearing masks and social distancing will always be the initial response to future pandemics.

Prof. Cole praised CEPI’s transformational approach noting that the 100 day mission has encouraged testing and stockpiling of a broad spectrum of antivirals.

Mr. Cueni stated that unfortunately many governments have moved onto other priority issues and there is less focus on pandemic awareness. Therefore scientists need to be present to raise these issues.

Prof. Cole commended the initiatives of the European Commission in this regard.
Dr. Hamaguchi stressed the need for technological improvement, especially for mRNA vaccines, to reduce overall costs.

An audience member asked about the rise in antivaccine views and distrust in science.

Mr. Cueni suggested that while the threat of antivaccine views cannot be ignored, trust in science has actually benefitted from COVID-19, and it is vital that scientists listen to and communicate with the public.

A member of the audience commented that the majority of emerging infectious diseases are of zoonotic origin, asking about the need for early prevention and risk reduction for zoonotic disease emergence.

Prof. Colwell stressed the need to understand environmental influences including animal populations, to understand epidemiological drivers influenced by weather events.

Mr. Cueni commented that initiatives to prevent inappropriate use of antibiotics in agricultural animal production do not go far enough.

Lastly, a member of the audience asked about digital sequencing information issues, in relation to access and benefit sharing regulations.

Mr. Cueni acknowledged that protection of biodiversity is important and he fully supported the Convention on Biodiversity (CBD) and the subsequent Nagoya Protocol and Access Benefit Sharing (ABS), but applying the transactional ABS approach to pathogens with pandemic potential was simply wrong. Nobody wanted to ‘preserve’ the diversity of harmful pathogens, they should be contained and biological material and genetic sequences of such pathogens should be quickly shared to enable fast development of treatments and vaccines.

Prof. Colwell added that science does not adequately understand the ability of microorganisms to share genetics and adapt quickly to changes in the environment or host, and this needs to be considered further.

Basic Science, Innovation and Policy

[Chair]

Haug, Gerald H., President, German National Academy of Sciences Leopoldina, Germany

[Speakers]

Ketterle, Wolfgang, Director, MIT-Harvard Center for Ultracold Atoms, Department of Physics, Massachusetts Institute of Technology (MIT), U.S.A. [Nobel Laureate 2001 (Physics)]

Chang, Lih Kang, Minister, Ministry of Science, Technology and Innovation (MOSTI), Malaysia

Carrozza, Maria Chiara, President, National Research Council (CNR), Italy

Eldesouki, Munir M., President, King Abdulaziz City for Science and Technology (KACST), Saudi Arabia

Spence AC, Michael, President and Provost, University College London (UCL), U.K.

Opening Remarks

Prof. Gerald H. Haug opened the session by noting the importance of science and curiosity-driven research in meeting the various global challenges. Breakthrough innovations often begin with new and unanticipated basic science discoveries. Basic research serves as an engine for innovation for science and technology (S&T) but requires favorable conditions which can often not be adequately reflected in policy. Prof. Haug shared that the panel would explore the questions of what preconditions are needed for basic research success, what frameworks allow it to transfer into applications, and how requirements can be better reflected in policy agendas.

Haug, Gerald H.

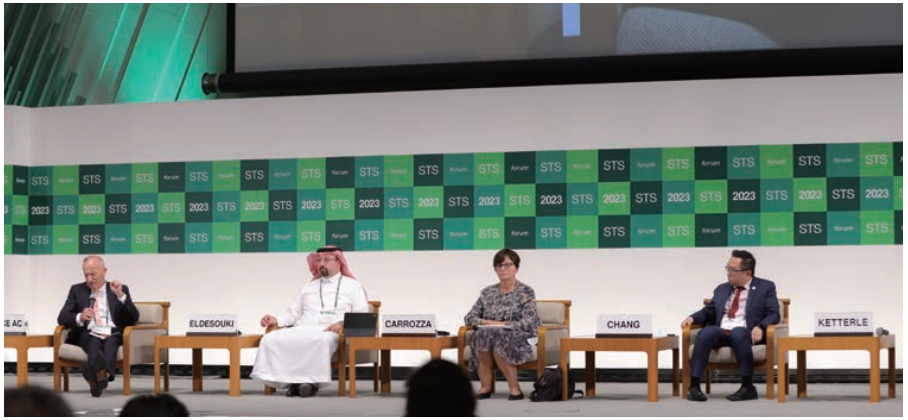
Prof. Wolfgang Ketterle began by sharing about his own experience of witnessing developments in quantum science that stemmed from purely curiosity-driven research. He emphasized the importance of such research and its role in unexpected technological advancements. Notably, the development of lasers happened before it had clear applications, but now it has many. More recently, atomic clocks have been developed with immense accuracy, and they may become the best way to predict earthquakes. Work must also be done with engineers to lead to practical solutions, but a stable ecosystem for fundamental research requires long-term funding and stability.

Prof. Ketterle also emphasized the importance of balancing research funding to solve the problems of both today and tomorrow. Such decisions will ultimately need to be made with the help of those with sufficient knowledge in science.

His Excellency Mr. Lih Kang Chang shared his ideas for balancing fundamental research and applied research. He shared that his priority is for the research to have value for mankind as a whole, regardless of whether it is fundamental or applied. The research must be people-centric, close to those on the ground, and change their lives and wellbeing. His Excellency Mr. Chang shared that in Malaysia, he strives to establish connections between industry and for research to propel sustainable advancement of society. While applied research is important for bringing products to the market, basic research expands knowledge needed for breakthroughs.

His Excellency Mr. Chang shared about the 10-10 Malaysian Science, Technology, Innovation and Economy (MySTIE) Framework, which is a tool for stakeholders to pursue innovation and aim to solve various problems faced by the country. The framework illustrates that multiple S&T drivers can be utilized to enhance competitiveness, and the government is committing more resources to fuel innovation, technological advancement, and economic growth. It seeks to foster a culture of creativity, empathy, and transform society for a prosperous future.

Her Excellency Prof. Maria Chiara Carrozza spoke on her perspectives as both a physicist and engineer. Disruptive innovation is based on fundamental research, and research programs must be well-balanced to shorten the time needed for development and implementation. However, the autonomy of science is also obtained through stable funding and a long-term perspective. Encouraging interdisciplinary research and overcoming silos between sectors are necessary steps to increase freedom and flexibility of research.



In terms of attracting and developing young talent in basic research, Her Excellency Prof. Carrozza emphasized the need for medium- and large-scale facilities providing research infrastructure. The curiosity of young people must also be nurtured for them to dedicate efforts towards global problems like saving biodiversity and developing models for understanding climate change. The existing paradigm for engineering must also change, as AI develops rapidly and introduces new solutions and problems.

His Excellency Dr. Munir M. Eldesouki shared his views about the challenge of balancing top-down and bottom-up approaches to research. Saudi Arabia invests significantly in allowing scientists to take creative approaches, but this alone does not solve existential problems the country faces. As part of Saudi Arabia's Vision 2030 reforms, focus on R&D and innovation is providing top-down scale, while the support given to fundamental research is maintained.

His Excellency Dr. Eldesouki further described how various reforms in Saudi Arabia have led to introduction of entrepreneurial leave programs, easing the flow between laboratories and the market. Science parks are also being opened to the private sector, along with incubators, fostering hundreds of new founders. This kind of supportive ecosystem has allowed momentum to build in a short span of time and can lead to effective translation of research into the economy while sustaining funding for basic science.

Next, Dr. Michael Spence AC highlighted challenges faced in current research policy, noting the delicate balance between global collaboration and national strategic competition. There is a consensus that it is positive to work together to address global issues including climate change and inequality, but countries also preserve information to maintain competitive edges in the knowledge-based economy. Dr. Spence AC outlined the factors behind uncertainty in research policy, mentioning that whether the scope of strategic competition primarily involves economic or military factors has significant implications on research funding and collaboration. Furthermore, determining who researchers should or should not collaborate with is a complex issue.

Dr. Spence AC then argued that three actions must take place. First, scientists and universities should engage in national-level discussions about what aspects of research should be preserved for the benefit of their nation, helping to shape policies governing research collaboration. Second, like-minded countries should work towards shared principles and agreements regarding research collaboration, helping to reduce confusion and conflicts in international scientific cooperation. Third, universities should clearly define their values and stance on the issue of openness versus strategic competition to clarify communication to both national governments and international organizations.

Discussion

Prof. Haug asked Prof. Ketterle to expand on his idea of a stable ecosystem for research.

Prof. Ketterle noted that he viewed stability as predictability, giving researchers assurance that they can fund their research teams for extended periods of time. The research environment in Europe is more predictable now than that of the U.S., so depending on the area of research, some ecosystems will be better than others for enabling discoveries.

Prof. Ketterle continued to explain that for his own research, he knew he could spend a few years to strive towards a big goal. Freedom to explore bold ideas is critical, as are systems and administration that provide flexibility on how research budget can be spent.

Next, Prof. Haug asked His Excellency Mr. Chang how he balances priorities of shorter-term wins versus basic science research.

His Excellency Mr. Chang explained that he tries to focus on the needs of Malaysia, and he believes that the government should facilitate dialogue and collaboration between industry and academia. For fundamental research, non-monetary value is determined through speaking with relevant parties.

Then, Prof. Haug asked Her Excellency Prof. Carrozza how she considered basic research when she was the Minister of Education, University and Research of Italy.

Her Excellency Prof. Carrozza shared that she tried to simplify research programs and reduce weighty bureaucracy during her tenure. This also involved shifting the focus of programs to final goals and challenges for researchers to address. Her Excellency Prof. Carrozza acknowledged the need for a diverse research environment including scientific leaders, technology experts, and facilitators to support research leaders.

Prof. Haug then asked His Excellency Dr. Eldesouki what role financial incentives play in the transfer of technology into innovation.

His Excellency Dr. Eldesouki explained the components of the Saudi strategy, which includes steering scientists and building linkages within the innovation ecosystem. He emphasized the importance of bringing startups physically closer to research labs to foster innovation, and mentioned that flagship projects and national missions engage various stakeholders to address common challenges from both top-down and bottom-up perspectives.

Next, Prof. Haug requested Dr. Spence AC to comment on the challenges facing basic research in the UK and beyond.

Dr. Spence AC elaborated on the significance of programs which provide stability for research funding, insulating it from local budgetary pressures. Universities and their leaders must play a role in helping governments navigate these challenges and ensure coordination between different government departments. University leaders must cover a range of responsibilities due to the nature of research policy.

Q&A

A member of the audience then asked the speakers about the importance of industry-supported basic science research, as this has led to some revolutionary scientific discoveries in the past.

Prof. Haug shared that German industry contributes double the amount of public funding research, totaling to 3.14% of GDP.

Dr. Spence AC shared that the UK has aspirational numbers for such contributions, but it is difficult to determine how much of the funding is dedicated to research at universities and research institutes.

His Excellency Dr. Eldesouki shared that Saudi Arabia currently has a low level of such support but is increasing it gradually. In addition, many low-cost initiatives have been successful in incentivizing private industry to increase research efforts.

Prof. Ketterle responded that the types of fundamental research done by industry in the past, such as those at Bell Labs, were quite unusual, and today much industry-funded

basic research surrounds computation. He added that various foundations provide critical funding for basic research, and fill gaps and inefficiencies in the current funding system.

Her Excellency Prof. Carrozza added that the issue of intellectual property is also critical to private-funded research, and it may be necessary to revise existing models to support innovation.

Another member of the audience then asked how universities should decide what research is kept for international public good versus national public good.

Dr. Spence AC replied that he wished for governments to have clear guidance relating to the criteria universities should take into account. Within universities, committees of researchers consider applications of government guidance in given areas. Much policy work is needed to determine better governance systems for such knowledge-related matters.

Closing Remarks

Finally, Prof. Haug reiterated that reliable and predictable funding is a key to science innovation, and a balance must be maintained with basic and applied research. Additionally, high degrees of freedom, autonomy, and a culture of trust between researchers are vital.

Science and Technology for Business

[Chair]

Brady, Terry, President and CEO, UL Research Institutes, U.S.A.

[Speakers]

Terashi, Shigeki, Executive Fellow, Toyota Motor Corporation, Japan

Roese, John, President & Global Chief Technology Officer, Corporate Technology Organization, Dell Technologies, U.S.A.

Sata, Yutaka, Executive Officer, Corporate Senior Vice President; Chief Technology Officer; Chief Information Security Officer, Toshiba Corporation, Japan

Liu, Mark, Chairman, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), Taiwan

Bednorz, J. Georg, Fellow Emeritus, RE-TRAITE Switzerland, Switzerland [Nobel Laureate 1987 (Physics)]

Opening Remarks

Mr. Terry Brady opened the session by stating that the world is at a profound inflection point, where the acceleration of change, increased risks in a hyper-connected, technology-reliant society, and ever-growing concerns about the unintended consequences of innovation affect every sector. Of course, innovations also have the potential to ameliorate critical global risks, but to do so, new technologies must typically be brought to worldwide scale, and it is the business sector that has historically been best able to accomplish that.

Brady, Terry

Mr. Brady then explained that the topics in the session would include artificial intelligence, superconductivity, and advanced manufacturing, among others. Across these diverse fields, however, there are common questions that merit attention. First, how can businesses play the most productive role in helping new technologies move quickly from basic research discoveries to commercialization? What sorts of public-private partnerships have shown promise for such transitions in the past?

Another question concerns the democratization of new technologies. While applications employing artificial intelligence have recently been made widely available, the development of the underlying AI products require resources that only a tiny handful of companies can realistically afford. What are the implications for public policy and possible regulation?

Mr. Shigeki Terashi agreed with Mr. Brady that the world faces various complex and intertwined social issues. For many of these, there are no defined roadmaps to a solution. One such issue is the realization of carbon neutrality. Toyota aims to tackle this issue by developing various types of electrified vehicles that use carbon-neutral fuels and these vehicles are rapidly gaining popularity. However, the energy situation differs by region, and to achieve carbon neutrality, it is important not to narrow down options. Toyota pursues multiple pathways while staying in touch with the situation and the realities of each region.

Another challenge Toyota is tackling is reducing traffic casualties by developing preventive safety and automated driving technologies. Toyota's research focuses not only on systems, but also people and the traffic environment with the aim of achieving a society with safe transportation and zero traffic accident deaths.

These two pursuits come together in Toyota's work with the Japan Aerospace Exploration Agency and other companies to launch a lunar rover in 2029. Toyota aims to develop a rover that can navigate the moon's landscape and enable people to survive its harsh conditions. The rover will be powered by a hydrogen fuel cell, while also generating and storing solar power. If water is found, it could be electrolyzed using solar-powered electricity and the resulting oxygen and hydrogen could be stored and used. Toyota hopes that this will serve as a template for the hydrogen society that Toyota is aiming for. The vehicle will also have a driver-assist function.

Mr. John Roese pointed out that, like any other disruptive technology, AI has an underlying set of dependencies and if they are not manifested, the aspirations of AI may not be possible. The AI era is very real and it is a rebalancing of work between people and machines but not mechanical work, rather cognitive work. The last major technological inflection that led to huge productivity enhancements was the launch of enterprise software systems such as customer relationship management systems. AI is poised to realize even larger productivity gains. Those are the lights.

There are also shadows, consisting of AI's own intrinsic issues, but also the aforementioned dependencies that must be worked through. The first dependency is that AI represents unprecedented capacity growth. The second dependency is that there needs to be infrastructure below AI to support it, such as a semiconductor production base and computing power, but it is largely not there. The third dependency is efficiency issues. If AI is placed in the wrong place, it generates huge inefficiencies. The fourth dependency is cybersecurity. The current cybersecurity space is broken and constantly reactive. Moreover, in the AI era, a trained AI model will be the digital instantiation of a company, its businesses, and its trade secrets. The fifth dependency is policy. If governments only develop policy for AI but do not solve the issues with the environment around AI, they will have effectively developed bad AI policy.

Dr. Yutaka Sata spoke about how science and technology and companies can tackle serious societal challenges. Science and technology play an increasingly crucial role in addressing such challenges in terms of development of systems to address challenges, and implementation in society. Toshiba is actively working on societal issues, particularly carbon neutrality and promoting circular economy. For that, active R&D essential.

Last year, Toshiba developed a superconducting motor with the same output of conventional motors but one-tenth the weight. This is the result of Toshiba's diverse technology. At the same time, it is also based on many years of research collaboration with universities. This is not the first superconductive application that Toshiba has developed. Toshiba has in fact produced others, but it is very careful in choosing the outcomes of its research, knowing that it will take a long time to witness the fruits of that research. After developing a promising technology, it is necessary to test it and implement it in society. The benefits and risks must also be analyzed and communicated carefully and precisely to society.

In that regard, in the area of quantum computing, Toshiba is leading an initiative to establish an industrial alliance known as the Quantum Strategic Industry Alliance for Revolution (Q-STAR). Q-STAR has constantly discussed applications of quantum technologies, proper communication to society, and educational programs to increase the number of quantum-literate people. Such vendor-user collaboration is essential for accelerating the implementation of science and technology in society, and science and technology are very important for a company like Toshiba to be able to tackle sustainable challenges.

Dr. Mark Liu spoke about a paradigm shift in semiconductor production. He began by looking back on various breakthroughs in AI application in the past few decades and pointed out that these major breakthroughs have always been supported by breakthroughs in semiconductor technology and advances in their computation power and memory access. Demand for more computation power and memory access continues to grow amid the advances in generative AI. As the progress of transistor scaling slows down, how can semiconductor technology continue to move forward?

Until now, advances in semiconductor technology have been about packing more transistors into the chip. Going forward, integration will need to rise up one level higher. Now, it will be about putting many chips into a tightly integrated, massively interconnected but small system. This move beyond 2D to 3D has been the paradigm shift in semiconductor technology production in the past 10 years or so.

At the same time, it is necessary to reduce energy consumption. For this, innovation is continuously occurring in many aspects, from new materials and devices to advances in lithography and system architecture. Over the past 15 years, the semiconductor industry has improved energy efficiency and speed by three times, every two years.

In the era of AI, new semiconductor technology is a key enabler for continued advances in AI applications. For the past 50 years, semiconductor development has been like walking through a tunnel, with everyone knowing that the path forward was to fit more transistors in the chip. Now the industry is preparing to exit the tunnel. Semiconductor technology is becoming harder to develop, but beyond the tunnel many more possibilities lie ahead.

Prof. J. Georg Bednorz presented on the energy transition and the potential contribution of a new technology based on superconductivity. New generations of superconductors are high performance materials that will replace copper lines in the long term. Wires cooled in liquid nitrogen can carry large currents up to 500 times larger than copper wires without resistance and no electricity losses. Such wires would also enhance the efficiency of the generation and conversion of electricity in generators and motors, with the potential to transform the whole energy sector. It also allows the construction of electrical components that are smaller by size and weight, enabling more powerful wind and hydropower plants.

In Germany, if this potential transformation is exploited, transmission and distribution networks, which are being stretched to their limits, would come under even greater pressure. However, new corridors for overhead lines or underground cables were met with vehement public opposition leading to delays in installation. Pilot projects have already shown that underground high-temperature superconducting cables offer only advantages. Despite this, the German Federal Network Agency does not even mention superconductivity in its plans for the expansion of the national transmission network. Nevertheless, research continues.

However, a broad market introduction has failed to emerge with potential users remaining reluctant to be first-movers. A change in funding policies should be made to enable support beyond the development of prototypes and allow testing under real industrial conditions, which would generate greater confidence in the technology. Politics should find solutions to create incentives for industrial users, while still ensuring fair competition. Otherwise, projects will remain in the prototype stage, and opportunities to develop superconducting technology into a key technology will be missed.

Q&A

A Q&A session was subsequently held and it began with a question about what Toyota and Toshiba can do, as top companies, to help strengthen the training of PhD students in Japan in the face of declining enrollment rates in PhD programs.

Dr. Sata replied that Q-STAR is establishing a new curriculum to educate not only PhD students but also young researchers in industry. Increasing the number of Japanese PhD students is certainly important for tackling societal issues. However, one problem is that many university professors and researchers work on only their own area of interest, rather than societal challenges.

Mr. Terashi agreed that this has been a longstanding issue and that it is not one that is easy to solve. Recently, Toyota has been collaborating with many universities and companies through which it hopes to reaffirm the importance of graduates of doctoral programs and work out a process for directing them to solving societal issues.

Next, an audience member asked whether it would be possible to propose to governments the establishment of a common platform where representatives from government, business, and academia could come together to jointly formulate policies and pool resources.

Mr. Roese replied that this is a great idea and has been done before in other fields, such as telecommunications. That has become more challenging in the cloud era and even more so in the AI era, due to increasingly rapid innovation. There is a speed mismatch between the pace of technology development and how fast governments and academia can move. However, slowing down innovation or speeding up government academia are both very hard to do.

Dr. Liu pointed out that the government cannot choose winners or losers, but should continue to work on global standard setting. As for business, it should engage in open innovation where a direction of research is set but to which everyone can contribute.

Prof. Bednorz suggested that the field of superconductivity is missing just such a platform, resulting in singular efforts and projects in many different countries.

A question was then asked about how to design effective funding programs that align scientific interest with business needs.

Mr. Roese suggested that funding agencies need to spend a lot of time with industry to understand where the gaps are, as they are not always obvious.

Dr. Liu pointed out that the situation in each country is different. Smaller countries need to envision what kind of industry they would want to have in the future and consider their own advantages and limitations, rather than emulating the United States or the larger European countries.

Next, an audience member asked what responsibility companies have to manage and mitigate the downsides of AI.

Mr. Roese answered that there must be disclosure to the consumer whenever AI is used to interact with them or produce the content they consume. In the longer-term, it is important to democratize the technology.

Closing Remarks

To close the session, Mr. Brady suggested that, although the name of the session was "Science and Technology for Business," it could be retitled "Science and Technology and Business." There is a circular flow of improvement to the world whereby businesses are starting to see themselves as having social responsibilities beyond profit-making and to recognize the opportunity to share their discoveries in ways that are helpful to society.

Key Messages from Concurrent Sessions

[Chair]

Kabat, Pavel, Secretary-General, International Human Frontier Science Program Organization (HFSPO); former Director General & CEO, International Institute for Applied Systems Analysis (IIASA)

[Speakers]

Ali, Ahmad Tajuddin, JOINT CHAIRMAN (INDUSTRY), Malaysian Industry-Government Group for High Technology (MIGHT); CHAIRMAN, MALAKOFF CORPORATION BERHAD, Malaysia

Colwell, Rita R., Distinguished University Professor, University of Maryland Institute for Advanced Computer Studies, University of Maryland College Park; Professor, Johns Hopkins Bloomberg School of Public Health, U.S.A.

von Braun, Joachim, President, Pontifical Academy of Sciences, Vatican City State; Professor for Economic and Technological Change and Director, Center for Development Research (ZEF), Bonn University, Germany

Diarra, Amadou, Senior Vice President, Global Policy, Advocacy & Government Affairs, Bristol-Myers Squibb, U.S.A.

Dlamini, Thulani, Chief Executive Officer, Council for Scientific and Industrial Research (CSIR), South Africa

VijayRaghavan, K., former Principal Scientific Adviser to the Government of India, National Centre for Biological Sciences; DAE Homi Bhabha Chair, National Centre for Biological Sciences, TIFR, India

Damerval, Thierry, President and CEO, French National Research Agency (ANR), France

Kotani, Motoko, Executive Vice President for Research, Tohoku University; Vice President, International Science Council (ISC), Japan

Ganokratanaa, Thittaporn, University Lecturer, Mathematics, King Mongkut's University of Technology Thonburi (KMUTT), Thailand [Young Leader 2023]

Mutlugün, Evren, Dean, Faculty of Engineering, Abdullah Gul University; Co-Founder, Nanome Nanotechnology R&D Inc. Co., Turkey [Young Leader 2023]

Diem, Stephanie Josephine, Assistant Professor, Nuclear Engineering and Engineering Physics, University of Wisconsin - Madison, U.S.A. [Young Leader 2019]

Opening Remarks

Prof. Pavel Kabat explained that the purpose of this session is to report on the key messages from the 24 concurrent sessions, which were filled with many interesting and challenging ideas, and which dealt with the potential conflict between the opportunities and the risks of advances in science and technology. The session would also provide an opportunity for Young Leaders past and present to share their thoughts and experiences from this year's meeting.

Kabat, Pavel

Report by the Young Leaders

Prof. Stephanie Josephine Diem expressed her gratitude to STS *forum* for establishing the Young Leaders Program and for providing a platform for the first Young Leaders Alumni meeting. The Young Leaders embody the flexibility and adaptability needed to swiftly confront global challenges.

The breakout sessions of the Young Leaders Program addressed topics that include health and medicine with a focus on aging, climate change, biodiversity, energy, water, innovation and health, academic community, and human diversity and leadership. The Young Leaders noted the urgent need to find sustainable solutions in an equitable way. They also stressed the need to expand networks, work together, and build interdisciplinary teams across nations and disciplines to create innovation solutions.

Furthermore, they recognized that STS *forum* offers an opportunity to break silos to create inclusive, innovative, and sustainable solutions to the world's challenging programs, and highlighted the value of expanding the program further and continuing the Alumni Network. They emphasized that the choices of today will shape the technologies of tomorrow, impacting generations to come. To design sustainable solutions, it is essential to involve everyone.

Prof. Evren Mutlugün spoke about his experience attending STS *forum*. He said that it was a transformative event that left him with profound reflections. The event featured extraordinary

discussions on critical topics, from climate change to AI, that shape the world today and will define the future.

A common theme among these discussions was that, in an interconnected world, collaborations across countries, sectors, and fields are essential for accelerating progress towards a sustainable future. The importance of the existence of different stakeholders in ecosystems, whether academia, government, or industry, was also discussed.

Prof. Mutlugün said that his attendance of STS *forum* reinforced in him the transformative potential of collaboration among government, industry, and academia to take on global challenges, while ensuring efficient dissemination to society as well. He called on the other participants to continue to engage in meaningful dialogue, foster partnerships, reduce inequities, and take sustainable actions to protect the planet.

Dr. Thittaporn Ganokratanaa shared her impressions from attending STS *forum*. She and the other Young Leaders deeply appreciated the rich discussions on essential topics for a sustainable future. They explored a wide range of topics from sustainable energy solutions to the ethical implications of advanced AI.

Their discussions and dialogs with Nobel Laureates highlighted the importance of curiosity, determination, and passion as keys to success. Besides the technical discussions and expertise, STS *forum* also embodied a spirit of collaboration, unity, and shared purpose, which resonated with the Young Leaders. The Young Leaders were also inspired by their interactions with various leaders and experts, highlighting the immense value of the Young Leaders Program. The Young Leaders share a common determination to build a more collaborative and innovative future together.

Key Messages from Concurrent Sessions

Dr. Ahmad Tajuddin Ali presented the key messages from the energy track. The session on New Technologies for Low Emission Transportation dealt with the fact that the transportation sector is a hard-to-abate sector and the importance of decarbonizing this sector for realizing

carbon neutrality globally. The session considered efforts to decarbonize the automotive, aviation, and maritime industries. The potential of batteries was also mentioned.

In the session on Fusion Energy, participants discussed the potential of fusion energy to reshape the energy landscape, as well as the long history of this technology, its great potential, and the importance of collaboration. They also highlighted how there is still much work to be done before fusion power plants can be realized, but the building blocks are there.

Prof. Rita R. Colwell summarized the discussions from the Climate Change concurrent sessions. The world is at the mid-point of the UN 2030 Agenda, but governments are not on track to meet several of the Sustainable Development Goals. Unprecedented climate events have coincided with health crises and geopolitical conflict. Faster and more robust mitigation and adaptation efforts, especially consideration of vulnerable populations, are needed. Scientists must provide best estimates of the impacts of climate change in ways that the public can understand and that motivates them to take adaptative action. Furthermore, education is important and should include indigenous and vulnerable populations.

In the Adaptation to Climate Change session, participants noted signs of progress and reasons for hope, while recognizing that equity and engagement with the local community remain essential. It is also important to develop cross-sector, transdisciplinary approaches. Moreover, science-based solutions must focus on the younger generation. In addition, climate change and biodiversity go together and holistic efforts to preserve ecosystems and developing adaptive solutions are needed. There also needs to be changes in regulation to enhance collaboration and long-term data collection. Furthermore, different countries have different needs, and country-specific solutions are required.

The session on Sustainable and Resilient Urban Environments took up new technologies such as satellite imaging, new construction methods, and multi-stakeholder initiatives, and participants noted that these will maximize the value of solutions and make them relevant to local communities. The participants in the session also recognized that scalability, education, and sharing of information can allow best practices to be replicated among different communities. Nevertheless, solutions must be locally oriented. Better and transparent education is also needed. In addition, green and renewable energy will be critical to developing sustainable and resilient societies.

Prof. Joachim von Braun presented key messages from the Earth and commons track, which consisted of sessions on Agriculture, Food and Water Security, Biodiversity and Ecosystem Services, and Deep-sea Exploration and Exploitation. In the sessions, the participants expressed deep concern about the state of the commons of the Earth, as well as concern about the intertwined issues of climate issues, biodiversity decline, and inequality and poverty issues. A systems approach was called for in all three sessions. The participants noted that, in order to achieve resilience, a stronger focus needs to be on how to balance adaptation, mitigation, and systems transformation. Participants stressed that COP28 provides an opportunity to follow up on COP27 with a focus on food issues and resilience. The value of genetic resource protection and management was also emphasized and the opportunities of biotechnologies for crop adaptation discussed.

In addition, participants called for more attention to be paid to the demand side, such as the need for healthy diets, reduced food waste and losses, and behavioral change for healthy food to meet that demand. They also called for the mainstreaming of biodiversity in future STS *forum* meetings. Furthermore, they highlighted the need to combine science and technology innovation with tested nature-based solutions, such as indigenous knowledge.

The participants also called for stronger attention to be paid to land-sea interactions under climate stress, as well as worrisome indications of high temperature increase in the deep sea, reduced ocean circulation, and reduced oxygen in the deep sea. Regarding deep-sea exploration, participants argued for the need to proceed with caution and that technologies and knowledge have not advanced to the point to enable deep-sea resources to be exploited sustainably. Lastly, participants discussed various existing global regulatory policy frameworks under UN Food Systems Summit processes, COPs related to Biodiversity, and COPs related to Climate, as well as the UN Law of the Sea and the need to link them together.

Dr. Amadou Diarra shared the key messages from the concurrent sessions on life sciences. In the session on AI in Health, participants talked about data challenges, including data collection, data curation, data collaboration, data communication, privacy concerns, and regulatory considerations. Furthermore, they discussed short-term versus long-term benefits of AI, with the former entailing increased productivity and the latter faster drug discovery at scale. Risks such as the trustworthiness of AI, poor quality/biased data, and health inequity were also discussed. Another topic was how AI can help leverage datasets to predict how genome mutations affect cell biology.

In the New Frontiers in Biotechnology session, participants discussed 1) advances in synthetic chemistry in parallel with biotechnology which have the potential to be combined to improve kinetics and targeting, 2) how new technologies enable personalized treatments, i.e., right treatment, right dose, right patient, right time, 3) the detection of several cancers from urine samples using the olfactory senses of nematodes, 4) nanotechnologies enabling liposomes to deliver traditional and cutting edge therapies to target tissues, and 5) promising developments in cell therapy including the likely next step change of off-the shelf cells.

Participants also discussed how to build trust in such new technologies and how to make them broadly accessible, as well as how to tackle antimicrobial resistance via collaborations and policy incentives.

The final session was on Healthy Aging. During the session, participants spoke about the inversion of population structures and the health and socio-economic issues this creates, keeping in mind the difference between chronological age and physiological age. The importance of food and nutrition to healthy aging, and the contributions that could be made by genetically modified organisms were also taken up. In addition, participants noted the need to enhance research and health systems to support healthy aging, rethink retirement ages and strengthen older citizens' legal protections. Another topic was the importance of happiness to healthy aging and the need to see healthy aging as an opportunity, not a burden.

Dr. Thulani Dlamini presented the messages from the track on innovative engineering. The session on Revolutionary Materials and Devices focused on developments such as nano semiconductors and materials that try to learn from nature and mimic biological systems. Revolutionary materials and devices offer potential new solutions to tackle climate change and are also fundamental to fully realizing the potential of current advances in AI. AI can also accelerate the pace of materials development. In all of this, it is necessary to define boundary conditions such as sustainability, zero carbon emissions, and circular economy. The social dimension must also not be ignored.

The next session was Quantum Science and Technologies. The focuses of the session included the need for continued investment in research and development to fully realize the potential of quantum technologies, the need to develop practical use cases to increase uptake of new quantum technologies, and, as one of the potential shadows, information security and privacy.

In the session on AI & Hyper Automation, the participants recognized that advances in AI have accelerated research and discovery of new materials for various applications. There are also many shadows, however, including issues of ethics, privacy, security, the need for regulation, and fear of job loss.

Prof. K. VijayRaghavan summarized the key points from the concurrent sessions on cooperation in science and technology. In the session on Science and Technology as a Driver for Development, participants spoke about the important role of social sciences in developing science and technology solutions for society. The importance of cooperation and collaboration, including with young researchers as equal partners, was also emphasized. Furthermore, participants discussed the need to direct global human resources and research at key challenges for humankind, such as climate change or pandemic risks.

In the session on Collaboration among Academia, Industry and Government, the participants discussed how global challenges are also opportunities for advancements in science and technology. They also discussed how business, academia, and government, as well as private foundations, can work towards mitigating future challenges. To ensure effective collaboration for achieving a sustainable and prosperous future, it is necessary to align the needs and resources of each stakeholder.

As for the session on Nurturing Innovation-based Startups, the participants talked about the many impactful startups that are making substantial contributions to addressing societal challenges, including the creation of some of the vaccines that were critical to combating the COVID-19 pandemic. A long-term commitment to investing in research and innovation and nurturing a culture of collaboration are important. To support innovation, academia must encourage and cultivate an innovation mindset. It is also necessary to promote innovation in education.

Dr. Thierry Damerval provided a recap of the discussions from the concurrent sessions on education in science and technology. In the session on Fostering New Generations of Scientists with Inclusion and Diversity, participants noted that inclusion and diversity are not only fundamental rights but enrich science, technology, engineering, and mathematics and drive innovation. Furthermore, diverse groups can develop creative solutions, and an environment that welcomes disagreement is necessary. It is also important to recognize everyone's contributions. Such diversity and inclusion need to be nurtured from an early age.

The participants in the AI in Education session noted that AI has the potential to free teachers from menial tasks and allow them to establish closer and more meaningful relationships with students. They also noted that the benefits and pitfalls of AI should be taught at all levels.

The final session in the track was Trust in Science. The participants discussed the importance of confidence in how research is carried out, in institutions, in scientists, and in what research is conducted. There are huge disparities in scientific knowledge, including across countries but also among social categories. The scientific process is difficult to understand for the public and political leaders. To tackle this, scientists need to be exemplary in how they conduct research, maintain scientific integrity, ensure fair data-sharing, uphold the quality of publications, and forge real human relationships with the public and policymakers.

Prof. Motoko Kotani summarized the key messages from the digital society track. Whenever new technologies emerge, society has huge expectations, but also fears. The latest developments in AI have a huge impact due to their speed and reach. The kind of society that digital transformation will shape depends on the wisdom of humankind. In all three sessions, cooperation across various sectors and disciplines was recognized as necessary for achieving a better and more sustainable society. Global partnerships to establish educational platforms were suggested to support early career researchers and students around the world, those from the Global South in particular.

In the session on Trust of Information in Digital Age, the participants recognized the importance of people's trust in information, particularly in fields that impact human life. Tools such as authenticity verification must be developed and applied to combat digital fraud. Data protection must also be ensured. Furthermore, data governance must be further developed. In addition, the public and private sectors should work together to bridge the knowledge gaps necessary to ensure trustworthy information.

In the session on Quest for Digital Equity, participants discussed the importance of achieving data equity in a global context and global efforts to bridge the digital divide, particularly for the Global South. Digitalization has the potential to exacerbate socioeconomic inequalities and even jeopardize liberal democracies, and the work of various institutions to combat these disruptions are welcome.

In the session on Data in AI, participants noted that AI relies on the availability of vast data for model learning and that the increasing amounts of data generated by AI algorithms offer both opportunities and challenges. AI can be utilized to solve societal problems, such as improving healthcare and optimizing the supply chain. It can also have transformative effects on new discoveries, hypothesis generation, and data interpretation.

It was proposed that multiple AIs trained in different ways may be able to operate in a democratic way to cross-check, collaborate, and solve issues.

Q&A Session

Following the opening remarks, Prof. Kabat began a Q&A session by asking the speakers whether they would leave this year's meeting more optimistic or pessimistic about the future of AI, and why.

Dr. Damerval said he was optimistic, believing that if AI is properly managed, it will free up time for teachers to establish new and more interactive relationships with their students.

Prof. Kotani was optimistic but cautioned that to ensure a bright and inclusive future, there needs to be discussion among diverse communities. To that end, discussion platforms such as STS *forum* are very important.

Prof. von Braun considered it necessary to take a sector perspective to AI. He noted that many positive impacts have been mentioned, but there are also many open questions in specific sectors such as potentially risky AI applications in military and in access to finance, as well as discrimination, and he stressed that AI must be considered a dual use technology.

A question was then raised by a member of the audience. He asked how it would be possible to ensure society can guide and manage the development of new technologies and ensure their deployment is beneficial rather than harmful to society, given that the technological developments are occurring faster than regulatory frameworks can keep up.

Prof. Diem stressed the need to bring diverse stakeholders into the decision-making process. This helps to tackle these issues, as well as foster engagement and trust among the communities that will be affected.

Next, a member of the audience asked about ethical considerations when implementing AI in low-income countries.

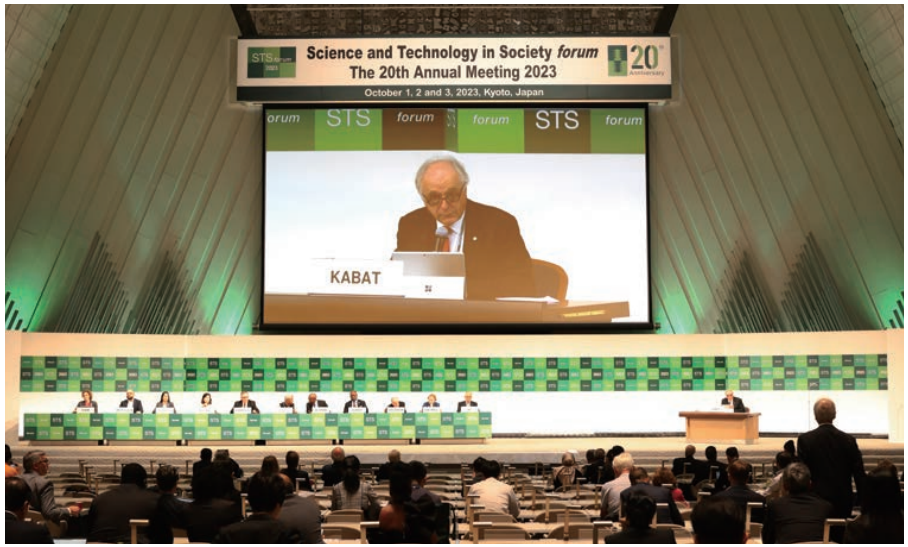
Prof. VijayRaghavan noted that there is no clear regulatory framework defining what can, should, or should not be done using AI, even in advanced countries. In low-income countries, there is even more potential for misuse as the technology is not as widespread. It may be useful to have an international panel, similar to the Intergovernmental Panel on Climate Change, to dynamically lay down regulatory points or advise governments.

Prof. Kabat asked if it is possible that people might be overestimating the capabilities of AI and how its capabilities should be accurately conveyed to the public.

Dr. Ganokratanaa pointed out that AI is already being used by the public in real-world applications. To enable people to use it appropriately and understand it, they need to be educated in the fundamental aspects of how AI works, and what types of services or functions use AI.

Prof. Colwell suggested that a more pressing priority is climate change, which AI could contribute to addressing. She pointed out that unless humans deal with this urgent problem, there may one day be no civilization left, rendering debate on AI moot.

Dr. Ali likened the situation to the development of nuclear technologies and emergence of fusion technologies. Like nuclear technologies, there are hopes and fears associated with AI and there is a need to ensure that people utilize it for ethical ends.



Closing Plenary Session: Science and Technology for the Future of Humankind

[Chair]

Serageldin, Ismail, Founding Director Emeritus, The Library of Alexandria, Egypt

[Speakers]

Barabino, Gilda A., Chair, AAAS Board of Directors/Past President, American Association for the Advancement of Science (AAAS); President, Olin College, U.S.A.

Stiernstedt, Göran, Chairman of the Board, Karolinska Institutet, Sweden

Córdova, France A., President, Science Philanthropy Alliance; former Director, National Science Foundation (NSF), U.S.A.

Komiyama, Hiroshi, Chairman, Science and Technology in Society *forum* (STS *forum*), Japan

Opening Remarks

Dr. Ismail Serageldin opened the session, expressed his pride to have been involved in STS *forum* from the very beginning, and noted that its discussions have always been essential.

Following Dr. Serageldin's opening remarks, Dr. Gilda Barabino spoke about the importance of the science and technology sector striving for a future where humankind is core to its work. The concept of humankind is being tested by advances in science and technology, such as discoveries about the wonders of the universe and the capabilities of large language models. One cannot underestimate the importance of the humanities to science and technology. Science is a human process. The more we embrace our common humanity and science as a unifier, the better we will understand what it means to be human and what it takes to ensure a sustainable future.

Serageldin, Ismail

Looking back on history, the scientific community has either used science to draw us together or to separate us. Genetic research is one example of science being misused in a way that created long-lasting gulfs in society, particularly among people of different races.

By contrast, efforts are now being made to bring different groups together to enhance the diversity and accessibility of science and technology. At the end of the day, it matters who is conducting science. A diverse group will decrease the chance that a prevailing set of views will bias the outcome of research and enable science to tackle critical challenges that affect communities differently.

Barabino, Gilda A.

Science is a social and iterative process, where people work together over time and use established processes to reach a consensus that can evolve in the face of new evidence. However, this is not well understood by the public. To demonstrate the value of science and technology to society, we need to apply social sciences to effectively communicate science and its benefits to society. We also need to redefine what it means to be a good scientist or engineer. Being a good scientist and engineer is not just about making discoveries and driving advances. It is also about embodying good ethics and integrity. It is essential that the public sees the scientific community as trustworthy. The scientific community can be a unifier and has a critical role to play in bringing together different countries to address common challenges. The scientific community should be human-centric, not leave anyone behind, use science as a unifier rather than a separator, communicate science's benefits to society, find ways to work together, and ensure humanity is at the heart of scientific work.

Stiernstedt, Göran

Prof. Göran Stiernstedt began his remarks by recalling the Koji Omi Memorial Lecture given by Dr. Svante Pääbo, who won the Nobel Prize in Physiology or Medicine in 2022, and the recent announcement of the awarding of the Nobel Prize in Physiology or Medicine 2023 to Dr. Katalin Karikó and Dr. Drew Weissman for their discoveries concerning nucleoside

Córdova, France A.

base modifications that enabled the development of effective messenger RNA vaccines against COVID-19. Prof. Stiernstedt noted that basic research links the work for which these two Nobel Prizes were awarded and pointed out that more resources need to be invested in basic research and more needs to be done to convince politicians of their value. Work also needs to be done to shorten the time between the basic research and the launching of an invention. Perhaps AI could be a tool for achieving that.

Prof. Stiernstedt also noted that this year's annual meeting has focused a lot on AI. AI could make significant contributions to a wide range of fields, including medicine and healthcare, in forms such as novel and more personalized treatments. However, AI can also be alarming to the public, and it is important to take people's concerns seriously. Some of these concerns, such as ethics and privacy issues, require the establishment of appropriate regulatory frameworks. However, this takes time, whereas the advancement of AI is occurring at breakneck speed. Furthermore, new strategies to combat misinformation and disinformation are essential. In addition, fostering trust among the public is of the utmost importance.

Above all, it is critical to defend free and independent research and academic freedom, both of which are constantly under threat. It is also essential to share knowledge and experiences, and to cooperate globally. STS *forum* is an excellent contributor to these goals.

Dr. France A. Córdova recalled some of the highlights from the past few days' discussions. All forms of science and technology have lights and shadows, and during STS *forum*, participants shared many more examples of the hope they hold in science and technology. AI was a central theme of this year's meeting, and it will have transformative effects on human society and even accelerate discoveries about ourselves as human beings. AI is also changing how we think about creativity.

This year's STS *forum* also discussed some key priorities for achieving a more just and equitable society, including clean renewable energy, more sustainable agriculture, clean water and its conservation, improved waste management, habitat restoration, resilience of cities, affordable healthcare, equitable access to digital technologies, accessibility and affordability of education, peaceful and equitable use of space and oceans, and ethical and responsible AI. This is a demanding agenda, but the spirit of STS *forum* suggests that it is an agenda within our reach.

Key to meeting this agenda will be partnership. Partnership can bring forth new ideas, lead to plans and commitment, and fortify resilience. Without partnership, no progress on global issues can be made. Besides academia, government, and business, philanthropic organizations also have a role to play. They aim to address important goals in science, science policy, and development of science workforce and can be strong partners for governments in funding scientific research. At STS *forum*, efforts to form essential partnerships are in their early stages. It is hoped that the circle of partnership and collaboration will continue to grow, and that in future meetings of STS *forum*, we will see wonderfully conceived partnerships that are working well.

Next, Dr. Serageldin looked back on past advances in science and technology and noted that every advancement in human society has been made possible by science and technology. However, the destructive and competitive paradigm of development that humankind

has taken is transgressing the planetary boundaries and threatening the ecosystems on which we all depend. In our own societies as well, discrimination is prevalent, hunger and poverty continue, and inequality among countries is rising.

However, all of these issues pale against the existential challenge of climate change. The world is not on track to reach the Sustainable Development Goals, including the goal of keeping global warming under 1.5 degrees. Redoubled efforts are needed. In addition, there needs to be greater commitment on human rights to enhance the concept of human security. Furthermore, conflicts and war are leading to the unprecedented displacement and migration of vulnerable populations. However, these populations are being shunned by many countries and left to suffer or even die. The rising number of environmental disasters will also lead to a rise in refugees.

Still, despite these many problems, there are also many possibilities linked to science, technology, and innovation. The latest technological developments in a wide range of fields, if properly deployed, can set us on a path towards a future where science and technology will refashion our economies and transform our societies for the better, while keeping our activities in harmony and balance with nature. This must, however, incorporate and be supported

by combining the knowledge of the natural sciences with the insights of the social sciences and the wisdom of the humanities. As we advance towards a better future, we need to have science-driven policies and evidence-based regulations. At the same time, we need to protect the interest and safety of the public, without stifling innovation, and for that we need to formulate ethical and safety guidelines that guide and encourage innovation.

Komiyama, Hiroshi

Based on the discussions at this year's annual meeting of STS *forum*, there are two fields that require further attention. First is the need to create a framework that allows humans to make full use of the power of intelligent machines. The second is the need to not only formulate actions for combating climate change, but also find novel means to fund them, means that are innovative, are large-scale, and reflect climate justice. The discussions of STS *forum* on these topics, as well as other emerging technologies, will continue, and it is hoped that STS *forum* will continue to provide more clarity on the difficult decisions that humans will face in shaping its future.

Following this, Prof. Hiroshi Komiyama closed the session, thanking the participants for their attendance and positivity, and expressing his hope that he would see them again next year at the 21st Annual Meeting of STS *forum*.

Concurrent Sessions

Energy
Action for Net-Zero Emission

[Chair]
Mason, Thomas, Director, Los Alamos National Laboratory, U.S.A.

[Speakers]
Ambrosetti, Gianluca, CEO and Founder, Synhelion, Switzerland
Gálvez Muñoz, Lina, MEP, ITRE committee Vice-Chair, STOA Panel member, European Parliament; Full Professor of History and Economic Institutions, Department of Economics, Pablo de Olavide University, Spain
Piketty, Laurence, Deputy Chairman, French Alternative Energies and Atomic Energy Commission (CEA), France
Saito, Tamotsu, Chairman, New Energy and Industrial Technology Development Organization (NEDO), Japan
Yoshino, Akira, Honorary Fellow, Asahi Kasei Corporation, Japan [Nobel Laureate 2019 (Chemistry)]

Opening Remarks

The chair began the session by pointing out the reality that, at the moment, globally, not enough is being done to reach net-zero, and not enough action is being made to reduce greenhouse gas (GHG) emissions, despite the fact the world understands what is going on and why, and knows the tools that can be used to combat climate change. Although progress is being seen, more action is needed to address the issues, and utilizing science and technology will be the easiest way to make change. As implied by the title of the session, "net-zero" will have to be a combination of emissions reduction and negative emissions technology to offset or to eliminate sources of CO_2.

Mason, Thomas

The speakers then talked about renewable fuels. It is widely known that fossil fuels are one of the main contributors to GHG emissions, as is the fact that electrification can make great strides in decarbonizing the transport sector. However, the inherent properties of fossil fuels make them hard to substitute. The solution lies in renewable fuels, which possess the same properties of fossil fuels, and can be used by existing infrastructure. The seeds of technology exist already, and existing technology needs more investment to be scaled up to meet demand.

The speakers then highlighted that science and technology are the easy part of the decarbonization process, but a lot more is required, including both private and global leadership, regulations, and budgeting. Collaboration will also be essential as people work together to build supply chains, while also taking into account the unequal effects that decarbonization will have on the world. Leadership will also need to accept the negative impacts of decarbonization and learn how to compensate.

The speakers next noted that the share of fossil fuel in the global energy mix is still high around the world, but GHG emissions also come from other industries, and systemic evolutions, energy sobriety around the world, massive CO_2 emission predictions, and alternate fuels will be required at various levels. The challenges are huge and technology development and upscaling will play a major role in these efforts.

The speakers then discussed the activities of the New Energy and Industrial Technology Development Organization (NEDO), which brings together academia and government towards addressing global environmental problems and enhancing industrial programs. NEDO recognizes that it is essential to implement various technologies to achieve a sustainable society, and these will be supported by the digital transformation. Furthermore, it is necessary to realize a sustainable human society in which development is achieved by harmonizing with the environment, and NEDO will contribute to the creation of such a society.

Lastly, the speakers highlighted three technologies that will be required to realize a zero-emissions society: renewable electricity, including solar and wind power, which are still insufficient due to issues such as cost; non-fossil fuels, such as hydrogen and synthetic fuels; and negative emission technologies, which remove CO_2 from the atmosphere. The speakers asked for participants to discuss what other new technologies are required and how they can be addressed.

Discussion

The participants then held a group discussion. They first discussed multiple aspects of energy, including how electrification through using renewable energy such as solar and wind will be essential. They also noted the option of using biofuels, but added that the use of biofuels should not be allowed to impact the environment, and so considered using synthetic fuels in combination. Nuclear energy was also discussed in the context of decentralized power systems, which could be monitored with AI to provide more optimal distribution. The participants also noted that time is of the essence, so solutions should use existing technology to provide results as soon as possible.

The participants also discussed technology to accelerate the transition to net-zero, as well as the role of industry, such as how it can bring new investments to technology that is more sustainable, and rethinking energy generation and the economics of energy in this new environment, as well as inclusive innovation. They also noted that public trust in science will be vital, and it must be encouraged to ensure the transition. There needs to be science for policy, not just the other way around.

The participants then considered the constraints that guide technology decisions towards social acceptance, which includes costs, fear, and different social acceptance constraints in different countries. They also noted that there is a spectrum of energy options to achieve the goal, and they need to be optimized. They also considered international grids that connect energy across countries and the constraints to this as well.

Some participants considered three viewpoints for net-zero. Firstly, collaboration between many players and stakeholders is necessary. Secondly, collaboration among industries and governments should focus on making roadmaps and sharing visions and lifecycle assessments. Thirdly, new innovations in technology should be made to achieve net-zero emissions.

The participants then discussed negative CO_2 itself and how to make a clear distinction between removal and carbon negative technology, noting that not all countries are able to decarbonize easily. Grid connectivity and modernization are another major challenge. Behavioral changes would also be required, including government policy. Consumers will have a bigger role to play in both consumption and storage, and so they need to be incentivized to act.

Lastly, the participants summarized the importance of optimizing existing technologies, the importance of nuclear energy, and identifying institutional challenges and not only solutions. There are also cultural issues related to energy use, and changing this culture may be a way to ensure supply and sustainability.

Energy

New Technologies for Low Emission Transportation

[Chair]

Terazawa, Tatsuya, Chairman and CEO, The Institute of Energy Economics, Japan

[Speakers]

Deblaise, Stéphane, CEO, Renault Korea Motors, Korea

Rothhardt, Lutz, Director, Development Japan, BMW Japan Corp., Japan

Loo, Lynn, Chief Executive Officer, Global Centre for Maritime Decarbonisation, Singapore; Professor, Chemical and Biological Engineering, Princeton University, U.S.A.

Watanabe, Tatsuro, Executive Officer, Chief Environment & Sustainability Officer, Mitsui O.S.K. Lines, Ltd., Japan

Putallaz, Sue, Co-founder and CEO, MobyFly, Switzerland

Jones, Dylan, Executive Director, Boeing Research & Technology Global Technology, Japan

Opening Remarks

The chair began the session by explaining that the transportation sector is responsible for 20.9% of global carbon dioxide (CO_2) emissions, and is considered a hard-to-abate sector. In order to realize carbon neutrality globally, the world must decarbonize this sector. Within transportation, there are many subsectors, such as automobiles, maritime transport, and aviation, and each of these subsectors also face challenges related to decarbonization, which include supply chains, infrastructure, innovation, global approaches, and alternative low carbon fuels in volume and lower cost.

Terazawa, Tatsuya

The speakers then discussed the automotive industry. The industry is putting a lot of effort into reducing fossil fuel emissions, mainly by switching to electric vehicles (EVs). Plenty of solutions to issues surrounding batteries exist, and these are constantly being addressed to improve efficiency. Beyond EVs, other solutions include using combinations of e-fuels and hydrogen in vehicles.

The speakers then highlighted that batteries are the main but not the only available technology to decarbonize passenger cars. Hydrogen Fuel Cell Vehicles are an alternative. Especially when it comes to scaling, the world is far behind its goals and reaching close to 100% coverage with only electric infrastructure will be very expensive. A combined electric and hydrogen infrastructure can be a cheaper alternative and will probably reach 100% decarbonization faster. Furthermore, there will be some countries that do not have the infrastructure to provide the electricity required for EVs. For these markets, new technologies will be required with, again, a leading option being the introduction of hydrogen.

Next the speakers turned to maritime transportation. Shipping is a global industry, and its emissions are also global. The world must do what it can now, as zero-carbon fuels for shipping will not be developed for a while. In the meantime, the maritime ecosystem needs to be readied for the use of future fuels. Actions that can be embarked upon today include creating guidelines and standards to safely handle the new fuels, developing new infrastructure and supply chains to support their use. The shipping industry transcends borders, so it is important to think about its role as an energy transporter too. Partnership and collaboration need to be coordinated at a systems level.

The speakers then suggested that the reason that decarbonization of the shipping industry is key is because it sits in the middle of supply chains that are necessary for human life. International shipping is considered a hard-to-abate sector because electrification is

difficult. However, while the industry has seen the potential of zero-emission fuels, mechanisms for sharing expensive costs of such fuels among the entire society remain to be debated.

The speakers also pointed out that in reality, green innovation is not without obstacles. These include increasing reliance on critical minerals, which presents challenges both environmentally and logistically. Potential innovations include hydrogen boats, and utilizing EV technology for shipping. Steps towards green future have begun, but to realize this vision, a united front will be essential.

The speakers then considered the aviation industry. Today air travel has reduced emissions associated with travel, and through safe business models, the aviation industry may achieve its goal of net zero by 2050. Collaboration is imperative, as is interaction between policies and technology. The four pillars for decarbonizing the aviation industry are to consider new airplanes, improve operational efficiency, use renewable energy including sustainable aviation fuels (SAFs), and advance technology. SAFs will be essential, as airplanes cannot be electrified like cars. SAFs can only be delivered through innovation and diverse partnerships.

Discussion

The participants then held a group discussion. On passenger vehicles, the main issues related to EVs was improving the distribution of the charging infrastructure, which will

require substantial investment. EVs are the most appropriate means for passenger vehicles for short distance driving mainly in cities. But for longer distance driving or driving in very hot temperature, in rural areas or in the developing world, other complementary alternatives such as hydrogen vehicles, plug-in hybrid cars and hybrid cars should also be pursued.

Looking at public transportation or heavy duty trucks, the approaches vary in comparison to ordinary vehicles. Hydrogen and renewable fuels could be used for them. But for passenger vehicles, the use of such fuels is – especially in cities - not efficient and they should be used with priority for sectors like fertilizer production, steel production, and heavy duty transport, that do not have other means for decarbonization. Moreover, a circular economy will also be needed to produce sustainable EVs. Optimization of the distribution of the charging infrastructure will also have to be pushed to follow the demand.

On the future of shipping, it is important to consider alternative fuels. One immediate action that can be taken is investment in transition fuels, such as blue ammonia and conventional fuels with lower carbon intensities. It is also urgent to set global regulations, develop an emissions accounting framework for low-carbon fuels, and implement a carbon price. Comments were also raised on the potential of nuclear energy as an alternative fuel for shipping.

It was pointed out that not enough research is being done to improve the efficiency of the shipping industry. Wind power on ships would help to reduce energy used, and wind generated in ports can also be used as a renewable energy source. Governments should also consider subsidies to companies to promote initiatives related to green energy.

Returning to transportation in general, on the question of what can be electrified, it was clear that EVs are the future, and the same battery technology provides a cheaper solution for both aviation and maritime transportation over short distances. For long-distance transportation, alternative sources such as hydrogen would be more useful.

Lastly, on the aviation industry, the speakers noted that it faces similar challenges to maritime transportation. Development of new platforms faces many challenges due to safety test requirements and regulations. SAFs will need to be introduced, and a global supply chain will be essential to secure their implementation. Safety and trust issues could also hinder public support.

Energy
Fusion Energy

[Chair]
Colombani, Pascal, Chairman Emeritus, Valeo; former Chairman and CEO, Atomic Energy Commission (France); Founding Chairman, Areva, France

[Speakers]
Konishi, Satoshi, Co-Founder & Chief Fusioneer, Kyoto Fusioneering Ltd., Japan
Budil, Kimberly S., Laboratory Director, Director's Office, Lawrence Livermore National Laboratory (LLNL), U.S.A.
Barabaschi, Pietro, Director-General, International Fusion Energy Organization (ITER)
Yoshida, Zensho, Director General, National Institute for Fusion Science, Japan

Opening Remarks

To begin the session, the chair stated that fusion, a process which combines two light atomic nuclei to release a very high amount of energy, has the potential to reshape the energy production landscape. It is inherently safe, and produces minimal long-life waste in comparison to fission. The fusion process itself generates no greenhouse gas emissions, which would make it a welcome contender in the fight against climate change. A recent breakthrough at the Lawrence Livermore Laboratory has shown that the fusion process can generate a net energy gain. Nevertheless, the chair pointed out that fusion processes are still very far from delivering energy at an industrial scale on a reliable and permanent basis, and that, if it were to happen, this would require sizeable investments. And although fusion research is useful for general technology development, the question of the timeline and investment cannot be neglected. The chair then set the scope of the session: address the status of current research, and delve deeper into the intricacies of nuclear fusion such as its science and the involved technologies. Status of global collaborations that are studying the fusion processes as

Colombani, Pascal

well as of start-ups developing complementary or alternative approaches would also be addressed.

The speakers then discussed how fusion is one of the possible candidates for the future of energy and sustainable human activities. Due to the current situation of energy and the environment, humankind is now seeing a very different time where energy is limited not by resources but by the environment. Thanks to investor support and steady public funding for fusion, a large amount of funding has been achieved, and the successful completion of fusion reactors will only encourage further investment. Even in the face of development, competition and economic activities are happening now.

The speakers then discussed international collaboration on fusion. There is a lot of expectations for fusion because of its ability to provide energy. However, different kinds of nuclear reactions will be necessary, in addition to traditional reactions using tritium. There is a question of scaling the types of reactors that can be built, and while there are many technical challenges, it can be done. The complexity of turning this into an economical source of energy still stands as one of the big challenges in science.

The speakers then highlighted the long history of fusion research. 60 years ago, there was a real interest in learning whether we could create controlled nuclear fusion in the laboratory, and this provided one of the most extraordinary intellectual leaps. Thanks to the development of laser technology, it has become possible to effectively couple energy and produce experiments with fusion yield greater than the input laser energy or target gain > 1. The next step is to consider how to advance from this scientific demonstration to the scale of fusion energy. A large amount of science and engineering is required for future fusion power plants. However, the building blocks for progress have been demonstrated.

The speakers then stated that the realization of fusion energy is often said to be a never-ending 30 years in the future. Several decades is the estimated time for engineering development and system integration, yet the uncertainty of physics and need for resources is delaying the start of this. However, venture capitalists are investing in projects, assuring support for development of systems for energy production. A more solid scientific basis will be indispensable. A paradigm shift has been seen in fusion plasma physics, and now science will be required to provide the guiding principles towards innovations.

Discussion

The speakers then held a discussion. While many start-ups are tackling development, there are many challenges to creating prototype reactors, including a lack of resources and investment.

It will be difficult to reduce the cost of fusion energy because of the nature of the technology. However, society understands that it needs to reduce its dependence on fossil fuels, and one of the only technologies available that can provide low carbon baseload energy is nuclear fusion. Another complicating factor is the regulatory environment.

However, the world is making progress towards improving energy utilization and conversion. Nuclear fusion may not contribute to this in a substantial way in the near term, but renewable resources alone cannot achieve the targets. There are long term benefits to fusion energy that bring a lot of added value, and that is a positive.

It is important to be realistic and manage people's expectations. Private sector companies are often optimistic, but many will fail. Many of these are relying on research institutes to solve technical problems for them, because they do not have the resources to implement the full spectrum of technology required.

There is also a large amount of hostility to nuclear power generation methods, and this could potentially include fusion if we do not effectively communicate with the public. There will always be people who do not listen to scientific explanations, and so it is important to raise the level of scientific literacy from a young age. The scientific community needs to engage with the public and be transparent in explaining the safety of fusion. Nuclear fusion has some interesting features, but it is important to measure the safety against the benefits. It is important for scientists to conduct research activities that the public can rely on.
There have been scientific advancements that people can further build on, and public investment has made it plausible to think about fusion energy. Investment is still needed to scale up the technology. Also, fusion is an innovative technology, and it is possible that new ideas will come from the same technology and physics.

On funding, there has been a big shift toward investing in energy technologies to address climate issues. Fusion is part of the potential options, with enthusiasm for producing energy through that process fairly high, but the outlook for potential success is long term. It will still require a lot of research and significant resources, and budgets have not caught up yet. However, the breakthroughs to date have really shown that this is the moment to lean into this technology, and there is an opportunity to drive it forward compared to past decades.

Climate Change
Adaptation to Climate Change

[Chair]

Murray, Cherry A., Deputy Director for Research, Biosphere2 and Professor of Physics, University of Arizona; Benjamin Peirce Professor of Technology and Public Policy and Professor of Physicss, Emerita, Harvard University, U.S.A.

[Speakers]

Kimoto, Masahide, President, National Institute for Environmental Studies (NIES), Japan

Su, Huey-Jen Jenny, President Emeritus, Distinguished Professor of Environmental Health Sciences, National Cheng Kung University (NCKU), Taiwan

Keller, Martin, Director, National Renewable Energy Laboratory, U.S.A.

Attig-Bahar, Faten, Member of Steering Committee, Future Earth Water-Energy-Food Nexus Steering Committee; Member, Tunisia Polytechnic School, University of Carthage, Tunisia

Takeuchi, Kazuhiko, President, Institute for Global Environmental Strategies (IGES); Project Professor, Institute for Future Initiatives (IFI), The University of Tokyo, Japan

Opening Remarks

The chair began the session by reminding the participants that at the current midpoint of the UN 2030 agenda, governments are not on track for several of the Sustainable Development Goals (SDGs). The world continues to experience unprecedented climate events that converge with crises such as pandemics, geopolitical conflict, and others. Referring to the Regional Action on Climate Change, the chair stressed the requirement for faster and more robust collaborative mitigation efforts, as well as the need for adaption, especially for vulnerable populations in the most affected areas, and to address SDG 13: Climate Action and other interlinked goals.

Murray, Cherry A.

The speakers discussed adaptation strategies in Japan, which is facing increased extreme weather risks. It is vital that scientists provide information including results of event attribution studies estimating the contribution of climate change to citizens to inform and motivate adaption efforts and include quantitative predictions and recommendations for agriculture and fisheries, while improving forecasting and early warning systems for both short- and long-term disasters.

Next, the speakers discussed various laws implemented by Taiwan from 2002 to mitigate climate change and support sustainable development, including the 2015 Greenhouse Reduction and Management Act, and the 2023 Climate Change Response act that addresses adaptation and implementation of climate resilient infrastructure in collaboration with individuals, corporations, and NGOs while including and educating indigenous and vulnerable populations.

The speakers then discussed the transition to climate resilient methods within the energy sector. There is optimism that new energy technologies can overcome climate change issues, especially in remote areas, however it is vital that these be implemented in a fair manner. An example was given of new electricity grid infrastructure being designed in Puerto Rico in collaboration with the local community, utilizing new technologies and computer modelling to create integrated plans for decentralized networks utilizing solar generation and energy storage.

The speakers next talked about the situation in Africa, where increased flooding and heatwaves are causing damage and community displacement. The speakers asked how to best foster adaption to climate change despite associated risks, highlighting the importance of cross-sector, transdisciplinary approaches similar to the international response

to COVID-19. A science-based solution needs to be found that features younger generations and underrepresented voices at the forefront, and builds capacity within vulnerable communities.

The speakers highlighted the synergy between the efforts on climate change and biodiversity loss and the importance of embracing a holistic paradigm. Japan has implemented several holistic approaches, such as the Satoyama Initiative and the Regional/Local Circulating and Ecological Sphere (CES). The Institute for Global Environmental Strategies (IGES) has made significant contributions to these efforts by, for example, establishing the Satoyama Development Mechanism and promoting the Asia-Pacific Climate Change Adaptation Information Platform (AP-PLAT). The speakers noted that solutions for climate change must be considered in a broader context and from multifaceted lenses.

Discussion

The participants then held a group discussion. While illegal ocean pollution and other climate issues affect every nation, there is no single governing body or overall framework to regulate these. Continuous change in governing bodies, as well as differing methods can make it difficult to collaborate and maintain long-term data collection. Therefore further coherence between frameworks, scientists and policymakers is necessary to work towards common goals. Digital transformation (DX) is key to integrating the UN 2030 agenda, SDGs, and Sendai framework, however developing countries require support and guidance on implementation. The importance of local level data was considered, and the participants shared successful examples of local level capacity building.

Next the participants discussed the difference between Japanese and African adaptations to water related extreme climate events. Adaptation infrastructure is expensive and can result in secondary environmental effects, so early warning systems can be one alternative. In Japan, additional flood mitigation infrastructure is necessary, however in Africa, food security is threatened by droughts, and the government is investing in moisture retention. Temperature increases also cause changes to infectious disease risks, as well as agricultural and fishery patterns, which must be studied further to optimize trade. Adaptation measures should be localized to each region and increased public recognition of the connection between extreme weather events and climate change offers a chance for governments to take action.

Adaptation within the health system was discussed, highlighting the difference between short term adaptions favored by policymakers and long-term adaptations that can be considered in academia. It is also important to address knowledge gaps and combine global knowledge to optimize the accuracy of climate model predictions, and ensure prosperity for future generations.

The participants emphasized that the image of renewable energy among the public should be improved through local education and stakeholder collaboration, to assist in propagating new renewable energy technologies including synthetic fuels. The participants also considered the roles of emerging technologies, industries, and cost factors.

The participants then discussed inequities between different countries and the necessity for improved forecasting to educate based on local factors, as well of methods to encourage the market to take social impact into consideration, through regulating or developing new products. Lastly, in lieu of resource disparity, the participants discussed the importance of nature-based solutions for devising various adaptation actions, supported with the example of Japan's rebuilding after the 2011 Great East Japan Earthquake. The participants emphasized the necessity of community buy in, noting technical and design challenges and the risk of creating new problems. The participants noted that there is no one-size-fits-all solution, while nature-based solutions are often cheaper and can provide multiple benefits. Economic feasibility and funding methods and sources, including public financing, private financing, public private partnerships, and skill development, must also be considered. Society must adapt both on the ground and through policy measures, while updating global governance mechanisms.

Climate Change

Sustainable and Resilient Urban Environments

[Chair]

Kudelski, André, President, Innosuisse - Swiss Innovation Agency; Chairman of the Board and Chief Executive Officer, Kudelski Group, Switzerland

[Speakers]

Kanda, Masato, Vice Minister of Finance for International Affairs, Ministry of Finance, Japan; Chair, Corporate Governance Committee, Organisation for Economic Cooperation and Development (OECD)

Ho, Teck Hua, President, Distinguished University Professor, Nanyang Technological University, Singapore

Takara, Kaoru, President, National Research Institute for Earth Science and Disaster Resilience (NIED); Professor Emeritus, Kyoto University, Japan

Đokić, Vladan, Rector, Faculty of Architecture, University of Belgrade, Serbia

López Casarín, Javier, Federal Congressman, Science, Technology and Innovation Committee, Chamber of Deputies for the Green Party; Chairman, Science, Technology and Innovation Committee, Chamber of Deputies for the Green Party, Mexico

Opening Remarks

To begin the session, the chair reminded participants of the need for actionable and scalable corrective actions to better protect the planet, focusing on the global level rather than just on individual or local goals. To avoid losing out economically, societies continue to prioritize acquisition of cheap energy over more costly sustainable infrastructure, while masking the effects through additional regulation of carbon emissions. Society must find breakthroughs, through investment in and diffusion of new technologies that ensure sustainable solutions become the most cost-effective option. Multidimensional value creation involving economic and societal value, job creation, and intellectual property must be implemented at all levels down to the individual.

Kudelski, André

The speakers then discussed ways to enhance resilience and sustainability of cities facing the pressure of rapid urbanization and aging, which compounded problems such as pandemics and natural disasters. Key levers identified through Japan's experiences are: (i) new technologies such as satellite imagery and drones to get more granular data; (ii) public finance to enhance financial viability of socially important projects; and (iii) knowledge sharing and collaboration among stakeholders.

The next topic discussed covered resilience initiatives in Singapore to improve energy and carbon efficiency, through the use of lower energy buildings, public transport, and sustainable energy production, and investments in low carbon technologies. Accountability and behavioral change were emphasized, as scalable individual choices and actions can help determine the future. Singaporean universities implement several sustainable initiatives, including wooden buildings, efficiency improvements, and reduced energy use, acting as a living lab to test new low carbon technologies.

The speakers next spoke about hazard response based on prediction, management, and recovery. The Japan Hub of Disaster Resilience Partners (JHOP) makes recommendations to overcome catastrophic disaster, by reflecting on past disasters, disseminating this information widely, and promoting capacity building, through stakeholder efforts in line with the Sendai framework. Disaster management systems should be developed through decentralized governance, local resources and resilient post-disaster rebuilding utilizing digital transformation (DX).

The speakers considered priorities in European urbanism, and challenges for higher education. Documents such as the UN 2030 Agenda, European Bauhaus, and European Green Deal Initiative address sustainability, inclusivity, and others. Society must develop effective plans, recognizing issues created by the transition to green energy, in collaboration with developing countries and scientific voices, through the three I's (Interest, Influence, Impact) approach. Inter-university alliances can also encourage research toward ethical and sustainable practices.

Lastly, the speakers addressed resilience in developing countries. For example, in Mexico City there are huge inequity gaps, and other priority issues to address such as health and poverty. It is difficult to change a population's point of view, but this can be addressed through long term investment, education, regulation, and accountability. Funding for transformation and innovation within construction and key infrastructure is necessary, especially for developing countries.

Discussion

The participants then held a group discussion. Regarding scalability, education and sharing can allow solutions to be replicated between communities, and remote monitoring can be used to fairly identify the current situation. The gradual and widespread nature of climate change makes it difficult for populations to sense its urgency and take action. Incentives such as free public transport and improvement of infrastructure may increase public motivation.

To make sustainability more actionable, education to raise community and stakeholder awareness of the relevant associated benefits of climate solutions can enable behavioral change. To reform carbon trade, instead of paying to pollute, polluters could fund research and development of technology for the developing world, which would require international collaboration and research. Participants also discussed the move from research to innovation, sharing of urban health and wellbeing issues for development of future cities, management and dissemination of information to benefit cities and implement value creation during city development. Greenwashing by city developers, and the capacity of the UN and governments to meet their goals were also addressed.

Education, including upskilling, reskilling and training, is an accelerator for achieving the SDGs. However, as with many SDGs, investment in education takes time to produce results. Underinvestment in education in countries that lack resources should be financed by global

financing solutions. The current multilateral system of financial institutions often applies less favorable conditions when lending to countries facing financial insecurity, and therefore funding is not adequate to meet the SDGs. An interdisciplinary outreach approach should be used to find structures, such as living labs and system innovation approaches, that can provide education to every stakeholder involved in an issue and diffuse sustainable technology, domestically and internationally. A need for regulation in terms of standards, taxes, and subsidies to incentivize the right pathways was also discussed, highlighting sustainability reporting initiatives that directly link to sustainable development in India and Europe.

Responses should be localized, with each region deciding its own best practice. New technology such as digital twins can be used to better equip responses, utilizing monitoring and recovery. Better and more transparent public education is needed to ensure information is trusted and multigenerational, so policy can support science-based solutions.

It is difficult for policymakers in developing countries that are still working towards providing basic resources to prioritize sustainable action. The participants spoke about how to make sustainable initiatives that may seem restrictive to developed countries more attractive, how to address the dissemination of false information, and the city or national levels at which responsibility should be taken. The participants recommended co-developmental and co-participatory techniques across communities and stakeholders, emphasizing that implementation can remain difficult even with high quality policy.

Climate Change
Green Technologies

[Chair]

Johnson, Ray O., Chief Executive Officer, Technology Innovation Institute, U.A.E.; Former Senior Vice President and Chief Technology Officer, Lockheed Martin Corporation, U.S.A.

[Speakers]

Bando, Kenji, General Manager, Robot Business Division, Precision Machinery & Robot Company, Kawasaki Heavy Industries, Ltd., Japan

Koundouri, Phoebe, Professor, Department of International & European Economic Studies, Athens University of Economics and Business & Technical University of Denmark, Greece; President, European Association of Environmental and Resource Economists; Chair of the SDSN Global Climate Hub, Italy

Beuttler, Christoph, Chief Climate Policy Officer, Climeworks AG, Switzerland

Evans, Chad, Executive Vice President & Chief Operating Officer, Council on Competitiveness; Board Treasurer, Global Federation of Competitiveness Councils, U.S.A.

Opening Remarks

The chair began by introducing the session, emphasizing how green technologies are key to solving many of the climate change issues faced today, and opened the floor to the speakers.

Johnson, Ray O.

Firstly, the speakers discussed the economic aspects of the sustainability transition and pathways toward implementation of the SDGs. International initiatives such as the SDSN Global Climate Hub assist countries in transposing their national policies into implementable pathways toward resilience and neutrality, working with stakeholders through holistic interdisciplinary approaches focusing on aspects such as human effects on the climate, climate health, and others.

Next, the speakers discussed the use of robotics in an environmentally friendly society.

Improvements to robotic technology is enabling the development of lighter and energy efficient devices in a wide range of applications including power generation. Green transformation (GX) should be centered on managing the energy supply and demand balance through to digitalization, and robotics will play a role in various solutions for digitalization and GX.

The speakers considered the role of emerging technologies such as carbon capture. To achieve the targets set by the SDGs and Paris Agreement, emissions must be reduced significantly, with most countries aiming for net zero emissions. Carbon dioxide removal was proposed as a solution to reach and maintain net zero commitments, while providing fossil independent carbon for use in products such as air transport, which cannot be easily electrified.

The speakers also spoke about the scope of sustainability challenges and opportunities, a multifaceted issue involving numerous stakeholders and encompassing the entire value chain from production to disposal. New models are required to enable rapid, disruptive transition that can implement and scale economic incentives and mature and emerging green technologies, while ensuring government and private engagement and supply chain security. The speakers noted the difficulty in determining individual and collective priorities, and the need to advance carbon capture and nuclear technology.

Discussion

The participants discussed carbon capture from air and biomass, and its utilization and storage, considering government policy, regulation, and funding necessary to scale this while ensuring just transition. Funding opportunities outside of government support can decide the fate of key emerging technologies, so community, academic, and scientific engagement in meaningful emerging solutions is necessary. Direct air capture of carbon is in the early stages of commercialization, but the issue is finding methods to drive its price down, while biomass carbon capture technology has been demonstrated in Africa but is not yet scalable.

The participants noted that the world is at a critical juncture for the expansion of renewable energy, but this is not necessarily recognized by policymakers or society. Documentation of best practices for solar and wind technology could be used in transitioning to and scaling of other renewable technologies. To empower science and successfully deploy sustainable initiatives, infrastructure for green technology development must be improved, and end consumers must be engaged earlier in the process. The participants also recommended an overall emphasis on resilience and redundancy, to avoid overreliance on certain technologies, as well as a more holistic approach that takes into account linked issues including water and food security, although these could further complicate existing systemic issues.

The participants highlighted diversity in how infrastructure issues are expressed around the world but stressed that society must prioritize speed and effectiveness over searching for solutions that are an ideal fit.

The participants also considered discussed increased use of robotics towards GX, to increase productivity, efficiency, and consistency, and optimize use of resources while reducing waste, to lower production costs within sectors including the medical industry, manufacturing, logistics, and agriculture. Robots can also implement ocean pollution cleanup and other tasks that are dangerous or difficult for humans, and can be used for predictions, and monitoring of wild animals or fish in research addressing biodiversity loss. With a 15-20 year lifespan per single use robot, robotic components can be recycled at the end of their useable life. Further AI implementation to increase performance within the robotics sector is required, and the data required to develop this must also be considered.

Lastly, the participants discussed holistic and interdisciplinary approaches, which are crucial for sustainable transition in energy, transport, land use, and marine systems. Current modelling technology can identify pathways towards implementation through a mixture of technology, policies, and financial instruments, to create a quantified system of KPIs to identify the status of green transition and encourage agreement between stakeholders. However aspects preventing green transition include the structure of the global financial system, which prevents developing countries from accessing adequate resources to meet climate goals. It is vital to create fiscal spaces for developing countries and improve the mechanisms of multilateral institutions that support the Global South, along with funding mechanisms for sustainable development as a whole. The participants discussed regulation and initiatives to enable transition financing in Europe, India, and the United States, stressing the need to initiate more public-private partnerships and avoid greenwashing. To further incentivize companies, profitability and sustainable development objectives should be aligned, and natural capital should be integrated into fiscal analysis, with increased analysis showing good performance from companies that invest in sustainable development. Policymakers must also create long-term policies that last beyond their political term, and the public must be educated in order to choose the right policymakers and demand green, digital, and sustainable solutions that can drive the market.

Earth and Commons

Agriculture, Food and Water Security

[Chair]

Falk, Jim, Professorial Fellow, School of Geography, Earth and Atmospheric Sciences, University of Melbourne, Australia

[Speakers]

Mauguin, Philippe, Chair and CEO, Research Insitut for agriculture, food and environnement, National Research Institute for Agriculture, Food and the Environment (INRAE), France

El-Beltagy, Adel El Sayed Tawfik, Chair, International Dryland Development Commission (IDDC); Professor, Arid Land Agricultural Graduate Studies & Research Institute (ALARI), Ain Shams University, Egypt

Chuang, Rita, Manager, Food Innovations, Spiber Inc.; PhD Candidate, Institute of Advanced Biosciences, Keio University, Japan

Narayanasamy Krishnasamy, Rajavelu, CEO, Crop Protection Business, Godrej Agrovet Limited, India

Konde, Agnes Asiimwe, Vice President, Program Innovation & Delivery, Alliance for a Green Revolution in Africa (AGRA), Kenya

Nakanishi, Tomoko M., Professor Emeritus & Project Prof., Graduate School of Agricultural and Life Sciences, The University of Tokyo; Auditor, Fukushima Institute for Research, Education and Innovation (F-REI), Japan

Falk, Jim

Opening Remarks

At the start of the session, the chair made introductory comments on the evidence of climate change, its substantial effects and impacts including the increasing frequency and intensity of natural disasters, and how it has been exacerbated through issues such as continued population growth, the inequitable distribution of energy, and regional conflicts. Beyond that, there are conflicts disrupting supply chains, price hikes for fertilizer and other agricultural inputs, and interruptions in global food supply. Capitalizing on known

positive measures, such as carbon sequestration through carbon farming, requires governments to provide economic and other incentives to be put in place.

The speakers noted that 3 billion people could not afford a healthy diet, malnutrition is deeply entrenched, and the global food system is a major driver of the environmental crisis. The solutions for sustainability require political changes, economic investment, and a research and innovation agenda at the world level. These include going to a resilient bioeconomy, nature-based solutions, and food efficiency.

The speakers mentioned the global state of malnutrition and emphasized that to implement adaptation in agriculture we must use the best of science including genomics to increase plant resilience and reduce emissions. Nations in the developing world should be empowered, management techniques for agriculture need to be improved, and greed, waste, and prejudice must be removed.

The speakers emphasized that currently there is enough food produced for 12 billion people, but hundreds of millions are still going hungry due to inequality in access to food. Precision fermentation technology may be able to supplement the benefits of localized food production, with reduced environmental impact, for a more resilient and circular bioeconomy.

The speakers noted the impacts of climate change and global warming on agriculture and that the increase in the metabolic rates of insects was leading to losses of crops. To combat

these challenges, public private partnerships, improving precision farming, crop diversification, and global cooperation on solutions were highlighted as significant.

The speakers highlighted that over 45% of land in Sub-Saharan Africa was highly degraded and that the anatomy of the agriculture system was failing. They emphasized the significance creating mass-scale irrigation solutions and focusing on efficient delivery systems from an input perspective to further increase yield while maintaining soil health.

The speakers brought up the issue of water and food security, and noted that the recent work done at the Fukushima power plant area to remove potentially contaminated topsoil resulted in a reduction of agricultural capacity. Measures such as improving soil quality, new and alternative ways to produce food, as well as ways to prepare for food disasters need to implemented, supplemented by further studies.

Discussion

In the group discussion, the participants highlighted that the most important topic at the center of international deliberations is food security, and that there should be more focus on mitigation on top of adaptation, and that we must incorporate risk uncertainty in a systems-based approach. Knowledge needs to be transferred and incentives must be implemented as part of business models. Specifically, soil recovery, land degradation, and food waste and loss are challenging areas that also have investment potential.

The significance of soil was also discussed, with major points including urban sprawls within infrastructure, agreed-upon principles to protect soil, as well as soil conservation and restoration. Possible key contributions could be the land degradation neutrality principle or a soil monitoring program. Plant, animal, and microbial genetic resources can also be utilized to strengthen food security under the threat of climate change, but even that may fail after a certain length of time, which can be prevented through international collaboration and the use of genetic resource centers. They also cited gene editing, food waste, and public health and nutrition as important areas of focus in the future.

The participants also discussed how to secure enough food for 12 billion people by 2050. Solutions proposed included genome-editing-based breeding, using synthetic foods utilizing biotechnology, and increasing public awareness of using advanced technology, such as gene editing or fermentation, based on biosafety regulations. They also questioned how to deploy advanced technologies to developing countries, which included solutions such as

ecological zone assessments to establish early warning systems, using transformational technologies such as AI in agricultural systems, and genetic resources such as gene banks to security diversity of crops and animals.

Participants also considered the relevance of technical innovations around integrated solutions that speak to the nexus of agriculture, water, and energy; accelerating access to climate financing such as carbon credits or innovations in mitigation; food loss and shorter value chains; and having science and evidence-based policies, particularly around incentives to make sure private companies are investing ahead of the curve.

The importance of data on soil and how it can contribute to sustainability and security was also discussed. The merging of the technology and agriculture sectors was also noted as influential. They also highlighted the use of cyber-physical systems, sensor data distributed in the field, and carbon sequestration, as well as encouraging students to study soil-related fields as we are lacking a sufficient number of scientists to help the world achieve sustainability.

The participants commented that the international process is far behind in bringing down emissions compared to what needs to be done. The solutions for each region are very different. They noted that the aim really must be nothing less than the SDGs. Some common themes that should be implemented in global projects include the improvement of soil, and genomics and biotechnology development in the context of biosafety, while avoiding monocropping and dependency on commercially produced chemicals.

Earth and Commons
Biodiversity and Ecosystem Services

[Chair]

Abdul Hamid, Zakri, Chairman, Malaysian Industry Government Group for High Technology (MIGHT) / ATRI Advisory, MIGHT / ATRI Advisory; former Science Advisor to the Prime Minister of Malaysia, Malaysia

[Speakers]

Böhning-Gaese, Katrin, Director, Senckenberg Biodiversity and Climate Research Centre, Senckenberg Nature Research Society; Professor, Institute of Ecology, Diversity and Evolution, Goethe University Frankfurt, Germany

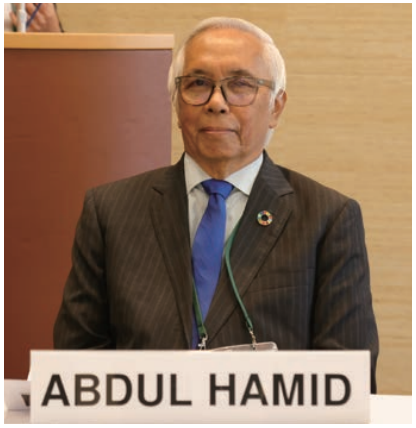
Fujita, Kaori, Professor/Senior Editor, Green Goals Initiatives and Graduate School of Life Sciences, Tohoku University / Nikkei ESG (Nikkei BP), Japan

Koh, Lian Pin, Professor & Director, Centre for Nature-based Climate Solutions, National University of Singapore; Singapore

Skipper, Magdalena, Editor-in-Chief, Nature, U.K.

Opening Remarks

To start the session, the chair spoke about how biodiversity coincides with climate change, investment in ecosystem services to help support species at risk of extinction, the dangers of biodiversity loss and its current declining trajectory, and possible ways that biodiversity could gain more traction in discussion. The chair concluded that it was important for communities engaged in the space to provide relevant and constructive advice as opposed to political messaging.



Abdul Hamid, Zakri

The speakers then discussed thoughts on why biodiversity was essential to humanity, from how insects pollinate crops to mangroves protecting ocean shores. Solutions to combat the declining trajectory of biodiversity loss included identifying effective conservation areas, developing sustainable protective structures, and improving areas such as plant-based diets and reducing food waste.

The speakers emphasized how biodiversity must be considered in conjunction with climate change and food systems transformation, and how economic growth must continue in order to generate the wealth required to protect the environment. They also pointed out the need for communities to engage with politicians to form action plans with standardized metrics that could be agreed upon.

The speakers then discussed what nature-based solutions were, why people should pay attention to them, and how they could be implemented. Examples included protecting forest ecosystems and combating the use of fossil fuels, carbon sequestering to reduce emissions, and improving the management of the food and forestry sectors. Opportunities in tropical regions and potential co-benefits for communities were also highlighted.

The speakers also commented on the relationship between biodiversity and business, specifically business supply chains and the disclosure of risks and opportunities. They specified activities companies should implement, such as identifying locations in supply chains that have an impact on nature, revitalizing nature through forest and mangrove regeneration, and providing IoT technologies to collect information.

Discussion

The participants then held group discussions where they highlighted the importance of interdisciplinarity. It is important not to just focus solely on science. Other aspects of society should be considered in order to adapt some of their perspectives and solutions. It was also stated that there is still a dire need for multi-disciplinary and multi-sectoral cooperation, that the world must increase efforts to create better incentives to bring about even more cooperation and a greater variety of communities together, and people must also consider human emotion and other behavioral aspects when making some of these decisions. It was also emphasized that training younger generations, empowering young scientists, and helping improve communication overall would have a significant impact.

The participants also discussed how conversations about nature in general tend to be taken for granted. Even though there is a lot of awareness and general appreciation for biodiversity loss, the subject must be engaged with and mainstreamed further. They also commented on engaging with all different sectors and urban communities, having a local focus and engaging with indigenous knowledge combined with research knowledge, diversifying biodiversity indicators, supporting businesses that are interested in aligning practices,

and addressing the current tensions across the SDGs between biodiversity solutions and economic growth.

The participants also shared views on sustainability in terms of economics, datasets across varies geographies, the level of urgency in the space given the increasing rate of population growth, social and political issues and balancing that with development, impacts on vulnerable communities and the inclusion of indigenous rights, and developing policies that sacrifice as little as possible. They also expressed views on the need for data collaboration and accountability, water management to make sure pollution does not increase, better urban planning, the inclusion of nature-based metrics, the development of infrastructure and the impact on nature and supply chains, the development of effective metrics and how to assign values to those metrics, as well as the need for an increased focus on agri-biodiversity.

The participants concluded that if the world looks at the major elements that affect humanity's survival, particularly that food production would be reduced by almost 50% by the year 2050, there is a need for major initiative to support institutions in creating breakthroughs in science and technology. The world must build bridges with resilience in order to continue moving forward into the future.

Earth and Commons
Deep-sea Exploration and Exploitation

[Chair]

Leinen, Margaret, Vice Chancellor, Scripps Institution of Oceanography UC San Diego; Vice Chancellor, Marine Sciences, University of California San Diego (UCSD), U.S.A.

[Speakers]

VIX-GUTERL, Cathie, Vice President, R&D Anticipation and Portfolio Performance, TotalEnergies, France

Fukushima, Tomohiko, A member of the Legal Technical Commission (LTC), International Seabed Authority (ISA); Deputy Director General, Seafloor Mineral Resources Department, Japan Organization for Metals and Energy Security (JOGMEC), Japan

Álvarez-Torres, Porfirio, Executive Secretary, Secretariat, CiiMAR, Mexico

Yamato, Hiroyuki, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC); Professor Emeritus of The University of Tokyo, Japan

Opening Remarks

To begin the session, the chair commented on field work in deep-sea compared to terrestrial work, the effectiveness of sound waves despite narrow bandwidth, the expense of utilizing ships, and resources unique to deep-sea including hyperthermal vents and manganese nodules, especially as the world deals with shortages of rare earth elements and challenges with oil and gas. The chair also noted the use of biomolecular techniques to identify the intense biodiversity in the ocean, that changes in the ocean have been quite dynamic and will probably change due to climate change quite substantially in the future, and the possibility of sustainably gathering resources from the ocean.

Leinen, Margaret

The speakers then discussed providing more clean energy to the population. They highlighted the development of deep-sea equipment and vehicles for mapping terrain and collecting materials, innovation in monitoring, genomic sequencing of deep-sea organisms, alternative methods for on-site DNA extraction.

They also provided examples of projects to mitigate carbon emissions and the utilization of geological carbon storage.

The speakers pointed out the overall stagnation in the regulation of exploitation from the perspective of rule-makers, as well as the importance of relying on well-established scientific knowledge and accumulated data. They also emphasized that taxonomic knowledge, which plays an important part in rule making processes, is scarce, possibly due to an unbalanced budgetary system and lack of funding.

The speakers then pointed out challenges in deep-sea exploration, including high pressures, extreme temperatures, and total darkness. They highlighted that the development of technologies that can withstand such conditions, and the high costs associated, was a significant challenge. There are also ethical and human safety concerns, and addressing these risks requires careful planning, international cooperation, and responsible resource management.

As much of the deep sea remains unexplored and poorly understood. Scientists face the challenge of mapping and studying this vast and remote environment to gain insights into its biodiversity and geological features. It is essential to understand the potential environmental impacts of mining and resource extraction, and scientists must assess how these activities can affect deep-sea ecosystems and develop mitigation strategies.

Governments and international organizations should establish and enforce regulatory frameworks that address deep-sea risks. These regulations should be based on scientific

knowledge and aim to strike a balance between economic interests and environmental protection. Companies involved in deep-sea activities have a responsibility to prioritize safety and environmental stewardship, and they should therefore invest in research, training, and technology to minimize risks and adhere to regulatory requirements.

Achieving a balance between knowledge and solutions for deep-sea associated risks requires a multidisciplinary approach involving science, technology, policy, and industry cooperation. It is essential to prioritize the protection of these unique and fragile ecosystems while harnessing their resources responsibly.

The speakers also commented on the vital role of deep-sea on climate and economic systems, knowledge gaps within the space, as well as the potential use of deep-sea resources and innovative observation and analysis methods for sustainable development. They also specified that AI could potentially enhance autonomous functions and digital twins could be utilized to improve monitoring and assessment.

Discussion

The participants held a group discussion, touching upon how deep-sea life will be acknowledged in policy development and the importance of governance and transparency. The participants also queried the effectiveness of the UN, noting it was well-organized but also quite bureaucratic, resulting in some fragmentation. They also raised questions about uncertainties in ocean exploitation as well as the idea of a moratorium on exploration until the industry can accumulate more data, but in order to accumulate data, industry is currently lowering emissions, utilizing carbon injection and storage, increasing energy efficiency, transferring skills and competencies, reducing costs, while keeping safety a top priority.

The participants questioned how results obtained from studies across different regions compared with each other, and it was noted that similar artificial impact experiments on deep-sea communities implemented in Japan, the US, some European countries and India had quite similar results. The participants also debated if global efforts will make progress and be able to answer some of today's challenges over the next decade. Although some progress seems to have been made, there seems to have been an overall lack of impact. An increase in the number of marine protected areas was mentioned as an area of progress. However, these areas are quite small and scattered, leading to a smaller overall impact than expected.

Given the need to accumulate more data, the participants agreed that science and technology was crucial. There are insufficient research ships due to a limited number of operators and high costs. Improved monitoring, survey, and analysis systems, which could potentially be supported by AI, would have a significant impact. How to avoid negative impacts on biodiversity when deep-sea mineral mining was also discussed. There was still a lack of data, and as a result, when in the decision-making process, a balancing of negative and positive effects was suggested.

The participants also mentioned potential innovations in deep-sea, where they raised the challenges in obtaining and transmitting information, the idea of populating the ocean with thousands of sensors, and the use of existing sub-marine cables as a persistent distribution system. Until people start addressing persistence and scalability that allows us to oversample the ocean, the world will be struggling with this challenge.

The participants also emphasized formalizing what results they wanted to see from future meetings such as STS *forum*, what the next steps they wanted to implement would be, and how to build upon everything that has been established thus far. They noted that levels of deep-sea circulation may have changed by as much as 25% and oxygenation may have also changed by double digits, which is a significant and alarming amount, especially as the world still does not know the consequences in terms of feedbacks to climate, impact on biodiversity, and the feeding cycles of organisms.

Life Sciences
AI in Health

[Chair]

McKinnell, Henry A., Chairman, American Associates STS *forum*; former Chairman/CEO, Pfizer, U.S.A.

[Speakers]

Batchelor, James, Associate Dean International, Professorial Fellow of Clinical Informatics and Healthcare Innovation, Clinical Informatics Research Unit- Faculty of Medicine, University of Southampton, U.K.

Hu, Jianying, IBM Fellow; Director, HCLS Research; Global Science Leader, AI for Healthcare, IBM, U.S.A.

Nagai, Ryozo, President, Jichi Medical University, Japan

Quake, Steve, Head of Science, Chan Zuckerberg Initiative; Lee Otterson Professor of Bioengineering and Applied Physics, Stanford University, U.S.A.

Opening Remarks

The chair opened the session by pointing out that, whereas many technologies in healthcare are very many years away from actual application, AI and especially generative AI seems set to have a much more immediate impact. He noted that cynics might suggest that no technology has ever revolutionized healthcare and that human health is immensely complex, while optimists would argue that AI is already disrupting healthcare. The chair explained that, during the session, participants would discuss which areas of healthcare AI technology could be applied, and what the associated benefits and challenges are.

McKinnell, Henry A.

The speakers first discussed data-related challenges. To effectively train and apply AI models to healthcare, it is necessary to pull together a vast array of complex clinical data, which are often collected in different ways, and to do so in a manner that would be useful for researchers, industry, and even the general public and that would enable collaboration.

Key aspects to consider are the collection of data, the curation of data, the collaboration of data, and communication about that data.

The speakers then turned their attention to how the new wave of AI developments has the potential to significantly advance human health in two important ways. The first, near-term benefit is in enabling productivity gains by automating or assisting certain tasks. The second, longer-term benefit is driving scientific discoveries at scale for accelerated drug development. There are, however, also risks that need to be managed. Key to that will be achieving trustworthiness, enhanced explainability, and policy priorities to address equity considerations.

Next, the speakers delved deeper into managing risks related to medical AI. Medical AI is increasingly being used in diagnosis, and it must, at the very least, be able to articulate its rationale. Its diagnostic sensitivity and specificity must also be defined and perpetually reaffirmed. Regulation pertaining to medical AI algorithms is also a matter of urgency. Furthermore, if corporations will have access to patients' biometric information, steps must be taken to prevent the widening of disparities.

Another topic was the intersection of basic research in cell biology and AI. Researchers have been developing cell atlases and molecular definitions of all the cell types of the

human body and managing this information in well-annotated and structured datasets. These datasets can be used to develop foundational models for trying to predict cell types from the genome and how those cell types change when the genome has a mutation, which will undoubtedly yield many future applications in health and medicine.

Discussion

Following the opening remarks, the participants held a group discussion. They first spoke about difficulties in accessing and sharing data, due to regulations, privacy concerns, and data sovereignty issues. Some technical solutions are possible, such as federated learning and differential privacy. More fundamentally, if it is possible to build trust and a sense of community among the public, they may be more willing to share their data. Legislation should also be considered, and perhaps the potential contribution of data-sharing to the greater public good could trump concerns of privacy.

Next, the participants discussed the stages from ideation and mechanics to deployment and implications, as well as the importance of trustworthiness at each stage. In ideation, some key questions are which is the right problem to solve, how to articulate that into an objective function, how to tell that it has been solved, and how to know the boundaries of the model. There was also discussion of whether social determinants or mental wellness factors could be incorporated in medical AI. In mechanics, the participants discussed how to extract broad findings with AI from biased data. As for deployment, the participants discussed the experience of deploying models for surgical operations in Saudi Arabia. The importance of explainability and providence for building trust and how explainability differs by stakeholder were also discussed. Regarding implications, the participants discussed how to ensure different parties have the right tools and access to data to ensure patients are kept safe.

The participants then considered nationality and whether or not anyone other than Americans should rely on ChatGPT, because it is made by an American company and is derived mostly from English-language data. Relatedly, they noted the need for more data from underprivileged populations. The participants also talked about the difficulty of accessing quality data in textual diagnosis, and how many large language models are trained on mass sets of data of variable quality, whereas a smaller set of curated data may be more useful.

Another topic was implications for the training of medics. The participants noted that the issue of over-specialization of medics could perhaps be ameliorated by specialists receiving generalist support from AI. On the other hand, AI advancements may lead to a need for fewer specialists. Furthermore, if the lower-level tasks that less experienced medics would normally perform and learn from can now be done by AI, it may become more difficult to train the next generation of specialists.

Next, the participants discussed the tension between academia and industry, whereby academia wants to publish its results, whereas industry may want to keep more information proprietary. There is also tension between competition and the collective good.

The participants also discussed ways to get the most out of AI, including educating patients, complementary tools such as those for digitizing and dealing with more heterogenous data, standards, and consideration of data protection and privacy concerns.

Finally, the participants spoke about data curation. One question they considered was whether this should be publicly funded for public good, or if it would be better to have a business model where a broker would take data from different sources and put them together in curated and well-structured data sets for AI. How hospitals could contribute to data curation and how they could do so in ways that maintain public trust were also discussed.

Life Sciences
New Frontiers in Biotechnology

[Chair]

Hengartner, Michael O., President, ETH-Board, Switzerland

[Speakers]

Meldal, Morten P., Professor of Chemistry, Department of Chemistry, University of Copenhagen, Denmark [Nobel Laureate 2022 (Chemistry)]

Hersey, Sarah, Vice President, Precision Medicine, Bristol Myers Squibb, U.S.A.

di Luccio, Eric, Executive Officer/Chief Technology Officer; Head of R&D center, HIROTSU BIO SCIENCE INC., Japan

Santos-Garcia, Arturo, Director, Technology-based Entrepreneurship/Technology Transfer Office, Tecnologico de Monterrey, Mexico

Yatomi-Clarke, Steven, CEO and Managing Director, Prescient Therapeutics, Australia

Opening Remarks

The chair began the session by looking back on the amazing progress that has been made in biotechnology and how the state of the field today would have been unimaginable 40-50 years ago. He then invited the speakers and the participants to discuss new frontiers in biotechnology, including which new technologies are making waves and which technologies are about to break through, how AI will impact biotechnology, as well as ways in which to increase access to and democratize such new biotechnologies.

Hengartner, Michael O.

Next the speakers considered how developments in organic chemistry have facilitated new advances in biotechnology. For example, it has enabled the development of new drugs such as glucagon-like peptide-1 analogues, which not only target a single receptor but have broad life-insuring effects on people. Evolution of chemical synthesis technologies has also allowed faster synthesis of compounds that have biological resemblance. Another area of success is new vaccines, such as messenger

RNA vaccines. Looking ahead, the use of click chemistry to improve the kinetics of pharmacological products will surely drive future developments in technology.

The speakers then discussed biotechnology developments in oncology. Great progress has been made in reducing patient deaths, but there is still so far to go. Fortunately, technological advances continue to be made, such as technologies that enable the detection of measurable residual disease very quickly. This supports a shift to more personalized treatments. It also broadens access to important information for patients that, for example, have tumors that cannot be safely biopsied. Advances in AI will also enable interrogation of the data generated from such technological developments.

Following this, the speakers took up N-NOSE as an example of how biotech can offer new and better ways to address major healthcare issues. N-NOSE is a new form of mass cancer screening that uses the sensitive olfactory sensory functions of nematodes to detect several types of cancer from urine samples. The technology is currently being further developed, with a particular focus on deploying N-NOSE screening in low- and middle-income countries to support early detection and intervention for as many people as possible through an agreement with the Global Health Equity Fund (GHEF).

In addition, the speakers discussed how biotechnology developments could potentially revolutionize blindness prevention. Intraocular injections have been transformative in the management of retinal conditions such as age-related macular degeneration and diabetic retinopathy, but have downsides such as cost and discomfort that call for a less invasive and more accessible solution. Nanotechnology has enabled the development of a topical lipid-based platform that uses liposomes to penetrate the protective barriers of the eye and to deliver traditional medicines such as steroids, as well as more cutting-edge therapeutics such as antibodies, fusion proteins, and peptides, to the target intraocular tissues.

Cell therapy was also discussed. Cell therapy has proven to be revolutionary for curing diseases, including in oncology, where autologous T-cells have enabled immune cells to recognize and kill cancer cells. Like any new technology, the first iteration is not perfect and work is being done towards ensuring better safety and efficacy, and more efficient manufacturing processes, which would in turn lower costs and make cell therapy more accessible. The next step-change will likely be the development and manufacture of off-the-shelf cells. Other future prospects include new therapies using other cells, such as NK cells and monoctyes, as well as potentially in vivo cell therapy.

Discussion

The participants then held a group discussion. First, they looked at various challenges and how to address them. One was how to set and prioritize next targets for biotechnologies. AI could help discovery of promising targets. The development of an atlas of interactions between particles and their targets would also be useful. The participants also looked at challenges in academia. For example, it is often easier to obtain initial funding than follow-up funding, a problem that could perhaps be ameliorated by establishing biotech hubs.

The participants then discussed the concept of providing the right dose of the right treatment for the right patient at the right time. As part of that, it is important to treat the fundamental disease and not just the symptoms, which requires an understanding of the disease pathway and convergence of different technologies. There is also a need to speed up the development process, but without compromising safety, and perhaps AI could play a role in improving prediction.

Another important theme discussed was trust among different stakeholders. It is not possible to apply innovative biotechnologies to the diagnosis and treatment of patients without their trust and the trust of their physicians. Ways of gaining their trust include presenting data on a technology's specificity and sensitivity, and working with patient advocacy organizations. Moreover, gaining the trust of industry is also essential for taking a finding in academic research through to commercialization.

In addition, the participants stressed the need to make sure advances in biotechnology do not lead to the widening of existing disparities. They noted that lessons could perhaps be learned from other fields, as this is a common challenge for all new technologies. The participants also suggested that it would be worthwhile redirecting some research and development towards less expensive diagnostics and treatments for the many in less developed areas of the world, rather than complex research and very expensive medical procedures for the few. Furthermore, they noted that discussion of accessibility usually revolves around cost and regulation. However, another relevant factor could be infrastructure. For example, for countries that lack adequate cold-storage facilities, a solution may be to make a compound more heat-resistant.

In this relation, the participants also discussed ways to lower the cost of cell therapy specifically, including creative payment plans based on patient response, support for increasing

the number of manufacturers, automation and streamlining of processes, the development of allogeneic cells, and identification of "super donors." They also touched on how AI could be used to improve cell therapy targeting.

In addition, the participants noted that development of antibiotics is not as valued as more expensive treatments, despite their life-saving properties. A major reason for this may be that they are not very profitable despite their costly development. Furthermore, the costs to healthcare systems of antimicrobial resistance (AMR), though high, are less visible than, say, cancer. One solution may be to form consortia for developing antibiotics. Another solution may be a subscription-like model, whereby people pay for antibiotics in advance to have access to them, but with the hope they do not ever need to use them.

The application of biotechnology to fields other than human health, such as bioindustry, biofuels, or agriculture was also discussed. In such areas, the challenges include, again, acceptance and inhibitive costs.

Life Sciences
Healthy Aging

[Chair]

Zerhouni, Elias Adam, Professor Emeritus, Radiology and biomedical engineering, Johns Hopkins University; Former Director US NIH, National Institutes of Health (NIH), U.S.A.

[Speakers]

Hahn, Maria, CEO and Founder, Nutrix AG, Switzerland

Kurth, Ann, President, New York Academy of Medicine; Faculty, Yale University School of Nursing, U.S.A.

Roberts, Richard J., Chief Scientific Officer, Research, New England Biolabs, U.S.A. [Nobel Laureate 1993 (Physiology or Medicine)]

Samuel, Didier, Chairman and Chief Executive Officer, French National Institute of Health & Medical Research (INSERM), France

Opening Remarks

The chair started by pointing out that aging is not a fixed parameter but a variable factor that is dependent on living environment, socio-economic conditions, and so on. He then noted that advances in the prevention and treatment of infectious diseases have greatly increased life expectancy around the world. However, those advances have not been equal. Furthermore, population aging has also led to the emergence of new health challenges, as well as socio-economic problems resulting from population structures becoming inverted pyramids. It is essential, therefore, for countries to have strategies for healthy aging. Moreover, the aging trajectory differs by person and the difference between a person's chronological age and their physiological one is a concept that is increasingly recognized.

Zerhouni, Elias Adam

Following this, the speakers discussed the distinction between lifespan and healthspan and how innovative technologies can be used to support aging populations and expand healthspans. As a country's population ages,

there is an increasing prevalence of chronic diseases, which increases the costs for health systems. Many countries also lack enough healthcare workers to manage patient populations with chronic conditions. Fortunately, there are tools available such as gSense, which uses devices to monitor patients remotely and utilizes generative AI, with the guidance of human teams, to provide personalized coaching to ensure patients stay on health plans.

Next, the speakers discussed how to enhance existing health systems so that they can deal with the growing need for health and human services as a result of the aging of populations. Important challenges include training and retaining healthcare professionals, informing caregivers, dealing with the migration of healthcare workers, making health systems more age-friendly (by addressing what is meaningful to patients, medications, mobility, mentation), better infection control, and fostering intergenerational interaction, among others. These challenges are also compounded by the effects of the climate crisis, to which older populations are particularly vulnerable. To overcome them, it will be essential to engage in intersectoral planning and prevention, implement evidence-based solutions at scale, invest in aging today, and integrate older people, rather than walling them off.

The speakers then discussed the link between healthy aging, and hunger and nutrition. Millions of people suffer from hunger or die young because of inadequate nutrition, such as vitamin A deficiency. This could be readily addressed by feeding them genetically-modified

(GM) crops with improved yields and enhanced nutritional value. However, some groups oppose GM crops and have campaigned against their safety, despite a lack of scientific basis, which has damaged the reputation of GM crops and prevented people suffering from hunger or nutritional deficiency from having access to them.

The next topic of discussion was important areas of research to support healthy aging. These include understanding the phenomenon of aging across multiple pathways, including discovering novel mechanisms of promoting healthy aging as a source of bio-inspiration for biomedical application, developing new drug strategies to target biological pathways of aging, and preventing delay and intercepting age-related disease onset. There also needs to be better understanding of global changes in healthy aging. Furthermore, it would be valuable to conduct comparative studies of aging trajectories among different populations to enable understanding of the heterogeneity of aging and the development of personalized solutions.

Discussion

Following the opening remarks, the participants engaged in a group discussion. They began by touching on some of the key components for supporting healthy aging. These include reeducating society on how to lead better lifestyles, nutrition, healthy living with a sense of purpose, technological developments, policymaking, public and private initiatives, promoting quality of life rather than just longer life/healthspan, and setting appropriate research priorities.

Next, the participants discussed GM foods in the context of good food being fundamental to healthy aging. Misunderstanding and misconceptions about GM foods are widespread, and they must be countered by the effective dissemination of scientific information and objective facts to the public. Furthermore, the benefits of GM foods extend beyond fighting hunger. They would enable the growing of crops in places where this would otherwise not be possible, preventing deforestation to clear room for arable land and thereby contributing to combating climate change.

Collaboration and prevention were also taken up as being essential for healthy aging. Collaboration among government, industry, and non-governmental organizations is key. Meanwhile, more prevention results in less medical intervention. One way to promote better prevention is to identify and monitor people at risk for particular chronic disease and encourage corrective lifestyle habits or early intervention. However, one issue is that

sometimes people cannot act on such information if they do not have easy access to public healthcare, which is particularly the case in low- and middle-income countries. This could perhaps be resolved by solutions such as telemedicine.

Another topic was signs of aging. Participants discussed the distinction between biological aging and chronological aging. They also noted the importance of using molecular markers for aging and the need to be able to measure aging to determine if interventions are having an effect.

Lastly, the participants agreed that, although societies often speak of aging as a burden, it is in fact an opportunity. That people are living longer and often healthier lives than before should be acknowledged as a positive achievement. Pairing the experience and wisdom of older people with the energy and enthusiasm of younger people is a winning combination. Furthermore, there are many people who may be chronologically "old" but biologically "young" and as societies get older, there is a need to reimagine and personalize retirement ages. The distinction between persistent good cognitive function vs physical and motricity health when becoming older is also an issue to be debated. If these people do in fact have to retire from one field, there may also be a valuable opportunity to facilitate skillset transfers by moving them to fields with shortages of labor. They should also be supported by lifelong learning opportunities. In addition, education should be provided to young people to prepare them for and ensure their own eventual healthy aging.

Innovative Engineering
Revolutionary Materials and Devices

[Chair]

Ohno, Hideo, President, Tohoku University, Japan

[Speakers]

Mitra, Sushanta, Executive Director & Professor, Waterloo Institute for Nanotechnology, Waterloo Institute for Nanotechnology, University of Waterloo, Canada

Moerner, W.E., Harry S. Mosher Professor and Professor of Applied Physics (courtesy), Department of Chemistry, Stanford University, U.S.A. [Nobel Laureate 2014 (Chemistry)]

Nikl, Martin, Professor, Head of Department, Department of Optical Materials, Institute of Physics of the Czech Academy of Sciences, Czech Republic

Van de Voorde, Marcel, Prof. & Executive Advisor to the President and CEO, IMEC Technology Institute - Catholic University Leuven; Former Executive & Director, CERN Geneva & European Commission Research Brussels, Belgium

Feringa, Bernard, Jacobus van 't Hoff Distinguished Professor of Molecular Sciences, Stratingh Institute for Chemistry, University of Groningen, Netherlands [Nobel Laureate 2016 (Chemistry)]

Yeh, Nai-Chang, Thomas W. Hogen Professor of Physics, Physics, California Institute of Technology (CALTECH), U.S.A.

Opening Remarks

Ohno, Hideo

In opening the session, the chair highlighted that revolutionary materials and devices would be fundamental to realizing the full potential of current advances in AI, noting that materials are everywhere and are fundamental to all aspects of our modern world. Meanwhile, we must be cognizant of important societal aspects for the future, such as resource conservation, environmental impact, and biodiversity.

First, the speakers talked about smart and functional materials beyond graphene, such as hexagonal boron nitride, molybdenum

disulfide, as well as biopolymers, and materials for additive manufacturing, which could enable new frontiers in devices. The speakers noted that materials go hand-in-hand with connected devices such as sensors and actuators, and with machine learning and AI used to process the large amount of data generated by these connected devices. The speakers noted that surface energy and surface properties are key aspects to understanding new materials in practice. The speakers also highlighted the importance of sustainability and meeting the SDGs, and our responsibility to the next generation through education.

The speakers then discussed the challenges of detecting a single molecule of about 1-2nm, for use as a probe for the nanoscale. A technique called super-resolution microscopy is used to overcome the optical diffraction limit, which enables use cases such as examining the RNA or DNA inside cells or exploring binding site behavior and structure inside polymers. The speakers discussed the information that can be obtained from the properties of the photons emitted using these non-destructive techniques, which can also provide information about nearby molecules.

Discussion then touched upon recent work on nano semiconductors, as well as incredible wide-ranging materials, both functional and structural, developed for space and aeronautics. On the topic of climate change and zero-carbon efforts, the discussion highlighted the

role of innovative materials for hydrogen generation and distribution, and also for nuclear fusion reactors. The speakers also touched upon raw material resource constraints, and the limitations of current recycling capabilities. The importance of international and multi-disciplinary collaboration was also discussed.

The discussion then moved to scintillators, which convert ionizing radiation into light, so that it can be detected by photodetectors. Today there is intense R&D underway to develop scintillators for various specialized applications from large-scale to nanoscale. Revolutionary techniques in crystal growth without expensive crucibles are now being developed.

The speakers than spoke about van der Waals materials, which have gained a lot of interest due to their novel electronic, optical, magnetic, ferroelectric, topological, superconducting, and mechanical properties. These materials consist of atomically thin layers, known as 2D quantum materials. Stacking the layers of these materials in different ways can create new properties, such as twisting to create a superconductor. Also, single defects in these materials can emit light with useful quantum properties. A bottleneck has been scalable production at sufficiently low cost. Chemical vapor deposition (CVD) growth at high temperatures is not compatible with silicon technology, but recently lower temperature and scalable CVD growth production has been developed so that the process can become compatible with Si-CMOS technology. The speakers noted that further development would require interdisciplinary and international collaboration.

The speakers then discussed how despite the successes of materials science, we still have much to learn from nature, as the materials in our bodies are dynamic, not static, and are able to adapt and self-heal. This is one of our challenges and hopes for the future, to generate living materials. Our bodies generate half our body weight in adenosine triphosphate (ATP) every day, but we do not need to consume half our body weight every day because our bodies recycle matter. Why can we not achieve the same level of recycling in the products and structures we create as that which we see in mother nature.

Discussion

The participants then held a group discussion. They first discussed key drivers for technology, and how the goals for humankind could be integrated into research questions. Government policies could also be considered to influence research aims and hiring of researchers. Science should not be only focused on returns, but also on scientific discovery,

reducing inequality, and sustainability, including in the education system. The topic of how to democratize data, which would accelerate material discovery, was also touched upon.

Participants then considered super-resolution microscopy, and how blinking effects might be used to characterize defects in materials. There are still many aspects of materials properties that we don't understand, where we find solutions, but we still have more to do to achieve a real understanding. We are now able to combine many techniques to achieve a particular characterization, and the potential for machine learning and AI to predict properties was discussed.

The participants then discussed further the importance of nano semiconductors, noting that the Japanese government has recently contributed to the establishment of companies to work on cutting edge semiconductors. They further discussed the contribution of materials to reducing climate change through green hydrogen. Discussion on collaboration noted the great example of CERN in Switzerland. The role of AI in materials investigation and materials development was also discussed further.

Applications of scintillators were also discussed, such as for medical imaging and military uses. The development of the technology is led by demands such as efficiency, resolution,

and speed of response. For low-dose detection, the use of organic materials or organic-inspired materials with self-healing properties was discussed.

Following this the participants then discussed the development of fully connected wafer-size van der Waals materials with millimeter-scale grain sizes, which came out of interdisciplinary research that enabled substrate-independent synthesis based on the principle of self-assembly. This new direction created discussions on potentially endless applications that could be enabled by this technology in industry.

The discussion then moved on to the wide-ranging applications of nanomaterials, and also macro-materials, including scalability issues. The use of flow synthesis in manufacturing was highlighted as a great advance in addressing scalability. A key issue with sustainability is that non-biodegradable plastics are much cheaper than biodegradable plastics. To have sustainable manufacturing we need green chemistry, and to be able to mimic nature we need to be able to understand complex systems. In addition to cross-disciplinary collaboration in science, we need to also work with social scientists, and also with industry. Finally, participants noted the importance of computational science for prediction of outcomes.

Innovative Engineering
Quantum Science and Technologies

[Chair]

Gutfreund, Hanoch, Executive Committee Chairperson, Israel Science Foundation (ISF); Professor Emeritus; former President, Physics, The Hebrew University of Jerusalem, Israel

[Speakers]

Curioni, Alessandro, IBM Fellow, Vice President, Europe & Africa and Director, IBM Research - Zurich, IBM Research Europe, Switzerland

Itoh, Kohei, President, Keio University, Japan

von Klitzing, Klaus, Director Emeritus, Low Dimensional Electron Systems, Max Planck Institute for Solid State Research, Germany [Nobel Laureate 1985 (Physics)]

Lefebvre, Julie, Vice President, Emerging Technologies Division, National Research Council Canada (NRC), Canada

Mlynek, Jürgen, Chairman, Falling Walls Foundation; former President, Helmholtz Association of German Research Centers, Germany

Opening Remarks

At the start of the session, the chair noted that quantum science and technology is an emerging fast-growing interdisciplinary field based on improved understanding of basic quantum phenomena such as superposition, non-locality, and entanglement, with possible applications in computing, communication, cryptography, sensing, simulation, and imaging.

Gutfreund, Hanoch

In most areas of science, technology plays an important role in methods for measurement, and in realizing applications. But in the case of quantum science, the field could simply not exist without technology, as qubits for research must be engineered and controlled using very sophisticated technology. He also noted that ongoing development will require long-term strategic effort for years to come, together with a long-term vision.

The speakers first pointed out that quantum computing is already a reality, even if in its early phases. There are still many advances in basic sciences that need to be made, however a roadmap exists toward creating systems with increasing numbers of qubits. Nevertheless, realizing quantum utility is going to come from integration of quantum computing with classical computing, and being able to segment problems into the quantum and classical domains synergistically. An additional challenge is the issue of reducing error rates, where much progress has already been made, with the aim of eventually mitigating errors through error correction. It was also noted that without achieving sufficiently fast interfaces between quantum and classical systems, it will not be possible to obtain the full utility benefits of rapid quantum solutions.

The speakers then discussed silicon quantum computing research, based on nuclear spin resonance and electron spin resonance, which eventually led to the realization of silicon quantum computing in 2015. The use cases for quantum computing also need to be researched, and to this end an IBM quantum computer network hub was established at Keio University in 2018. Every few months improvements are seen in the capabilities of the chips, and after five years, the chips are now like a first grader at elementary school. Investors remain involved because they see the future use cases, such as in accelerating Monte Carlo simulations. The speakers pointed out that companies bring hundreds of problems seeking solutions, but only around 1 percent are problems are found to be suitable to be tackled by quantum computers, with the remainder better tackled by classical supercomputers.

The speakers then discussed the recent intensifying of interest in quantum with the 2022 Nobel Prize in Physics being awarded for research advances related to quantum entanglement, and an increasing number of organizations engaging in quantum research. One of the main driving forces for renewed interest in quantum was felt to be the fear by nation states that the ability of quantum computing to break encryption ciphers would put countries without this technology at a strategic disadvantage. It was also noted that China is investing heavily in this area, and that certain entities were pursuing independent research without collaboration or sharing. However, the speakers noted that great achievements such as the realization of a new system of units based on stable quantum units and quantum physics was something that could only be achieved through broad international collaboration.

The speakers then highlighted the role of government in quantum science and technology to ensure that advances can continue with sustained support and are not derailed by a "valley of disillusionment" effect. It was noted that Canada was supporting research in quantum networking, as this is seen to be one of the keys to realizing the full potential of future advances in quantum technologies. It was also pointed out that multidisciplinary development and international collaboration, as well as the creation of standards, would be important for progress.

The speakers also discussed the expected first applications and products of quantum technologies, highlighting sensors, followed by communication, and then computing. However, the challenge of the intersection between electrons used in calculation and photons used in communication was raised as an issue to be resolved. In addition to basic science, the real challenges now lie in the engineering domain, but there is less interest from academia here, so contributions from technology companies will be required.

Discussion

The participants then held a group discussion. They first discussed how the seminal paper co-authored by Einstein in 1935 that intended to show to the scientific community that there is something wrong with quantum, in fact ended up solidifying quantum mechanics and leading to the quantum revolution.

The participants then raised the question of whether individuals need to be concerned about the security of their encrypted data, such as credit card information. It was noted that while information encrypted with today's encryption algorithms could be broken with quantum computing techniques at some point in the future, and perhaps sooner than had initially been predicted, newer encryption quantum-resistant algorithms already being created can provide protection from quantum techniques for new data and real time data in the future.

Some concern was raised that students might miss out on basic physics due to an increase of interest and focus on quantum, although it was noted that there is obviously enormous overlap. Concerns were also voiced about how to maintain diversity in the field, as little change has been seen in the low numbers of women pursuing degrees and careers in science.

The participants noted that compared to other transformational technologies such as lasers or semiconductors which had quickly become widespread after their discovery, quantum has not achieved the same explosive growth due to the level of difficulty involved. The reasons for limitations in applications were discussed, with one of the key limitations being the transfer of data. The key opportunities, it was noted, are in simulation of molecules and atoms, problems connected to global optimization, and in the overlap between quantum computing and machine learning or AI.

It was pointed out that to transfer data from real world to quantum world it is necessary to cheat in some way, and that there is the possibility of mistakes. However, it was noted that if there is some way to verify the answer in the real world, the quantum approach can still be valid. It is, however, difficult to prove whether the quantum approach is always going to be better.

On the topic of hype surrounding quantum computing, the participants asked whether in the future everyone would have a quantum computer, and whether there is any practical application that can be seen as a benefit to society. It was noted that when a "grand challenge" is set, it is possible to achieve unbelievable results in a short amount of time, but the general consensus was that the properties of quantum computers meant that they would not be practical in the home. It was noted however that the laser was initially viewed as a solution looking for a problem, and that nobody can know what will happen 20 years from now if quantum computers exist.

While the future cannot be predicted, it has highlighted that following science-based advice, identifying gaps to be able to advance, and providing funding as necessary to fill in the gaps, are key to enabling progress.

The participants pointed out that the biggest differentiator in quantum today is the engineering knowledge gained from many years of semiconductor development, and a key enabler will be achieving the optimal combination of quantum and classical computing. The question was raised of the role that photons play in quantum, and it was agreed that there are multiple possible solutions for solving problems in the quantum domain, with no obvious winner yet.

Responding to remarks from the audience, the chair summarized the discussion, saying that as scientists we can ignore the popular hype around quantum computation and concentrate on the ordinary phase in the evolution of quantum physics, with a new element - the essential role of engineering in this process.

Innovative Engineering
AI & Hyper Automation

[Chair]
Thompson, Herbert Hugh, Managing Partner, Crosspoint Capital Partners, U.S.A.

[Speakers]
Kearns, Paul K., Director, Argonne National Laboratory, U.S.A.
Dowling, Michael, Chairman of the Board, MÜNCHNER KREIS; Prof. Dr., Faculty of Business and Economics, University of Regensburg, Germany
Mencer, Oskar, CEO, Maxeler Technologies, U.K.
O'Herlihy, Alan, Founder & CEO, Everseen, Ireland
Günther, Oliver, President, University of Potsdam, Germany

Opening Remarks

The chair opened the session by remarking on the unbelievable thirst to adopt AI and Large Language Model (LLM) technologies, because of the immediate gains that can be seen, and questioned whether there may be hidden shadows that would only become apparent later. The chair also noted how difficult data segmentation and protection is in LLM-based generative AI systems and how careful manipulation of prompts could reveal data that was not intended to be shared.

Thompson, Herbert Hugh

The speakers first discussed the great applications for AI in scientific research, including acceleration of discovery. There is also hope for a future where the loop could be closed on hypothesis-driven experimentation in areas such as drug discovery and novel semiconductor materials development, potentially fundamentally changing the way science is conducted. This will require great collaboration to create common tools for research, and already some partnerships, including public-private partnerships, are being created to focus on these areas, and international partnerships are also

desirable. It will be important to build public trust and democratize access to these incredible new tools.

The speakers then discussed how AI technologies impact businesses, and the key areas where generative AI will impact automation, such as language generation, computer vision, virtual assistants, data synthesis, content personalization, and robotic process automation (RPA). Studies have estimated that a large proportion of total productivity gains over the next 3-4 years will come from generative AI, which equates to trillions of dollars in gains. Other estimates cited were that personal productivity gains of 20-30% per person might be seen. However, they noted the issues in the areas of data quality, bias, copyright, privacy, and security.

The speakers pointed out that compared to the early understanding of neural networks and what would be needed to achieve generative AI, eventually it was found that a probabilistic model of the next word in a sentence would be sufficient to create a generative LLM that reasonably represents the way the brain generates language. Language is the interface to humanity, and so large language models are extremely useful to humans, provided we can trust the output. Rather than replacing humans, LLMs can be leveraged to enhance human

abilities. It was suggested that it may be beneficial to train personal LLMs that individuals nurture to enhance their memory.

Next, the speakers delved into the topic of Hyper automation, highlighting that much of today's AI discourse is dominated by Large Language Models (LLMs) like ChatGPT. These models necessitate substantial structured data and immense cloud computing power. However, in real-world applications, decisions often need to be made in a split second at the edge, not in vast data centers. The speakers emphasized the burgeoning potential of Hyper automation in processing real-time, unstructured video data. This methodology is presently enabling companies to perform process shaping at scale and in real-time at the edge. This is achieved by applying game theory, knowledge theory, and behavioral economics to orchestrate and optimize complex interrelated processes.

The speakers acknowledged existing practical and ethical hurdles, especially concerning privacy, bias, safety, and large-scale compliance, yet agreed that with the right combination of human oversight, technical expertise, and well-thought-out policies, these challenges can and will be effectively addressed.

The speakers then considered the use of AI in the academic context. It was suggested that the thinking regarding plagiarism by students will likely shift toward an acceptance of the use of generative AI to produce a skeleton text, so that the student can focus on adding their unique inspiration, as it is not unreasonable to expect that in the very near future the great majority of texts will be produced partly or sometimes fully by AI. Prompt engineering, or how to write effective prompts to generate a desired output will also become an important topic that should be taught. It was suggested that the potential use of AI to provide personal tutoring to students should be embraced by academic institutions.

Discussion

The participants then held a group discussion. The participants stated that AI would likely find applications many fields, such as automation of optical inspection, potentially improving product quality, while reducing time and energy use. In addition, it was suggested that applying domain specific knowledge could further increase the potential efficiency gains, for example in the life sciences.

The participants then discussed the potential positive uses of vehicle tracking technologies and the potential misuse of that information. They also touched upon displacement

of workers, and jobs that will disappear, but noted that there would be opportunities for reskilling and application of personal knowledge in areas that would provide fulfilling work. Regarding beneficial applications in the drug discovery process, the potential of negative effects for the African genotype were noted, due to their lack of representation in data.

The participants then noted then despite many bright lights of AI, such as improved quality, speed, sustainability, performance, and systems that are much more customized yet affordable, there are also potential dark shadows, related to trust and data security.

The participants noted that while AI can be trained for specific tasks, often large general AI models seems to perform better even at specific tasks, which may be due to broader knowledge being linked to creativity. However, despite the vast amount of knowledge in these models, their intelligence is not yet at highest level. The question of human supervision of AI models was also raised, generating many differences of opinion, although where life is on the line, it was felt that it is more important to have a human in the loop.

The participants pointed out that students are more open to using AI more than faculty staff, and suggested that this might also extend to industry, where younger staff may be eager to use AI to create competitive advantage, while their bosses may be more cautious.

Cautions were also raised by the participants that ChatGPT cannot distinguish between true and false without additional symbolic knowledge, and therefore – at least at this point – often states things that are blatantly untrue. It was suggested that ChatGPT might be improved by being more humble in the way it phrases its output, or even by providing color indications of the confidence level of its responses. Finally, the participants noted human behavior changes based on the technologies available to the younger generation and pointed out that the younger generation growing up today with ChatGPT will not know a world without generative AI assistants.

Cooperation in S&T

Science and Technology as a Driver for Development

[Chair]

Walport, Mark, Foreign Secretary, The Royal Society, U.K.

[Speakers]

Mante, Priscilla Kolibea, Co-Chair, Global Young Academy, Germany; Senior Lecturer, Department of Pharmacology, Kwame Nkrumah University of Science and Technology, Ghana [Young Leader 2021]

Najib, Dalal, Senior Director, Science and Engineering Capacity Development, Policy and Global Affairs, National Academies of Sciences, Engineering and Medicine, U.S.A. [Young Leader 2023]

Haryono, Agus, President, Indonesian Research and Innovation Fund (IRIF) National Research and Innovation Agency (BRIN), Indonesia

Sakr, Mahmoud M., President, Ministry of Higher Education and Scientific Research, Academy of Scientific Research & Technology of Egypt (ASRT), Egypt

Watanabe, Koichiro, Senior Advisor of Higher Education, Human Development Department, Japan International Cooperation Agency (JICA), Japan

Seeberger, Peter H., Vice President, German Research Foundation (DFG), Germany

Opening Remarks

Walport, Mark

The chair started the session by stating that people are also a driver for development along with S&T. It is crucial to distribute S&T around the world, and ensure that social sciences, engineering, and technology developments can be used to contribute locally. One of the biggest challenges is the transmission mechanism between policymakers and science.

Next, the speakers noted that now the potential of S&T development is higher than ever as it can offer solutions to provide sustainable growth. Social sciences are a key to understand interaction between individuals

and society in search of the solutions to challenges. Cooperation and collaboration are important to release the full potential. When establishing cooperation and collaboration, it is important to bring young researchers along and make them equal partners, as they represent the future of scientific research, and play a key role in innovation and unlocking groundbreaking solutions. Investment into young scientists is investment into the future. The speakers noted that the access to digital resources is essential for research and innovation, and digital disparity and infrastructure should be addressed.

Another topic the speakers discussed was the need to mobilize human resources and research worldwide to address global challenges together. Efforts to foster North-South and South-South collaborations must be doubled down on, as the recent coronavirus pandemic has exacerbated the North-South divide. The speakers then discussed the importance of S&T programs in developing countries bringing together young researchers to foster cross-disciplinary knowledge exchange and facilitate collaboration. The four key points of such initiatives were highlighted. First, promoting cutting edge technologies and basic research is as important as capacity building and applied research. Second, successful partnerships based on intellectual reciprocity are bidirectional and equitable. Third, providing local opportunities for young researchers and leveraging the global diaspora are essential for countering brain drain and promoting brain circulation. Fourth, there is a need to establish a system supported by a coalition of funders to enable R&D.

The speakers then noted the need to improve the scientific literacy of more general audiences, and that local and global policies should be developed based on scientific evidence. Innovations should be brought to the public to demonstrate the effective use of budgets and the impact of S&T. One of the solutions to speed up the utilization of scientific evidence is to merge research institutions, or to enable its cooperation. Additionally, funding agencies are important to ease the engagement with stakeholders.

Next, the speakers discussed how to direct S&T to support countries' efforts to achieve sustainable development. Global challenges require global effort to mitigate the impact of global issues. However, these challenges vary from region to region, depending on its geographical location, technological readiness level, and availability of resources. Open science is a key for development of accessible science. It implies access to big data and satellite images, software, early warning system networks, as well as the technological localization and flow of technology from Global North to Global South. The speakers also

mentioned the importance of funding in the field of green innovation and green technology to conserve the biodiversity.

Next, the speakers pointed out that S&T development can strengthen the strategies to achieve SDGs and enable cooperation between research institutions in Japan and developing countries. Solutions to some issues could be found by cooperation between governments, institutions, industrial and private sectors. The speakers also stressed the necessity of higher education in developing countries to make S&T a driver for development. Increasing the number of skilled professionals is possible through creating networks between leading Japanese universities and universities in neighbor countries, as well as by raising the level of student exchange.

Next, the speakers touched on the importance of the chemical industry transformation, which can play an important role in mitigating waste and reducing carbon dioxide (CO_2) emissions. Changing the system is a big challenge, so new materials and new processes based on renewable resources and recycling will be key. Addressing this challenge is a task for the next 30 years.

Discussion

Moving to a group discussion, the participants touched on the need for action and not only commitments regarding global collaboration in S&T. Next, it was noted that funding agencies should be transparently accountable. Then, the importance of mobilizing resources in South-South cooperation was discussed through the perspective of various countries.

Student and research exchanges are easy mechanisms to enable exchange between developing and developed countries, which should be considered by funding agencies. The participants identified key steps to achieve S&T development. First is having a uniform research platform to enable innovation exchange between developing and developed countries. Second, participants agreed that there is a need for policies to be driven by governments to enable collaboration with academia. Third, public and private investments in human resources are crucial.

Next, the importance of academia and industry cooperation in policy making was discussed, as well as how stakeholders define development, and the need to support local projects through local funding agencies.

The participants then added that long-term research is more equitable and beneficial than short-term research. The support of higher education and young researchers as a driver for development was emphasized. The question of how to evolve private companies was also raised. It was suggested that companies should take part in solving challenges.

Open science was discussed in terms of accessible opportunities and quality education. Access to advanced education and institutional capacity topics were also raised. The participants then discussed funding issues and approaches to intensify funding from private agencies.

Next, the participants stated that development is an essential part of humanity, so we must get funding agencies to support such development.

Lastly, the participants noted that the accessibility of education varies from country to country, so we should focus initially on training professionals to provide basic education.

Cooperation in S&T

Collaboration among Academia, Industry and Government

[Chair]

Kumar, Ashwani, Senior Advocate Supreme Court; former Union Minister of Law & Justice; former Member of Parliament (Rajya Sabha), Supreme Court of India, India

[Speakers]

Armonaitė, Aušrinė, Minister of the Economy and Innovation, Ministry of the Economy and Innovation of the Republic of Lithuania, Lithuania

Sunami, Atsushi, President, The Sasakawa Peace Foundation; Special Advisor to the President and Adjunct professor, National Graduate Institute for Policy Studies (GRIPS), Japan

Limpijumnong, Sukit, President, National Science and Technology Development Agency (NSTDA), Thailand

Markides, Karin, President and CEO, OIST - Okinawa Institute of Science and Technology, Japan

Kawahara, Katsumi, Executive Officer, Industry-Government-Academia Collaboration Division, Vice Center Director, Technology & Innovation Center, Daikin Industries, Ltd., Japan

Opening Remarks

The chair began the session by noting that solutions to global challenges will determine the future of our world, and this session is a step to identify the challenges and suggest solutions. Humanity has faced various challenges through its history, requiring novel solutions which are not beyond human capacity. The chair also emphasized that the ethical and legal transformation of global AI activity needs to be thoroughly debated. AI is one of the transformative advancements of the 20th century, but poses several challenges that defy human ingenuity.

Kumar, Ashwani

The speakers stated that in recent years society has faced various challenges such as pandemic, wars, and the energy crisis, but each crisis has been an opportunity for S&T advancements. It is crucial to think about how business, academia, and government can

work towards addressing future challenges. AI is a powerful tool that can be used for good or for bad, hence it is necessary to have a purposive debate on various aspects. AI can be used for collecting big data and using it to create case studies that will help make predictions to prevent future crises.

The speakers also touched on the role of private foundations and their collaboration with governments, academia, and industry. It was opined that the Triple Helix model is a standard for cooperation, but different models for different parts of the world may be more effective, and they should be considered by funding agencies. Creating a global funding platform will enable collaborative solutions globally. Another possible initiative is to create a community of researchers and institutions supported by funding agencies to support research to tackle global issues.

The speakers then discussed the goals of diverse stakeholders. For example, the economic growth of a state is only possible when the development and well-being of society are supported. As for academia, universities are particularly interested in nurturing new generations of researchers and professionals. Industry's main aim is for sustainable growth with profit. The challenge is to align the needs and resources of each stakeholder to ensure an economically and socially sustainable world order.

It was highlighted that trust is a key for productive collaboration, which will require novel standards. Universities and research institutions will need to collaborate with industries on the global scene to build a sustainable future.

Finally, the speakers opined that innovations need not be based on individual research but on comprehensive collaborations between organizations. Exchanges between professionals from different institutions will accelerate the process. It was also mentioned that in today's rapidly changing era, it is necessary to utilize cutting-edge technologies in a wide range of fields and to acquire new technologies from external sources to enable sustainable business growth.

Discussion

The participants moved to the discussion and highlighted that humanity is facing similar challenges around the world. Now, there is a need to identify an agenda defining strategic directions for each country, to ease the cooperation between the stakeholders. Funding and the importance of the shift from governmental to public fundings were also discussed.

The participants also talked about cultural differences and similarities in academia. They agreed that governments, academia, and industry do speak different languages, so it is crucial to find a solution to make sure that the communication is equitable, and all the stakeholders share their goals.

Building trust is the essential step for collaboration, and requires an active dialogue to identify relevant challenges and goals. It was noted that a platform for discussions to generate ideas is crucial. Governments require alignment at local, national, and international levels, and scientists need international representation. The possible value of the integrated global scientific approach for humanity must be indicated.

Next, the participants continued by discussing types of foundations, and how funders can reach the best results as most funding agencies are only aiming to support concrete research. Society tends to be skeptical, so there is a question of how to build trust and transparency in discussions between industry and government.

The participants then agreed that the roles of various stakeholders are different, so communication is essential to avoid misunderstandings and find collaborative solutions. To make

the Triple Helix model work, it is crucial to involve the general public in dialogue and allow journalists to become a bridge between society and institutions.

The next topic discussed was trustable relations, which are a fundamental aspect of multis-takeholder interaction. Long-term problems are not easily solved, so there is a need to create a framework to improve communication. Different sectors need to be aligned to create effective policies and take a step back to better understand each of the actors.

Lastly, it was noted that society should eventually shift to the collective consciousness.

Cooperation in S&T

Nurturing Innovation-based Startups

[Chair]

Lim, Chuan Poh, Chairman of the Board, Singapore Food Agency (SFA), Singapore

[Speakers]

Isaksson, Darja, Director General, VINNOVA (Sweden's Innovation Agency), Sweden

Cullins, Melanie, Director General, National Programs and Business Services (NPBS), National Research Council Canada (NRC), Canada

Fujimori, Yoshiaki, Chairperson of the Board of Directors, Oracle Corporation Japan; Senior Executive Advisor, CVC Japan, Japan

Mazur, Eric, Academic Dean of Applied Sciences and Engineering, Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University; Past President, The Optical Society, U.S.A.

Anderson, Samantha, Co-Founder and CEO, DePoly, Switzerland

Wong, Kee, Managing Director, e-Centric Innovations Pty Ltd; Non-Executive Director, Australian Energy Market Operator, Australia

Opening Remarks

The chair began by saying that humanity uses the advancements of S&T, but they often pose serious challenges. S&T have the power to produce innovation to tackle global issues, supported with investment, society, and global collaboration. COVID-19 is one of the latest global health problems, which has impacted the global economy, society, and health system. The pandemic facilitated the creation of some effective vaccines that were developed by startups, through cooperation with public agencies, manufacturers, pharmaceutical companies, and other entities globally. The chair also added that it is crucial to support innovation-based startups but there are many challenges that require new policies.

Lim, Chuan Poh

The speakers then highlighted that there are many impactful startups making a substantial, positive contribution in addressing societal

challenges. Long-term commitment to keep investments into research and innovation has been a top priority, both for the private and the public sector. It is also necessary to nurture a culture of collaboration to take risks together, experiment with new ideas, and learn from failures. One of the biggest issues is lack of talents, and to solve that problem good educational systems are crucial, but it is also important to enhance our ability to build an inclusive and diverse ecosystem to move faster and improve the quality of the ecosystem as a whole.

The speakers then noted that startups have varying needs to be addressed at different stages. Early startups' management teams are often not complete, so creating a network of private-sector experts can impact the firm's trajectory. When the startup is ready to introduce its first product to the market, there is always a challenge to find clients, so innovative procurement may help overcome such barriers. It is also crucial to consider market intelligence and connections for scaling up production. Co-innovation across borders as well as designing a business model for scaling may be a solution to find novel ways to connect startups with GVCs and new markets.

The next topic discussed was governmental funds and their role for startups in different regions, as governmental support is an inevitable part of an ecosystem. The speakers

emphasized that innovations are not possible without failures, and they should be viewed as a step to success. It is also essential to adjust educational systems, as well as enable communication between large companies, startups, and governments.

To support innovation, academia must not only encourage thinking about intellectual property as a counterpart to advancing knowledge, but also train future innovators by cultivating an innovation mindset. There is a need to change the traditional educational system to promote out-of-the-box thinking and innovation, which is not possible without failures, and change should be done through a collaboration of educators and society.

Next, the speakers stated that many startups begin at universities, so it is necessary to have access to fundings during early stages, which may help to make first steps in building a team or creating networks. The financial-driven mindset of investors should involve some impactful aspects, and an understanding of the possibility of failure.

The speakers then explained that each country should manage its risks by putting together incentives and investments, and building clusters that can benefit the ecosystem. Innovation does not always require creating something new, and does not always involve technology or entrepreneurs. The participants also discussed corporate innovation and the ways it can improve customer experience, process improvements, and product or service representation. There are three points to consider. First, early-stage investments within corporations may facilitate innovations and the creation of new startups. Second, combining corporate funds will be a way to scale up. Third, government investment funds are essential to promote innovation and startups in various sectors. By bringing governments, academia, and industries together, it is possible to create a sustainable ecosystem that serves every stakeholder.

Discussion

The participants moved to the discussion of governmental leaderships and the amount of investments into innovations in various countries. Serendipity should be taken as an advantage, and the STS *forum* may be a base to create connections of startups with those who provide innovational culture.

Next, the participants touched on ecosystems and their adaptation in various regions considering the effect they may have on economies. It was also noted that grants play a huge role in supporting startups.

The participants also agreed that innovation starts with people and their ideas. To enable innovation, it is important to encourage society to participate in research, or to look beyond their fields by changing the existing educational systems. The participants then touched on the ways regulatory authorities can benefit when collaborating with academia.

Next, the participants agreed that it is important to provide holistic models to support startups, and to help them build and improve research capabilities.

Another topic discussed was intellectual property management issues, which startups often encounter. As most of the startups stem from university research, there is a need for guidance from bigger companies, governments, and investors.

The participants then noted that there should be some solutions found to help startups avoid common failures and to speed up their scaling, and agreed that creating entrepreneur programs may help to nurture professionals participating in startups.

S&T Education

Fostering New Generations of Scientists with Inclusion and Diversity

[Chair]

Silver, Mariko, President/CEO, Henry Luce Foundation, U.S.A.

[Speakers]

Fujigaki, Yuko, Executive Vice President, Professor, The University of Tokyo, Japan

Mandal, Hasan, President, The Scientific and Technological Research Council of Türkiye (TÜBİTAK), Turkey

Phiri, Martha, Director, Human Capital, Youth and Skills Development, AFRICAN DEVELOPMENT BANK, Cote d'Ivoire

Leyser, Ottoline, Chief Executive, UK Research and Innovation (UKRI); former Director, Sainsbury Laboratory, University of Cambridge, U.K.

Marwala, Tshilidzi, Rector, United Nations University; Under-Secretary-General, United Nations

Falk, Adam, President, Alfred P. Sloan Foundation, U.S.A.

Chen, Wen-Chang, President, National Taiwan University, Taiwan

Opening Remarks

The chair opened the session by highlighting that diversity and inclusion are enriching science, technology, engineering, and mathematics (STEM) and driving innovation. The definition of diversity and the related challenges vary by country and cultural context. Regarding gender diversity, even in countries known for advanced gender equality, the average share of female researchers is only 30% and the wage gap is another issue that needs to be addressed. To find solutions for challenges including climate change, the best minds are needed in the sciences, regardless of their background.

Silver, Mariko

The speakers next addressed the importance of cultural change. Biases of scientists are also ingrained in their research results and affect their understanding of nature. Hence, diversity and inclusion are not only relevant

for innovation but also for scientific knowledge production. Japan ranks low among OECD countries in terms of proportion of women studying science, making it crucial to raise awareness among faculty, staff, and students alike.

The speakers emphasized that to address highly complex and variable challenges such as global pandemics and climate change, developing a new type of knowledge creation is vital. While efforts including the Net Zero Emissions by 2050 Scenario and the Sustainable Development Goals (SDGs) by 2030 are ongoing, diversity is key to completing the green transition. Not only gender, but the inclusion of migrants and students with special needs must also be considered, as well as diversity among decision makers.

The speakers identified inclusion as a step toward resolving poverty, using Africa as an example. The COVID-19 pandemic demonstrated the critical role of science and technology for the future of mankind. Considering the issue of mismatched skills, STEM education must teach the skills necessary for driving sustainable and climate-resilient growth. Supporting women in STEM, leveraging AI, and fostering partnerships between academia and the private sector are important steps for building the required infrastructure.

The speakers stated that to create diverse groups that can develop creative solutions, an environment that welcomes disagreement and difference is necessary. To build this new

research culture, assessments must be made more inclusive, recognizing excellence beyond current academic norms, including experience and engagement with a wide range of stakeholders. Furthermore, the full range of roles required to enable the scientific endeavor should also be considered in discussions about inclusion.

Next, the speakers hypothesized that the creation of equal and just systems was only possible through diversity and inclusion. Providing equal education opportunities, experiences abroad, and an interdisciplinary curriculum can contribute to the diversity necessary for achieving sustainable development. Excluding part of the globe from access to technology and knowledge will perpetuate inequalities and hinder creative solutions to climate change. Empowering young people from diverse backgrounds is necessary to challenge the exclusive nature of the STEM curriculum.

The value of discussing the topic in a global context was emphasized, as academic leaders, governments, foundations, and the private sector can contribute to shaping the educational ecosystem. The role of institutions is vital, and grants to universities with concrete plans for diversity, equity, and inclusion can be a crucial step to achieve a systematic change of culture in the scientific community.

The speakers concluded that diversity and inclusion are integral to raising the next generation of scientists. A safe environment for people of different backgrounds must be created, including support networks for international students, promotion of women in STEM with flexible solutions for managing work and family obligations, and affirmative action to include those from less privileged socioeconomic backgrounds.

Discussion

The participants acknowledged that both attracting and retaining people of diverse backgrounds in the STEM field must be discussed. Data needs to be collected to identify the reasons for leaving scientific institutions, such as through exit interviews. Regarding the inclusion and retention of female researchers, special attention must be given to cultural differences and childrearing. Institutions need to provide resources to support all members, regardless of gender, to retain a diverse pool of scientists.

The participants highlighted the importance of nurturing interest in science at the early stages of K-12 education by introducing diverse role models. Furthermore, the use of storytelling to enhance public engagement, the role of peers and peer review, and the

responsibility of leadership to create explicit and transparent rules were discussed. The issue of hierarchy among the sciences—with social sciences at the bottom, despite their importance in climate change measures—was also addressed.

The participants also mentioned the need to increase the use of affirmative action at universities in Japan and identified a lack of eagerness among Japanese students to engage in internationalization following the COVID-19 pandemic. Other challenges in academia include women being viewed as a token to fill a quota, the role of the lingua franca, English, being either inclusive or exclusive, and the role of AI in potentially mitigating existing barriers.

The participants agreed that a superficial approach to diversity and inclusion would not suffice. Instead of focusing exclusively on numbers and quotas, the overall objective needs to be considered, addressing both conscious and unconscious biases. Another important question raised was how to manage disagreement and facilitate discussion without isolating those with differing opinions.

Finally, the participants emphasized the importance of statistical evidence for assessing diversity, equity, and inclusion. The roles of private and public universities, and the impact of education subsidies were also mentioned.

S&T Education
AI in Education

[Chair]
Tan, Eng Chye, President, National University of Singapore (NUS), Singapore

[Speakers]
Chaudhuri, Subhasis, Director / President, University, Indian Institute of Technology Bombay (IIT Bombay), India
Fuchs, Alain, President, Université PSL (Paris Sciences & Lettres), France
Quirion, Rémi, Chief Scientist of Quebec, Canada; President, International Network for Governmental Science Advice (INGSA)
Steen, Tomoko Y., Director & Professor, Department of Microbiology and Immunology, School of Medicine, Georgetown University, U.S.A.; External Advisor, Office of Health Services; Federal Research Division, Library of Congress

Opening Remarks

To start the session, the chair pointed out that for beneficial use of AI in education, the perspectives of learners, educators, researchers, and institutions need to be considered. Universities should educate students how to harness AI tools in a responsible and ethical way, and leverage and evaluate outputs from AI. In using AI, our students must demonstrate originality, voice, and intellectual engagement with content, and contribute to discourse.

Tan, Eng Chye

According to the "The Future of Jobs Report 2023" by the World Economic Forum, job growth in the technology sector involving AI is significant, and analytical thinking, evidence-based argumentation, and communication skills are predicted to have the highest value. Concurrently, continuing education will be crucial as many existing skills will become obsolete, so upskilling and reskilling of the workforce will be required. Enabling educators to equip learners with soft skills such as inter-disciplinary thinking and discernment will be integral.

The speakers remarked that while the discussion often focuses on generative AI and creativity, discriminative AI and decision-making should also be addressed. Metacognition in education deserves particular attention, as many aspects of learning processes are still not understood. While AI is more efficient in some respects, some aspects of our understanding cannot be replicated by AI, such as eureka moments. Additionally, the urgent issue of students' mental health could be addressed by assessing well-being through speech pattern analysis.

Next, the speakers highlighted the importance of interdisciplinarity and basic research to make AI more reliable, fair, and secure. Cognitive sciences, psychology, linguistics, neuroscience, humanities, computer science, and engineering, among others, can all benefit from AI utilization. Furthermore, experts in ethics and philosophy need to be involved in discussing ethical and privacy concerns such as data security, biases, and technology overreliance. Interdisciplinary collaboration is vital to introduce AI smoothly in all departments and let learners of all ages benefit from it.

The speakers also addressed the concrete benefits and risks of AI use in various disciplines. In medicine, AI can be used to increase the speed and efficiency of diagnostics. However,

the output is not yet fully reliable and must not be used blindly. The knowledge and ability to make correct judgments are crucial for developing student skills. Dual use of AI technology was mentioned as a significant threat, and military service of brain-computer interfaces (BCI) was given as an example. The ethical component must always be considered from an interdisciplinary perspective to ensure the utilization of AI benefits humanity.

Lastly, the speakers emphasized the importance of providing inclusive AI education, possibly starting as early as kindergarten. Training professors and educators at all levels of education must provide students with knowledge about the upsides and downsides of generative AI. As regards the Sustainable Development Goals (SDGs), generative AI can contribute to achieving "Goal 4: Quality Education". Collaboration with civil society through public discourse is vital to successfully utilizing AI, potentially contributing to bringing science and culture closer together in the spirit of Mr. Koji Omi and the STS *forum*.

Discussion

A group discussion among the participants followed this. The participants first discussed the importance of social acceptance of new technologies, referring to the example of genetic engineering, which came to a halt as it was deemed too risky by large parts of society. Regarding regulatory bodies and frameworks, variation among countries is inevitable as evidenced in the different approaches taken to regulate the utilization of ChatGPT in education. While harnessing AI algorithms can be beneficial in many fields, humans need to make the final decisions, which was illustrated using the example of triage of patients in hospitals.

AI can contribute to making education more inclusive by providing students with individualized feedback instead of assigning grades. Resistance toward AI in the classroom will possibly change, as was the case with the implementation of the use of calculators and open-book exams. One risk of increased personalization of education is the lack of shared experience, which is integral to fostering empathy. Different countries take distinct approaches to mitigate risks like biases and factual incorrectness, with the US being more open while European countries are taking a more conservative stance.

In addition, the participants discussed curriculums and teaching methods for upskilling, reform of school systems, the meaning of teaching AI, and ways of assessing the understanding of students. The fundamental objective of education needs to be considered, as not only higher education but also the K12 curriculum will be affected by the challenges. Making AI safe and accessible while allowing students to be collaborative and focus on

non-cognitive skills is a key question, especially for the education of children and young adults.

The participants pointed out issues surrounding the mental health of students, such as AI utilization increasing the distance between professors and students, making the assessment of students' mental wellbeing difficult. Regarding plagiarism and intellectual property, definitions of terms are subject to change as technology advances, but AI must always be implemented in line with the existing data protection and privacy guidelines in each country.

Lastly, the participants highlighted that the task of educators is to help students increase their understanding of AI while also nurturing their cognitive and non-cognitive skills. The involvement of senior professors, who are on average less inclined to integrate AI into teaching than their younger colleagues, is also required. Finally, it was noted that as all countries worldwide face the task of crafting AI regulation policies, sharing the outcomes of approaches among countries could contribute to more efficient policymaking.

S&T Education
Trust in Science

[Chair]

Leptin, Maria, President, Research Funding, European Research Council (ERC); Professor, Institute for Genetics, University of Cologne, Germany

[Speakers]

Fowler, Nick, Chief Academic Officer, Research Networks, Elsevier, U.K.

Imbens, Guido, Professor, Stanford University, U.S.A. [Nobel Laureate 2021 (Economics)]

Yonath, Ada E., Director of The Helen and Milton A. Kimmelman Center for Biomolecular Structure and Assembly, and The Martin S. and Helen Kimmel Professor of Structural Biology, Faculty of Chemistry, Weizmann Institute of Science, Israel [Nobel Laureate 2009 (Chemistry)]

Papič, Igor, Minister, Ministry of Higher Education, Science and Innovation, Slovenia

Parikh, Sudip S., Chief Executive Officer, American Association for the Advancement of Science (AAAS), U.S.A.

Smith, Brooke, Director, Science and Society, The Kavli Foundation, U.S.A.

Opening Remarks

The chair opened the session by addressing the importance of trust in science, which is the foundation for solving global issues. While society expects scientists to provide solutions, there is a perception of increased trust issues of society toward science. To what extent these perceptions are true needs to be discussed and assessed. Another relevant topic is trust among scientists themselves, especially in terms of accuracy of published data and research.

Mason, Thomas

The speakers highlighted that public trust is essential for science to reach its full potential. Science must be conducted in a trustworthy way and likewise, communication among scientists and with the public must be based on trust. Since the public prefers clear

and simple messages, the complex nature of science is a hurdle. Effective communication can only be realized if all stakeholders of the scientific community take initiative.

Furthermore, the speakers stated that currently there is a high potential for growth in almost every discipline of science, which is not understood by many people outside of the scientific community. Relationships are the base for building trust, so speaking to the public and offering solutions does not suffice. Engaging as part of the community is required and the new generation of scientists needs to be provided with the necessary skill sets.

The speakers emphasized that trust must be painstakingly earned and meticulously maintained. Even though science journals have implemented guidelines regarding the use of AI, dealing with submissions that utilized AI tools is difficult. The higher number of retractions of articles creates distrust and tensions among scientists. These challenging times call for better ways of publishing to disseminate and validate scientific knowledge.

Gaining the trust of young people, who might become scientists themselves one day, deserves special attention. In general, it can be difficult to achieve trust. Additionally, loss of trust happens when information is proven to be incorrect, or when there are great uncertainties, as was the case during the COVID-19 pandemic. Scientific research and forecasts cannot be fully trusted, as the scenarios created today might be proven wrong in the future, which makes trust in science ambivalent. Furthermore, the public's interest in and feelings toward science greatly depend on science literacy.

Trust in science is highly complex as it can refer to trust in institutions, individual scientists, or disciplines. Blanket statements about "distrust of science" can be conflated feelings about climate change or vaccines. Reducing, simplifying, and shifting this narrative to one of general distrust can create challenges. It can ignore personal beliefs, lived experience, community, and culture. Instead of overemphasizing distrust issues and becoming defensive, taking tactical approaches with humility and empathy – where the scientific community truly listens to communities – can retain and broaden existing trust.

Finally, some of the speakers pointed out that policymaking regarding science always relies on the science literacy of the public. The enhancement of science literacy provides the necessary foundation for informed policy making to address global challenges. Additionally, challenges exist when decision makers must create policies only based on those aspects of science that are in line with their own political positions.

Discussion

Next, the participants had a set of separate group discussions. They talked about the role of belief systems affecting trust in science worldwide. Distrust in science can also be rooted in historical suppression and exclusion. Scientists need to consider the values and experiences of different communities. Overall, integrity and ethics are crucial, and scientists must maintain positions as neutral communicators of knowledge. A dialogue with the public across cultures, societies, and countries must be fostered.

The participants stressed communication and addressed the issue of how to determine the level of attention that different points of view deserve. To increase science literacy, critical thinking needs to be developed at an early age as a fundamental civil skill set. While exclusion must be criticized, a healthy degree of gatekeeping can be beneficial. The participants also noted that science must show more humility towards indigenous knowledge systems, which have been contributing to nutrition science and research on sustainable food systems recently. Furthermore, relationship building is integral amid the polarization of society.

While skepticism among scientists can be fruitful, mistrust between science and the public is toxic. Media training is a valuable skill for scientists, as the public consumes science content through the news and other media outlets. As visualization of data and numbers is an impactful tool to convey research results to the public, statistics need to be taught at an early age. The participants also pointed out that trust and belief in one field of science can have a positive ripple effect that carries over to other fields.

The trust of scientists themselves in the system being vital for the integrity of science, and evaluating science and research were also discussed, questioning the encouragement of scientists to increase their number of publications, which has resulted in more incremental science instead of deep research. Globally, trust remains ambivalent after the COVID-19 pandemic to varying degrees, with the politicization of scientists as an ongoing issue.

Lastly, the participants highlighted that distrust is very nuanced and requires multifaceted solutions. People define truth not only based on science, but also religious beliefs and lived experiences. Increasing trust can be achieved by including members from different backgrounds in the scientific community. At the same time, pseudo-science, distortion of facts by business, and suppression of certain areas of science further complicate communication. A fact based conversation with the public, in which both sides focus on listening to each other, is necessary to build trust.

Digital Society
Trust of Information in Digital Age

[Chair]

Blanco Mendoza, Herminio, President, IQOM, Inteligencia Comercial; former Minister of Trade and Industry, Mexico

[Speakers]

Schwier, Allison, Acting Science and Technology Adviser to the Secretary of State, Office of the Science and Technology Adviser to the Secretary, U.S.A.

Homma, Naofumi, Professor, Research Institute of Electrical Communication, Tohoku University, Japan

Isaacs, Eric D., President, Carnegie Institution for Science, U.S.A.

Angel, Marc, MEP, Vice-President responsible for STOA, European Parliament

Opening Remarks

The chair began the session by recognizing the importance of ensuring trust of information in the digital age. He explained that a recent news report highlighted how information warfare between global superpower nations is leading to massive investment to shape information that may not necessarily align with truth. Such challenges must be discussed by a wide range of experts to enhance trust in critical information sources that impact lives, and to navigate the complexities of the digital age's information landscape.

Blanco Mendoza, Herminio

The speakers then pointed out that trust is necessary for both upholding the ideals of truth and reason—key principles within the Age of Enlightenment—and serving as the foundation of modern democracies. Erosion of trust in traditional institutions and the rise of digital technologies have led to a precarious information landscape. The speed, reach, and precision of multi-modal digital content, including that generated through AI, gives rise to an asymmetric power balance, weakening the public's ability to determine trustworthiness

of information. Trust-building efforts must address both rational and emotional factors, promote media literacy and critical thinking, and utilize technological tools to combat misinformation. Simultaneously, underlying infrastructure must incentivize truth and transparency to lead to development of an updated democratic institution which combines reason, transparency, and inclusivity to protect human rights and address challenges posed by misinformation.

Next, the discussion delved into trust of information from a security viewpoint. Safeguarding data is an important starting point for trustworthy information, but cooperation with laws and regulations is vital. Another growing issue is that of digital fraud, with malicious actors spreading false information. While authenticity verification is an important tool against this, the humanities and social sciences must also be involved in solutions. Finally, source verification and creating a digital trust infrastructure were mentioned as important steps towards fostering trustworthy technology, especially with the widespread use of generative AI. These issues, while partially falling under the umbrella of security, will require cooperation across various sectors and disciplines.

The speakers then turned to the topic of AI's positive effects in science and technology, including implementations in search engines, automation of mundane tasks, and freeing

up time for researchers to carry out other meaningful work. Data privacy and data quality assessment continue to be major challenges, so involving experts for validation, developing rule-based guardrails, and implementing authorship attribution are important steps. Experts in science and technology must be transparent and communicate effectively to build trust with the public. While the challenges faced today are more complex than ever, an effective blend of approaches and standards can further unlock the potential of AI to positively impact the world.

The speakers then explored the role of trust of information from a political perspective. Building trust between scientists, technologists, legislators, and the public is essential for facing the challenges of the digital age. For digitalization to be effective, the public requires guarantees for the use of technologies, industry requires a reliable ecosystem to attract customers, and governments must enforce effective regulations. Data protection is a major issue, but progress varies greatly in many parts of the world. Moreover, data governance is integral for both legislators and companies, and must be further developed. The loss of trust in both politics and science poses a threat to democracy, so accelerated collaboration across the public and private sectors will be needed to mitigate risks of new technologies and bridge the knowledge gaps necessary to ensure trustworthy information.

Discussion

On the topic of fake news, questions were explored including the optimal timing for detecting it and defining parameters to detect. The credibility of users spreading news was also discussed, along with the philosophical question of determining what types of people may be more or less prone to spread fake news. The risk of large language models being trained on fake news was also mentioned as a major issue, highlighting the importance of developing methods to adjust and refine models.

While verifying accuracy of information was covered extensively, the participants also contemplated the need for fast validation technologies. As many such technologies still require much time to process, an ordinary user may prioritize speed, so this must be considered.

The issue of false information generated by AI having perceived trustworthiness was also pointed out. Combined with regional diversity and issues of regional distrust, a range of solutions will be necessary to gain trust and safeguard science's position as a reputable source. Since trust also is built through personal exchanges and communications,

scientists must expand their circles to include the public with effective messaging, including on ethical issues.

The participants proceeded to discuss the potential approaches to AI regulation, and generally agreed that a sectoral approach would be necessary to cover the breadth of AI technology. Additionally, the actual risks of AI technologies must be made understandable to the general public in order for suitable regulation to take shape.

Finally, the participants revisited the topic of misinformation, and its harmful effects on a transnational level. While there are many potential regulatory solutions, issues surrounding civil liberties, including suppression of legitimate speech, require careful consideration. Determining accountability for misinformation is another challenge with legal implications. Rather than forcing a model to be "truthful," an impossible task, the participants suggested treating the effects of misinformation and focusing on education for the general public, allowing them to discern truth from fiction.

Digital Society
Quest for Digital Equity

[Chair]

Adem, Alejandro, President, Natural Sciences and Engineering Research Council of Canada (NSERC), Canada

[Speakers]

Eamchotchawalit, Chutima, Governor, Thailand Institute of Scientific and Technological Research (TISTR), Thailand

Hassan, Mohamed Hag Ali, President, Sudanese National Academy of Sciences (SNAS); Sudan

Ito, Joichi, President, Chiba Institute of Technology; Co-founder, board member, chief architect, Digital Garage, Japan

del Pino-Matute, Eloísa, President, Spanish National Research Council (CSIC), Spain

Opening Remarks

The chair began by explaining how digital technology has facilitated and transformed communication, education, research, and health, but digital inequities remain both among and within nations. This digital divide persists and deepens as new digital technologies emerge, and unless the global community is able to contribute, innovation will be stifled. Various stakeholders must cooperate to address these immense challenges.

Adem, Alejandro

The speakers proceeded to emphasize the importance of achieving data equity in a global context. Global efforts are needed to bridge the digital divide, including initiatives for internet access, digital literacy, and equal participation in the digital economy. The example of Thailand was mentioned, where scientific institutes have supported small- and medium-sized enterprises through provision of technology and digital tools. Programs have led to increased income and enhanced skills, benefitting communities and individuals. However, the Global South still faces many

challenges, such as connectivity issues and adapting to local contexts to create meaningful and sustainable digital equity.

Following this, the speakers highlighted the disparities in internet accessibility between developed and developing countries. Not only is digital infrastructure needed, but a majority of those in the 46 least-developed countries lack reliable access to electricity. The proposed Global Digital Compact from the UN Secretary-General, if adopted in 2024, could be a landmark on the path to an open, free, inclusive, and secure digital future that universally benefits individuals. To achieve digital equity, it is paramount to increase access to online educational resources to foster research collaboration, utilize advanced AI models to progress digital literacy and empower indigenous communities, and forge both North-South and South-South partnerships to provide resources, expertise, and technology for bridging disparities.

The speakers then shifted the scope of discussion to the U.S. and Japan, describing the potential of AI translation to enable unprecedented inclusion in research, across cultures and languages. Simultaneously, large language models (LLMs) are resource-intensive and cost-prohibitive. It is possible that symbolic AI, rather than deep learning, could be used for certain applications and be more accessible to developing countries. AI must empower people, its biases must be addressed, and counterfactual explainability must be promoted. These issues have consequences in the areas including medicine, law, and aspects of everyday life. Inevitably, many engineers will be needed to face the numerous challenges,

so improving the social status and integration of technical professionals in countries like Japan will be necessary to accelerate digital transformation in society.

Next, the challenges posed by technological disruption were discussed. In terms of socio-economic impact of digitalization on labor markets, a trend of job polarization is emerging, with mid-level jobs occupied by the middle-class that are disappearing, replaced by robots and computers. The new jobs created are, on one hand, high-paying jobs in companies and in cutting-edge sectors (what some authors have called “brains jobs”), and, on the other hand, there are jobs in a number of companies (delivery, transport, hotels catering, retail, logistic, personal care, personal services) that create very low-paying, short-term, part-time or precarious jobs (“lousy jobs”). Digitalization has the potential to exacerbate socioeconomic inequalities and provoke an imbalance of power between individuals, countries, and regions, and even jeopardize liberal democracies. Various institutions are attempting to combat these disruptions by bolstering training programs in all areas of knowledge, including the humanities and social sciences, while raising digital skills of individuals to equip them for new jobs. Simultaneously, AI research must strive towards improving worker productivity, not just automation.

Discussion

The participants then held a group discussion, beginning with the issue of how different sectors can bridge the digital divide. Educational platforms are one important element, and solutions must be specific to domains and localities. In addition, funding organizations must support young researchers and students from developing countries through fellowship programs.

The participants also noted the importance of digital literacy programs coming from public-private collaborations. Developed countries will also need to facilitate technology transfer in developing countries to enable them to create their own tailored programs to enhance digital capabilities.

Then, the participants shared that forcing standardization of technology is not always appropriate, as new technologies such as blockchain can be part of the solution. In addition, connected learning is important to meet learners where they are and amplify support to them. This is particularly important for the young, elderly, and those with disabilities.

It was also mentioned that digital literacy skills must be taught separately from technical skills like programming, and policymakers must understand the distinction.

The story of Estonia was mentioned as an example of a "digital nation," which has undergone rapid changes in the past three decades and overcome many challenges. These rapid advancements were matched with changes in education, to bring along citizens and ensure the government could be of service to the people and provide digital services as a common good.

Other ways to advance digital equity were discussed, including improvements to data collection, training people to train others within their in-groups, and the power of monetary incentives to accelerate digital transformation, as evidenced by internet banking adoption in Thailand and India during the COVID-19 pandemic.

The participants also pointed out the importance of a wider perspective and self-reflection of society, beyond just identifying individual problems.

The participants raised concerns on the shadows of new digital developments, such as the rise of technical and social engineering fraud stemming from the adoption of electronic payments. Furthermore, during the transition period between technologies, the interfaces, such as those between paper and digital in Japan, must be maintained to prevent issues.

The discussion also touched on a range of potential solutions to maintain critical operations amidst disruptive technological shifts, and further facilitate digital access of indigenous populations. Distrust of technology remains a major challenge, but key to learn from past international collaborations and success stories seen in developing nations.

Digital Society
Data in AI

[Chair]
Flandrin, Patrick, former President, French Academy of Sciences; Director of Research, Physics Laboratory, The French National Centre for Scientific Research (CNRS), France

[Speakers]
Naganuma, Miho, Senior Executive Professional, Digital Trust Business Strategy Department, NEC Corporation, Japan
Quest, Stephen, Director-General, Joint Research Centre of the European Commission (JRC)
Kaski, Kimmo, President, Finnish Academy of Science and Letters, Finland
Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Senior Strategist, Z Holdings Corporation, Japan
Screven, Edward, Chief Corporate Architect, Oracle Corporation, U.S.A.
Kawazoe, Katsuhiko, Senior Executive Vice President, Representative Member of the Board, Nippon Telegraph and Telephone Corporation, Japan

Opening Remarks

The chair explained that recent progress in AI relies on the availability of vast data for model learning. As AI algorithms generate increasing amounts of data, this introduces both opportunities and challenges, with issues encompassing technical, economic, ethical, legal, and societal aspects. The chair encouraged participants to think of how algorithms are fed, how they operate, and how the products of such algorithms are used.

Flandrin, Patrick

The speakers first explored various ways in which AI can be utilized to solve societal problems, such as improving healthcare and optimizing the supply chain. Private companies are under pressure to manage and govern data to ensure transparency and accountability, and this requires them to consider organizational, ethical, and social aspects. Three points were highlighted for achieving effective management and governance: data access, algorithm transparency,

and the interactions between humans and AI. Prioritizing human-centric AI development over full automation is critical.

Next, the discussion delved into the importance of providing scientific evidence for policy creation. AI models are trained on immense datasets, leading to numerous problems involving biases, privacy, copyright, and disinformation. Trust in AI relies on the quality and veracity of data, and to improve this trust it is necessary to take an ethical, safe, and human-centric approach to data use. Additionally, clear guardrails must be set to guarantee transparency and accountability. Finally, when implementing AI, it is necessary to have guidelines and regulations for use, rigorous monitoring and evaluations of impacts, and measurement and auditing to mitigate risks.

The speakers then pointed out how scientific publications are illustrating the potentially transformative effects of AI on new discoveries, hypothesis generation, and data interpretation. For example, deep learning AI models in the medical field can be used to aid in disease classification. The reliability and biases of datasets must be examined carefully, especially when many models lack explainability. The reliability of data in terms of trustworthiness, as well as defending against adversarial uses of AI, are other vital considerations.

Next, four major points regarding data in AI were introduced. The first was addressing uneven access to data and the limitations of existing frameworks for privacy protection. The second was the origin and ownership of data, examining data ownership in the interaction between platforms and users. The third was trustworthiness of information, and how it can be ensured for output of generative AI. The fourth was integrating AI while respecting the autonomy of individuals, and fitting into the principles and practices of human-centric design.

The role of companies in managing data for other companies and governments was then discussed. Cloud infrastructure has unlocked the potential of AI models, and this is fundamentally transforming how applications are implemented, how data is accessed, and how people view data. Combining secure enterprise data with base large language models (LLMs) can provide relevant results for specific tasks, while reducing resource costs. Generative AI has potential to change many industries and is already increasing productivity of doctors and unlocking new possibilities for personalized treatment recommendations.

Finally, the speakers explored the key limitation of AI being unable to deny its own outputs. It was proposed that multiple AIs trained in different ways may be able to operate in a democratic way to cross-check, collaborate, and solve issues. However, as these types of AI systems advance, the technological frameworks that enable them will also need to evolve, such as through next-generation network platforms for direct optical communication.

Discussion

The participants then held a group discussion on a range of topics, including validation and ownership of data. Instituting the right oversight and ensuring reliability of data used in AI is another critical element. However, as technological advancement will not stop, regulation must adapt accordingly.

Then, the participants explored the various frameworks for privacy regulation in regions around the world, noting their respective strengths and weaknesses in terms of balancing potential benefits and mitigating threats. The roles of different actors in generating knowledge and differentiating relevant versus nonrelevant information to protect were also raised as important considerations.

The quality of data was emphasized as a key aspect of AI development, and the benefits and risks of having multiple AIs communicating were debated. While determining whether specific mechanisms are suitable depends on application areas, a benefit of AI is its ability to be tailored to particular applications.

The participants also discussed philosophical aspects of AI, including how to define whether AI is producing truthful output, and how to determine who to trust in making such definitions.

Next, the discussion went into education and acceptance of the “new normal” of AI in society. It is important to identify the areas in which AI is making improvements to life, define the shifting concept of data itself, and prepare those who will be responsible for managing these complex systems.

Various geopolitical considerations of data in AI were mentioned, such as adapting LLMs to languages with relatively few speakers and addressing the biases inherent to AI models. Finally, the participants discussed data interoperability as an area for AI to provide vast benefits, such as in healthcare.

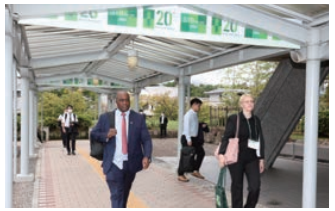
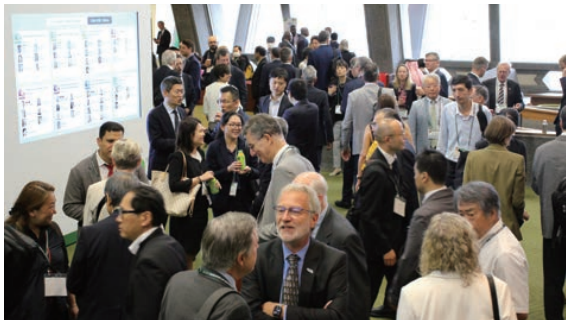
20th Anniversary Annual Meeting Photo Gallery

September 30



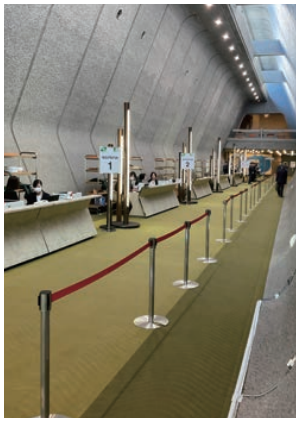


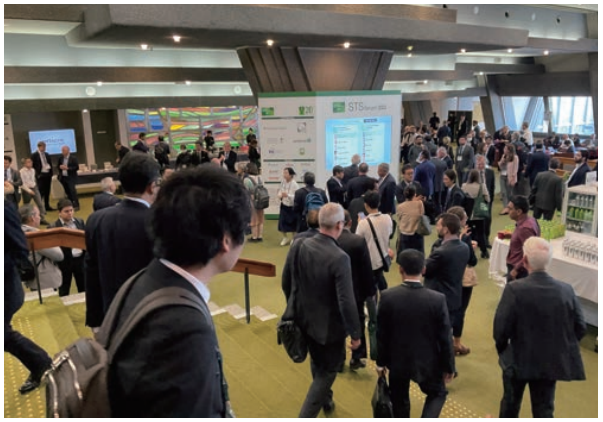

October 1 – The 1st Day

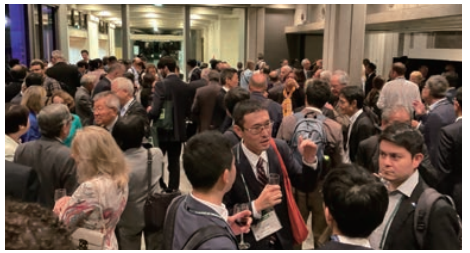





October 2 – The 2nd Day







20th Anniversary logo

The five-storied pagoda symbolizes Kyoto and Japan.

The mirroring of the upper and lower elements represents “Lights and Shadows.”

Science and Technology in Society *forum* (STS *forum*)
20th Annual Meeting
Kyoto, Japan, October 3, 2023

Statement

1. The 20th Annual Meeting of the Science and Technology in Society *forum* took place from October 1 to 3, 2023 in Kyoto, with the participation of nearly 1,500 global leaders in science and technology, policymaking, business, and media from over 80 countries, regions, and international organizations.

Artificial Intelligence

2. One of this year’s revolutionary advancements is the emergence and rapid progress of generative AI. This innovation signifies progress in science and technology, offering the potential to connect disparate fields of knowledge, extract essence from each, and integrate them in previously unimaginable ways. However, integrating AI into daily life presents risks and challenges. We must carefully evaluate the technology, recognizing both its potential and its challenges, to ensure that its benefits are universally shared and not divisive.

3. The rapid rise of Artificial Intelligence (AI) has had a transformative impact, but its dependence on vast internet-fed human data raises concerns about bias, job displacement, misinformation, and opacity in algorithms, challenging various aspects of society. Despite its potential, many experts worry about embracing AI without addressing these issues, underscoring the need for a clear approach as humanity deepens its collaboration with machine-based intelligence.

4. The advancement of AI also holds significant potential to revolutionize the field of healthcare. However, obtaining large-scale medical data can be challenging and may suffer from incompleteness or bias. The quality of data used to train AI algorithms is also crucial for their accuracy. These issues highlight the need for establishing frameworks and ongoing monitoring to expand the benefits of AI in the field of healthcare.

Digital Equity

5. Digital technology has facilitated and transformed almost every aspect of our lives, including communication, education, research, business, and healthcare. However, since the beginning of this digital revolution, its impact has been uneven and currently, about one-third of the world's population remains unconnected to the internet. Unequal access and distribution of digital technology limit individual opportunities and deprive the global community of diversity in ideas and contributions that drive innovation. Finding ways to bridge the digital divide is an urgent challenge.

Trust in Information

6. In contemporary society, trust in information is indispensable for personal choices, business decisions, and government policies. Various risks challenge this trust, from misinformation and disinformation to biases and lack of transparency. Data manipulation and ethically questionable research also erode trust in information sources, as do security breaches. Ultimately, distrust in information exacerbates social and political divisions, hindering constructive dialogue and decision-making. These risks must be acknowledged and addressed through policy-making and multifaceted collaboration.

Climate Change

7. There is a broad scientific consensus that increased CO_2 concentration in the atmosphere is a driving force behind climate change. Despite commitments from countries worldwide to reduce emissions, we have yet to reverse the trend of increasing emissions. To achieve net-zero emissions within the necessary timeframe and avoid unacceptable environmental consequences, we require technology development, infrastructure investment, and policy changes. The industrial sector poses the most challenging and time-consuming task in terms of decarbonization due to its complex energy use. Considering the difficulty of complete decarbonization in some sectors, we must explore negative emissions options to offset remaining emissions. But these efforts at mitigation of GHGs emissions, must be accompanied by expanded efforts at adaptation and resilience, especially for the poorest and most vulnerable populations, who are already suffering the consequences of the extreme weather events.

Food and Water Security

8. With the evidence of global warming now incontrovertible, and ever-increasing amounts of greenhouse gases in the atmosphere, food and water security in the global system are central to the well-being and potential survival of many millions of people. Climate change is only one of many stressors on the global system, among them environmental destruction and regional and global conflict, all in the context of increasing incidences of natural disasters.

   The food and Agricultural Sector is currently the major consumer of water withdrawals, and is also a major emitter of GHGs. Yet it also has enormous wastage and much of the food produced never reaches the consumer. Thus mobilization of new technologies, from genetically improved crops to the use of remote sensing and ICT to optimize soil, water and nutrient management, in a Climate Smart Agriculture (CSA) and precision agriculture is essential.

Biodiversity

9. A 2005 report by the Millennium Ecosystem Assessment found that 60% of global ecosystem resources were degraded or unsustainably used. In 2019, the Intergovernmental Platform on Science-Policy Advice on Biodiversity and Ecosystem Services warned that one million out of eight million species are threatened with extinction. Despite a 2010 plan to halt biodiversity loss, none of the 20 Aichi Biodiversity Targets were met by 2020. After four years of negotiation, the Kunming-Montreal Global Biodiversity Framework was adopted in December 2022, aiming to protect biodiversity, restore ecosystems, and safeguard indigenous rights. It set a goal to putting 30% of the planet under protection by 2030 and increasing financing for developing nations, emphasizing the vital role of the private sector in addition to government responsibilities. The global Gene Banks are a vital resource for humanity, and the very large collections of accessions need to be fully genetically analyzed and catalogued, to increase the searchability and analytically driven utilization of the sample accessions.

Preparing for the Next Pandemic

10. Preparing for the inevitable next pandemic is the highest priority for humanity. The rate at which zoonotic infections are affecting human populations is likely accelerating, primarily associated with climate change, and thus monitoring diseases in both wildlife and domesticated animals is crucial. To ensure quick delivery of tests, vaccines and treatments in an unfolding pandemic, rapid sharing of data and sequence information is vital. Testing, tracing, and containing any new pandemic are essential, as are establishing research protocols and infrastructure and keeping them on standby in preparation for the next pandemic. Much greater equity in the access to tests, vaccines and therapeutics should be ensured for all regions and people.

Basic Science

11. Today, we face ever greater challenges: climate change, food security, increasing energy demand, rising social inequalities or the outbreak of epidemics are just some examples. Science has a key role to play in addressing such complex issues, and curiosity-driven research helps lay the foundations for more effective approaches to meet these challenges. Basic research can lead to breakthrough innovations, but requires certain framework conditions in order to fully develop its innovative potential, which are often not adequately mirrored in policy goals. Sufficient funding doubtlessly is an important aspect for basic research to flourish, but policy agendas must also focus on creating optimum conditions allowing for basic research to be translated into application and innovative technologies.

Collaboration

12. Collaboration among industry, academia, and government is essential for advancing science and innovation in the modern knowledge-based economy, harnessing the strengths of each sector to drive progress, economic growth, and societal advancement. Industry brings market insights and resources, academia provides theoretical frameworks and environments for knowledge exploration, and government offers regulatory frameworks, funding, and a macro-level perspective on national priorities. However, the tripartite model has its challenges such as power imbalances and sometimes conflicting goals. To address power imbalances among tripartite collaborators and mitigate risks of technology misuse or abuse, there is a need to cultivate an environment of stakeholder inclusion, open discussion, promotion of interdisciplinary solutions and building regulatory frameworks that facilitate effective cross-sector implementation. International collaboration is also needed for developing scientific monitoring and early warning systems as the world faces ever more risks.

Space Utilization

13. Fifty years on from the completion of the Apollo program, the frontier of space is finally opening up. Access to space, previously monopolized by a few superpowers, is becoming increasingly open to the general public due to the proliferation of commercial enterprises. At the same time, using space for security and surveillance purposes has expanded. Global accessibility to space promises increased international cooperation, economic opportunities, new types of technological innovations, advanced communication, comprehensive environmental monitoring, and scientific advancements. However, challenges related to governance, ethical dilemmas concerning surveillance safeguards, and the potential for militarization will arise. Cooperation and collaboration are required to establish norms and regulations that promote the peaceful and equitable use of space.

14. Our explorations of these and other issues are far from over. We will continue our interactions and discussions to accompany the evolving lights and shadows of science and technology in the world. We look forward to convening again next year in Kyoto and have agreed to hold the 21st Annual Meeting of the STS *forum* from Sunday, October 6 to Tuesday, October 8, 2024.

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As of October 20, 2023

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