19th Annual Meeting

STS *forum* 2022

Summary

October 2, 3 and 4, 2022

Kyoto, Japan

Science and Technology in Society *forum*

Summary of STS *forum* 2022

STS *forum* 2022 - 19th Annual Meeting

October 2-4, 2022

Plenary Sessions | Concurrent Sessions | By Invitation Only

October 1, 2022 (Saturday)

10:00-18:30	Registration (for all STS *forum* participants) [The Prince Kyoto Takaragaike]	12:00-12:50	Young Leaders Network
		12:50-15:30	Dialogue between Young Leaders and Nobel Laureates
		12:30-15:30	11th Global Summit of Research Institute Leaders
		13:30-17:50	Regional Action on Climate Change (RACC14) [Room A]
		14:00-16:40	Kyoto Symposium
		15:30-17:00	Academy of Engineering Presidents' Meeting
		15:30-17:30	Board Meeting
		16:00-17:50	S&T Ministers' Roundtable
18:00-20:00	Networking Plaza [The Prince Kyoto Takaragaike]		

October 2, 2022 (Sunday)

08:30		Doors open and Registration starts at the Kyoto International Conference Center (ICC Kyoto)			
10:00-11:00 60 min.	100	**Opening Plenary Session 100: World in 2022 — What do we need from S&T? [Main Hall]**			
11:00-12:00 60 min.	101	**Plenary Session 101: Path to Sustainability [Main Hall]**			
12:00-13:40 100 min.		Lunch and Networking Time	12:00-13:30	CEO Meeting	
			12:00-13:30	CTO Meeting	
			12:00-13:30	University Presidents' Meeting	
			12:00-13:30	Heads of Private Foundations Meeting	
13:40-14:40 60 min.	102	**Koji Omi Memorial Lecture 102: Conversation with Prof. Joseph Stiglitz [Main Hall]**			
14:40-15:10		Coffee Break			
15:10-17:10 120 min.	103	Energy	Climate Change	Earth and Commons	Life Sciences
		Action for Net-Zero Emissions [Room D]	**Adaptation to Climate Change [Room A]**	**Agriculture, Food and Water Security [Room J]**	**Preparing for the Next Pandemic [Room C-1]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		Revolutionary Materials and Devices [Room K]	**Science and Technology as a Driver for Development [Room C-2]**	**Inclusion and Diversity in STEAM Education [Room B-1]**	**Big Data (Opportunities and Risks) [Room B-2]**
17:10-17:40		Coffee Break			
17:40-18:40 60 min.	104	**Plenary Session 104A: Breaking Silos in Research: How can Inter-disciplinary Research be Effectively Conducted? [Main Hall]**		**Plenary Session 104B: Groundbreaking Technologies [Room A]**	
18:45-19:20 35 min.	105	**Plenary Session 105: How can Chemical Industry Contribute to Next Zero Society [Main Hall]**			
19:40-21:00	106	Official Dinner [Event Hall]			

October 3, 2022 (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	**Plenary Session 200: Analysis and Synthesis in Science -- The Human Body and Mind [Main Hall]**			
10:10-10:40		Coffee Break			
10:40-12:40 120 min.	201	Energy	Climate Change	Earth and Commons	Life Sciences
		Transitional Path toward Renewable Energy [Room D]	**Financing the Sustainable Economy [Room A]**	**Biodiversity and Ecosystem Services [Room J]**	**Future of DNA- & RNA- based Technologies [Room C-1]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		Quantum Science and Technologies [Room K]	**Collaboration among Academia, Industry and Government [Room C-2]**	**Science Literacy for All [Room B-1]**	**Pandemic of Ransomware [Room B-2]**
12:40-14:10 90 min.		Lunch and Networking Time		12:40-14:10	Funding Agency Presidents' Meeting
				12:40-14:10	Academy of Science Presidents' Meeting
14:10-16:10 120 min.	202	Energy	Climate Change	Earth and Commons	Life Sciences
		State of the Arts Energy related Technologies [Room D]	**Negative Carbon Technologies [Room C-1]**	**Protecting Ocean Environment [Room J]**	**Preserving Health in the 21st Century [Room A]**
		Innovative Engineering	Cooperation in S&T	S&T Education	Digital Society
		Autonomous Robotics [Room K]	**Fostering New Generations of Scientists [Room C-2]**	**New Systems of Learning [Room B-1]**	**Information Authenticity and Governance [Room B-2]**
16:10-16:40		Coffee Break			
16:40-17:50 70 min.	203	**Plenary Session 203A: Basic Science, Innovation and Policy [Room A]**		**Koji Omi Memorial Plenary Session 203B: Lights and Shadows of AI [Main Hall]**	
17:50		Move to the venue			
18:30-20:30	204	Special Dinner at The Westin Miyako Kyoto (shuttle bus provided from ICC Kyoto to site)		20:30-22:00	Council Meeting

October 4, 2022 (Tuesday)

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

Table of Contents

Program 2

Plenary Sessions

Opening Plenary Session: World in 2022 -- What do we need from S&T? 8
Path to Sustainability 15
Koji Omi Memorial Lecture: Conversation with Prof. Joseph Stiglitz 21
Breaking Silos in Research:
How can Inter-disciplinary Research be Effectively Conducted? 27
Groundbreaking Technologies 33
How can Chemical Industry Contribute to Next Zero Society 40
Analysis and Synthesis in Science -- The Human Body and Mind 44
Basic Science, Innovation and Policy 51
Koji Omi Memorial Session: Lights and Shadows of AI 57
Key Messages from Concurrent Sessions 63
Closing Plenary Session: Science and Technology for the Future of Humankind 71

Concurrent Sessions

[Energy]

Action for Net-Zero Emissions 78
Transitional Path toward Renewable Energy 81
State of the Arts Energy related Technologies 85

[Climate Change]

Adaptation to Climate Change 89
Financing the Sustainable Economy 93
Negative Carbon Technologies 97

[Earth and Commons]

Agriculture, Food and Water Security 101
Biodiversity and Ecosystem Services 105
Protecting Ocean Environment 109

[Life Sciences]

Preparing for the Next Pandemic 113
Future of DNA- & RNA- based Technologies 117
Preserving Health in the 21st Century 121

[Innovative Engineering]

Revolutionary Materials and Devices 125
Quantum Science and Technologies 129
Autonomous Robotics 133

[Cooperation in S&T]

Science and Technology as a Driver for Development 137
Collaboration among Academia, Industry and Government 140
Fostering New Generations of Scientists 144

[S&T Education]

Inclusion and Diversity in STEAM Education 147
Science Literacy for All 151
New Systems of Learning 154

[Digital Society]

Big Data (Opportunities and Risks) 158
Pandemic of Ransomware 163
Information Authenticity and Governance 167

Statement 171
Board Members 178
Council Members 180
Members 186

Plenary Sessions

Opening Plenary Session: World in 2022 -- 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

Gabriel, Mariya, Commissioner for Innovation, Research, Culture, Education and Youth, European Commission

Nzimande, Bonginkosi Emmanuel "Blade", Minister, Department of Higher Education, Science and Innovation, South Africa

Panchanathan, Sethuraman, Director, National Science Foundation (NSF), U.S.A.

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., welcomed the participants to the 19th annual meeting of STS *forum*, thanking them for their attendance and the sponsors for their contributions. He then explained how, throughout the history of humankind, society and civilization have continued to advance, but at a slow pace, until the Industrial Revolution, from which point these advances greatly accelerated, powered by science and technology and resulting in, for example, significantly increased human life expectancy.

Chair: Komiyama, Hiroshi

At the same time, however, there are also many issues that cast shadows on the future of humankind. Human activities have had an enormous impact on the Earth. For example, manmade objects cover the Earth's surface. Furthermore, one third of the CO_2 in the atmosphere is produced by human activity. Can humanity solve these problems and create prosperous societies, or will it fall into ruin? The answer depends on humans and their actions.

That said, there are reasons for hope, such as renewable and non-fossil-fuel energy sources. In addition, many manmade materials are reaching a state of saturation and recirculation, whereby it will no longer be necessary to harvest them from nature; rather it will be possible to recycle them from artificial objects. Recycling can also be powered by solar energy. It is therefore possible, in theory, to develop a circular and sustainable society, and there are scientific and technological developments to support that. However, it is necessary to address issues such as social divides, poverty, and war.

Human knowledge is also another source of hope. Virtually all issues can be resolved if the right knowledge is appropriately mobilized. The COVID-19 pandemic is an excellent example of this, with the scientific community developing effective vaccines so rapidly. At the same time, knowledge must be mobilized and integrated across different disciplines. However, its vastness and scattered nature make this very difficult. Nevertheless, action must be taken to that end.

STS *forum* is a venue for discussing the issues facing humankind from a long-term perspective of hundreds of years. It is also necessary to incorporate new perspectives, so STS *forum* has established a Revenue Committee to discuss how to further grow the organization. Sadly, however, STS *forum* has also lost two towering figures in founder and former Chairman Koji Omi and former Prime Minister Shinzo Abe. To commemorate the invaluable contributions and founding vision of Chairman Omi, this year's annual meeting includes two Koji Omi Memorial Sessions.

Science and technology have the potential to either bring humanity a disastrous future or a bright one. Humankind must discuss how to break silos in science, politics, and many other areas to find a path to the latter. One initiative to that end is the Platinum Society Network, which envisions a sustainable and prosperous world where all can achieve self-fulfillment.

In closing, Prof. Komiyama stated his belief that, if all participants of STS *forum* come to their own conclusions and take action to transform society, humanity will move in the right direction. He also noted that this year's annual meeting is the first to be held in person in three years and looked forward to wide-ranging discussions across disciplines and fields of activities.

Kishida, Fumio

Mr. Fumio Kishida, Prime Minister, Japan, began by expressing his condolences on the loss of former Minister of Finance Koji Omi and former Prime Minister Shinzo Abe. As founder and Chairman and as Honorary Chairman, respectively, they made special contributions to the concept of STS *forum*, which is to provide not only scientists, but also politicians, business leaders, journalists, and others the opportunity to gather together and hold dynamic discussions on science and technology in society.

This concept of collaboration continues to grow in importance. For example, it lay at the heart of the rapid development and rollout of vaccines against COVID-19 through the joint efforts of governments, scientists, businesses, and citizens. Moreover, no one country can tackle such issues alone and all countries must work together.

Japan values science and technology and has been enjoying growing expectations in this area from around the world. The Japanese government is pursuing a new form of capitalism that seeks to turn social issues such as climate change into engines of growth. Innovation through science and technology is a major driver of this concept. The Japanese government will enhance basic research, including investment in people, and promote global brain circulation with like-minded countries. As for economic security, the Japanese government will foster public-private partnerships in areas such quantum technology, AI, and biotechnology. It will also formulate principles for the appropriate use of science in collaboration with other countries. It is hoped that STS *forum* will also act as a compass for the appropriate use of, and collaboration in, science and technology.

Ms. Mariya Gabriel, Commissioner for Innovation, Research, Culture, Education and Youth, European Commission, opened her remarks by paying tribute to Chairman Omi as founder of STS *forum*, and stressing that the participants have a duty to carry on his vision and spirit.

She then asked a question: What is needed from science and technology? Firstly, science and technology should help society anticipate needs, and develop knowledge and technologies that benefit society in the long term. Science and technology also help find solutions to current and future challenges, such as global semiconductor shortages. The European

Union has long been investing in such semiconductor technologies to reinforce the industry. Another important area of research for solving future challenges is in technologies for addressing future raw material shortages.

From the opposite perspective, what do science and technology need from governments? They need sustained public investment in research, and the European Union has continued to increase investment as a percentage of GDP. Beyond investment, science and technology need collaboration, synergies, and people. Governments need to support the scientists who drive science and technology forward. To that end, the European Union is working to reform systems for evaluating and nurturing researchers, and to incorporate diverse perspectives.

Gabriel, Mariya

Nzimande, Bonginkosi Emmanuel “Blade”

The European Union’s Horizon Europe program for research and innovation is open to the world, and Japan, for example, has produced many successes in cooperation with this program. The European Union considers it important to take a value-based approach to science and technology, and believes that science and technology developed in such a way are drivers of growth and prosperity. Humanity may face many challenges but collaboration in science, across countries, researchers, and disciplines, will lead the way to solving them.

Dr. Bonginkosi Emmanuel “Blade” Nzimande, Minister, Department of Higher Education, Science and Innovation, South Africa, started by stating that science and technology embody some of the best qualities of humanity, have lifted millions out of poverty, and have, on average, improved quality of life for a large part of humanity. They are also tools for a more humane and equitable world, enabling humans to live in greater harmony with the natural world. However, the world is faced with three overarching planetary challenges: changes in the climate system; the persistence of deepening levels of inequality, poverty

Panchanathan, Sethuraman

and unemployment in the world; and a failure to establish and maintain a truly democratic and multilateral system of international collaboration.

The world is constrained by economic difficulties that create poverty and unemployment. New forms of science and technology are needed to tackle them. For example, there is a need to scale up science and technology investment. There is also a need for more equitable ways to deal with the planetary health challenges that have been exposed by the COVID-19 pandemic. The pandemic has revealed the positive side of science and technology, such as the rapid development of vaccines, but also the negative, including the hoarding of vaccines and export restrictions on pharmaceutical ingredients.

South Africa is investigating the establishment of a multidisciplinary center for the study of future pandemics for the African continent linked to climate change. This must be linked to advancing a research and development agenda for the continent. Another central challenge for humanity is finding new and less harmful energy sources than fossil fuels. In this regard, South Africa and Japan are collaborating on developing a green hydrogen economy.

In closing, Dr. Nzimande stated that he is looking forward to attending the Tokyo Green Transformation Week and continuing to develop green hydrogen partnerships with Japan, and invited the participants to attend this year's World Science Forum, which South Africa is hosting.

Dr. Sethuraman Panchanathan, Director, National Science Foundation (NSF), U.S.A., declared that global collaboration among like-minded partners is at the heart of the best science. It is made possible by shared fundamental values, including openness, transparency, reciprocity, research integrity and respect for intellectual property, among others, and by shared aspirations. STS *forum* founder and former Chairman Omi understood this well. Dr. Panchanathan expressed his condolences on Chairman Omi's passing, noting that Chairman Omi set out a vision for global collaboration that can be carried on for decades.

Dr. Panchanathan then expressed his belief that science should be global and that it is necessary to bring together global expertise to address global challenges. An example of truly global collaboration is the recently captured first photos of a black hole. This was only made possible by the coordinated efforts of hundreds of researchers from several countries working together with observations from eight telescopes around the world.

Tokura, Masakazu

It is also necessary for nations to unleash all their talent, across geographic and socioeconomic spectrums. They must boost their existing talent-development efforts, which have much room for improvement. If they do not, they will miss an opportunity to achieve the dream of solving global grand challenges.

Another important consideration is ensuring the full adoption of solutions. The pandemic taught humanity several lessons. One is that the world can unleash talent and knowledge anywhere and everywhere. On the other hand, while science has produced unbelievable solutions, the solutions are often not fully adopted, because the perspectives of the social, behavioral and economic sciences have not been included, or not included early enough. Transdisciplinary collaborations need to happen upfront. The NSF is promoting collaboration across all disciplines, as well as partnership with industry, foundations, educational systems and others to ensure the design of comprehensive and targeted solutions that can be developed into technologies that can deployed at speed and scale.

Mr. Masakazu Tokura, Chairman, Keidanren; Chairman of the Board, Sumitomo Chemical Co., Ltd., stated that STS *forum* provides a valuable opportunity for global leaders, distinguished scientists, and other experts to discuss major issues in science and technology and the future of humanity, together. In recent years, the global socio-economic environment has become increasingly uncertain, with a number of pressing issues ranging from health and medical problems to climate change, energy, food, and national and global security. One of the major causes of these issues is excessive capitalism and the trend towards shareholder supremacy, resulting in growing and entrenched social disparities and deterioration of the Earth's ecosystem.

Capitalism promotes free and open competition, efficient allocation of resources, and advances in science and technology. However, considering the challenges produced by excessive capitalism, it is now time to change capitalism's course. Sustainability initiatives such as the Sustainable Development Goals (SDGs) are gaining momentum. It is necessary also to develop social common capital, such as social infrastructure and institutional capital. Keidanren is working to establish sustainable capital and is committed to establishing Society 5.0 and achieving the SDGs by incorporating social perspectives into market economics. Science and technology are key to promoting a more sustainable society, to solving social challenges, and to achieving sustainable growth.

Finally, Mr. Tokura expressed his belief that STS *forum* is the ideal venue for bringing together the wisdom of distinguished scientists, political leaders, and business leaders to discuss such ideas internationally, and share their valuable views and insights. He expressed his wish for the annual meeting to be a success and produce fruitful discussions on how science and technology can address the problems the world faces and pave the way to a better and sustainable future for humanity.

Path to Sustainability

[Chair]
Dijkgraaf, Robbert, Minister, Ministry of Education, Culture and Science, Netherlands

[Speakers]
Andersen, Inger, Under-Secretary-General of the United Nations and the Executive Director of the United Nations Environment Programme, United Nations
Nishimura, Yasutoshi, Minister of Economy, Trade and Industry, Ministry of Economy, Trade and Industry; Member, House of Representatives, Japan
Uchiyamada, Takeshi, Chairman of the Board, Toyota Motor Corporation, Japan
Al-Khowaiter, Ahmad O., Chief Technology Officer, Management, Saudi Arabian Oil Company, Saudi Arabia

[Online Speaker]
Munasinghe, Mohan, Chairman, Munasinghe Institute for Development (MIND), Sri Lanka

Opening Remarks

Dr. Robbert Dijkgraaf spoke of the greatest challenges facing humanity, namely averting climate change and the destruction of biodiversity. Stemming environmental pollution and the continued production of greenhouse gas emissions will only be possible by taking an integrated approach. The Netherlands and its government are committed to ecological and social sustainability and upholding the international treaties on sustainability that it has signed. The Netherlands is committed to sustainability and is aiming for a target of 60 percent reduction of carbon dioxide emissions by 2050. Science and technology will also play a pivotal role in creating the awareness in society to achieve these targets and they are key to overcoming these global challenges.

Chair: Dijkgraaf, Robbert

International cooperation is vital to realize a sustainable society as global challenges evidently require global solutions. This cooperation cannot take place without the support

and development of young talent in the fields of science and technology. Research and innovation, too, must be a critical area of focus because it is basic research that will bring about the creative and innovative solutions that will help address the global challenges of climate change and loss of biodiversity by leveraging humankind's imagination and curiosity. Moreover, most importantly, the cooperation to solve these challenges will not be truly realized without effective public engagement with society in balance with politics and business.

Ms. Inger Andersen addressed the technological and societal challenges the planet is facing and highlighted that the contemporary model of economic growth has created a triple planetary crisis of climate change, pollution and biodiversity loss. Furthermore, the international frameworks for addressing global sustainability and carbon emission targets such as the Paris Agreement are impeded by the current trajectory that has been shown to be insufficient to meet such targets. Thus, global action should be taken in a multitude of approaches. The fields of science should be accessible and understandable to all to empower all stakeholders to address global challenges with the right toolbox and to disarm those who use misinformation and false facts to support their arguments. In this regard too, scientific facts should not be held behind paywalls to help the diffusion of scientific fact into international discourse. Moreover, academia and intellectual institutions must be fully engaged in cooperation to help humanity address these global challenges. Further to this point, the youth, young leaders and young scientists will need the proper support and training on sustainability; sustainability will need to be studied by all, in all fields, to realize global sustainability targets.

The solutions to climate change will bring benefits in the long term, but this is not the first time that humanity has addressed such challenges. However, urgency must be a priority. Solutions could also be realized by studying nature itself as forests offer natural cooling mechanisms for heat in the environment and provides protection during storms. Science needs to be proactive and diversify to meld ideas and deliver solutions working with nature, diverse stakeholders, and the youth.

Mr. Yasutoshi Nishimura spoke on how Japan will transform its economy and society to decarbonize with a stable energy supply and strengthen its circular economy. Japan has set the bold goal to become carbon neutral by 2050 and to reduce greenhouse gas emissions by 46 percent by 2030. It will take strong action to ensure a stable supply of energy in the face of international conflict such as the Ukraine invasion.

Furthermore, it will develop a carbon pricing framework to maximize emission reductions and accelerate investment and expediate the decarbonization of society. Notably, it will provide 14 billion U.S. dollars over 10 years to spur investment in decarbonization technology and promote investment to create new carbon markets. In addition, it will promote expansion of climate change reduction targets by including companies in frameworks. Also, the current administration has begun a demonstration project for a carbon credit market. Japan also promotes cooperation in the field of clean energy with the United States, particularly around hydrogen and ammonia technologies.

Toward the realization of a sustainable, circular economy, the Japanese government has invested in bio plastics and other bio innovation with national companies, such as hydrogen bacteria to absorb carbon dioxide from the environment. The administration will make bold investment of 1.2 million U.S. dollars from its green energy fund to investigate plant-derived biopolymers, which have characteristics similar to plastics. Other examples of its progress to a circular economy are the medals for the Tokyo 2020 Olympic and Paralympic Games, which were made from recycled small metals waste. The goal is for Japan to create a virtuous circular and growth-oriented autonomous consumption and production system.

In international fora, Japan will chair the G7 and provide guiding leadership for the G7 nations to the pathway to energy security and carbon neutrality. Also, it will be host to the Osaka Kansai Expo which will be a testing ground for future societal innovation. Through these efforts, Japan will contribute to the realization of a sustainable path for the entire world.

Mr. Takeshi Uchiyamada stated that humankind was facing complex global issues that are difficult to solve and that will require innovative solutions. In the course to address carbon neutrality in transportation, electric and fuel-cell vehicles have been developed by automakers. However, such products are only a part of the solution. When considered by lifetime carbon impact, the carbon footprint of these products, in fact, is best understood in the relationship with grid energy producers and industrial processes that are used to create and to fuel such vehicles. Therefore, carbon neutrality must be considered from a long-term perspective and include the entire energy system ecosystem. The solution for transportation, for example, must also include air transport, ships, and trains, which cannot be electrified in the same way as passenger vehicles. The same is true of other energy intensive industries such as steel making and power generation.

Therefore, it is evident that hydrogen, as an energy source and energy carrier, will be a critical part of the energy transition. Japan and other countries are investing in developing the infrastructure necessary to adopt these energy technologies to increase the options available to reduce global carbon emissions. China, also, is investing in fuel-cell technologies for transportation. Nevertheless, challenges remain in reducing costs of hydrogen infrastructure development, creating affordable supply, and expanding demand. Organizations and companies in Japan, such as the Japan Hydrogen Association, are promoting the cross-industry scale use and adoption of the hydrogen supply chain. Mr. Uchiyamada stressed that not limiting options is important for achieving carbon neutrality and expressed his hopes that STS *forum* will serve as an opportunity for such cooperation.

Mr. Ahmad O. Al-Khowaiter stressed the need for a pragmatic path to sustainability following realistic and fact-based discourse to bring the world to sustainable energy systems. Aramco shares the values that science and technology are the solution to the global challenges. Global wealth as measured by GDP remained low for thousands of years until the 1800s, when it sharply rose due to the discovery of hydrocarbons such as coal which brought the huge scale of energy use seen today. Scaling energy solutions is the greatest challenge that humanity faces, and all nations will need to consider how to sustain quality of life and scale energy use to the future. All stakeholders need to be pragmatists and should use existing energy systems and only replace what is necessary. Oil and gas have met most of the energy needs of the 20th century and will continue to do so as they are cheap, are energy carriers and energy storage, and are transportable. Also, carbon materials are the enablers of the energy transition, used in the creation of membranes, polymers and chemicals that underlie wind and solar technologies. The energy transition will require all parties to work together

rather than apart, as careful consideration is given to the level of investment in existing oil and gas infrastructure. All pathways involve hydrocarbons, but there will be changes in the way oil and gas are consumed. Producing the lowest carbon intensity oil is vital and this will be sought via reducing the emissions that are produced in production and transport. This, along with the transition of liquid and natural gas to hydrogen, whereby Japan and its partners will help create the standards for blue hydrogen, will be the basis of infrastructure investment that facilitates the transition.

Prof. Mohan Munasinghe explained that the best way to achieve sustainability will include integrating the triangle of economic prosperity, social progress, and environmental protection, and getting onto the balanced inclusive green growth (BIGG) path. These are the means with which humankind can simultaneously overcome poverty, inequality, biodiversity collapse, and climate change. Weak leadership at the top, in particular, may be addressed by better leadership at the middle level, including city mayors and company CEOs; it is at these levels that leaders are more willing and able to push for solutions.

By 2030, the ecological footprint of humanity will require two planets to sustain our lifestyles. Furthermore, consumption is inequitable, with 85 percent of consumption done by 20 percent of the richest people – more than 70 times the consumption of the poorest 20%. The global rich are using more than one planet worth of resources, which is why we lack resources to help the poor. World leaders have offered 75 years of broken promises. The 17 Sustainable Development Goals (SDG), approved universally in 2015, contain the same elements that were in the 1947 UN Universal Declaration of Human Rights. So, progress has been poor. In 2021, nations spent almost $2 trillion on armaments, but only $160 billion on assistance for the poor. The reports from the Intergovernmental Panel on Climate Change shows that global warming is manmade and that the global poor will suffer the most, which is unjust because they did not create the problem. The best way to limit climate change is to integrate climate policies into an overall sustainable development strategy.

It is up to the scientific community to activate the sustainability implementation triangle – businesses and civil society working with governments, and pushing them to apply sustainable solutions. With balanced inclusive green growth, the rich countries have one path, and the poor countries have a different path, namely the inclusive green growth tunnel to expand their consumption more sustainably, without following the unsustainable path of the rich nations. Incorporating sustainability with corporate stakeholders is the way to reach the SDGs. In addition, the goals can be achieved by motivating youth, through social media, and

by using popular music to reach millions with the message of sustainability. Furthermore, sustainable producers and consumers should be brought together to form self-sustaining sustainable markets. As the global economic center of gravity is moving deeper into Asia in the 21st century, Japan has the economic, social and environmental resources to lead the sustainability transition, including the shift towards a more multi-polar, peaceful world order. Most critically, humanity must avoid war at any cost, especially nuclear war.

Closing Remarks

Dr. Dijkgraaf thanked the panel for their discussion and encouraged the participants of STS *forum* to share their ideas and engage in conversation throughout the rest of the symposium to further the discussion.

Koji Omi Memorial Lecture: Conversation with Prof. Joseph Stiglitz

[Chair]
Wallberg, Harriet, Professor and former President, Karolinska Institutet, Sweden
[Speaker]
Stiglitz, Joseph E., Professor, Economics, Columbia University, U.S.A. [Nobel Laureate 2001 (Economics)]

Opening Remarks


Chair: Wallberg, Harriet

Prof. Harriet Wallberg opened the inaugural Koji Omi Memorial Lecture. She first expressed her condolences for the loss of founder and former Chairman Koji Omi and former Prime Minister Shinzo Abe, who were deeply involved in STS *forum*. She also thanked Chairman Hiroshi Komiyama for organizing the Koji Omi Memorial Lectures. With the passing of Chairman Omi, STS *forum* has lost a great leader. However, his spirit is not lost and will live on into the future.

Prof. Wallberg then introduced Prof. Joseph E. Stiglitz.

Keynote Lecture

Prof. Stiglitz delivered his keynote lecture. Science and technology can be used to create solutions but also to create problems. This has never been more apparent. For example, science enabled the rapid identification of the virus causing COVID-19 and the quick development of an enormously effective mRNA vaccine against it. In addition, advances in knowledge about social organization enabled production of the vaccine in record time. This was a major human and scientific achievement that was truly global.

Stiglitz, Joseph E.

On the other hand, there were also major failures, with the hoarding of vaccines by advanced countries and the refusal to allow those in the developing world to use the intellectual property. This resulted in a situation that is sometimes referred to as vaccine apartheid. This situation exacerbated difficulties for developing countries to keep their economies going, produced enormous resentment in large parts of the world, and even resulted in weaker support for Ukraine in the war against Russia than would have been hoped.

Another example of the two-edged sword that modern technology represents is advances in communication, i.e., modern telecommunications. Modern technology has enhanced our ability to communicate rapidly with each other. However, this has led to unprecedented levels of misinformation and disinformation, which has generated enormous societal harms.

Technologies have exacerbated these social harms but may also offer tools for containing them. However, that will not happen on its own. AI has enabled targeted virality and it will take corresponding advances in technology to contain its adverse effects. Advances in regulation to limit social harms are also needed. However, mega high-tech firms are using their market power to suppress and undermine competition, which is essential for generating innovation, harming the pace of progress and standards of living, and increasing inequality. There is a further danger of these firms using their political power to get trade agreements that embody legal frameworks that limit signatories from curbing their monopolistic practices and from engaging in social harms.

Globalization and new communication technologies have enabled social harms to move quickly across borders. They also enable the spread of anti-scientific attitudes globally. Many in the world have forgotten that advances in science and knowledge have increased standards of living, including life expectancy. These attitudes have undermined support for science and the ability to implement policies based on science to respond to critical global issues, such as the pandemic and climate change. In fact, the transition to a green economy, with today's advances in science and technology, would actually produce both economic and environmental benefits.

It is necessary to ensure that advances in science and new technology actually enhance wellbeing. Concerted public efforts at all levels are needed to maximize the benefits of science and technology and to contain their harms. Advances in economic science have enhanced the understanding of why the world cannot simply rely on markets. Adam Smith's conjecture that the pursuit of self-interest would lead to the wellbeing of society has been shown, in general, to be wrong. Markets are often short-sighted and have limited ability to assess risks, as demonstrated in the global financial crisis of 2008 and the lack of resilience in the current crisis.

Chairman Omi spoke of advancing the lights and managing the shadows of science and technology. If there is political will, advances in social sciences have shown how to design policies that enable the reaping of the full benefits (advancing the lights) and curbing of the harms (managing the shadows) of advances in scientific knowledge. An adequate intellectual property framework is needed for ensuring this, as is the leadership of the scientific community.

Conversation

Prof. Wallberg asked Prof. Stiglitz what the keys are for avoiding a future crisis similar to the pandemic.

Prof. Stiglitz replied that an appropriate intellectual property framework is needed not only to prevent the hoarding of knowledge but encourage the active sharing of knowledge. It is also necessary to combat misinformation and disinformation, which resulted in a lack of trust in government and science.

Prof. Wallberg said she was impressed by how well academia and industry collaborated to rapidly rollout vaccines, and noted that Prof. Stiglitz seemed to be suggesting that better information-sharing among governments is needed.

Prof. Stiglitz believed that the issues occurred when the profit motive arose, and intellectual property rights were allocated. Intellectual property rights can, as was the case on this occasion, create highly conflictual situations. What was particularly shocking was that the vaccines were developed with taxpayers' money, and yet governments were unwilling to share the knowledge and benefits.

The World Trade Organization (WTO) has developed an intellectual property framework that allows the use of intellectual property by anybody under a compulsory licensing. However, the issue is that intellectual property is increasingly complex, resulting in increasingly expensive compulsory licensing processes. Countries such as South Africa and India requested that these costs be waived, but many countries did not accept their requests.

Prof. Wallberg then asked how misinformation and disinformation could be tackled.

Prof. Stiglitz believed that this is one of the fundamental questions of modern society. AI can at least detect a lot of misinformation and disinformation, if they are statements that are clearly scientifically untrue. Most countries already have laws for regulating speech in terms of ensuring truth in advertising and preventing false claims. However, these need to be adapted to regulating virality, which is different from regulating speech. It is necessary to limit the speed with which misinformation and disinformation spread, as well as to develop social "antibodies" against them.

Prof. Wallberg then turned to Prof. Stiglitz's book *Globalization and Its Discontents Revisited*. It posits that the economic order sold as the best possible answer, i.e., the liberalized, globalized, free market economy has not been delivering for many years. The book also addresses many failures of globalization, but ends on a positive note, that the United States and the world will create a better and fairer globalization. Prof. Wallberg asked how that could be achieved.

Prof. Stiglitz answered that, first it is necessary for more citizens to understand the limits and also the power of the market to create a divided society. Younger people in particular seem to understand the current system is not working. As Prime Minister Fumio Kishida mentioned in Session 100, the world needs a new kind of capitalism, one that is better balanced. Capitalism that puts profit over lives is flawed.

Prof. Wallberg wondered how much this new capitalism would even out the inequality between developed and less developed countries.

Prof. Stiglitz observed that there is an understanding in Europe that, if there are huge disparities between European countries and surrounding countries, the migration pressure will be huge, so it is in European countries' self-interest to reduce disparity. In addition, in regard to tackling climate change, most emissions are produced in the developing world,

and it is in the self-interest of developed countries to support and show greater solidarity for the developing world than was shown during the pandemic.

Q&A Session

A member of the audience noted that, after the pandemic, many countries, particularly developing ones, are facing huge debt overhangs. There has also been rethinking of supply chains, with a recognition of the need for more robustness in supply chains and national security considerations in globalization measures.

Prof. Stiglitz noted that, even before the pandemic, many countries had debts. During the pandemic, they have suffered reduced revenues and increased social costs, and their debts have ballooned. Prof. Stiglitz also commented on the U.S. policy of raising interest rates to combat inflation. He noted that the current inflation is due to supply side factors, and that raising interest rates will not help produce more oil and food, solve shipping shortages, and so on. Furthermore, it will raise the value of the dollar and therefore many countries' debts, which are denominated in dollars.

A member of the audience then asked about the key factors for realizing a new form of capitalism, and what the difference with the current form of capitalism might be, noting that the current form does not place a value on natural capital or human capital, which are considered externalities.

Prof. Stiglitz suggested that, under the new capitalism, the world will need to learn to live within planetary boundaries, which humanity is now pushing up against. Economists' instinct is to treat these as externalities and to price them to encourage people not to abuse them. One example is the social cost of carbon, but it needs to be priced appropriately, and most countries have not set prices high enough. Research shows that setting a higher carbon price would not have an adverse impact on the economy.

A comment was then raised by the audience echoing Prof. Stiglitz's point about the role of legal frameworks for combatting future pandemics.

Prof. Stiglitz added that many countries have not taken enough measures to address public health, both in terms of legal frameworks and otherwise.

Breaking Silos in Research: How can Inter-disciplinary Research be Effectively Conducted?

[Chair]

Fujii, Teruo, President, The University of Tokyo, Japan

[Speakers]

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.

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

Nagaoka, Keiko, Minister, Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan

Yoshino, Akira, Honorary Fellow, Asahi Kasei Corporation, Japan [Nobel Laureate 2019 (Chemistry)]

Opening Remarks

The session was opened by Dr. Teruo Fujii, who started by describing some of the impacts of the pandemic on people's lives. While the world is moving to the post-pandemic stage, it still faces many challenges, both old and new. One longstanding issue is climate change and the extreme weather events it has produced. While the international community is making efforts to reduce emissions and combat climate change, the conflict in Ukraine has exposed the vulnerabilities of such efforts.

Chair: Fujii, Teruo

These vulnerabilities span different disciplines. Their solutions also therefore require an interdisciplinary approach, which in turn requires the breaking of silos. In that regard, the University of Tokyo has promoted dialog among different stakeholders. Dialog is more than just an exchange of information, but an attempt to understand one another, and to build mutual understanding and trust.

The University of Tokyo also considers it necessary to reconsider the structure of silos, and

is aiming to break down barriers between natural sciences and social sciences, and to transform undergraduate education. Furthermore, the University of Tokyo is promoting collaboration with the private sector. Such collaboration begins with the establishment of a shared vision, before tackling specific issues. In addition, the University of Tokyo has developed mechanisms to encourage future generations of academics to broaden their interdisciplinary mindsets, and to apply such interdisciplinary perspectives to tackle global challenges.

Dr. Ray O. Johnson spoke about the nature of the problems humanity faces today and organizational structures. Many of the Sustainable Development Goals (SDGs), for example, encompass multiple fields and require interdisciplinary approaches. As for organizational structures, there is an increasing trend among universities, including at the undergraduate level, of bringing people together from different fields to solve problems. Invention can be defined as the creation of ideas, and innovation of turning ideas into goods and services. Interdisciplinary approaches are important for both, but especially the latter.

Dr. Johnson also touched on competitiveness and its lights and shadows to call for more collaboration. Organizational and national competitiveness is certainly important. However, looking at the SDGs and the types of solutions that are needed, it is important to remember that the enemy is not the other country, but the problems that the world faces.

Finally, Dr. Johnson explained that his organization, the Technology Innovation Institute, is focused on research applications and outcomes, and pointed out that focusing on outcomes is an effective way of putting together interdisciplinary teams. The institute is made up of 10 centers, each with between 50 and 150 people, spanning 63 nationalities, despite being only two years old. That speaks to the power of teams with different expertise and nationalities to solve problems.

Dr. Magdalena Skipper started by stating a truism: Science knows no boundaries. Cross-disciplinary research is more important than ever, and most of the current pressing issues in the world are multidisciplinary and global. If experts from different disciplines had not come together, the pandemic situation would be much worse today. The role of social and behavioral scientists can also not be overlooked, as it is no use developing a solution if no one will accept it.

Interdisciplinary work is more often inclusive of under-represented groups and involves more cases of co-creation. To promote interdisciplinary research, it is necessary to change preconceptions about who does research and about traditional disciplinary boundaries. Education and mentorship are both important for developing an interdisciplinary mindset. Prizes or funding that are explicitly for collaborative and interdisciplinary work are also effective.

Journal publishers can and do play a role in raising the profile of multidisciplinary research and facilitating its dissemination. Nature has always been a multidisciplinary publication. It has also launched new publications such as Nature Sustainability, Nature Energy, and Nature Food to support research across silos. A major challenge for cross-disciplinary work is for it to be recognized by peer reviewers, who are usually experts in only one field, for its novelty. This can have funding and publication implications. Nature seeks to overcome this by having the overseeing editor synthesize the reviewer reports while looking at each reviewer contribution.

Ms. Keiko Nagaoka began her remarks by explaining that the Ministry of Education, Culture, Sports, Science and Technology (MEXT) is the ministry for creating the future. Recently, Japan revised the Basic Act on Science, Technology and Innovation with the aim of generating comprehensive knowledge. Such knowledge is essential for promoting interdisciplinary research. Diverse knowledge must be gathered to discover new points of view and

identify social problems that may be overlooked. To that end, MEXT is supporting young researchers to engage in challenging research. It has also launched platforms to support diverse stakeholders.

MEXT is also promoting the development of human resources. Society is shifting from valuing material goods to spiritual wellbeing. It is therefore necessary to foster young human resources who accept many different values. MEXT is also promoting entrepreneurship and business formation, as well as reforming graduate school education in the humanities and social sciences. There is also a need for international human resources. MEXT is supporting educational institutions to reform their curricula and provide education in new fields, such as digital technologies, and helping young researchers study overseas.

Dealing with the problems humankind will face in the future will require new areas of knowledge. Interdisciplinary research will be an important part of humanity's common efforts to deal with these issues. MEXT will do all it can to promote it.

Dr. Akira Yoshino spoke about research silos and interdisciplinarity, touching on the difference between the silos among physicists and that among chemists, based on his own experience. No new innovation can be born within a silo. It is therefore essential to break down such silos.

Dr. Yoshino's field, the development of lithium ion batteries, belongs to the field of electrochemistry, a combination of electronics and chemistry. Electronics belongs to physics in a broad sense, and many of the researchers who participated in the lithium ion battery research were physicists or chemists. The physicists generally valued theory over experiments, tending to think for a long time before conducting experiments, while the opposite was true of the chemists. Each approach has its own advantage and one is not better than the other.

Dr. Yoshino explained how he tried to break down the silos between them. One approach was to have mixed teams of physicists and chemists as much as possible. Another was educational efforts to change the thinking of researchers. For example, Dr. Yoshino encouraged physics to take the approach normally taken by chemists, and vice versa to the physicists.

Discussion

Dr. Fujii started the panel discussion by asking the panelists for ways to encourage or appropriately evaluate the interdisciplinarity of young researchers.

Dr. Johnson suggested the setting of key performance indicators (KPI), the specifics of which may depend on the technology-readiness level.

Dr. Skipper replied that interdisciplinary research goes hand in glove with collaboration. Acknowledging collaboration and how one researcher's contribution contributes to a field far from their own could encourage interdisciplinarity. She also wondered if it would be possible in the future to train researchers who did not see themselves as belonging to any one discipline.

Dr. Fujii agreed with the importance of ensuring that the education and training of young people is interdisciplinary.

Ms. Nagaoka highlighted the importance of interdisciplinarity not only in natural science, but also the humanities and social science. MEXT will promote educational reform to promote interdisciplinarity, especially in university graduate schools.

Dr. Johnson mentioned the greater understanding of the importance of the connection between technological advances and their impact on people, or the lights and shadows, so to speak. He suggested that better understanding of social behaviors and their integration into the technological development would be highly valuable.

Q&A Session

An audience member asked at what stage people should be trained or educated with knowledge that integrates both social sciences and natural sciences.

Dr. Johnson replied that, in the past, university education was aimed at the development of the whole person, but as technological education has become more complex, this element of education seems to be disappearing.

Dr. Skipper commented that Nature was born as a journal for natural sciences, but that in the past decade, it has expanded to include social sciences. Indeed, it is becoming

increasingly difficult to distinguish between the two. Dr. Skipper also pointed out the value of incorporating interdisciplinary perspectives in the earlier stages of education.

Dr. Yoshino commented that research themes at companies are usually interdisciplinary, and that there is demand from companies and society for talent with a wide range of knowledge.

Next, a member of the audience asked about how to prevent strict requirements for co-authorship from discouraging researchers to co-author collaborative and interdisciplinary papers.

Dr. Skipper agreed that, while every author has some responsibility for a manuscript, strict criteria could prevent people who have made contributions from getting recognition. She also shared the case of patients working with medical practitioners to design clinical trials but not being recognized as authors due to strict authorship definitions.

Concluding Remarks

Dr. Fujii invited the panelists to make concluding remarks.

Dr. Johnson stated that interdisciplinarity is essential for solving problems and encouraged participants to be more inclusive of other fields and ideas when creating teams.

Dr. Skipper called for greater focus on the collaboration aspect of interdisciplinary and pointed out that collaboration and cooperation can contribute to a healthier research ecosystem by making it more open and transparent.

Ms. Nagaoka noted that all panelists share a recognition of the importance of interdisciplinary research. She expressed her belief that there is no shortcut to promoting interdisciplinarity and highlighted the need for everyone to share their knowledge and wisdom.

Dr. Yoshino stated that the only way to solve the global challenges faced by humanity is to bring together the wisdom of people in different fields.

Groundbreaking Technologies

[Chair]

Copan, Walter G., Vice President, Research and Technology Transfer, Colorado School of Mines; former Director, National Institute of Standards and Technology (NIST), U.S.A.

[Speakers]

Mahajan, Vivek, Corporate Executive Officer, SEVP, CTO, Fujitsu Limited, Japan

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

[Online Speakers]

Thorp, Holden, Editor-in-Chief, Science Family of Journals, Science / American Association for the Advancement of Science (AAAS); Rita Levi-Montalcini Distinguished University Professor, Washington University in St. Louis, U.S.A.

Hauser, Hermann, Co-Founder and Partner, Amadeus Capital Partners, New Zealand

Terry, Paul, CEO, Photonic Inc., Canada

Opening Remarks

Dr. Walter G. Copan introduced the topic of Groundbreaking Technologies and brought up various aspects for the panelists to consider during the discussion. In order for pioneering, foundational technologies to advance the human condition, restore environmental quality and mitigate climate change, their risks must be understood and addressed. Exascale computing is set to drive global civilization to the next level and contribute to transforming the modern world. Computing is now ubiquitous – and advances in this field will continually have an impact on all industries. Artificial intelligence and machine learning are driving innovation in all aspects of life and in research, revealing new solutions to problems. One “light” of this technology is realtime delivery in the fields of logistics and location-based services. However, this can be cast in “shadow” by the privacy issues that come with such tracking. The power of artificial intelligence demands that the private and

Chair: Copan, Walter G.

public sectors engage in principles-based standardization that provides a foundation of trust. Another issue present in this technology is that biases can become evident, such as in facial recognition. This requires that systems be retrained and bias performance measured. Moreover, intellectual property has been an enabler, creating innovation and entrepreneurship that has provided seeding for groundbreaking technologies.

The mechanisms that shaped the creation of the current technologies must be revisited and new approaches created for groundbreaking technologies in the hydrogen economy and the quantum computing era. Quantum-resistant cryptographic algorithms are needed for the contemporary security industry, as quantum-based computing systems will be able to break our current encryption methods. Nevertheless, other disruptive technologies such as blockchain have led to streamlining in financial industries and for trusted supply chains, while synthetic biology has shown its impact in the development of COVID-19 vaccines. As humanity seeks to maximize the benefits of such technologies, how they should be introduced and how we shall protect against the "shadows" must be comprehensively addressed.

Mr. Vivek Mahajan commented on how the groundbreaking technologies align with Fujitsu's focus on bringing innovation and trust to its stakeholders and society. Sustainability is intrinsically linked to digital transformation as organizations, cities, and nations need to manage the data required to achieve sustainability. This digital transformation can be viewed from five perspectives: computing that is essential for deriving insights from such data; networks to connect; artificial intelligence to make decisions on the data; security to be imbedded; and research and innovation achieved from the insights. These are essential aspects when implementing technology to solve issues in addressing sustainability. In the future, edge computing will be more widely adopted and accessed via cloud platforms. However, while quantum computing is not yet ready for commercial application, quantum simulation will be commercially available.

These new technologies will also necessitate the adoption of new approaches in working with technologies for sustainability. One example of these where new approaches will be needed is in the adoption of ammonia for a sustainable society, and its new production methods. In networking, there will be huge advances as the fundamental technology will be no longer based on the electric network and 5G, but will be based on the photonic network and 6G. Moreover, artificial intelligence will contribute to greater security and sustainability in agriculture by improving food yields via satellite imagery and to optimize farming practices based on data.

Dr. Holden Thorp spoke on the impacts and issues that arise in the open publishing movement and the advances in synthetic biology. Disclosure of code and data publicly for every published paper will raise issues in how the accompanying data is stored and hosted. The application of artificial intelligence has been seen in the breakthroughs in analysis of protein and RNA structures. These breakthroughs in protein and RNA analysis allow for a multitude of applications in drug discovery. The move to open data is helping academics or small institutions to predict protein structures. The application of artificial intelligence in clinical care provides benefits in being able to provide diagnosis for treatment and by reducing human error. The code that underlies this must be publicly available for this to work as it relies upon a certain scale of data. However, there are many complicated ethical, security and commercial aspects yet to be discussed in the implications of disclosing this code and data publicly.

Dr. Hermann Hauser spoke on the social and political aspects that surround groundbreaking technologies, and how the role of intellectual property can be understood. As seen with the

rapid development of COVID-19 vaccines due to advances in synthetic biology, protein structure prediction is now available for application. However, there are issues regarding who has access to such technology. These issues become more complex when considering the geopolitical aspects as nation states race to claim technology sovereignty. This has the potential to lead to inequities globally. The United States, China, and, to some extent, Europe will be sovereigns. Europe has traditions in accommodating its diverse cultures and states, whereas the other hegemons do not.

This dynamic is clearly visible in the semiconductor industry, where circumstances involving Taiwan Semiconductor Manufacturing and ASML have recently created a bottleneck causing supply shortages. Dr. Hauser called upon the participants to discuss how this bottleneck can be avoided in the development of the nascent nanoscale semiconductor technology. States will need to identify if they have the critical technology domestically, if they have multiple access points to a technology, or, if not, if their access is provided unfettered via some international treaty or agreement. This dynamic must be understood to avoid dependencies.

Dr. Samantha Anderson spoke of the current state of disposal and recycling of plastic waste. Contemporary modalities for polymer waste management include either recycling, energy capture incineration facilities, or disposal via landfill. Due to the widespread use of plastics in applications from polyester clothing to food packaging, this situation is reaching a crisis point. Plastic particles are being accumulated in the oceans, in food chains and even in people's bodies. Dr. Anderson's firm, DePoly, conducts recycling of PET plastics by converting PET waste to its monomer building blocks at low temperature. The company and its technologies seek to further sustainability by reducing the total energy demand of recycling compared to conventional methods.

This approach toward a circular economy achieves a higher standard than existing conventional methods toward high production quality that can further reduce carbon emissions. Attention must be paid not only to the technological and environmental aspects of its adoption but also to the public perception. The public image of the word "chemical" itself may belie the technology's benefits, if the word may be wrongly associated with perceived unecological and non-sustainable technologies.

Dr. Paul Terry stated that the fundamental architecture of the qubits that form the basis of quantum computing systems mean that the technology could easily surpass contemporary supercomputers and that its power can be increased exponentially. The addition of each qubit to a system has the potential of doubling quantum computing capability. The technology is currently near an inflection point as its computational power is extremely vast. And soon, very powerful quantum computers will be commercially available and will have the potential to disrupt every industry. Personalized medicine, agriculture, and finance will all change due to this technology. Moreover, the first quantum computer will immediately be able to break the current RSA encryption that underpins modern encryption methods, and changing to quantum-resistant encryption will be a radical divergence.

Discussion

Mr. Mahajan brought up the fact that quantum computing will bring about massive changes due to how the technology is able to scale, its fundamental architecture, and the fact that moving from the electric network to the photonic network will bring unprecedented speed to computer networks. Mr. Mahajan also noted that the modern cloud infrastructure is dominated by U.S. companies, and the rest of the world is its consumer. He also clarified that Taiwan Semiconductor Manufacturing Company is currently the sole provider of certain classes of microchips because of the cost of foundry building that dissuaded U.S. companies from directly investing in such infrastructure.

Dr. Thorp added that the issues of regulation and access to quantum computing will be critical. If quantum computing allows for the designing of a drug for one individual, the regulation and production of such a personalized drug would be problematic. He also commented that the United States and China will also have impacts on the acceptance of these technologies due to their positions of power.

Dr. Anderson stated that the mechanism to make a drug, the legal entity which will patent it, and how policy will adapt are all important elements to consider. Policymakers will aim to please all parties but ultimately some will be unhappy.

Dr. Hauser added that the United Kingdom has realized that it cannot rely on its special relationship with the United States as completely as it had in the past.

Dr. Terry commented that during the inception of the internet, there were many standards in competition with each other, but that there is no standard yet for quantum computing. He also stated that there were many other issues to address such as how a quantum computer is to be used, that quantum networking will blur the line between computing and networking, and whether each nation would have access to do quantum computing, or if it would it be provided for by international treaties.

Dr. Copan asked Dr. Thorp to comment further on the "lights" and "shadows" of open publishing.

Dr. Thorp stated that open access publishing would remove barriers for reading works, but that it would raise barriers for publishing such work. He added that consideration needs to be paid to how it would be funded, as funding agencies would get the final say on the levels of openness.

Dr. Hauser added that the technology of ARM chips became widespread, and luckily it did not get absorbed by a monopoly.

Dr. Copan inquired as to the aspects that policymakers must take into account regarding polymer recycling.

Dr. Anderson stated that they would have to take into account the ownership of the materials and the suitable recycling facility. She added that policymakers must adapt quickly so as not to shut out innovation in the field.

Q&A Session

A member of the audience inquired as to the technology readiness level of DePoly.

Dr. Anderson stated that DePoly was at technology readiness level seven, and that it was going through a funding round.

Another member of the audience asked if the panel could provide any clarity on the often-touted 40 billion U.S. dollar cost associated with developing semiconductor manufacturing.

Mr. Mahajan stated that chip design can be done in many places but that a large portion of the manufacturing cost is for the development and installation of the foundries. This cost challenge is further compounded by the fact that the technology is ever-developing as innovation continues.

Closing Remarks

Dr. Terry brought the session to a close by stating that the world was moving from globalization to regionalization, whereby countries will need to control supply and access to technologies, and address immigration and training to remain competitive in these nascent fields.

How can Chemical Industry Contribute to Next Zero Society

[Chair]

Ishii, Naoko, Executive Vice President, Director of Center for Global Commons, Professor of Institute for Future Initiatives, The University of Tokyo, Japan

[Online Speakers]

Holliday, Jr., Charles (Chad) O., Chairman, Holliday Resources LLC; former Chairman of the Board, Bank of America; former Chairman and Chief Executive Officer, DuPont, U.S.A.

Stuchtey, Martin, Founder and CEO, The Landbankig Group GmbH, Germany

Opening Remarks

Chair: Ishii, Naoko

Prof. Naoko Ishii opened the session by stating that an important theme of this year's STS *forum* annual meeting is how to achieve sustainability within the planetary boundaries and exploring the pathways to get there. There are multilayered and interlinked crises facing the world, including energy, food, nature, and climate change, exacerbated by the crisis in Ukraine. There is a need to accelerate the transition to sustainability, and this session will look at a concrete way to turn a major issue into a major opportunity, using the chemical industry as an example.

The Center for Global Commons at the University of Tokyo worked together with Systemiq to explore chemical pathways and examine how the chemical industry can be a leader in the transition to sustainability. The results are published in a report called Planet Positive Chemicals. The report was only possible through collaboration among all stakeholders along the value chain, and was supported by Mitsubishi Chemical.

Prof. Martin Stuchtey, who co-authored the report, explained that it puts the chemical industry center stage. This industry is a driver of economic growth and at the center of

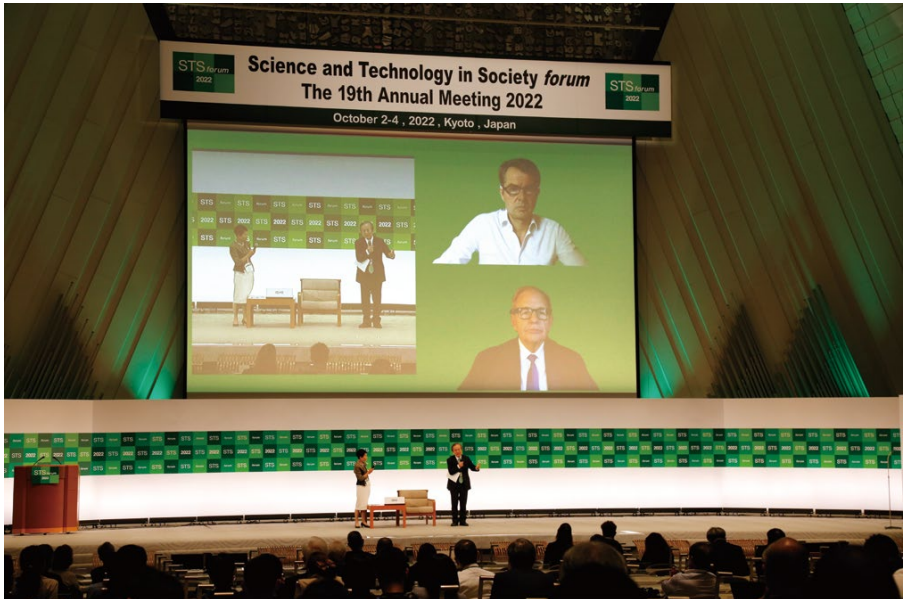
innovation. However, the context around it has changed, with increasing recognition of the environmental issues posed by the industry's products and production processes. The world is also facing various crises, including material shortages, supply chain constraints, and climate change. The chemical industry is in the middle of these crises.

However, it can also be a beacon of hope, which is the subject of the report. The report applies a "planet positive" lens to the industry, looking at whether it can exist within the nine planetary boundaries. The report's findings were positive. The industry could become carbon negative by 2040 and a carbon sink by 2050. However, if it does not, it could derail the broader transition efforts of society.

The chemical industry is a huge and ubiquitous one. It affects all sectors of the economy. It also has a palpable negative impact on the planet. Furthermore, it is very difficult to change the industry, because of factors such as its ubiquity, life cycles, and the high level of expertise of those working in it. The report explores eight key chemicals, one of which is ammonia. On the one hand, ammonia could potentially be produced with zero-emission green power, deliver fuel for many hard-to-abate industries, and feed hungry populations. However, it is also a key challenge. Its production is hugely energy intensive. Its use as a fertilizer could also result in biodiversity loss.

The chemical industry cannot be decarbonized. It needs to be de-fossilized. The report calls for the chemical industry to take actions along both demand-side and supply-side vectors. On the demand side, circular economy approaches such as reduction, reuse, substitution and recycling should be taken. On the supply side, it is necessary to green a lot of energy, use non-fossil feedstocks, and capture some residual emissions. If done, this could turn the industry into a carbon sink. There are manifold other benefits as well, including increasing the output for industry, producing new revenue streams, creating new jobs, and eventually making production cheaper.

To achieve this, three trillion capital expenditure for infrastructure development is needed. More importantly, there needs to be a major transition in system policies across all stakeholders. There are reasons for optimism, as there is momentum and activity in financial and political sectors. There is also a technical and economic possibility. However, it would be a mistake to think that systems naturally gravitate to those best possible outcomes. Rather, an unprecedented and collective act of leadership and character would be needed.



Dr. Charles (Chad) O. Holliday, Jr. spoke about how to bring the various stakeholders on board. He explained that the chemical industry has made a major transition before, sharing an example from the discovery, at a Dupont plant, that workers there developed bladder cancer at a higher rate than the general public. This changed the mindset around the toxicity of chemicals and the chemical industry, and ushered in many new processes.

Dr. Holliday also explained that he is part of the Mission Possible Partnership, which aims to transition four of the six most hard-to-abate sectors: aluminum, steel, cement and chemicals. He agreed that transitioning the chemical industry is the hardest because its reach is so diverse.

Dr. Holliday then shared an anecdote from a previous annual meeting of STS forum in which he declared that the Earth is in trouble, referring to the transition from fossil fuels. A Nobel prize winner spoke after him, pointing out that it is not the Earth that is in trouble, but the humans. The Earth will survive this crisis, but humans will not, if they do not take action.

Discussion

Chairman Hiroshi Komiyama began by expressing his agreement that the chemical industry is the most difficult to transform, and that its influence is very widespread. He also noted that the report, Planet Positive Chemicals, is highly comprehensive. He then explained that Japan is trying to transition its own chemical industry, but is aiming to do so by combining it with the forestry, mechanical, and other industries. One important consideration is shifting feedstock from fossil fuels to other carbon sources. One option is to use captured CO_2, but such CO_2 contains much hydrogen. Another idea that is showing promise is to use wood as the new feedstock of the chemical industry. It will be difficult, but there are reasons for optimism.

Prof. Stuchtey appreciated the comprehensive and integrated approach proposed by Chairman Komiyama.

Dr. Holliday said that the chemical industry can implement the recommendations proposed by the report. Now it needs to take action.

Prof. Ishii agreed that this must be done, and that failure is not an option.

Analysis and Synthesis in Science -- The Human Body and Mind

[Chair]

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

[Speakers]

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

Kawato, Mitsuo, Director, Brain Information Communication Research Laboratory Group, Advanced Telecommunications Research Institute International (ATR), Japan

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

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.

Opening Remarks

To open the session, Prof. Hanoch Gutfreund explained that while humans are physical-biological entities that include the brain, what makes humans "human" is the non-physical entity that is the mind. The world is beginning to address the mind-body connection in a biological context and recognizing its importance.

Chair: Gutfreund, Hanoch

The study of the mind is highly interdisciplinary and produces large datasets, and any analysis of such a dataset as a whole may lead to the discovery of new phenomena, laws and theoretical concepts. These two interconnected phases of research, analysis and synthesis, are the hallmark of the study of big datasets in various fields. Biology and neuroscience have generated an astonishing amount of information through the traditional techniques of experiment and observation. Nevertheless, more still needs to be invested in the analysis and synthesis of the accumulated information.

Lasty, Prof. Gutfreund explained that the session will address the challenge of analyzing and synthesizing information about the mind from perspectives that include AI, the implications for policy decisions, funding schemes, and training of young researchers.

Prof. Gutfreund then introduced the panelists. In particular, he explained that Prof. Katja Becker, who was scheduled to attend the session, was ultimately unable to, and provided an overview of her intended presentation. Prof. Becker had intended to speak about how contemporary malaria research transcends disciplines. Such research shows deep connection with some fundamental trends in the development of the human body, including the mind and culture. Science and technology and research for the benefit of humankind cannot ignore the humanities and social science.

Prof. Becker had also intended to speak about the different fields of research related to the theme of this session to which the German Research Foundation has allocated funding. Of particular interest is the effort to build a national infrastructure to manage large bodies of research data, to provide better accessibility and network the data nationally and internationally.

Prof. Michael O. Hengartner began by explaining that the human mind is incredibly complex and capable of amazing feats, such as learning, memory, and consciousness. However, these capabilities are not restricted to humans and found in other animals. They also differ in terms of the level of complexity. The different parts of the brain can be separated and studied physically and functionally, before combining those studies to understand the whole.

Progress in understanding the brain and mind have required new technologies for sensing and manipulating brain technologies. Progress has been slowest in studying and understanding consciousness, in large part because it is so difficult to measure. Overall, progress in the study of the brain and mind has depended, and will continue to depend, on technological progress.

Better understanding of the brain will enable the building of computers that can emulate or at least imitate brain functions. In part, such systems already exist. Advanced machines would also have the ability to learn from memories. Programs that speak human language are increasingly powerful. It follows that, eventually, it may be possible to recreate consciousness in silico. In such a case, however, would it be possible to even recognize it as consciousness? Even then, it is not clear how humanity would react.

Dr. Mitsuo Kawato spoke about his definition of computational neuroscience, how analysis by synthesis works in neuroscience, neural synchronization and compartmentalization in the cerebellum, and the shortcomings of current AI combined with future computational neuroscience. First, he defined computational neuroscience as understanding brain functions to the extent that they can be recreated in the real world.

As for analysis by synthesis in human minds, data-driven science, rather than hypothesis-driven science, is a growing trend in biological fields. For 15 years, Japan has been developing multi-disorder functional magnetic resonance imaging databases to develop markers for various mental and developmental disorders, in order to aid diagnosis and develop better treatments.

Meanwhile, work on internal models of cerebellum has revealed that dimension reduction in this system is essential for learning from small samples. Neural filings and compartmentalization in the cerebellum of many neurons seems to be an essential element of this.

As for current AI and consciousness, while current AI is very efficient, it is still data-driven. The brain can learn from very small samples and AI has yet to learn the secret of this capability. There are various theories of consciousness and work is ongoing to develop new types of neural networks based on those theories.

Prof. K. VijayRaghavan pointed out that *Escherichia coli*, a tiny bacterial cell, is about 1 cubic micron, while the volume of a cell body is about 12,000 times larger, yet the two share many features in common. All cells sense their environment and respond to these cues, and 100 years of research have greatly enhanced understanding of the cell, yet it is still not possible to move from this to predict responses of cells to multimodal influences.

If that is the case, what possibility is there to understand how the brain works, let alone the mind? First, understanding the complexity of the brain helps. Large brains like those in humans can do amazing things. Biologists are seeking to improve understanding of the evolution, physiology, and developmental biology of the brain and mind using technologies such as imaging, microscopy, and DNA/RNA sequencing.

Understanding of nerve cells has improved dramatically through animal studies. These studies have pointed to the many shared features of higher-level functions thought to be unique to humans. Comparative studies of brain development and function are now a

thriving area of research. There is also greater access to large amounts of data and effective methods for analyzing large datasets. Combined with hypothesis-driven and exploratory research, this provides the design and analysis of top-down theories of brain function, including theories of the mind and consciousness.

Prof. Rita R. Colwell emphasized the need, in 21st century science, to link social, behavioral, and economic sciences directly and initially into all research. There is a tendency for those in the natural sciences to only attempt to explain their work to the layperson at the termination of a project, when in fact, the effects and results of research on the human body and mind should be considered initially.

In the field of metagenomics, work is ongoing to elucidate the complex communities in the gut and how the compounds they produce affect humans' sense of wellbeing and disease. New research shows that highly processed food can create compounds that alter human behavior and even addiction. These developments need to be explained to the public. Rather than post-experimental application of research, more thought should be given to societal impact.

In the United States, every proposal to the National Science Foundation (NSF) includes a "broader impact requirement," which involves explaining the research to the public. This encourages awareness of the community from the beginning of the research. If the research can be understood and shared, it enhances the capacity of the research, as well as the support for it.

Discussion

Prof. Gutfreund noted that the higher functioning of the brain, such as learning and memory, have been the subject of research in neural science and other domains. The more enigmatic concept is consciousness, the measure of which is very difficult. So too, is defining it. Prof. Gutfreund asked Prof. Hengartner to try.

Prof. Gutfreund also asked the speakers to comment on emotions. Philosophers distinguish emotions and sensations. What is the link between emotions, and the brain and mind?

Prof. Hengartner suggested that consciousness is being aware of one's surroundings or oneself. Defining emotions is even harder as there is no consensus among scientists. They are perhaps strong feelings that color the conscious self. Emotions are linked to

sensations and have a neuro-physiological basis. Emotions are perhaps the conscious part of sensations.

Prof. VijayRaghavan commented on emotions versus sensations. When a crisis occurs, the parameter space in neural circuits changes into a completely different state because of neural modulators. This has been analyzed at higher levels in animals in relation to reasons such as anger and fear. There is not yet a good understanding of emotions, but some idea of which part of the brain is involved.

Dr. Kawato commented on whether it is possible to objectively measure consciousness. There are four major theories. The most popular one, but one that is not highly respected by neuroscientists, is the integrated information theory (IIT) of consciousness. Proponents believe that it is possible to quantify integrated information simply by counting the dynamic states and partitioning the system into different parts. However, this is very different from usual biological or physical theories.

Prof. Hengartner added that IIT posits that any system whose complexity exceeds the complexity of the sum of its parts has some element of consciousness. However, that is hardly calculable. The theory is interesting, but it is hard to prove or falsify.

Prof. Gutfreund asked if it is possible to think about artificial human minds and whether it makes sense to do so.

Prof. Hengartner suggested that, looking at parts of what the mind is made up of, that already exists. However, the question, again, is how to measure and verify consciousness.

Prof. Colwell suggested that the use of AI to analyze the complexity of the metabolism and being able to identify how those compounds influence behavior is going to be extremely instructive as it will enable mapping of pathways and gene interactions. This will help explain behavior and might explain consciousness.

Dr. Kawato pointed out that, in animal studies, various reinforcement learning schemes are employed to verify consciousness. Perhaps some analog could be developed for AI.

Q&A

Questions were then invited from the audience. An audience member noted that subjectivity is a key aspect of discussions on the mind and consciousness, and asked whether the feeling of being conscious or “human” can be replicated in a machine.

Prof. Hengartner pointed out that not being able to relate to the consciousness of another human or another species does not mean that one can deny that someone or something is conscious. Therefore, if a machine were conscious, it is not clear how humans would recognize or even accept that.

Next, an audience member pointed out that neuro-analysis research shows that a small part of the brain is responsible for ethical decisions and that, when this is disrupted, so too is the ability to make ethical decisions. The audience member asked what regulations

and other rules might be needed to ensure safe research and prevent potential misuse of researchers' work.

Prof. Hengartner replied that there is a new concept called neural rights that considers the protection of minds from such manipulation as a human right and that certain parts of the mind should remain inviolable.

Another question concerned whether it would be possible to bring about something akin to artificial cognitive empathy.

Prof. VijayRaghavan cautioned against trying to explain all emotions in terms of brains and their functions. The influence of cultural norms and traditions should also be considered.

Dr. Colwell believed that advances would be incremental, but eventually it should be feasible.

Prof. Hengartner thought that emulating empathy would be very difficult but imitation of humans' emotional responses may be possible.

An audience member contrasted consciousness and sentience, suggesting that the latter concerns being aware of one's existence and seeking purpose in one's life. He asked if it would be possible to recreate sentience in machines.

Prof. Hengartner answered that humans have instinctive goals and that such basic goals can also be easily programmed into machines. However, consciousness gives humans the ability to supersede such instinctive goals. Programming such "moral" goals in machines would be much more difficult.

A question was raised regarding how to foster greater connectivity between the social sciences and biology, to take advantage of the knowledge of both.

Prof. Gutfreund agreed that it is important to synthesize such information. Analysis and synthesis are essential for the study of any complex topic, not only the human mind, but also, say, climate change. Every such study should also not ignore the humanities and social sciences from the beginning.

Basic Science, Innovation and Policy

[Chair]

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

[Speakers]

Kajita, Takaaki, President, Science Council of Japan; Distinguished University Professor, Institute for Cosmic Ray Research, The University of Tokyo, Japan [Nobel Laureate 2015 (Physics)]

Eldesouki, Munir M., President, King Abdulaziz City For Science & Technology (KACST); Advisor to the Chairman of the Research Development and Innovation Authority (RDIA) heading the foundation team for the establishment of the RDIA in Saudi Arabia, Saudi Arabia

Vilela, Evaldo Ferreira, President, National Council for Scientific and Technological Development (CNPq), Brazil

Ho, Li-Mei Lora, Senior Vice President, Europe & Asia Sales, Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC); TSMC ESG committee Chairman, Taiwan

Opening Remarks

Prof. Maria Leptin opened the session and stated that citizens around the world are entitled to expect research to solve problems. Some people believe in protecting the right to conduct curiosity-driven research, while others believe that in times of crisis, research should be focused on innovation and societal need.

Chair: Leptin, Maria

Prof. Takaaki Kajita started by posing a question: What is basic science? Many people understand that science and technology are responsible for many aspects of everyday life. Much of this is based on curiosity-driven basic research. Basic science seeks to expand the horizon of human understanding of nature. At the same time, it has the potential to improve people's daily lives.

Prof. Kajita joked that his areas of research, neutrinos and gravitational waves, are both examples of basic research that are completely useless for improving daily life. Even if the outcomes of basic research can be used to improve people's lives, that process takes a very long time. Nevertheless, they can and do transform our lives.

For example, quantum mechanics is an area of basic science that was born out of the curiosity of physicists who wanted to understand the structure of atoms, which would not be possible based on classical physics. Quantum mechanics make possible smartphones and other devices that are ubiquitous today. An examination of the history of mankind includes many such examples and shows that the pursuit of basic science is essential.

His Excellency Dr. Munir M. Eldesouki talked about how policymakers try to balance basic and applied research. Policymakers' work is measured by GDP and jobs. The return on investment is frequently applied to the assessment of research investment. However, basic research outcomes are often measured by intangible assets. Policymakers need to work in a smart way to continually demonstrate the impact of basic science. It takes courage for policymakers to invest 10-20 years in the future, a time when they will no longer be in a position to be rewarded for the investment.

Saudi Arabia currently spends about 50% of its R&D funding on basic research. That enabled the development of a strong foundation. Much of this basic research is conducted through collaboration with international partners. Saudi Arabia categorizes research into the Discover, Develop, and Deploy phases. It is increasing R&D investment as a percentage of GDP and will increase the funding for Deploy projects, without decreasing the total amount of basic research funding. Saudi Arabia also wants the private-sector contribution to grow in support of the applied component. Saudi Arabia is also open to building on discoveries made in other countries and applying them domestically. This can save on costs and development time, while still producing benefits for Saudi Arabia and mankind. There are tradeoffs between basic and applied research, but international collaboration can help share the risks and rewards.

Prof. Evaldo Ferreira Vilela talked about the importance and integration of collaboration among science and technology networks in Brazil. In the 1980s, Brazil first focused on developing national priority areas of science and technology. It then focused on interdisciplinarity and established the National Institutes of Science and Technology (INCTs). This is the most important program to Brazilian science and INCTs span a wide range of fields. In

recent years, they have been called to respond to interdisciplinary crises such as the Zika virus, the oil spillage off the Brazilian coast, and food security, among others.

Network analyses show that many INCTs are working together to address important and challenging research fields, such as nanocarbon technologies. Looking to the future, further convergence can be expected, including in pursuit of the Sustainable Development Goals (SDGs). Brazil will further reinforce its science and technology convergence and integrate the INCTs with other scientific programs. It will also encourage interaction with the productive sectors of society.

Ms. Li-Mei Lora Ho presented on how semiconductor technology is contributing to modern but sustainable lifestyles. Semiconductors have been at the heart of technological innovation, including advances in computation power, cost reduction and energy efficiency. Energy efficiency is now the single most important requirement for all of Taiwan Semiconductor Manufacturing Company's (TMSC) customers. In the case of mobile phones, for example, computing power and battery life are the key specifications. Low power consumption is also a necessity for any product connected to the Internet of Things.

The semiconductor industry and energy efficiency are changing all aspects of people's lives, such as enabling work or study from home, or making vehicles safer and more energy efficient. Ultimately, semiconductors can help conserve energy and support a low-carbon economy.

TMSC believes that growth and the natural environment can coexist. TMSC has committed to achieving net zero emissions by 2050. It has set three checkpoints. In 2025, its goal is to stop gross emissions. In 2030, emissions must revert to 2020 levels. In 2050, it will achieve net zero. These ambitious targets will require collaboration across the value chain.

Discussion

Prof. Leptin noted His Excellency Dr. Eldesouki's point that knowledge can be generated anywhere but deployed domestically. She asked if this was not misleading, suggesting that to deploy knowledge from another country, it is necessary to have people who have been trained to be able to use that knowledge.

His Excellency Dr. Eldesouki acknowledged that the country deploying the knowledge needs to have the right talent and the right industry linkages. The situation varies by country and the role of governments is important. It also varies by industry and sector, and depends on the maturity of the industry and the strength of the scientists. In some cases, government intervention may be needed.

Prof. Leptin asked if basic research should still be funded if it never produces anything useful.

Prof. Kajita pointed out that the other role of basic research is to expand knowledge about nature.

Prof. Leptin agreed and pointed out that it is clear that the public cares and is curious about nature, given that the first photos of a black hole, for example, made frontpage news.

She then asked if a country like Brazil can afford to fund basic research.

Prof. Vilela answered that it can, but it depends on the capacity of the people. Links with industry are also necessary for funding efforts to turn basic research into applications.

Prof. Leptin noted that one of the problems for TMSC in pursuing sustainability is the great dispersity of its production. She asked Ms. Ho to elaborate on this point.

Ms. Ho explained that, from a consumer angle, TMSC aims to help consumers save energy. On the manufacturing side, however, with new products, TMSC is consuming less energy, but the equipment is more complicated, so total energy consumption increases. Therefore, efforts to find energy savings, more efficient equipment, and substitute materials are needed.

Q&A Session

Prof. Leptin then invited questions and comments from the audience. The first comment concerned the use, in Hungary, of the term "discovery science" instead of "basic science." The goal of basic science is to discover new things, including learning more about nature, while the term "basic" can have negative connotations.

Another audience member commented that basic science should also leave room for research that is driven entirely by curiosity and free of any ideas of any application, that is, research on the frontiers of science and not supported by traditional thinking. Such "crazy" ideas could one day yield very important and valuable breakthroughs.

Prof. Kajita agreed that there should be some mechanism that supports research that is based on crazy ideas, noting that such ideas are typically not approved for funding. He wondered what could be done to ensure such projects are supported.

Prof. Leptin pointed out that review panels typically operate by consensus when selecting projects for funding. Perhaps another approach might lead to more crazy research being approved. One idea that has been floated is to select the projects that receive the most diverse evaluations from panel members. However, no agency currently takes such an approach. Another idea is to first conduct an assessment of feasibility to verify the merit of the project and that it makes a basic level of sense, and then to allocate funds at random to any projects that had passed this assessment. That eliminates any potential bias of the panelists and can lead to the approval of projects based on wild ideas. The Volkswagen Foundation has introduced such a system for a limited program.

Ms. Ho commented on how crazy ideas fit in a corporate environment. Companies are profit-seeking, so management teams are typically averse to funding such research. However, they should have the courage to set aside some investment for such research, because these are the ideas that could yield huge benefits in the long-term. That is in fact what TMSC is doing.

Next, a member of the audience expressed the view that it is a false dichotomy to connect "basic" and "useless." As a case in point, Norway recently launched a number of research centers that have a clear purpose in mind, but are focused on basic research.

His Excellency Dr. Eldesouki explained that, in his organization, research is aligned with national priorities. That said, free, bottom-up research is accepted and funded if it is in areas considered to be of high national importance.

An audience member pointed out that the idea of a linear flow from basic research to application is a false and vastly simplified narrative. The reality is much more diverse and messy. However, such a clean narrative is useful for securing research funding.

Prof. Leptin agreed and believed that researchers should be honest and tell it how it is. However, she also acknowledged that, unfortunately, many politicians want simplicity and are not interested in hearing the complex truth. She thanked the panelists and audience for their contributions and recognized the understanding and support of basic science shown in the discussion.

Koji Omi Memorial Session: Lights and Shadows of AI

[Chair]

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

[Speakers]

Kitano, Hiroaki, Senior Executive Vice President and CTO, Sony Group Corporation; Professor, Open Systems Science Unit, Okinawa Institute of Science and Technology Graduate School, Japan

Screven, Edward, Chief Corporate Architect, Oracle Corporation, U.S.A.

Kaski, Kimmo, President, Finnish Academy of Science and Letters, Finland

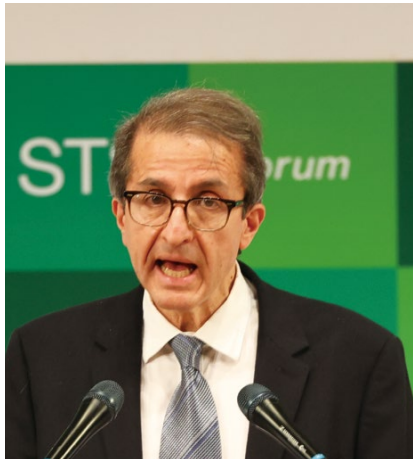
[Online Speakers]

Bell, Genevieve, Distinguished Professor and Director, School of Cybernetics, Australian National University, Australia; Senior Fellow and Vice President, Intel Labs, Intel Corporation, U.S.A.

Cerf, Vinton Gray, Vice President and Chief Internet Evangelist, Google, U.S.A.

Opening Remarks

Dr. Alejandro Adem opened the memorial session by recognizing the legacy of founder and former Chairman Koji Omi. Then, he introduced the topic of the session. AI has been one of the most transformative technological developments in human history. In modern society, AI fuels fully autonomous actions, human ability augmentation, and promises efficiency, accuracy, reproducibility and productivity, making it particularly appealing to scientists and engineering researchers. However, there are lights and shadows when it comes to AI, including complex ethical issues. AI for Good is a digital platform of the UN which aids in identifying practical AI solutions for advancing the UN SDGs. Using AI to benefit society will require sustained effort across many fields.



Chair: Adem, Alejandro

Distinguished Professor Genevieve Bell began by acknowledging the location from which she

was joining the discussion virtually and paying respect to elders past and present and indigenous peoples around the world. She explained that in Australia, it is common to begin conversations in such a way to locate oneself within a greater context. She shared her deep interest in the stories of technology and the lessons to learn from such stories. AI has a long history stretching back to the middle of the 20th century, first being coined in 1955. Computing had become increasingly sophisticated in the decade leading up to that point, which led to revolutionary ideas pioneering modern AI. In 1946, cybernetics emerged and theorized an approach to next-generation computational systems that encompassed technology, culture, and the environment. For the next 10 years, cybernetics would heavily inform discussions the future of computing. Yet, by 1956, computing had lost much of the cybernetic contexts of systems and dynamics surrounding the technology itself. These aspects must be incorporated back into the story in 2022. The School of Cybernetics at the Australian National University aims to refit cybernetics for the 21st century to rethink and retool for how we design, build, regulate, and manage complex, dynamic systems and AI at scale.

Then, Dr. Vinton Gray Cerf shared his view on the lights and shadows of AI by focusing on machine learning (ML). Google has invested heavily in ML applications which take in and organize enormous amounts of information, then carry out complex processes, such as identifying cancerous versus non-cancerous cells through images. Natural language analysis is a similarly powerful tool. Dr. Cerf also described large-scale ML projects being carried out at DeepMind on the folding of some 200 million proteins.

However, the brittle nature of ML systems means that novel inputs can lead to unpredictable failures and errors. Generalized networks help avoid some such problems, but it is not possible to predict the ways neural networks may fail. Policy should recognize weaknesses in the systems, introduce safeguards, and use human intervention when necessary. Dr. Cerf stressed that STS *forum* tasks scientists and researchers with giving good advice to policymakers, and resulting policy should be applied properly in turn to technology makers.

Dr. Hiroaki Kitano pointed out that deep reinforcement learning has opened new possibilities in three major functions: being able to identify patterns beyond human recognition, opportunities for new commoditization, and expanding creativity. Dr. Kitano described the work being done by Sony together with creators, and explained that AI helps creators generate new ideas, while maintaining their own unique style.

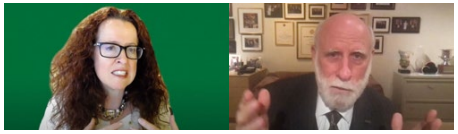
Then, Dr. Kitano described the shadows which are particularly prominent in the area of AI ethics, illustrated by examples of bias in facial recognition and fake data, image, and sound generation through AI. The policy implications and education on AI are crucial. A recent AI strategy in Japan is considering AI to help with clear and present dangers like national resilience and planetary resilience. AI solutions must be a combined collaboration with fields like agriculture, physical simulations, and engineering. Finally, Dr. Kitano emphasized that cybersecurity and responsible AI practices will be necessary to build public trust and encourage people to contribute their own data to these efforts.

Next, Mr. Edward Screven explained that AI tools are cheaper and better than ever before. At Oracle, there was previously a dedicated team of data scientists who would work to solve a single problem. Now, there is a set of tools that was created which has allowed all engineers to create their own effective ML-based models, and this is shaping decisions made by organizations. However, since models require training data, issues of data confidentiality arise, and data security becomes vital. Ensuring data is used in a fair, ethical, legal, and non-biased manner is critical.

Technologies are emerging to solve these issues, and to help ensure models based on consumer data cannot be reverse engineered by malicious parties. Finally, Mr. Screven pointed out that AI techniques are only useful if they are used. Companies and organizations must be good custodians of user data and understand the associated risks.

Prof. Kimmo Kaski then explained about research related to health and social data. By 2025, more than 1023 bytes of data are expected to be generated worldwide. The data will serve as a goldmine for AI and other computational science research, but access, along with privacy and ethical issues, pose challenges. Some successes are being seen in developing automated, cost-effective tools to augment medical practices and diagnostics. Deep learning has become very efficient in certain cases, but it is necessary to go beyond this and gain insight into the properties of health and social systems, understanding the structure, how it functions, and responds under different conditions. Network science and computational modeling approaches must be taken to analyze complex linking structures and their constituents and find plausible mechanisms between them, enabling a holistic understanding of systems.

Lastly, Prof. Kaski gave an example of Alan Turing, a forefather of computing and AI, and someone with deep interest and cross-disciplinary approaches to problem solving. An



inquiring mind is important to see major progress, as evidenced by individuals like Alan Turing and Koji Omi.

Discussion

Dr. Adem opened the discussion by asking about the unexpected opportunities and challenges on the horizon for AI.

Mr. Screven said that AI has fundamentally changed software development at Oracle, but possible social implications of long-term interaction with AI systems should be explored.

Then, Prof. Bell talked about the artistic and creative experiences emerging with AI, with an example of the Tracker Data Project in Australia, which made sense of data from an aboriginal perspective to create an art installation.

Dr. Adem then asked the speakers how governments, policymakers and researchers can ensure AI is trustworthy, used responsibly, and remain free of biases.

Dr. Kitano said many people are seeking out answers to this question. Focus is shifting to how to create trustable AI, since without trust it will not flourish in society.

Prof. Kaski added that AI serves as a great toolbox for new discoveries, yet there are other computational and data science methodologies that may be better suited to certain problems and go beyond what AI can do.

Prof. Bell pointed out that many voices from diverse backgrounds must join the table to have conversations about trust in AI.

Q&A Session

A member of the audience asked about AI use in the medical field, and who will ensure patient confidentiality.

Mr. Screven said that there are techniques to measure the degree to which a model will leak information, and preventative techniques for such leaks. Policymakers must create a rubric for acceptable margins of error, and standards must be set to enable effective policy.

Dr. Kitano added that tracking temporal data of patients is important, but some governments do not allow for such data due to its higher data breach risks. In countries like Japan, predictive healthcare is only enabled in private industry.

Prof. Bell noted that concepts of private data can change over time. Elements like how data was collected, stored, moved, and connected to, are important considerations. More dynamic solutions will necessary, especially for international collaboration.

An audience member then asked about safety in the case of unintended consequences of AI, and whether those working on AI are being serious enough about this.

Mr. Screven explained that there is already strong demand among users of AI to ensure that factors going into systems are reasonable and explainable. Working across fields like social research may help identify and address unintended consequences.

Dr. Kitano said that companies avoid harmful products, but warned of malicious uses of AI, such as small weaponized drones.

Prof. Bell added that some challenges could result from the possibilities of algorithms reproducing errors at scale and speed. It is important to learn from history about how technologies can transform society.

Prof. Kaski noted that it would be beneficial for researchers to gain access to models made by companies for research purposes.

Mr. Screven added that Oracle Labs has programs for outside collaboration, but this also introduces need for tighter customer data security. Precautions at each step are necessary.

A member of the audience next asked how AI and ML handle ingrained biases, and how this is being prevented.

Mr. Screven explained that AI is full of methods and systems to reduce biases, including implicit ones, generate explanations, and measure degrees to which different factors impact a decision. If there is a desire for a certain outcome, one can independently measure the degree to which the tools reach those goals.

Dr. Kitano added that it is important to determine what biased data is, find underlying bias in society, and rebalance models. Work is ongoing to increase transparency and make data fair. In cases with material impacts on lives of individuals, considering not using AI is important.

Prof. Bell stressed the importance of examining how data is collected, the sensors, the actions performed, and the learning models, to see the fuller picture. The worldviews and preconditions that existed prior to it becoming data should be considered, and this process is long and ongoing.

Finally, a member from the audience then asked which use cases of AI would be good to adopt in developing countries, while managing issues like data sovereignty.

Dr. Kitano noted that major technology companies are implementing initiatives of AI for positive purposes in developing areas. It is in the interest of all to solve sustainability issues globally.

Key Messages from Concurrent Sessions

[Chair]

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

[Speakers]

Pacheco, Carlos Américo, Executive Director, State of São Paulo Research Foundation (FAPESP); Professor, Institute of Economics, State University of Campinas (UNICAMP), Brazil

Augustine, Lauren Alexander, Executive Director, Gulf Research Program, The National Academies of Sciences, Engineering, and Medicine, U.S.A.

Abdul Hamid, Zakri, Chairman, Atri Advisory; former Science Advisor to the Prime Minister of Malaysia, Malaysia

Ndlovu, Hlumani, Lecturer & Principal Investigator, Integrative Biomedical Sciences, University of Cape Town, South Africa [Young Leader 2022]

Ohno, Hideo, President, Tohoku University, Japan

Dogterom, Marileen, President, Royal Netherlands Academy of Arts and Sciences (KNAW); Head of the Department, Bionanoscience, Delft University of Technology, Netherlands

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

Pironneau, Olivier, former Vice-President / Foreign Secretary, Applied Mathematics University Paris-Sorbonne, French Academy of Sciences; Professor, Applied Mathematics, Sorbonne University, France

Paredes Villanueva, Kathelyn, Associate Researcher, Faculty of Agricultural Sciences, Gabriel René Moreno Autonomous University, Bolivia; Asociación Mujer Forestal Bolivia [Young Leader 2022]

Rosenvinge-Thürmer, Ulrik, CEO, Empatik AI, Sweden [Young Leader 2022]

Chair: Tan, Eng Chye

Opening Remarks

Prof. Eng Chye Tan opened the session by congratulating STS *forum* on the holding of another fruitful event. The topics covered this year covered a wide range from how science and technology (S&T) can contribute to great progress, the challenges to this progress in times of uncertainty, and the importance of continuing progress in less popular fields. Answers to such questions could have profound implications on the trajectory of R&D in the years ahead. Prof. Tan emphasized

that humankind is facing an inflection point in its development, and now holds the power to do great good, but also great harm.

Prof. Carlos Américo Pacheco presented the discussions from the concurrent sessions on energy. The first session focused on the transition to a net zero economy and the key role of energy. Major worldwide systems will need to be overhauled to connect society and change behaviors, in order to incorporate renewable energy into society's infrastructure. There are many considerations in the transition, such as scale and regulations. There are also enablers, such as data to reduce costs and engaging citizens to address demand. More stringent monitoring of progress needs to be reached.

The second session focused on renewable energy, and what to expect in the coming decade. Humanity faces a dire need to shift from a carbon-based to a sustainable framework. Speakers described gaps including renewable energy with innovation as a key, diversifying energy supply to establish reserves, and ensuring recycling and reuse. The climate crisis was likened to the COVID-19 crisis, and speakers described many actions that would be important to change old mindsets.

In the third session, cutting edge technologies were discussed as potential solutions to energy issues. While these technologies are important to develop, analyzing energy issues per sector will help find pragmatic solutions. It was mentioned that 85% of all emissions could be abated using existing technologies, so investment must increase in renewable energy urgently. Finally, given the varied circumstances facing each country, solutions must be adapted as well. Energy transport and social acceptance of technologies require collaborations on a broad scale.

Dr. Lauren Alexander Augustine shared the points made in the concurrent sessions on climate change. The first session talked about the hazards of climate change, including weather changes, food crises, and rising sea levels. Removing carbon and developing a better understanding of the threats will require greater scaling of investment and activities, from a hyper-local scale to international scale. A focus on youth and the future workforce is important, but equally important is learning from young scientists today.

Then, Dr. Augustine described the third session, which covered technologies necessary to reach net zero. It is necessary to investigate and invest in negative emissions technology to achieve the goal. In order to do this, training a new work force, and collaborative efforts by

scientists and other experts on a massive scale are necessary. There is large demand for such technologies in areas like energy and transportation.

The second session covered financing. There must be a focus on emerging economies and decarbonizing portfolios of energy. Current trajectories towards goals were discussed, as was the need for increased public-private partnerships and financing. All three sessions discussed the need for strategic discussion and redundant strategies, and S&T are vital to understand the world and adapt towards a safer, more resilient world.

Prof. Abdul Hamid Zakri spoke on the messages from the concurrent sessions on Earth and commons. The world is in a precarious situation, with problems like food and water security, and some 1 million species of plants and animal species under extinction threat. Those facing food crisis are growing in number. The COVID-19 crisis has accentuated the vulnerabilities in the supply chain and the necessity for food production and distribution, so countries must learn from experience and prepare adequately for the future.

Additionally, the world is becoming more urbanized. With less land for agriculture, innovation is necessary for survival. Harnessing S&T to do urban agriculture will become increasingly important, but it remains to be seen whether new food products will be accepted by the public. Biodiversity loss is another major issue, as global goals have not been met. However, S&T holds potential to create rich biodiversity farms in developing countries, such as in South America and Southeast Asia.

The oceans are also facing unprecedented changes including sea level rise and ocean acidification. There must be greater focus on marine resources, and S&T can help with global data sharing. Finally, knowledge regarding marine issues should be drawn from those in coastal communities, including indigenous communities, in order to tackle the existential threats posed within the area of Earth and commons.

Dr. Hlumani Ndlovu next summarized the points from the concurrent sessions on life sciences. One key point raised was the topic of inequalities. In a post-COVID-19 world, some countries still do not have sufficient vaccination levels. Early warning systems for emerging disease threats must also be developed further. AI can play a key role in this prediction, as well as in informing the world about health threats. Such uses of AI will require careful handling to remain fair and just, so that people without resources are not punished by science.

Another key area of discussion was DNA- and RNA-based technologies as a tool to allow products to reach the market faster. New therapeutics and vaccines were developed at record pace during the COVID-19 pandemic, and this field will have implications for future crises. New tools should continue to be developed and allow for replacement of medicines as necessary.

The discussions also covered the necessity of protective equipment availability worldwide and being able to augment the manufacturing of supplies and supply chain systems. A thread running through all three sessions was on the importance of science communication in an understandable manner, to build trust with the public.

Prof. Hideo Ohno presented the key messages from the innovative engineering sessions. The first session covered revolutionary materials and devices, and how they would be crucial in solving carbon neutrality and creating a sustainable economy. Topics including biomanufacturing, electrochemical energy conversion processes, and applications of conducting polymers were discussed. Scalability is still an issue in many areas, so a more holistic approach is needed to innovate and decrease costs of parts and materials.

The second session covered quantum science and technology. A key point of discussion was on the importance of building public understanding of what quantum technologies are, and their capabilities and limitations. They will not replace conventional computers, but rather be complementary in solving the computationally hard problems. Quantum technology also carries risks, notably to cybersecurity. Therefore, building quantum-resilient systems will be crucial.

The third session was on automated robotics. Robots have gone through several major shifts to reach their current level. Autonomous vehicles are one major area of automation research, as are teleoperated avatars to open new possibilities for work and social interaction. Finally, amidst fears that robots and AI will replace human workers, it is important to develop entirely new functions and possibilities in society through AI.

Prof. Marileen Dogterom reported the outcomes from the cooperation in S&T sessions. The first session focused on S&T as a driver for development, with a keyword of “exchange.” There are great possibilities for developing economies to use sustainable technology, but challenges are different for different countries. In some countries there is still a lack of strong ties between research and education with local industry. It will be important to

exchange information and insights, bridge the inequity gap, and take further steps towards open science. It is also essential that a career in S&T remains attractive for young talent.

The second session was themed on collaborations between academia, industry, and government, with a key phrase of “breakdown of barriers.” Despite experiences of the past, silos persist. Formal programs are being introduced to stimulate collaborations, but it is also critical to develop better understanding about why barriers exist, and not pursue a one-size-fits-all solution. Coming to terms with differences will allow for better efforts to align incentives and expectations and find common frameworks for collaboration, as well as encourage movement between sectors and industries.

The third session focused on how to foster new generations of scientists, with a keyword of “diversity.” This refers to diversity in student population as well as educational courses and career tracks. General job satisfaction in academia is on the decline, so it is vital to attract and retain talent to S&T. Solutions will depend on cultural traditions and exchanging best practices will help to make progress. Broader training can enhance mobility between sectors and encouraging young people to follow their curiosity through a diversity of educational tracks will allow them to be flexible going forward.

Mr. Terry Brady summarized points from the concurrent sessions on S&T education into eight key areas. First, the world today requires new approaches to learning about issues and advancements in science and technology. Those advancements must be leveraged to reimagine the experiences and outcomes of educational systems. Second, STEAM, which incorporates the arts, humanities, and social sciences into S&T, enables learners to apply different ways of thinking to real-life problems. This helps develop collaborative, creative, and critically thoughtful citizens who understand kindness and openness. Third, biases and inequities persist in S&T. Identifying factors that drive gaps and developing policy to address those gaps will continue to be important. Fourth, the discussions illustrated that science is no longer just for scientists. Scientific literacy among lawmakers and regulators, broadcasters and journalists, and regular people are very important.

The fifth point was that pursuit of science discoveries must be objective, ethical, and apolitical. Communication about the discoveries must be factual, intelligible, and apolitical. Sixth, digital learning, though accelerated during the pandemic, must improve greatly. Seventh was the value of lifelong education, as labor markets and skills evolve at a fast rate. Different approaches may be necessary for older learners. Finally, educational competition

is emerging between traditional institutions of higher learning and companies that offer education and training for specific job skills.

Prof. Olivier Pironneau spoke on the concurrent sessions on digital society. The first session was about the opportunities and risks of big data. Technical tools for collecting data are growing greatly, but rules such as determining ownership are underdeveloped. Business opportunities are vast, but AI engines require massive resources, penetrate private lives, raise ethical issues, and impact basic human rights. Citizens expect the government to solve issues, but due to regulation differences in each country, solutions vary.

The second session was on the pandemic of ransomware. There has been exponential growth in cyberattacks. The culprits are very clever, well-prepared, and usually operate from a rogue country, safe from international laws and punishments. If nothing is done about this, it will proliferate rapidly. Solutions at an international level will be necessary. Data related to ransomware is often not shared due to business concerns, but further cooperation will be necessary moving forward.

The third session covered the themes of information authenticity and governance. In an age of fake information, defining the truth is becoming increasingly challenging. In science, credibility is vital, and it is the duty of scientists to state scientific facts in simple terms and reach out to common people, to make sure the truth is spread. Education must improve to teach young generations a critical approach to consuming media.

Dr. Kathelyn Paredes Villanueva expressed her gratitude, on behalf of the Future Leaders, for the opportunity to participate in STS *forum* and interact with many top-level experts, as well as other young leaders. She also expressed that interacting with Nobel laureates was inspiring. She shared her hope for future increases in Latin American participants, and

emphasized that a perspective of including nature itself, gender, and local stakeholder relationships is vital for the development of technologies as well as for the organization of future STS events.

Mr. Ulrik Rosenvinge-Thürmer shared that he was honored to accept an invitation to STS *forum* as an entrepreneur, and he learned that the STS *forum* community is highly motivated to create solutions for the future of humanity and the planet. As a founder of a technology startup aimed at understanding emotions through AI, he was intellectually stimulated by the various discussions. Mr. Rosenvinge-Thürmer's primary takeaway was that for the first time in history, humanity is conscious about its capacity to steer its own evolution. By aligning goals in science with those in industry, increased collaboration across stakeholders will pave the way for innovations that will be instrumental in creating changes needed in the world.

Comments from the Audience

The first audience member commented that food and agriculture is a key discussion area and asked the speakers if they had thoughts about the taxation of the use of digital information, such as in areas of food and agriculture.

Prof. Ohno mentioned that efforts are ongoing in Japan to check and monitor environments for biodiversity. He stressed that biodiversity is extremely important and will likely be a future session topic at STS *forum*.

The second audience member suggested that women in S&T be a subject of a future plenary session. On the topic of S&T contributing to the net zero transition, she called on fellow scientists to agree on scientific processes and lead by example.

The third audience member raised three points that did not have sufficient visibility in discussions. First, countries decide on priorities for science considering national progress, national security, and their own goals, not global solutions. Second, the fruits of S&T drive progress, but we must consider if they will drive equity. Third, science depends greatly on understanding and support from the wider public.

The fourth audience member pointed out that cybersecurity is still underrepresented in discussions and called on fellow scientists to further consider issues surrounding data safety and privacy when developing solutions.

The fifth audience member described three major challenges to S&T: increased competition for budget resources; competition for talent between academia and industry; and competition for attention from the public.

Discussion

Prof. Pacheco noted that the COVID-19 pandemic illustrated the possibility for international collaboration among scientists, but there were still issues concerning national priorities. STS forum is one of the most important places to discuss such issues.

Dr. Augustine commented that scientists and engineers should provide examples of how their work is being manifested, through case studies of where solutions worked and did not. Such exchanges can be very influential and bring together the collaborative society part of STS forum.

Mr. Rosenvinge-Thürmer emphasized that having more transparency between the scientific community and the public could facilitate recruitment and education and promote innovation more quickly. The public should be allowed to better understand what is happening in science.

Closing Remarks

Prof. Tan noted that the session illustrated the continued great potential of S&T to shape human outcomes in the future. Societies have various priorities, so alignment is vital, and solutions must be individualized. There will be uncomfortable changes to the way people work, and stakeholder commitment and collaboration is a necessary step to build a deep and broad social support system to deliver benefits of S&T.

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

[Chair]

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

[Speakers]

Ardenghy, Roberto Furian, President/CEO, Brazilian Petroleum and Gas Institute (IBP), Brazil

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

[Online Speakers]

Kleiner, Matthias, Professor, Technical University of Dortmund, Germany

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)]

Opening Remarks

Dr. Pavel Kabat began by thanking the leadership of STS *forum* for their work to make this year's face-to-face event a success. Then, he began the closing plenary session on science and technology for the future of humankind, and introduced the speakers.

Chair: Kabat, Pavel

Mr. Roberto Furian Ardenghy began by sharing insight into energy and the situation of technology in Brazil. Brazil is making great effort on the energy front. Over 80% of power is renewable. A large percentage of cars can run on ethanol fuel. Much of the energy matrix is renewable. Figures like energy matrices highlight the fact that each country has its own specific situation for energy. Therefore, exchange and sharing are invaluable to find what can be an applicable solution in other countries.

Ardenghy, Roberto Furian

Then, Mr. Ardenghy introduced three concepts: energy transition, energy security, and energy poverty. Energy transition is a focus now with issues surrounding climate change and international agreements. Energy security was exposed as a critical issue by the conflict unfolding in Europe. Energy poverty highlights the importance of ensuring technologies and processes are adapted to low-income and large population parts of the world. Cheap energy is also crucial.

However, fossil fuels will undeniably play a role in coming decades. It will not be possible to fully replace the 80% of energy that they provide in the world today. Therefore, improvements must be made in the way fossil fuels are used and produced. Brazil is actively implementing technologies like carbon capture, storage and usage, electrification of producing platforms, and separating oil and gas taken the sea floors. These are dramatically reducing the amount of carbon emitted in oil production. Oil companies will begin caring more about the amount of emissions per barrel produced when considering providers to work with.

Mr. Ardenghy pointed out that it will be important to not just pursue new sources of energy, but also examine what is being done now. There is an organization called the Oil & Gas Climate Initiative (OGCI), which was created recently to tackle how to improve efficiency and new technologies in the oil industry. They seek to accept the responsibility for the contributions to climate change caused by oil and gas companies. Research is showing that only one out of three carbon molecules are used efficiently in the current situation, leading to a two-thirds loss of efficiency. The other issue is consumer use of energy. Changing habits and consumer patterns in a positive direction will be difficult, but necessary.

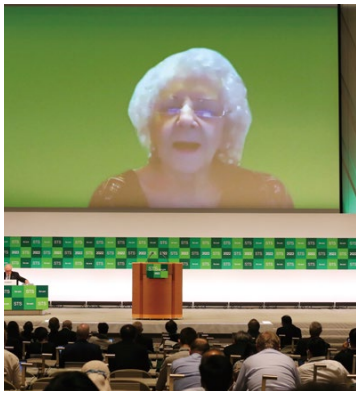
In addition, Mr. Ardenghy outlined three pillars that will be important in looking to the future: new energies, better efficiency with what is currently being done, and changing consumer attitudes. Such areas will guide society towards a new future for energy in the world.

Prof. Matthias Kleiner commented that STS *forum* had proven to him the importance of science and technology in society. Faced with great crises and catastrophes on a global scale, spanning issues from the environment to food, health, inequality, and more, progress in

sustainable efforts is more important than ever. Prof. Kleiner noted that the Werner Siemens Foundation in Switzerland just opened a call for creating a new research center for technologies for sustainability and sustainable use of resources. Such a research center will bring us forward to reach the UN SDG targets and it will be funded by a 100-million-dollar grant. Prof. Kleiner is managing the selection process which just began with an idea competition. Up to five ideas will be awarded with an research prize of one million dollars each.

Kleiner, Matthias

However, the efforts of researchers are not enough. There needs to be dramatic change of behavior of mankind: new mindsets, new ethical standards, and new attempts to end inequality, hunger, and poverty. Military conflicts and wars like the aggression war of Russia in Ukraine must come to an end. The global consequences of climate change are a tall task, and the destruction brought to humanity through wars does make it even worse. Already, many places around the world are being greatly affected by climate change.



Yonath, Ada E.

Prof. Kleiner emphasized that communication must be enhanced within science and be carried out as an integral part of working. In addition, scientists should be aware whether they are part of the solution, or part of the problem. Science and technology is what made possible the situation on Earth we find ourselves in. Therefore, at large, a global era of new enlightenment is needed for politics, societies, science and technology, and it will need more impact from the social and political sciences, along with philosophy and the whole range of the humanities.

Prof. Ada E. Yonath noted that global views of science and different ways of working have led to tremendous change. Then, she shared about her own journey, starting from being a curious young person who wished to understand how genetic code is expressed. This led

Serageldin, Ismail

to further pioneering exploration into the structure of ribosomes, laying the foundation for messenger RNA, a critical discovery that enabled the development of the COVID-19 vaccine.

Prof. Yonath pointed out that she learned about the ribosome through crystallography, which required development of new procedures and collaboration on a major scale. Eventually, a new technique was developed to replace crystallography, cryo-electron microscopy. Trying to gain a deeper understanding of fundamental science has led to insight into how resistance is developed, and finding ways to fight resistance. The cumulative efforts of past research have allowed for progress which no one would have ever believed possible.

Prof. Yonath said that her own scientific journey was kickstarted by curiosity, but the progress from those times is now working in medicine. Now, her work on ribosomes is focused on understanding mutations in ribosomes, and trying to detect them, fight them, or both. Some 25% of all cancers and a severe anemia are related to mutations in ribosomes and there are over 80 different possible mutations. Given the scale of scientific problems, connections between basic science, medical science, and applicable science are incredibly important.

Finally, Prof. Yonath said that those thinking about science should also be thinking about how science evolves and the way we approach it.

Then, Dr. Kabat introduced Prof. Ismail Serageldin, who read the closing statement of the 19th STS *forum*.

Concurrent Sessions

Energy
Action for Net-Zero Emissions

[Chair]
Semeria, Marie-Noëlle, Chief Technology Officer, TotalEnergies, France

[Speakers]
Keller, Martin, Director, National Renewable Energy Laboratory, U.S.A.
Monks, Paul, Chief Scientific Adviser, Department for Business, Energy and Industrial Strategy, UK Government; Professor of Atmospheric Chemistry and Earth Observation Science, School of Chemistry, The University of Leicester, U.K.
Oğuz, Emre, R&D Director, Arçelik A.Ş., Turkey [Future Leader 2017]
Yamada, Koichi, Senior Research Advisor, Center for Low Carbon Society Strategy, Japan Science and Technology Agency, Japan

Opening Remarks

The chair began by explaining that the COVID-19 pandemic revealed the impact of human activity on greenhouse gas (GHG) emissions. To get to net zero there are huge challenges that require changing the worldwide power system and acting with society to change behaviors, keeping in mind that not all countries start at the same place. She added that there are increasing problems in supply owing to the war in Ukraine, which shows the challenges of energy supply security and availability. Sustainability, security and affordability are all connected, and drastic measures on a larger scale are required.

Chair: Semeria, Marie-Noëlle

The speakers then explained that in order to accelerate the integration of renewable energy into society and infrastructure also requires governments and others to show communities that the transition to renewable energy is possible, and added the importance of scientists around the world collaborating in projects that demonstrate this.

The speakers then stated that solutions are needed in order to adapt to climate change and make societal changes. One of the key enablers for adaptation will be using digital information and data to increase efficiency and reduce costs, and engaging citizens by addressing demand.

The significance of appliances was also discussed. Households consume a third of current electricity, so efficiency of appliances at home will be important, as will the way consumers use these appliances. Digitalization will allow consumers to track their appliances and raise their awareness, thereby helping to achieve targets.

The speakers then noted the need to quantify the implementation of reduction measures and disseminate the changes in GDP. They added how Japan has developed a system for quantifying future costs and a database for calculations, in order to show what costs will be required and how future GHG emissions and GDP will change.

Discussion

The participants then engaged in a group discussion, and began by discussing the need to learn from the recent COVID-19 crisis. The most important lesson is the need to reduce inequality. Some countries will need to reduce consumption while others will need to increase it. There is also an unwillingness in some countries to face the issues in society. Education will also be vital as students will need to be engaged and be aware of the situation.

The participants also discussed Japan's system of using future energy compositions and GHG projections. They stated that it would be important to determine the costs and determine an accurate and efficient process, as this will become motivation for products. They added that although the energy situation is different from country to country, the ways of thinking and actions are exactly the same.

Then, the participants highlighted four key points that will be necessary to accelerate the path to zero emissions. The first point is funding the transition to renewable energy. Collecting money from the public must be done with clear use and full transparency for it to be socially acceptable. The second point is creating a lifecycle and circular economy, such as using the materials from past projects to create new ones. The third is innovation. Technology is ready for the transition to renewable energy, but the scale of deployment is massive, so there will need to be a tradeoff between long lifecycles and reuse. The fourth point concerns regulation, where the impact of actions must be transparent and visible. The

participants also added that there should be a common global tax on GHG emissions in order to prevent certain countries avoiding reparations.

Participants also talked about how, while countries are committed to GHG reductions, roadmaps and action plans to achieve these commitments remain quite weak. In order to achieve net zero, there must be concrete plans and objectives, and these must be monitored year-by-year and have solid milestones. Every country will have different roadmaps, but respective governments will need to exercise their plans solidly to achieve net goals.

Lasty, the participants noted the importance of electrification, and of the electricity grid becoming decarbonized to achieve goals. However, they added that most of the technology that exists may achieve mid-level targets, but to reach net zero, an acceleration and development of new technologies will be crucial.

Energy
Transitional Path toward Renewable Energy

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

[Speakers]
Terazawa, Tatsuya, Chairman and CEO, The Institute of Energy Economics, Japan
Mesot, Joël, President, ETH Zurich, Switzerland
Okamoto, Hiroshi, Exective Vice President, CTO, TEPCO Power Grid, Inc., Japan
Charojrochkul, Sumittra, Executive Director, National Energy Technology Center (ENTEC), Thailand
Cudré-Mauroux, Nicolas, CTO, Research & Innovation, Solvay SA, Belgium
Barros, Nathan, Professor, Institute of Biological Science, Federal University of Juiz de Fora (UFJF), Brazil

Opening Remarks

The chair opened the session by talking about how, while there have been remarkable advances in society over the last 10 years, climate disasters have brought new and unanticipated challenges. When we think about the energy transition, we need to make it clear we have an urgent problem and plans must be shaped by the realization that we can no longer prevent damages. He added that while countries must consider roadmaps and implementation strategies, it is also crucial to consider public policy and public communication to make sure that the strategies are accepted.

Chair: Isaacs, Eric D.

The speakers then described four gaps to be addressed; renewable energies, with innovation playing a key role for countries lacking in renewable resources; decarbonizing the non-power sectors to reduce greenhouse gas (GHG) emissions; diversifying energy supplies from Russia to obtain new, stable resources

to be used to produce blue hydrogen in the future; and ensuring sustainability of critical minerals through usage reduction, development of alternatives, recycling and better mix of technology that requires less critical minerals consumption. Innovation will have a major role to play in addressing these gaps, backed by public policies addressing cost differentials in particular to incentivize investment.

Building on this, they discussed how strategies to achieve public acceptance will be critical. Various international studies show that the transition is feasible, but appropriate boundary conditions must be put in place to accelerate this. On monitoring the efforts being made, they proposed using apps and other methods to monitor emissions by individuals and societies.

The speakers then discussed four important actions needed to maximize the use of renewable energies; improving energy efficiency through alternative means, combined with digital technology, to add value; effective use of renewables in disaster response; ensuring diversity of primary energy sources, including nuclear and CCUS; and promoting digital and green transformation. They also emphasized the importance of interdisciplinary and international cooperation.

Next, the speakers stated that results will not be achieved by remaining on the current path. Switching to renewable energies is one way to solve the climate problem, but the first big step is to change mindsets. There are many ways to reduce energy consumption, but changes in habits are much easier than capturing excess carbon. They also noted that circumstances and natural environments vary from country to country, so a one-size-fits all solutions will not be appropriate. Rather solutions must be appropriately tailored to each country.

The speakers emphasized the need for innovation, and added that the climate issues must be treated as a crisis, the same as the COVID-19 pandemic. They added that there is no single easy solution, and that everyone in the world is facing the same problem. The world needs to think about what concrete measures are needed and what key points would make a difference.

Lastly, the speakers talked about hydropower. Hydropower has a crucial role in the transition to renewable energy, and there must be new developments through science and technology, such as technologies to collect and use the methane emitted from the surface of hydropower

or to strategically plan the locations of new dams. For the existing dams, technologies are needed to improve the systems by increasing turbine efficiency and energizing non-power dams. Additionally, hybridization by combining hydropower plants and solar power plants is crucial for a renewable future. Finally, the development of pumped storage reservoirs is essential to increase storage capacity in the near future.

Discussion

The participants then engaged in a group discussion. They began by discussing the potential of hydropower in more depth, including the benefits it would provide such as oxygenation of water sources and biodiversity. They also discussed the need to make existing technologies more efficient, such as reducing GHG emissions, and the role of nuclear.

The participants also considered what the focus points of the energy transition would be. They talked about which critical aspects like supply chain issues would need to be addressed for scalability. Additionally, they discussed the need to push for solutions both on a near-time scale like advancing solar energy and on a long-time scale including considering more movable energy storage solutions. They also emphasized that one of the biggest

challenges is not technology, but policy reform and the need for political leadership and sharing information with the public.

They also contemplated energy transition pathways and how they are affected by the different experiences of different countries. They noted that development of renewable energy plants and challenges vary by country, and there must be ways to overcome those respective challenges. They also mentioned hydrogen once again, as well as the trade-offs to renewable energy. The ground is ready for new technology and measures, but there are issues related to the scarcity of resources.

The participants then noted four points related to the transition, namely the timeline, the importance of science and technology, the role of governments as drivers, and investment. They agreed that there is a disconnect between efficiency and renewable energy in different countries, and that policies will have a much bigger role to play, especially in the developing world. There should also be policies to make people recognize the importance of reducing energy use.

They then considered a framework that could be applied to all regions, wherein mission or task force committees would address specific issues, then make recommendations and receive funding needed to implement measures. Such a framework would help in developing the required infrastructure for energy transitions.

Finally, the participants emphasized that there is an imminent need for technologies, due to the war in Ukraine, and a need to look at existing technologies. Also, because of differences across countries and phases of development, the energy transition requires policies that address a global scale. Policy engagement is also required in terms of international cooperation, and we must look from a total energy perspective, including safety measures.

Energy
State of the Arts Energy related Technologies

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

[Speakers]
Ishimura, Kazuhiko, President & CEO, National Institute of Advanced Industrial Science and Technology (AIST), Japan
Putallaz, Sue, Co-founder and CEO, MobyFly, Switzerland
Schlögl, Robert, Director, Department of Inorganic Chemistry, Fritz-Haber-Institut der Max Planck Gesellschaft; Vice President, Leopoldina, Germany
Tada, Eisuke, Director-General, interim, ITER Organization

Opening Remarks

The chair began by asking what technological pathways aid humanity in reaching a better place for energy generation and use in all its forms. One of the major challenges involved is facing climate change. While there have been advancements towards decarbonization, it is hard to face it as an immediate problem. Some technologies can help reduce greenhouse gas (GHG) emissions and provide more resilient supply, but others can exacerbate the situation in responding to climate constraints. Therefore, it is important to look at what technology options exist and try to find choices that reinforce stability and supply, helping us tackle longer term climate change issues.


Chair: Mason, Thomas

The speakers then explained about the recent actions by Japan towards green growth, including the specific actions by the National Institute of Advanced Industrial Science and Technology (AIST). It is not yet clear what would be most effective in achieving carbon neutrality, so extensive technological development must continue. At the same time, it is important to narrow down the list of effective technologies.

The speakers also noted that analyzing energy issues per sector might help to find pragmatic and adapted solutions. Renewable energy has not been promoted enough, and investments to increase energy self-sufficiency and independency at various levels will be needed. They also introduced a study that showed that 85% of GHG emissions could be abated using existing technology, emphasizing that actions can be taken now to solve the problem.

They also highlighted the importance of chemistry as a solution for energy transitions. Chemical technology offers the tools and can contribute substantially to the energy transition. The basic technologies exist today at scale but not in the systemic contexts for transport and storage of energy. For the global supply of green molecules, critical improvements of the technology portfolio are needed for which we need to understand chemical conversion technology better in order to integrate it with energy systems.

The speakers finally explained the initiatives undertaken by the ITER Organization on hydrogen fusion technology. Such technology can produce huge amounts of energy, and if ITER can successfully develop the necessary technology, fusion will provide a nearly unlimited energy source that can be uniformly and securely distributed, and because it does not produce GHG emissions, it would help to combat climate change.

Discussion

The group then began discussions by highlighting four key points. Firstly, every country is different so there must be international collaborations in different sectors and there will be great potential for cross-border collaboration. Secondly, most countries will have to import energy, including renewable energy, leading to a need for discussions on what will be the best ways to transport energy, including from chemical technology aspects. Thirdly, social acceptance will be a key area to address, and it will be necessary to get the public behind renewables at an early stage. Fourthly, all the previous points require international collaboration, so participants will need to encourage their policymakers to come together to find new ways to collaborate and help each country.

The participants also noted that the energy mix will vary across different regions, and the transition will depend on how to make the best of those mixes. Energy is also related to economic balance, so it is important to think what is most available in each country and what will be the best way to support carbon neutrality, factoring in consumer demand. The participants also mentioned that the world is aware of the need to pay carbon taxes, but

governments must show that those taxes are being used for a noble cause in order to get social support. Another perspective was that changes must come from regulations, and have to be collaborative.

The participants agreed that future energy demand will be multi-layered, and requires inputs from various people at different levels. The infrastructure that will be built will differ geographically. A lot of areas will need more energy and that will have to come from high energy carriers.

Then, the participants discussed fusion energy in greater detail and how they can operate in the ITER Organization's framework. Fusion is a big game changer, and it should be accelerated, but the challenge is that, because fusion will be needed on a large scale, it will require increased demands in materials, so the future material aspects must improve greatly. Also, because fusion is categorized as nuclear, public outrage will be a challenge to be addressed for better understanding. Each country has to consider fusion as part of the roadmap for carbon neutrality, and global collaboration will bring global energy sustainability.

Finally, the participants discussed the incentives around new technologies, and how to get individuals and larger groups to adopt new technologies. These include voluntary options such as financial incentives, or regulatory incentives. They also reiterated that some countries around the world have different energy consumption levels and some countries cannot adopt renewable fuels. Pre-empting the renewable energy game yields a big advantage.

Climate Change
Adaptation to Climate Change

[Chair]

Falk, Jim, Professorial Fellow, School of Geography, Earth and Atmospheric Sciences, University of Melbourne; Emeritus Professor, School for Humanities and Social Inquiry, The University of Wollongong, Australia

[Online Speakers]

King, David, Founder & Chair, Centre for Climate Repair, Centre for Climate Repair Cambridge; Chair, Climate Crisis Advisory Group, U.K.

Kennel, Charles F., Distinguished Professor and Director Emeritus, Scripps Institution of Oceanography, University of California, San Diego (UCSD), U.S.A.; Distinguished Visiting Scholar, Centre for Science and Policy, University of Cambridge, U.K.

Dawson, Richard, Director of Research, School of Engineering, Newcastle University and UK Climate Change Committee (Adaptation Committee), Newcastle University, U.K.

Kim Chiang, Kai, Commonwealth National Climate Finance Adviser for Seychelles, Commonwealth Climate Finance Access Hub, U.K.

[Speakers]

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

Shaw, Rajib, Professor, Graduate School of Media and Governance, Keio University; Chair, United Nations Science Technology Advisory Group for Disaster Risk Reduction, UN DRR, Japan

Chair: Falk, Jim

Opening Remarks

The chair began by stressing the importance of adapting to the numerous impacts of climate change via addressing adaptation capacity and resilience. The converging risks of climate change include inequality, food insecurity, agriculture, and the spread of disease. The path to solve these crises involve a global responsibility to provide for economically disadvantaged populations and provide access to the science and pathways to a net-zero economy. Nations need to collaborate fully to back up existing agreements. R&D funding, integrated

government action and global financial support are also required. Furthermore, support for strategies, and a greater focus locally, regionally, and nationally is needed to allow communists to solve for local problems.

The speakers discussed the measures that would be needed to help create a manageable future and for humanity to overcome unprecedented challenges. Greenhouse gas impact is already producing extreme weather events. The Arctic Circle is heating at four times the rate of the rest of the planet. A global strategy is required to analyze the current position and to take action to refreeze the Arctic. Reducing greenhouse gases will also require new thinking and new strategy. Restoring the biodiversity of the world's oceans should be considered as a biodiversity target. A coalition of the willing could lead the way.

The speakers also discussed the difficulty of identifying the best path to adaption to climate change due to complicating factors. Climate change and biodiversity loss are important, but humanity needs to consider how to divide its resources and how these two crises will interact in the future. Furthermore, reaching zero carbon will not remove the existing carbon and only stop the increase in extreme weather events. These crises may culminate in 2050 at the peak demographic period and this may be the maximum threat period, with maximum convergence of climate change and biodiversity loss.

Furthermore, the speakers engaged in discussion regarding the urgency of the challenge, how the risks are starting to interact and compound, and the need for transformative adaptation action. The impacts and risks will increase substantially, and the impact of climate change will not be equitable. Current global actions have had some positive benefit, but are not fast enough, nor of sufficient quantity. Moreover, there needs to be better monitoring of adaptation, as humanity is not on track to achieve a climate-change-resilient world.

The speakers agreed on the need for urgent action but also the need to take more approaches towards hybrid pollution and more caution on the way to adopt adaptation solutions. The participants called for more accountability and transparency in monitoring adaptation actions. Humanity needs to build resilience to be prepared for uncertainty and provide the capacity and ability to adjust to varying challenges, thus, transformative adaption and not incremental adaption is required.

The speakers also noted that the effect of climate change has been proven through extreme events and loss of diversity on the economy. The next decade will be critical, and science

should create knowledge-based approaches to allow an equitable future for all. Adaptation and transdisciplinary solutions are important. The role of the youth is also critical to create resilience across generations. Furthermore, awareness of the importance of adaptation, mitigation and resilience, should be raised among the youth.

Following this the speakers discussed the risk landscape that is becoming more complex, showing that climate inaction and the likelihood and impact from infectious diseases are great. The speakers also discussed the digital divide as it compounds the risks. All parties involved need to think about the evolving nature of the risks and the non-climate factors, such as migration. The risks cannot be solved through only short-term adaptions, and long-term consequences must be considered. Adaptive governance is also needed. Also, the role of the youth and innovation and the role of the private sector should be considered.

Discussion

The participants discussed how current world energy production would be needed to engage in carbon capture, as that was the energy that produced it in the first place. The possibility of natural planting could be also considered.

The participants also noted that real, and not just symbolic, involvement of youth is needed. They also stated that education could play a crucial role in bringing awareness, and that the youth of today respond well to immersive learning.

The participants also considered whether the Intergovernmental Panel on Climate Change reporting process was still appropriate. They suggested that climate change advisory groups filled with experts could produce more agile reports and debated the frequency of IPCC reports. However, they also noted the value of IPCC Special Reports such as 1.5C, the comprehensive nature of Assessment Reports, and the benefits of government review in the IPCC process.

In addition, the participants talked about the refreezing of the Arctic. This could be done via aerosol dispersion into the atmosphere to cool the Earth like volcanic eruptions, or by creating white cloud cover for the polar region for several months with salt crystals. However, the participants also cautioned that minimizing interventions would be less likely to create unintended side effects. Reducing demand and consumption, and ensuring everything we do and build has climate resilient development principles at its heart, would be more effective. For example, why are we still constructing buildings that are not fit for the future climate?

Furthermore, the participants discussed the possibility of nuclear power and the possible downsides from neutron production creating nuclear hazards in fusion.

The participants also discussed which communities were most important to engage and co-participate in developing and implementing adaptation solutions.

The participants mentioned that new forms of capitalism and the value systems embedded in adaption would be important to ensure equal access. They also discussed that indigenous communities know how to live within their ecosystems and should be incorporated into the discussions as stakeholders.

Climate Change
Financing the Sustainable Economy

[Chair]

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

[Speakers]

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

Koll, Jesper, Global Ambassador, Monex Group; Board Director, OIST - Okinawa Institute of Science & Technology, Japan

Ozeki, Hiroshi, President and Chief Executive Officer, Nissay Asset Management Corporation, Japan

[Online Speakers]

Koundouri, Phoebe, Professor, Department of International & European Economic Studies, ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS, Greece; President, European Association of Environmental and Resource Economists, Italy

McBain, Darian, Chief Sustainability Officer, Sustainability Group, Monetary Authority of Singapore, Monetary Authority of Singapore, Singapore

Sandor, Richard L., Chairman of the Board & CEO, American Financial Exchange, LLC; Chairman and Chief Executive Officer, Environmental Financial Products, LLC, U.S.A.

Chair: Kanda, Masato

Opening Remarks

To start the session, the chair remarked on how humanity has developed through its Anthropocene and its resulting crisis of climate change for the planet. The finance markets and the Japanese government are addressing this climate crisis by creating new investment vehicles to drive sustainability. The past focus of nation states on GDP growth as a marker of progress should be reconsidered as humanity aims to realize a sustainable path forward.

The speakers first spoke on the catastrophic risk of not achieving net zero greenhouse gas emissions by 2050 and the current failing trajectory of achievement of the Paris Agreement. Industry processes in certain fields such as concrete and steel are high greenhouse gas emitters, and policy and financing to address these difficult to abate sectors are much needed. Risk of investment in carbon emissions reduction can be averted via private and public financing mechanisms.

Next, the speakers discussed the difference between decarbonizing individual financial portfolios and decarbonizing entire economies, and considered the emerging and developing economies that are to be the drivers of green growth. Reform of multilateral development banks and developing financial institutions is necessary due to their outdated financial practices. Transition financing has low visibility and transparency currently, and this disincentivizes investment in the emerging and developing world.

The need for resilience in sustainable financing, the pandemic and its resulting economic recession, the population crisis, the energy crisis, and the loss of biodiversity were also discussed. Moreover, it is important that sustainability performance is measured in humanity's attempts to meet the Sustainable Development Goals and the Paris Agreement to address these various crises. Recent projects to address these crises are being funded according to their ability rating and assessment as projects for sustainability that can monetize the natural habitat.

Another topic was the poor performance on climate change actions in the face of increasing extreme weather events. Therefore, technology needs to be leveraged at scale for financing with better access to and trust of data to enable successful actions. The integration of fintech in sustainability, high quality climate disclosures and blended financing for decarbonization are all vital to achieve 2050 goals. Skills on sustainable financing and the integration of society will also be critical in this regard.

The speakers then discussed net zero investment initiatives and how risk, return, and sustainability are included in investment portfolios. Sustainable financing firms seek ESG investment vehicles, but current investment methods will not realize net zero alone. Therefore, the finance industry should address hard-to-abate industries in its approach to sustainability. Good investment for the future should be the mantra as portfolio managers make investment decisions.

In addition, the topic of perception and reality as it relates to sustainable markets was broached. The historical perception of issues such as acid rain and the perception of carbon pricing have been seen to be out of kilter with the reality of the actual situations and these perceptions did not fully appreciate the successful outcomes of such initiatives for the environment. This disassociation of perception and reality is similarly true with the negative perception of China's carbon emissions despite its seven recently created spot markets that will reduce emissions.

Discussion

The participants then engaged in a group discussion on carbon pricing and the practical reality of applying carbon taxes. The measuring of carbon emissions and intensity in automotive and buildings industries is also a topic that was discussed.

The discussion then covered measuring the carbon emissions of China and India and practical paths forward to help realize agreement on their targets in international fora. The path towards decarbonization was said to be possible with support from the private sector, although Track I negotiations remained difficult.

The participants also discussed the restarting of nuclear power plants in Japan, the use of nuclear more broadly to support the achievement of sustainable energy targets, and incentives to develop new nuclear technologies.

The discussion then turned to the topic of practical measures for improving the performance of sustainability frameworks in real time and across all sectors and the topic of which economic market settings can realize all aspects of ESG, whereby ideas were shared on the ownership necessary to achieve social cohesion, upskilling and reskilling for sustainability, and regional characteristics.

Greenwashing and standard setting for sustainable investment and how this affects micro, small and medium-sized enterprises was discussed. Any standards will need to ensure compliance within a country and across countries. SMEs will need simplified reporting mechanisms to facilitate compliance.

Then, the discussion moved to address the various macro political issues, geopolitical situations, inflation, and the rate of economic growth and how these impact ESG investment and necessitate complex approaches.

The participants then spoke on the profitability of sustainable investment in hard-to-abate sectors rate of return, the perceptions of ESG investments for final beneficiaries, and the relationship of private investment in the realization of net zero targets. The discussion also highlighted the importance of translation and dispersion of English-language sustainability data and the disparity between ESG financial ratings.

Engaging discussion was then held on the topics of mainstreaming sustainable finance and the homogenizing and commoditizing of sustainable financing via standards.

Climate Change
Negative Carbon Technologies

[Chair]

Marshall, Larry, Chief Executive, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

[Speakers]

Ishizuka, Hiroaki, Chairman, New Energy and Industrial Technology Development Organization (NEDO), Japan

Wilcox, Jennifer, Principal Deputy Assistant Secretary for Fossil Energy and Carbon Management, U.S. Department of Energy; former Professor, Department of Chemical Engineering, Worcester Polytechnic Institute, U.S.A.

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

Tanguy, Philippe A., Chief Strategy Officer, HTEC; Adjunct Professor and Past University President, Montreal Polytechnique University, Canada

Opening Remarks

The chair began by starting the discussion on the future technologies for emissions reduction and inquired as to the paths for real action. In order to realize net zero, negative emissions technologies will be required to abate the portion of carbon emissions that cannot be recovered naturally, and training of workforces will be necessary to deliver these technologies, including for technologies such as kelp forests and sea grass for Australia. Patently, global collaboration will be vital as humanity seeks a secure market for zero carbon technologies.

Chair: Marshall, Larry

The speakers first explored the topics of sustainable technologies for the removal of carbon dioxide, the circular economy, and how they will need to be adopted in an integrated manner. Development of direct capture and

use is currently being researched as are natural carbon sinks, such as biomass. Carbon sequestration is also being investigated in technologies such as carbon fixation in concrete and ocean related storage. However, technology for storage in forests is already in place.

The speakers then discussed the necessity of carbon removal but also the need for better ability to quantify the benefits of natural storage and a better understanding of the base line of natural carbon removal. Direct capture will scale up to counterbalance the hard-to-decarbonize sectors. A huge amount of energy will be needed for carbon capture, but technology may be able to leverage existing energy infrastructure and existing energy use to reduce costs. Also, both power generation and direct air capture could be done together, too. There are barriers for this at scale due to the fact that some capture may be done in communities that have already been affected by gas or oil extraction. Carbon also may not need to be removed in some cases but could be used as a chemical feedstock for synthetic sand or hydrogen. Hydrogen from this process could be used to decarbonize the hard-to-abate transport sector. In addition, governments also need to address incentives via federal tax credits to finance the transition.

Carbon emission reductions targets and negative carbon emission solutions, including hydrogen and efficient fuel cells were also discussed, as well as power-to-chemical conversion into feedstocks using surplus renewable energy. However, existing approaches for such technologies have problems in scaling. The challenges for the adoption of these technologies are the establishment of a carbon credit system and other financial schemes. Toshiba is to make a plan for a 70% reduction in carbon emissions but reaching net zero will be difficult as the corporation's carbon footprint is linked to its customers and wider society. These stakeholders will, too, be incorporated in the process for mutual consensus. Other corporations could utilize green corporate venture capital or properly manage forests for carbon dioxide capture.

The speakers then emphasized the role of hydrogen to address the hard-to-abate sectors and the key requirement for supply chain transparency. They explained that the production methods of hydrogen are region dependent. In some cases, opportunities exist for the development of negative carbon production technologies. In Quebec, emissions from the power sector are very low due to the use of hydropower making green hydrogen produced by water electrolysis a very attractive method to decarbonize industry. The thermochemical conversion of biomass coupled with carbon capture and storage (or use of carbon dioxide) could be an alternative to make carbon negative super-green hydrogen, although

the adoption of biomass-based technologies requires careful supply planning (harvesting, transportation, long-term supply capacity). Presently, there is a lack of clean product standards, in particular the origin of the embedded carbon or hydrogen. It is therefore difficult to assess the durability in a whole product cycle. Leadership and coordination will be important to resolve these issues as well as devising impactful measures in carbon pricing and guarantee of origin. Carbon needs a higher price, so that emitting carbon dioxide is more costly than adopting clean technologies. Taxation, regulations and financial incentives are important to promote clean hydrogen and drive change towards decarbonization.

Discussion

The participants engaged in a group discussion, identifying questions on durability and recognition of the technology, the standards of capture and how to determine the baseline, true emissions rates, changing dynamics of trust, and the possibility of nuclear energy since it is now more viable due to geopolitical shifts, in particular small modular reactors. They also discussed the limitations in policymaking, particularly in the United States, the need for claims of carbon data to have regular validation and robust monitoring, and how far electrification can take emissions reductions to achieve the Paris Agreement's targets.

The participants also raised points on the topics of scale for the technologies and the size of the carbon value chain. Due to its size, there is a need to address the separation of carbon dioxide apart from its utilization. High emissions industries are more limited in the decarbonization technologies that they can use, and thus, they should prevent carbon emissions at the source. They also broached topics such as the possibility for commercialization and clear governance that is linked to net zero targets. Certification and validation of this must be conducted independently and frequently. Furthermore, exchange of skills in these technologies will also help the technologies gain a foothold. Perception of the technology is also important, as it is seen in a negative light in policymaking circles in India. There is also a need for wider collaboration for technology and scientific education via sharing platforms internationally.

In addition, the participants discussed the challenges in understanding the exact magnitude of carbon dioxide that is being removed and by which processes, and the future power-to-chemical processes to capture carbon dioxide and turn it into building materials, along with discussion on the use of biomass chemical energy that could be combined with carbon capture.

Earth and Commons
Agriculture, Food and Water Security

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

[Speakers]
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
Thi Thi Soe, Lecturer, Department of Agricultural Economics, Yezin Agricultural University (YAU), Myanmar [Young Leader 2022]
Kida, Kate, Vice President, Greenland, Japan
Tetrick, Josh, Co-Founder & CEO, Eat Just, Inc., U.S.A.
Deshpande, Varun, Managing Director, Good Food Institute (GFI) Asia, Singapore

Opening Remarks

The chair introduced the speakers and addressed the increasing pressure faced by the world's food and water supply chain, which is further threated by climate change, extreme weather events, and disruption from international conflict and pandemic events. Being a highly urbanized country, Singapore is both food and water poor, with over 90% of Singapore's food imported. With a goal to produce 30% of Singapore's nutritional needs by 2030, Singapore is looking into sustainable indoor urban farming solutions and future foods such as advanced biotech-based protein production. The chair called for countries' strong commitment and cooperation to discuss forward-looking policies and identify areas for collaboration to help achieve food and water security.


Chair: Lim, Chuan Poh

First, the speakers discussed the food and water supply in arid climates, in relation to the impact of increased temperature, which

may exceed three degrees by 2050. This increase is projected to cause a 25-50% reduction in food production, against a population increase from eight billion presently to ten billion by 2050. Enhanced genetic resources, using advanced genetic engineering tools and alternative crops, are required for different dynamically changing agro-ecologies. In addition, optimized, efficient water use using precision and smart agriculture is highly needed as an adaptive tool. National programs for modernizing irrigation systems in Egypt were mentioned. Increased adaptive and coping capacity and human resource development are necessary to sustain food production and stability in dry areas. Dynamic assessment is essential at regional and local levels, not only to sustain farming capability but also to sustain people's livelihoods.

Next, the speakers moved onto the security of edible oil production in Myanmar, where there are edible oil import restrictions. Household consumption of edible oil has been affected considerably by reduced purchasing power following the COVID-19 pandemic. Further research is needed into industry use of edible oil, and new technology is needed to ensure local production and quality management. Developing countries must have regulatory policies to ensure adequate domestic production capability and encourage innovation.

Vertical indoor farming as a sustainable agricultural solution was then considered. To feed growing populations, significantly more food must be grown using fewer resources. Hydroponic vertical farming could provide up to a 250% increase of production by land required, with water efficiency and pesticide-free production. Climate proof vertical farms in local communities could reduce distribution costs and reduce wastage at the production, distribution and retail levels, offering up to a 90% yield versus 40% for traditional agriculture.

The next topic was meat cultivation as an approach to food scarcity. Cultivated meat is produced from cells cultivated within a bioreactor without farming livestock, requiring far fewer resources. The biggest challenge to cultivated meat is scalability, as larger production vessels are needed to enable production at a similar or cheaper price than traditional meat products. Countries such as China and Singapore are among the first to encourage the production and sale of cultivated meat.

The speakers also spoke about other alternative proteins. Protein supply is a key challenge to future food security. Industrial animal-based protein production causes significant CO_2 emissions, and can be a vector for disease. Alternative proteins have a lower environmental footprint however measures must be taken to ensure a fair supply to developing nations.

Alternative proteins are accepted by consumers, however synthetic food products must have rigorous biosafety measures implemented both by producers and regulators.

Discussion

A group discussion was then held. The participants discussed the nutritional value of food in relation to price, with a view to ensure nutrition to those with lower purchasing power. Global sustainable strategies and frameworks must also be put in place to secure food supply chains. The topic of ethical and sustainable consumption was also discussed, and the participants raised the importance of addressing animal rights issues. The prejudice and rejection towards insect-based proteins as another alternative sustainable protein source was discussed.

Next the participants discussed the challenges of sustainable food cultivation and development against a backdrop of climate change, noting the importance of accessibility, security and biosafety requirements for new alternative foods. Adaptation funding must be used appropriately to implement new crops, new agro-management techniques and increased human resource capacity, with fair distribution and a focus on adaptation.

The participants noted that while work has already been done to improve production productivity and cost, waste within the distribution chain must be addressed for food security. The pandemic and climate issues continue to have a drastic impact on the food supply chain, and more engagement in the transition from our current model to a sustainable one is needed, with adoption of postharvest technology and improvements to the whole value chain necessary to support capacity building for rural farmers.

The participants discussed the future of food supply chains after COVID-19. Investment in collaborative, multidisciplinary, accessible research was noted as necessary for continued development, as was the need to translate academic research into the policy domain. The participants called for international cooperation and investment in talent development and research for both traditional and new agricultural methods, as well as government incentives and investments in advanced technologies and research and development. Support should also be provided to assist farmers with the transition towards an advanced and sustainable urban agriculture and food industry.

The chair closed the session by thanking the speakers for sharing their knowledge and reiterated that multiple solutions will be needed for the future, with adequate support and funding needed for both traditional and future agricultural methods.

Earth and Commons
Biodiversity and Ecosystem Services

[Chair]

Duszyński, Jerzy, President, Polish Academy of Sciences (PAS), Poland

[Speakers]

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

Nilsson, Elisabeth, Chairman, Knowledge Foundation (Stiftelsen för Kunskaps- och kompetensutveckling), Sweden

Konarzewski, Marek, Professor of Biology, Faculty of Biology, University of Bialystok; Corresponding Member, Division of Biological and Agricultural Sciences, Polish Academy of Sciences, Poland

Wangdi, Norbu, Program Specialist/Project Manager, Program Development Department, Royal Society for Protection of Nature, Bhutan [Young Leader 2019]

Koh, Lian Pin, Professor & Director, Centre for Nature-based Climate Solutions, National University of Singapore; Nominated Member of Parliament, 14th Parliament of Singapore, Singapore

Opening Remarks

Chair: Duszyński, Jerzy

The chair began the session with a few words from the Polish mathematician Stefan Banach, on the importance of analogies. Complex issues within biodiversity have many analogies, and issues such as climate change, the pandemic, and the energy crisis, all converge with the question of how to conserve biodiversity. It is not possible to solve a global issue regionally, and economic and societal factors, public knowledge and decision makers must be taken into account. Additionally, while policy makers decide based on the short term, biodiversity conservation is a long-term problem. The chair encouraged participation in the discussion, with the

aim to conclude with ideas on how to tackle biodiversity and ecosystem challenges from various perspectives.

Firstly, the speakers pointed out that, despite our increasing reliance on the abiotic elements of nature, biodiversity is integral to ecosystems, and biodiversity loss can lead to the collapse of ecosystems and ecosystem services. Biodiverse ecosystems can offer technological solutions, and carbon stores like tropical forests, peat bogs and oceanic phytoplankton must be conserved to avoid contributing to carbon emissions. Landscape approaches like those of the Satoyama Initiative, involving stakeholders, are needed to conserve biodiversity while maximizing synergies and minimizing trade-offs with other sustainable development goals.

Next, the topic of industry accountability in the mining and minerals industry was discussed. Industry must work with biodiversity conservation in mind to set goals, allocate human and financial resources and analyze and document environmental impact. For example, some copper mines in Sweden work with the local community to provide management plans and baseline studies for over 10 years, involving compensation and creation of dead wood at mining sites to encourage bird life and outdoor activities.

The speakers then considered an actor-network approach to biodiversity. While it is simple to define biodiversity as a significant ecosystem feature measured in number of species per area, there is a need for a collaborative scientific network combining diverse multi-disciplinary knowledge, to identify the main human and nonhuman actors in biodiversity loss, including communities and industry stakeholders, and how their interactions could be adapted to better promote conservation.

The next topic was biodiversity conservation measures in Bhutan, where there is wide commitment to net zero carbon emissions and 60% national forest cover is constitutionally required. These include landscape based targeted strategies for critically endangered species conservation, forest restoration, and integration of biodiversity into existing farming and community systems to encourage sustainability while preserving socioeconomic status.

The speakers also spoke about carbon prospecting in Singapore. Preventing rainforest loss is vital to protect crop pollinator habitat, ensure water security and reduce carbon emissions. Carbon prospecting maps can help to raise policy maker and industry stakeholder awareness of investment opportunities in forest carbon projects across South America and Southeast Asia.

Discussion

Next, the participants held a group discussion. Many relevant points were raised, including the socioeconomic system and how ecosystem relates to community. Participants spoke about examples such as the need to both protect agriculture and address conservation issues in Madagascar, and landscape erosion in response to sea level rise in Myanmar.

The participants also discussed interdisciplinary and integrative processes within the scientific and engineering disciplines, noting the need for better engagement with urban planners and citizen stakeholders when developing solutions. To improve integration, cooperation from landowners, local and national governments and corporations is needed, with new metrics for maintaining biodiversity beyond sustainability and net zero metrics also required.

Participants suggested a new framework to address biodiversity loss, considering both academic and industry perspectives. Singaporean measures to promote ocean and rainforest protection and ecotourism were given as an example of effective government environmental policy. The participants also called for governments to implement subsidies to address the costs for small businesses to meet sustainable development goals in balance with inflation, and for further collaboration between academia and industry.

The participants also encouraged further fair international collaboration, noting that as the effects of biodiversity loss will have a more drastic effect on developing nations, it is the responsibility of developed nations to provide subsidies and funding.

The participants addressed the importance of the private sector in implementation of biodiversity measures throughout the supply chains of globally expanding companies, the potential benefits of carbon prospecting services, and social and cultural barriers to the access and sharing of quality biodiversity related data for projects.

Real examples such as deforestation in Bolivia and the challenges of implementing forest conservation as part of Japan's Satoyama initiative in the face of an aging population and countryside depopulation were presented, and the importance of striking the correct balance between development and conservation legislation was noted.

The participants also discussed the importance of including model voices when developing diplomatic science, and the importance of implementing the knowledge in a way that mobilizes action.

The chair closed by thanking the participants, and addressing the imbalance of the discussion, noting the comparatively low representation from developing countries, despite the necessity for diverse viewpoints to properly understand the wide range of complex biodiversity issues. The chair reiterated the necessity to take natural, economic, social and education issues into account, and to collaborate across disciplines and regardless of political climate.

Earth and Commons
Protecting Ocean Environment

[Chair]

Yamato, Hiroyuki, President, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

[Speakers]

Barthel, Alice M, Scientist, Fluid Dynamics (T3). Theoretical Division, Los Alamos National Laboratory, U.S.A. [Young Leader 2022]

Connon, Brian, Vice President Ocean Mapping, Saildrone, U.S.A.; Fellow, Institute of Marine Engineering, Science and Technology, U.K.

Swartz, Derrick, Special Advisor to SA Minister of Higher Education, Science & Innovation, Department of Higher Education, Science, and Innovation; Special Advisor: Ocean Sciences, Nelson Mandela University, South Africa

Tolstoy, Maya, Dean, College of Environment, University of Washington, U.S.A.

Opening Remarks

The chair started the session by welcoming the speakers and participants and introducing the points of discussion. Unprecedented changes to ocean environments such as ocean heat uptake, ocean acidification and sea level rise are causing fast-paced ecosystem degradation with widespread effects. Ocean heat waves, high tides, ocean pollution and fishery depletion have had devastating effects on coastal communities and climate change refugees. The chair suggested a focus on ocean science, technology, and scientific collaboration, with co-design and co-development in cooperation with various stakeholders including governments, research institutes, private companies, etc., and asked the participants to share their own opinions as to what will be necessary in the future to make this happen.

Chair: Yamato, Hiroyuki

Firstly, the speakers discussed the necessity of continued ocean modeling and monitoring. Bringing the ocean back to a sustainable state requires informed decisions and changes to prevent community threats such as tropical storms, ground water contamination and supply chain disruption. While ocean flow and climate effect simulations have progressed with new technology, it is necessary to expand gathered data and measurement capability, utilizing machine learning technology and improving and combining regional models for more accurate modelling and prediction.

Next the speakers proposed the use of unmanned surface vehicles (USVs) to better map marine protected areas. Oceans are being exploited to meet demands for food, energy, and mineral resources, disrupting the sea floor and affecting coastal communities and marine wildlife. USVs can autonomously patrol and map protected marine areas, taking a variety of bathymetric measurements to support ocean research and climate models, while identifying vessels and endangered wildlife using sensors and machine learning enabled imaging.

Observation measures in the West Indian Ocean were discussed next. The Indian Ocean, which supports the livelihood of eight countries through trade traffic and food, oil, and gas supply, is facing a potential humanitarian crisis due to climate change, overfishing and degradation of marine habitats. To understand the area's future capability, a long-term observatory has been established, aiming to educate, improve models and frameworks, utilize indigenous knowledge, and start future adaptation dialogues with policymakers.

The speakers considered the next steps. Despite various ocean system model development, cross-disciplinary ocean functions are still not fully understood, impacting wider climate predictions. Collaboration between multiple scientific disciplines to create a multinational ocean monitoring system on par with climate monitoring systems is needed to test climate models and analyze degradation, including deep ocean measurements. Scientists must work in respectful partnership and directly with impacted communities, and push industry and government to unify and address the problem at the source.

Discussion

The participants next held a group discussion. One point raised was the challenge of data collection at a local and global scale. Participants discussed new methods of collecting ocean data via ocean sensors, satellites and coastal communities, the associated cost of data collection, and the difficulty in gathering sustained funding from governmental, commercial, and philanthropic sources.

The participants compared current climate and ocean science to space science, which has high levels of private sector investment, and discussed how to engage with communities to collect high-quality and time-series data that could be built into ocean and climate models, as well as the challenges in integrating local climate models and global ones.

Participants also pointed out the reluctance of scientists to make hard prognoses and recommendations, and methods to deal with uncertainty, educate, and encourage change despite imperfect climate models, noting the importance of effective communication with the general public to allow individuals to make changes in their own lives to mitigate climate effects.

Another topic was the need for better ocean monitoring systems, and how funding issues have restricted ocean monitoring infrastructure, with land-based monitoring systems cheaper and more common than those at sea. Military data was noted as a potential source of further information to feed into existing models and systems, however local knowledge must be better integrated and interdisciplinarity must be encouraged, with a focus on better dialogue with stakeholders across the seascape.

While fisheries were widely acknowledged as unsustainable, the participants felt that overfishing does not receive adequate attention or funding. Progress in recent years to ocean agriculture was praised, and it was noted that for some species farming is more sustainable than fishing and could offer avenues towards private ownership and entrepreneurship.

The participants discussed the need for a global ocean monitoring system, that could be integrated with climate and terrestrial monitoring regimes to better understand complex biophysical issues in the oceans, atmosphere, and land masses, and suggested improvements to oceanic data sharing, noting that national oceanic observatory data is not always shared internationally, and more ambitious efforts should be put into developing robust data networks in under-served oceanic regions, with particular attention paid to developing country efforts. The participants proposed a review of initiatives to identify the gaps in ocean modelling and the establishment of centralized knowledge and data hubs to allow further national and international scientific collaboration.

The chair closed the session and thanked the participants for their knowledge, addressing the need for further international collaboration and policy development.

Life Sciences
Preparing for the Next Pandemic

[Chair]
Fineberg, Harvey V., President, Gordon and Betty Moore Foundation, U.S.A.

[Speakers]
Mehra, Narinder Kumar, Vice President, Indian National Science Academy (INSA), India
Gálvez Muñoz, Lina, Vice-chair of Committee on Industry, Research and Energy, Group of the Progressive Alliance of Socialists and Democrats, European Parliament, Belgium; Full Professor of History and Economic Institutions, Department of Economics, Pablo de Olavide University, Spain
Suzuki, Rami, President & Representative Director, Moderna Japan, Japan
Yamada, Koichi, Senior Vice President, Anti-Infectives Business Unit Div., FUJIFILM Toyama Chemical Co., Ltd., Japan
Zerhouni, Elias Adam, Professor Emeritus, Radiology and biomedical engineering, Johns Hopkins University; former Director US NIH, National Institutes of Health (NIH), U.S.A.

Opening Remarks

At the start, the chair noted that the COVID-19 pandemic has gripped the world over the past three years. However, the history of public health is characterized by long periods of neglect, interspersed with periods of panic, as in the current case. In military strategy, it is said that no plan survives first contact with the enemy. Likewise, no plan survives first experience with a new pandemic. Each pandemic has distinct features, but the responses to pandemics reveal recurring shortcomings, and recommendations from previous pandemic experiences tend to be implemented only partially, or not at all. Can humanity plan and put in place preparations to enable a more effective response to the next pandemic?

Chair: Fineberg, Harvey V.

The speakers first noted the importance of considering inequities hindering pandemic preparedness and response across nations. They pointed out the need to strengthen a network of integrated disease surveillance programs. In addition, it is necessary to promote a “One Health” approach to the study of emerging infections. Furthermore, regular international collaboration and communication on pandemic preparedness are required. As for technology, a system for collective investment in mRNA tools, common standards and procedures for clinical trials, and new types of vaccines, would be useful. Also necessary is transparent communication and an information system that supports best allocation of resources.

Next, the speakers considered initiatives to improve the response to cross-border health threats. This includes the strengthening of existing agencies, as well as consideration of new ones, for example, for emergency preparedness and response. Health data can be used to improve healthcare delivery, while protecting privacy. Another useful approach is to support policymakers by commissioning experts to explore future techno-scientific trends. Agility is also important, which can be facilitated by strengthened foresight and capacity, and the development of a reliable and adaptable crisis response methodology. Environmental, social, and political factors may also be important for dealing with future pandemics.

Improvements around vaccine development, approval, and deployment were also discussed. One such area for improvement is regulatory harmonization, such as whether vaccines can be approved in the absence of clinical trial data, as well as clinical trial requirements, including the ideal level of diversity among subjects. Incorporating real-time, real-world evidence on vaccine effectiveness is also valuable. Another area for improvement is study of the spectrum of individual vaccine experiences, both in terms of effectiveness and safety. Research and development on mRNA technologies are underway, and in future, the mRNA platform may apply to other fields such as rare diseases, personalized cancer vaccines and even to regenerative medicine.

Another topic was how to get profit-oriented organizations to invest more in drugs for infectious disease. Such organizations naturally invest in areas where large profits can be expected and not in those where such profits cannot be expected. Until this pandemic, infectious disease drugs were not a priority for investment. The automotive industry offers a clue for a possible approach to get companies to contribute to strengthening pandemic preparedness. Governments could create a rule whereby, whenever companies create a blockbuster, they should invest 1% of the income therefrom into research and development of new anti-infectious agents or transfer the income to another organization that would do such work.

The speakers then discussed preparations for the next pandemic from an R&D perspective. First, a global viral and bacterial surveillance system would allow fast response and the detection of worrying patterns. This could also be assisted with AI. Second, it is necessary to meet the requirements to quickly launch clinical trials for vaccines for viruses with pandemic potential. Third, the world should develop a widely distributed global vaccine manufacturing system prepositioned for vaccine production. Finally, attention should be given to the development of non-vaccinal treatments.

Discussion

A group discussion was then held. The participants first discussed a disease surveillance system, addressing issues such as how data are gathered globally, privacy concerns, sharing of data between academia and industry, and transparency. They also discussed the importance of interdisciplinary research for making effective use of data. Various inequalities, not only in data, but also resources, were also discussed.

Next, the participants raised the importance of ensuring the sustainability of international systems for dealing with future pandemics, including having long-term funding. Systems of surveillance and possible detection are important and could include not only testing of individuals but also environmental monitoring, such as waste-water surveillance. A professional, non-political international early warning system is also needed. Furthermore, an integrated global system for manufacturing and supplying vaccines is required. Globally harmonized regulations would also be helpful.

The participants suggested that an organization such as the World Health Organization should develop a template or checklist for national pandemic preparedness and develop lists of obligatory measures and optional measures based on socio-economic conditions, culture, and so on. Countries should put in place the necessary preparedness measures themselves, or in collaboration with others, in advance of the next potential pandemic.

Another topic discussed was fostering trust in science, such as by improving science literacy and communicating actively, including on social media. Scientists should also have more faith in the public to understand more nuanced advice.

The participants also discussed investment, including in basic research in infectious diseases, stabilizing the supply chain for related technologies, and the rising generation of investigators. More students should also be directed towards research, especially on infectious diseases.

In addition, the participants noted the importance of preparing for the social and human impacts of pandemics, such as development of more home-based treatment environments, as well as care for people's mental wellbeing and school education. They also noted that existing diseases should not be forgotten, pointing out that many other treatments were put on hold during the pandemic.

Lastly, it was also pointed out that one way of preparing for the next pandemic is to complete the response to the current one. The rollout of vaccine programs is still a work in progress for many countries, and the pandemic is still ongoing.

Life Sciences
Future of DNA- & RNA- based Technologies

[Chair]

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

[Speakers]

Caneva, Sabina, Assistant Professor, Precision and Microsystems Engineering, TU Delft, Netherlands [Young Leader 2022]

Ligner, Emmanuel, Danaher Group Executive, President and CEO, Life Sciences, Cytiva, U.K.

Fire, Andrew Zachary, Professor, Departments of Pathology and Genetics, Stanford University School of Medicine, U.S.A. [Nobel Laureate 2006 (Physiology or Medicine)]

Hayashizaki, Yoshihide, Representative CEO, DNAFORM, Japan

Suga, Hiroaki, Professor, Department of Chemistry, School of Science, The University of Tokyo, Japan

Opening Remarks

The chair opened the session by discussing the use of DNA and RNA in agriculture to enhance the yields of plants and make them more nutritious. There is also an opportunity to mitigate climate change, for example by planting trees that have been engineered to absorb more CO_2 and help the atmosphere. Scientific analysis shows that genetically modified crops are not dangerous. Despite this, there is a strong anti-GMO movement in Europe. This has also spread to other countries, sometimes making those with food shortages reluctant to plant GMO crops. This needs to be corrected with more appropriate regulation. Politicians need to also have the courage to explain the safety of GMO crops to the public.

Chair: Roberts, Richard J.

The speakers then discussed the development of new technologies to understand biology at the single-molecule-level. This is important because, for example, the human genome

and proteome contain information that is essential to human health. Novel nanopore technologies such as photonic nanopores and DNA-origami nanopores enable the rapid extraction of such information. Such technologies demonstrate, also, the importance of interdisciplinary research, as such innovation happens at the interface of different disciplines. They also reinforce the importance of fundamental research, even research for which the application may not immediately be obvious.

The speakers then turned their attention to ways to promote the continued development of mRNA-based therapies. COVID-19 and the rapid development of mRNA vaccines have demonstrated that such technology can be a game-changer. However, unlike other technologies, there does not yet exist an mRNA technology platform. More and earlier collaboration between industry and scientists is needed. Only then will it be possible to develop personalized therapies and large-scale mRNA or DNA-based therapies.

Next, the speakers discussed the potential application of DNA surveillance sequencing in the prospective design of vaccine candidates. DNA sequencing is so advanced and inexpensive now that it should be possible to sequence samples from individuals with any evidence of novel infectious disease, quickly identify candidate sequences which could represent new or mutated pathogens, and start developing vaccines in small batches that would be ready for use in a clinical trial as soon as a clear need was evident. That would greatly accelerate the process of producing vaccines in advance of potential pandemics.

Another topic was the value of making greater use of the characteristics of DNA and RNA technologies, such as rapidly producible, and highly safe and effective vaccines. These technologies are highly valuable, and their continued development is essential. Efforts should be made to accelerate the development speed of DNA and RNA drugs, as well as other therapeutics, to keep up with the speed of viral mutations. Faster approval processes would help as well. In addition, the ability to predict when such mutations will occur enables planning of appropriate vaccine production volumes and prompt shifts to vaccines for new virus variants.

The application of peptide technologies for gene delivery was also discussed. Gene therapy has huge potential, but is limited by the difficulty of delivering genes to specific cells. One technology that can help is the random non-standard peptide integrated discovery (RaPID) system, which enables the creation of small macrocyclic peptides encoded with mRNA. Such macrocyclic peptides can interact with and often inhibit the targets of the proteins.

They can also be grafted to the loop of a protein, and this protein can be reconstituted to actively bind to the intended target. This enables the creation of bi-specific or even tri- or tetra-specific antibodies.

Discussion

Following the opening remarks, the participants held a group discussion. They first spoke about DNA sequencing, RNA sequencing, and protein sequencing and fingerprinting. Most biological processes are related to protein-protein interactions. Protein sequencing will deepen understanding of how proteins function. However, there are various gaps that need to be closed, such as between basic research and application in the field, between developers and users of the actual technologies, and between clinicians and informaticians for enabling effective use of the data. Scalability is also an issue.

Next, the participants discussed social acceptance. Society can be wary of adopting new technology. COVID-19 vaccines were developed and deployed rapidly, but such speed can be frightening. No matter how amazing it is, a technology that is not accepted cannot be implemented.

Relatedly, potential roadblocks to adoption of DNA and RNA technologies were also raised. Possible factors for this include policies not keeping pace with technological developments, the availability (or appearance of availability) of existing therapeutics that seem to work fine, and the need for more networking and collaboration among international institutes.

The speakers then spoke about how to further enhance vaccine development. There is room to develop even better mRNA vaccines in terms of, for example, weaker adverse effects. Prediction capabilities to prevent further transmission would also be useful, as would faster approval processes and a globally harmonized framework based on common criteria. It is also necessary to ensure diverse representation in clinical studies.

The value of scientific communication was also discussed. It is essential to enhance scientific communication to the public, who are the ones intended to ultimately benefit from these technologies. To that end, it is necessary to ensure that basic research is explained, and the benefits communicated. Effort should also be made to package scientific communication in accessible ways. In addition, scientists should work together to better inform policymakers and enhance the science literacy of the whole of society, including underrepresented populations.

Lastly, the participants stressed the importance of basic science in general, not only mRNA. Besides mRNA, there are many DNA and RNA technologies, as well as bacteria-based delivery systems that are worth investigating and developing further.

Life Sciences
Preserving Health in the 21st Century

[Chair]

Nagai, Ryozo, President, Jichi Medical University, Japan

[Speakers]

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.

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

Suzuki, Toru, Professor/Chair of Cardiovascular Medicine/Associate Dean, The University of Leicester, U.K.; Project Professor, Institute of Medical Science, The University of Tokyo, Japan

[Online Speakers]

Darzi, Ara, Professor of Surgery, Faculty of Medicine, Imperial College London, U.K.

Abdool Karim, Quarraisha, Associate Scientific Director, Centre for the AIDS Programme of Research in South Africa (CAPRISA); Pro Vice Chancellor, African Health, University of KwaZulu-Natal, South Africa

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

Chair: Nagai, Ryozo

Opening Remarks

To begin the session, the chair spoke about the healthcare system in Japan. Japan introduced universal health coverage 60 years ago. This system is supported by over 800 hospitals, which, on a per capita basis, is several times that of other G7 countries. Ensuring the sustainability of the healthcare system is a major issue for Japan. The system is neither market-driven nor state-controlled. 80% of hospitals are privately owned, but the government manages healthcare finances. This makes the system hard to control. During the pandemic, the government was criticized for its inadequate information gathering and

disclosure. Digital reforms, such as the digitalization of administrative procedures, was also considered to be slow.

First, the speakers talked about how to apply the lessons from COVID-19 to transform global healthcare systems. Any plan for future pandemics must include better surveillance of pathogens, evolutionary AI to predict their development, a maximum 100-day target for the preparation of new vaccines, faster development of therapeutic drugs and clinical trials, better global trial cooperation, better diagnostics and testing, stockpiling of the right personal protective equipment, and a strong data strategy. The COVID-19 pandemic has presented a challenge, but also a once-in-a-century opportunity to reorient global medicine to truly focus on healthcare rather than sick-care.

The next topic of discussion was technologies related to the microbiome. Studies have been conducted to examine whether there is a connection between the microbiome and the differences in the severity of the symptomatology of COVID-19 and its persistence among patients. Initial findings suggest that there is. Technological developments have enabled the more precise and in-depth analysis of the microbiome, which may in turn enable more accurate characterization and treatment of infections.

The speakers then spoke about scientific outreach and communication to enhance pandemic preparedness. The COVID-19 pandemic has seen an exceptional mobilization of the research community, the free flow of ideas, and collaboration among academia, industry and government. This has been welcome and should be supported by data-sharing platforms, as well as quality controls and standardization to ensure research integrity and appropriate advice. Scientists must actively engage the public, and while communicating complexity and uncertainty is very challenging, scientists must clearly communicate what is known and unknown to ensure trust.

The speakers also discussed other lessons learned from the pandemic. One is the impact of COVID-19 beyond the pandemic itself, such as delays to diagnosing and treating non-communicable diseases, as well as delays in regulatory bodies' reviews and guidance on non-COVID-19-related developments. Another lesson is the power of data, if leveraged appropriately, such as by ensuring national and supranational data quality standards, ensuring representativeness of diverse populations, data interoperability, and data governance. Collaboration and sharing of technologies and knowledge is also essential.

The speakers then compared the medical systems of the UK and Japan. Japan has a statutory insurance medical system that covers almost all inhabitants. The UK has a similar publicly funded health system. Both systems are under pressure from aging societies, leading to difficulties such as longer admissions and more complex diseases. The COVID-19 pandemic has highlighted the need for data-driven health and digital transformation. This has already been enacted in the UK. Japan is at an earlier implementation stage. The pandemic has also drawn attention to health inequities. Different areas of the UK have populations with different racial compositions, and the pandemic revealed health inequalities between people of different backgrounds.

The importance of investment in science and health, particularly in Africa, was also discussed. Investments in response to HIV and AIDS in Africa have established a strong platform for studying, diagnosing and treating HIV/AIDS. It was possible to pivot this diagnostic platform for diagnosing COVID-19. Africa's strong information systems also enabled the monitoring of the evolution of the COVID-19 situation in many countries. Furthermore, it was possible to sequence SARS-CoV-2 and identify emergent variants of concern. However, one of the challenges in Africa was a lack of national or continental capacity to develop interventions, resulting in a large gap in access to vaccines, for example.

Discussion

The participants then held a group discussion. They first discussed the use and sharing of data. Data sharing is critical for accuracy of diagnosis and using precision medicine for treatment. Good data governance, such as a uniform system for storing and managing research and clinical data, can greatly facilitate clinical trials and other data-driven research.

Following on from this, the participants spoke about how some of the resilience of certain patients to COVID-19 may be due to the unique composition of their microbiome. Better understanding of the microbiome could enable more precise treatment, such as by manipulating the composition of the microbiome to provide protection or combat an infection.

The future role of AI in medicine and healthcare was also discussed. The participants noted data collection is essential for ensuring effective AI application. AI is already being applied in diagnostics. It can also be applied across the spectrum of predictive analytics, beginning with pathogen surveillance. It could also be useful for predicting new disease variants. Ultimately, AI can be transformative and has the potential to greatly improve many aspects

of medicine, but there is positive and negative potential. Regulation will need to catch up to the technological developments in AI.

The need for better international collaboration for the next pandemic was also highlighted. For example, there needs to be some kind of solidarity mechanism such as a global fund to support the responses of countries with fewer resources. On the positive side, the current pandemic has helped establish international networks that may enable more agile collaboration in future.

In addition, the participants noted that non-communicable diseases are increasingly recognized as a key issue for healthcare systems. There is a need to use technologies to realize a paradigm shift from reactive medicine to preemptive medicine, which will be important not only for addressing future pandemics but also for non-communicable diseases.

Innovative Engineering
Revolutionary Materials and Devices

[Chair]

Hashimoto, Kazuhito, President, Japan Science and Technology Agency (JST), Japan

[Speakers]

Di Carlo, Dino, Professor and Vice Chair, Department of Bioengineering, University of California, Los Angeles (UCLA); Deputy Director, Precision Advanced Technologies and Health Systems for Underserved Populations, National Science Foundation Engineering Research Center, U.S.A.

Dutton, Siân, Professor in Physics and Solid State Chemistry; Director, Winton Programme for the Physics of Sustainability, Cavendish Laboratory, University of Cambridge, U.K. [Young Leader 2022]

Hultman, Lars, Chief Executive Officer, The Swedish Foundation for Strategic Research (SSF); Professor, Thin Film Physics Division, Department of Physics (IFM), Linköping University, Sweden

Mustre de León, José, Director General, Dirección General, Center for Research and Advanced Studies of the National Polytechnic Institute (CINVESTAV), Mexico

Uosaki, Kohei, Fellow and Executive Advisor to the President, National Institute for Materials Science, Japan

Kim, Eunkyoung, Provost, Yonsei University, Korea

Chair: Hashimoto, Kazuhito

Opening Remarks

To begin the session, the chair pointed out that materials and devices make crucial contributions to the revolutionary development of humankind. This manifests across many industries, and especially in alternative energies, making them a key to reaching carbon neutrality. It is important for experts across various fields to come together to discuss the possibilities of materials and devices in addressing challenges facing the world.

Following this, the speakers discussed biomanufacturing as a critical piece of the sustainable economy. Despite numerous benefits of biomanufacturing, its development is mired by bottlenecks, notably the transferring to production environments. Cells adapted to grow in labs are generally not robust enough to survive in production environments at scale. To address this, engineers need access to improved production environments, must rethink the design-build-test cycle of bioengineering to include robustness as a critical element, and collaborate on a large scale.

Next, the speakers explored the need for materials and devices to be used in multiple applications and tackling problems in an interdisciplinary manner. New material systems development, energy storage at scale, and metrics are vital elements of success. There are many possible ways in which a new material can generate a step change, enabling integration into new devices and leading to commercialization. Battery technology is one area, but the principle of increasing efficiency to scale up is more broadly applicable.

Another subject of discussion centered on how many of humankind's problems are based on materials. A key strategy for sustainable development is improving and re-engineering materials. Therein lies great opportunity, but also challenges including high R&D costs and risks of inappropriate regulation. Some problems are more urgent in time scale. Consequently, application-inspired basic research, robust and versatile development of usage profiles of materials, and green development should be highlighted. It will be increasingly important for funding agencies to not spread resources too thinly.

In the area of replacing older generation solar cells, points were raised regarding the need to rethink the basic atomic understanding of how defects interact with properties of materials. New techniques often require the use of specialized and expensive facilities, which will accelerate the pace of replacing first-generation photovoltaics. Another challenge lies in developing a theoretical understanding of basic materials, which can sometimes be a decades-long process, but may aid in implementation of energy solutions. For very new materials, the challenge lies in visualizing which applications may be important, then determining future implementation.

The discussion also covered topics surrounding electrochemical energy conversion devices such as batteries and fuel cells, which are key in short-term and long-term energy storage. Materials are vital in realizing such devices. Finding non-precious metals to be used as electrocatalysts is one vital research area, as is development of different battery technologies

beyond lithium-ion batteries. Close interdisciplinary collaboration is required to overcome many of the challenges in these multi-step processes. Collaborations on an international scale are best, but come with difficulties surrounding competition.

There was also discussion on new applications in the field of conducting polymers. Energy loss poses a major challenge to sustainability, and windows can account for some 50% of energy loss in buildings. Current solutions remain restricted in use, so taking a different approach through conducting polymers can open many possibilities, allowing for greater control and very low energy consumption, and even harvesting heat energy. Innovative ideas like research within conducting polymers hold much potential in energy saving and moving towards a carbon neutral society.

Discussion

The participants then took part in a group discussion. They first discussed about control and compartmentalization of cell cultures. Current industry approaches require much improvement, and meanwhile venture capitalists are seeking novel areas of application. Development of central facilities and simulations with AI are possible paths to deepen understanding of cell interactions.

Participants also discussed about ways in which properties of materials can be identified for applications. Barriers in funding and publication and siloed knowledge are currently obstructing efficient progress. For sustainability, it is also important to recognize processes that take materials back to their starting constituents to be reused and repurposed. Additionally, an idea was raised to introduce a prestigious prize in material sciences to motivate faster progress in the field.

On the topic of funding of research, participants pointed out that a multi-faceted approach considering industry, academia, and policy is crucial. Mobility of knowledge, outcome research where outcomes can be transferred to industry, international collaborations including private companies, and better understanding cultural differences, are all important in overcoming challenges. Young generations play a key role in addressing global challenges in the future.

The participants then moved to the topic of how to accelerate material sciences development and suggested that a machine learning-based approach with robotics could be critical. However, many challenges lie within the area of data. Industry partnerships with

academia and having increased crossover could be beneficial, as current approaches remain too fragmented.

Following this, the participants talked further about applications in the area of materials, and their limitations. Scalability was identified as a major roadblock, inclusive of reliability and safety.

Participants also noted that in areas such as space travel, sustainability comes to the fore-front, and will be vital in the progress of efficient space travel and interplanetary habitation.

Finally, participants mentioned that governments could play a role in remedying the loss of appetite in industry for pursuing basic research. Public perception often misses out on the social good aspect of public funding leading to private profit regarding research. Both universities and governments can aid in illustrating this point, and increased industry investment in basic research can further strengthen collaboration with academia.

Innovative Engineering
Quantum Science and Technologies

[Chair]

Kerenidis, Iordanis, Founder and Director, Paris Centre for Quantum Computing; Head of Algorithms, QC Ware, France

[Speakers]

Blais, Alexandre, Scientific Director, Institut quantique, Universite de Sherbrooke, Canada

Morimoto, Norishige, Chief Technology Officer and Vice President, Research and Development - Japan, IBM, Japan

Nakamura, Yasunobu, Director, RIKEN Center for Quantum Computing; Professor, Department of Applied Physics, The University of Tokyo, Japan

Smith, Peter G R, Associate Vice-President (International Projects), University of Southampton, U.K.

Opening Remarks

Opening the session, the chair explained quantum computers at a high level. He noted that they are not necessarily faster, but rather fundamentally different compared to conventional computers. New hardware will need to be developed, and in this regard much progress has been made in the past two decades. Applications must also be limited to areas where quantum technology can provide an advantage.

Chair: Kerenidis, Iordanis

The speakers next discussed about the field of quantum communications and implications for cybersecurity. Quantum computers can solve factoring problems that would be other-wise impossible for classical computers, and this carries major risks. Security systems will need to be reworked in a world with quantum computers. Many companies were late to inte-grate machine learning, and thus do not wish to miss the opportunities presented by quantum computers. Collaboration across disciplines in quantum-related fields will be vital.

Following this, the speakers noted that quantum underlies many of the significant technologies used in daily life. Quantum acceleration for certain tasks must be better understood, but this problem remains difficult due to a lack of fully functional quantum hardware. However, the pace of progress is exceeding expectations and some quantum advantages are emerging. The race towards quantum technologies is beginning with large companies and nations competing, but more fundamental research is necessary, and this requires collaboration. Furthermore, talent must be cultivated.

Another topic raised by the speakers regarded the history of exploration of quantum computers starting from the 1970s, leading up to current efforts. Having a quantum network opened to scientists at an early stage serves as an important resource for accelerating progress. Having a physical presence of quantum computers also helps to inspire young people and pique their interest in the field. The coming years will see major progress in increasing the scale of quantum computers, but their applications must be continually evaluated.

The speakers then discussed about how quantum mechanics as a new concept has changed modern understanding of nature and unlocked new applications of physics. Studies in quantum mechanics have been ongoing for more than a century, but the research was not focused on the level of information processing. Widening the scope of research to include information processing has led to the next major leap to quantum information science, but will also be a challenging task in engineering, requiring collaboration.

Following this, the speakers discussed the importance of geopolitical considerations concerning quantum computing and quantum technology. The moon landings were largely driven by a military push towards building rockets, and similarly quantum computing has implications on cybersecurity and code-breaking, key interests of militaries. Additionally, numerous economic consequences come to the surface. Market sizes of countries must be considered, as does the entire supply chain when it comes to quantum technology. Few countries will be capable of creating the primary technologies, so international dialogues must be ongoing.

Discussion

The participants then engaged in a group discussion. The participants noted that there is a disconnect between commercialization and fundamental research. Only focusing on commercialization can lead to false expectations and timescales, resulting in disappointment and delays. Additionally, problems are further amplified by a lack of trainees and stifling of international connections from inappropriate regulation. Further breaking of silos will be necessary going forward.

Then, the participants discussed the interactions between quantum hardware and algorithms, and the steps necessary to reach commercialization. Materials and parts are relatively easy to acquire, but making the quantum hardware itself is a major struggle due to quantum decoherence. There has been much progress in improving stability of qubits, but there remains much work to be done. Every qubit doubles the possibilities, so the future potential of algorithms is vast.

The participants then talked about the need to make quantum physics and technologies explainable to non-experts to develop a workforce for the future. Currently, most people involved are those with PhDs, so the education about quantum technology needs to

begin at the high school level. However, this alone would lead to too slow a change, so the private sector must also make investments in education. In addition, the current lack of talent in the world means that companies must share resources, and not only compete with one another.

After this, the discussion expanded on the ideas regarding security and initial use cases for qubits and quantum computers. While human resources problems persist in 2022, the next decade will see major growth in talent. Despite this, collaborations between academia and industry will be vital in coming years. Public knowledge and accessibility should be built upon education about use cases in health, financial systems, and security.

Finally, the participants discussed about the physical needs and limitations of quantum computers. Early attempts at applications have been specialized devices for specific purposes, but general quantum devices are not yet available. However, research advancement in the past decade has aided in the commercialization of areas including quantum communication. The ultimate goal of the field is to improve how computation aids in solving important problems, and a notable byproduct of progress in quantum computing is that it inspires computer scientists to return to past problems with fresh ideas and approaches.

Innovative Engineering
Autonomous Robotics

[Chair]

Haddadin, Sami, Executive Director, Munich Institute of Robotics and Machine Intelligence, Technical University of Munich (TUM), Germany

[Speakers]

Doi, Kazuhiro, Corporate Vice President, Alliance global VP, Research Division, Nissan Motor Co.,Ltd., Japan

Yablonina, Maria, Assistant Professor, Daniels Faculty of Architecture and Robotics Institute, University of Toronto, Canada

Ishiguro, Hiroshi, Professor, Systems Innovation, Osaka University, Japan

Guglielmelli, Eugenio, Vice Rector for Research, Campus Bio-Medico University of Rome, Italy

Opening Remarks

The chair began by pointing out that robotics and machine learning have undergone multiple major shifts in past decades. First, robots were only used in industrial applications, such as automobile manufacturing, for certain repetitive tasks. Later, they emerged from safety cages, becoming more lightweight and reliable, and expanded to households and healthcare. A robot is an AI system with a body, but they have been lacking a sense of touch. Consequently, the shift underway now involves input: detecting contact, manipulating environments, and sensing forces, through areas like computer vision and touch. Robots must also be multi-purpose across different domains, and the domains where robots will have a major impact should be defined. With these developments, intelligent robots could be a game changer to solving major societal challenges such as demographic change and labor shortages.

Chair: Haddadin, Sami

The speakers then moved the discussion to the topic of autonomous vehicles, a major area propelling progress in AI and robotics research. Most traffic accidents are caused by human error, so automated driving assistance has been developed with a focus on safety. However, the possible benefits of autonomous driving extend beyond safety. In a world faced with numerous demographic issues including an aging population, mobility is key to meet the needs of people. Driverless technology is still not at a point of being truly useful to society, but meanwhile, there are many ethical issues to be resolved when it comes to regulations and acceptable safety standards.

Next, the speakers discussed about the intersection between robotics and architecture. Like the automotive industry, robotic applications in architecture and construction began with industrial robot arms. However, in recent years the possibilities have expanded greatly. Taking inspiration from nature, such as spiders building web structures, can lead to new robotic designs and unlock new approaches to solving problems. Robotics should not be limited to automation of existing tasks, rather it should be more creative. One integral step towards such progress is the promotion of interdisciplinary and horizontally structured team building.

The next topic of discussion turned to humanlike robots. For simple tasks, a non-humanlike robot serves its purpose. However, there are certain everyday situations where humanlike robots can be beneficial. Human interactions are driven by countless non-verbal and subtle cues, and by working on humanlike designs, it is possible for researchers to gain a deeper understanding of humans themselves. Although challenges remain, cybernetic avatars and teleoperation could be key to solving a variety of problems worldwide.

After this, the speakers emphasized that a structured approach is important to understand how robotic systems are developing. Additionally, the lights and shadows of robotics must be at the forefront of discussions. Robots can release people from repetitive work to enable more creativity, but they could potentially displace and de-humanize others in their reorganization of activities. Human-centric, sustainable, and resilient robotics will be coming in the short term. It is also important to individualize and personalize human-machine interactions, and empower the light and avoid the shadows of robotics.

Discussion

The participants then engaged in a group discussion, starting with areas of application where robotics will continue and flourish, including industrial, as evidenced by needs which arose during the COVID-19 crisis. Function and cost are most important in both deployment and market acceptance. It was noted that in defining tasks of robots, the robots must have enough intelligence to understand unclear environments to be considered clever.

Next, the participants discussed social problems such as defining tasks to be handled by humans and by robots. Machines in daily life are far simpler than complex robots, and therefore easier for society to accept. Additionally, the ethical problems that arise from issues, like safety in autonomous vehicles, are large-scale and require extensive debate.

Following this, the participants pointed out that society needs to trust robots, but the task of building trustworthy robots is challenging in and of itself. Robots can be extremely powerful, and programmers are tasked with quantifying inherent dangers. Loss of jobs is another issue to tackle, so creating entirely new functions in society through robotics will be vital in future development.

Expanding on the idea of trust in robotics, the participants discussed how the form of the robot will be important. Possibilities include non-intimidating forms and softness. In addition, there must be well-defined standards for performance of robotics systems, so a regulatory approach or certification approach could be implemented.

Finally, the participants emphasized how education and training needs to be developed and adapted to a world increasingly influenced by robotics and automation, not only to address labor dislocation, but also bring together various disciplines and fields. Some individual leaders can put together pieces from disparate fields and package them into solutions, but the possibilities enabled by groups collaborations are even greater. Opportunities like the STS *forum* are ideal to develop ideas to change the world from the information age to this age of action.

Cooperation in S&T

Science and Technology as a Driver for Development

[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]

Abdurakhmonov, Ibrokhim, Minister of Innovative Development, The Ministry of Innovative Development, Uzbekistan

Kayashima, Nobuko, JICA Ogata Sadako Research Institute for Peace and Development/ Advisor to the Executive Director / Senior Research Advisor, Japan International Cooperation Agency (JICA), Japan

Handoko, Laksana Tri, Chairman, National Research and Innovation Agency (BRIN), Indonesia

Foley, Cathy, Australia's Chief Scientist, Australian Government; former CSIRO Chief Scientist, Executive, CSIRO, Australia

Opening Remarks

The chair opened the session by emphasizing the value of Science, Technology, and Innovation (STI) that allows for further increases in innovation. And through this focus to meet the Sustainable Development Goals (SDGs), the UN launched the ten-member Technology Facilitation Mechanism to facilitate the sharing of information, best practices, and policy advice among stakeholders. The Global Pilot Programme on STI for SDGs was also started to work on tailored STI roadmaps with the support of the World Bank and the Government of Japan.

Chair: Murray, Cherry A.

The speakers discussed recent developments in Uzbekistan, the bridging of science and technology with education, the three-year specific strategies for innovation, and how particular attention was paid to human

resources. Various initiatives in the country included competitive grants, higher education coverage, and innovation in the creation of employment and engagement by the government.

Next, they noted the impacts of the COVID-19 pandemic and climate change, the concerns of supporting groups that may be more vulnerable, and emphasized that solutions could be found at a higher rate when priorities are placed on education. JICA has and continues to support the creation of STI ecosystems though various projects and partner incentives.

They then commented on challenges unique to various countries, the impacts of low critical mass in terms of resource supply, and the importance of resource allocation. Describing the coordination and integration among 72 research institutions in Indonesia, this critical mass is being achieved through resource mobility programs, funding research grant schemes, and increased accessibility for all participants.

The speakers then mentioned how scientists could respond to the call for science as a driver for development as governments are increasingly looking to those that will offer solutions. Because global challenges necessitate global solutions, collaboration becomes increasingly significant. This placed a spotlight on the need to bring everyone's collective resources together in an interconnected effort.

Discussion

Engaging in group discussions, the participants spoke about how to use STI to, most importantly, improve quality of life, but at the same time on how to utilize STI to improve monetization and commercialization as well. IP licensing was also said to have an impact on the innovation cycle at various levels within universities and national labs. They also touched upon bridging the inequity gap between research-intensive universities among various countries and how to utilize the worldwide university network.

The participants also talked about developed countries having an understandable focus on workforce training for the SDGs, while emerging countries had an additional focus on creating jobs, gaining critical mass, and delivering economic benefits to the country. A beneficial goal could be delivering processes that would benefit a given country depending on their specific stage of development. Centralized facilities were also an important component of supporting exchanges between countries, as well as the value of investment in STI for the SDGs to be fulfilled. They added that communicating that the SDGs are a global challenge rather than a nation-by-nation challenge will be a key solution in the future.

In addition, the participants stated that 70% of all research papers being behind paywalls was an issue as this was valuable knowledge that could potentially be used. The role of universities was also highlighted given that it would be difficult to measure the impacts of research. This led to metrics that could be especially important for use among younger researchers, leading to the measuring of spinoffs, patents, and innovations from universities. It was also noted that writing reports in a tone that the broad public could understand and making sure they reach the right audience could only benefit researchers.

Lastly, the participants placed attention on the work that needed to be done in terms of international collaboration. As we are all facing similar issues and challenges, despite having differing local situations, increased cooperation to further innovation would help advance positive impacts globally.

Cooperation in S&T

Collaboration among Academia, Industry and Government

[Chair]

Sulaiman, Mohd Yusoff, President & Chief Executive Officer, Malaysian Industry-Government Group for High Technology (MIGHT); President, Malaysia Rail Industry Corporation (MARIC), Malaysia

[Speakers]

Zielke, Judi, Chief Executive Officer, Australian Research Council (ARC), Australia

Kanatharana, Janekrishna, Executive Vice President, National Science and Technology Development Agency (NSTDA), Thailand

Nakanishi, Tomoko M., Professor Emeritus & Project Prof., Graduate School of Agricultural and Life Sciences, The University of Tokyo; Professor Emeritus & former President, Hoshi University, Japan

Stewart, Iain, President, National Research Council Canada (NRC), Canada

Mahrenholz, Carsten C., Founder and CEO, COLDPLASMATECH GmbH, Germany

Opening Remarks

To start, the chair expressed his hope that the session would help bolster collaboration and continued discussions among all participants long after the end of the forum. With the escalating number of challenges around the world, these issues must be met at a quicker pace, which makes cooperation and enhancing the dynamic relationship among academia, industry, and government increasingly important.

Chair: Sulaiman, Mohd Yusoff

The speakers pointed out the significance of funding research that could translate into long-term national benefits such as job creation, boosting the economy, and improving the well-being of citizens. True collaboration takes long-term effort with strong frameworks and dedication to the maintenance of those efforts. And embedding a strong understanding of how to identify underlying issues is also essential.

Next, the speakers discussed their experiences in the industry sector in Thailand, where an Industry 4.0 platform was developed through partnerships with the government and academia. This platform was comprised of four components: the development of assessment tools, incentive schemes from government, metrics describing the abilities of solution providers, and an upscaling platform for workforces in partnership with universities.

Next, thoughts on collaboration from the perspective of universities were given. Universities are now feeling pressure to seek collaboration for funding, which is now a worldwide tendency. As the growth in collaboration has slowed in Japan in recent years, a new cross-employment system has been developed to help broaden workers' experience and to boost involvement in both universities and private corporations.

Another topic was on three mandates currently implemented in Canada through a national funding program and running a lab network. These mandates included the advancement of knowledge and exploratory style research, supporting government mandates, and a long-term mandate to encourage commercialization for business innovation. In response to challenges today, domestic collaboration across ecosystem actors and internationally oriented collaborative approaches to solving problems are essential.

The speakers then discussed perspectives from the private sector, emphasizing that the focus of those involved in science, industry, and politics are quite different, leading to inherent translation issues. Great ideas don't get to market since the needs of markets are not always understood, which is why priority must be given to bridge the gaps between these silos.

Discussion

The participants then engaged in a group discussion. They first spoke about various funding models, the differing urgencies among universities, industry, and government, and the importance of accurate translators and communications.

It was also mentioned that cooperation between universities and the Japanese government has been slow recently, but that the government is currently creating evaluation models to measure the effectiveness and impact of technology licensing organizations.

There was then a dialogue on the massive amount of effort that is being put into the university sector and the funding agencies that support them, to ensure the development of

talent that thinks about both the development of research and the translation of potential benefits. On top of the numerous initiatives to get good ideas to market, one of these efforts was to encourage a culture for students and universities to be conscious of market needs and not solely great ideas. They also highlighted the number of skills needed not only for research, but also to set up companies and bring products to market.

The participants also highlighted the differing expectations of academics and industry, how strategic intentionality can help bridge the gap between the two, and how innovation can be expanded upon through interdisciplinary and transdisciplinary research.

The participants also discussed that ensuring an alignment of motives and expectations, building an ecosystem that brings together various lines of thinking, and a reference architecture for establishing accomplishments could be meaningful goals to have. Then it was stated that there were barriers to bringing the science, university, and government spaces together. Solutions to overcoming those barriers included helping increase understanding and flexibility across disciplines, and implementing networking tools for members in the STS *forum* to facilitate progression.

It was also highlighted that implementing common frameworks to manage conflicting interests, and having a common language for scientists and academics to communicate effectively with members of industry could be beneficial. In addition, strategic development based on systematic thinking, having an integrator or facilitator to bridge gaps between silos, and to increase funding to enable for the inclusion of more stakeholders would also be of interest. Lastly, all the participants agreed that the STS *forum* was a great way to build relationships and partnerships to increase cooperation and communication among everyone involved.

Cooperation in S&T
Fostering New Generations of Scientists

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

[Speakers]
Bjelke, Katarina, Director General, Swedish Research Council, Sweden
Kawai, Maki, President, National Institutes of Natural Sciences (NINS), Japan
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]
Tschinkel, Yuri, Director, Mathematics and Physical Sciences, Simons Foundation; Professor of Mathematics, Courant Institute of Mathematical Sciences, New York University, U.S.A.

Opening Remarks

To start the session, the chair commented on how science was essential for sustainability, the economy, as well as for citizens and decision-makers. By inspiring students, providing plenty of information in terms of guidance, and creating enough skilled teachers for training, a sufficient pool of talent that can reach its full potential can be established to foster new generations of scientists.


Chair: Petit, Antoine

The speakers commented on promoting the attractiveness of careers in the science field, efforts on marketing those selling points, and the lifting up of role models to inspire others around them. The group also mentioned engaging with students early on, creating equal opportunities for all backgrounds, and the need to retain talents within science long-term.

Next, the speakers discussed the styles of training available to students, the possible

impacts that could have in the future, and the importance of students having the freedom to choose paths they want to take to engage their curiosity. The group also commented on the challenge of diversity in particular fields in Japan and on how to engage them.

Another topic was on the multidimensional nature of the research field, the advantage of having multidisciplinary training and knowledge, as well as engaging in collaboration across sectors and among those with various disciplines. Employee retention at institutions was also raised as an issue, but that it could be solved with the proper incentives.

The speakers then discussed how to nurture scientists from the view of both universities and institutions. Importance was placed on increasing awareness among younger generations, learning diverse schools of thought, and how positive relationships can develop out of engagement with those in different fields. The importance of early involvement in governance and supporting scientists at risk was also mentioned.

Discussion

The participants first spoke about gender equality and the promotion of women within Sweden and Norway, where they actively try to balance the various aspects of equality, as well as implement assessments, and engage with feedback from those assessments.

The group also talked about relations between Asian countries and the exchange of knowledge created through science within the region, also mentioning the innovations developed in cooperation with politicians in Japan.

The speakers noted that concepts of open science and the responsible conduct of research demand the conducting of research in a more transparent and collaborative manner. And when engaging with stakeholders, it is good to keep common goals in mind as well as the fact that stakeholders come from diverse backgrounds. The issue of mastering a specific discipline versus engaging in multidisciplinary work was also raised.

Trends in age in the field of mathematics were also mentioned, but also that age was not the best criteria in terms of selection. Rather, experience is gained more through being involved in projects. The subject of diversity was also raised, which led to questions and issues in terms of selection processes. There is plenty of talent, but more can be done, such as with the improvement of schools and earlier engagement.

All agreed on the importance of researchers and scientists in society. As most research is done at universities, there is a disconnect between university and industry and what skills can actually be transferred. The subject of broader training outside of science-specific aspects was also raised.

The group also discussed working environment attractiveness, the balance that is sought among the working generation today, the issue of selectiveness and retention in PhD programs, bottlenecks that appear to be hindering career path progression, languages needed for international careers, and mobility between sectors. Women and gender equality in science was also brought up, and the group found that there were a number of parallels in approaches to solutions when engaging younger generations.

In regard to Africa, the need of funding, hierarchical systems, international collaboration, and mentorship to increase experiences was also discussed.

Lastly, all agreed on the importance of and need for new generations of scientists.

S&T Education
Inclusion and Diversity in STEAM Education

[Chair]
Hassan, Mohamed Hag Ali, President, The World Academy of Sciences (TWAS); President, Sudanese National Academy of Sciences (SNAS), Sudan

[Speakers]
Cauce, Ana Mari, President, University of Washington, U.S.A.
Goh, Christine, Director, Director's Office, National Institute of Education, Nanyang Technological University, Singapore
Borrell-Damián, Lidia, Secretary General, Science Europe, Belgium
López Casarín, Javier, Federal Congressman, Science, Technology and Innovation Committee, Chamber of Deputies for the Green Party; President, Science, Technology and Innovation Committee, Chamber of Deputies for the Green Party, Mexico

Opening Remarks

The chair opened the session by noting how science, technology, engineering, and mathematics (STEM) is crucial in preparing students for current and future jobs. Addressing real world problems, however, requires integrating social sciences and humanities, i.e., the arts, into those subjects (STEAM). In particular, the use of inquiry-based science education can promote skills required by future leaders, namely critical thinking, creativity and problem-solving. The chair highlighted the challenges for STEAM education such as gender imbalance, and the benefits of international collaboration in education and research.

Chair: Hassan, Mohamed Hag Ali

The speakers first noted that education has a vital role to play in addressing humanity's grand challenges through nurturing the next generations who have the necessary knowledge, skills, values and attributes. STEM education in Singapore was introduced as an exemplar of how to nurture STEM learners who are curious, creative and collaborative, and are keen to be the positive change in

their world by applying their STEM competencies to real-world contexts using skills developed from other subjects and disciplines.

Next, the speakers reiterated the importance of future leaders in leveraging cutting-edge science to solve global problems. Providing an education for students to prepare to contribute to the public good, and rewiring education to spark innovation that can be applied to the real world were two strategies discussed. Partnership of faculty and community is important as well.

Another topic was on opportunities and challenges regarding diversity in STEAM education in developing countries. There is incentive to balance gender biases as it has been proven to lead to more creative research and education. The speakers outlined ways in which policymakers can work to define policies that address discrimination.

The speakers then noted that the challenges facing emerging nations regarding inclusion and diversity in education and society first need to be identified. Restructuring the prevailing unequal system, and educating newer generations to the value of interconnectedness is necessary. Education has to be considered as an investment not cost, and its policies have to be consistent in the long-term to engender real changes.

Finally, the speakers considered the importance of diversity and the barriers to inclusion. Individuals from different backgrounds are required to provide creative, case-specific solutions to diverse global problems. Good communication of scientific findings is also important, hence reinforcing the necessity of the human component in STEM education. Systemic issues such the lack of inclusion need to be addressed by all sectors through cultural change.

Discussion

The participants then engaged in a group discussion. They first noted that the participation of women in science differs depending on the fields. They also pondered on how to increase the number of women role models through incentives. The issue of work-life balance was also discussed as women in Japan are expected to do household chores. To retain and increase talent, Japanese universities provide childrearing leave. Meanwhile, online communications serve to increase accessibility for the physically disabled. Interdisciplinary collaboration and therefore STEAM education is important for science to meaningfully contribute

to society. However, there may be resistance among teachers to change. It is vital for countries to share best practices with others.

The participants also talked about the opportunities and challenges for STEAM education in various countries. Common challenges include the lack of coordination and direction regarding the use of resources and people, and the lack of STEAM education at tertiary levels. Possible solutions to resolve cultural issues of girls excelling in STEAM fields yet not choosing careers in these fields include increasing online global interactions to showcase women role models to girls, setting a legal framework to change cultural attitudes that hinder girls from choosing these careers, and regarding STEAM as a concept to build a coherent curriculum on, rather than interpreting them as separate disciplines that ought to be integrated.

Finally, the participants focused on gender disparity in STEAM. Systemic issues such as the lack of diversity in STEAM are pervasive across countries. The group came up with solutions, including collecting the necessary data to understand the situation women face in universities and what can be done to change it. Having strong female role models and

male advocates for gender equality, as well as interdisciplinarity, may help increase gender diversity. Moving forward, both top-down strategies and grassroots solutions are necessary.

The chair concluded the session by emphasizing that the continuity of discussion of STEAM education is important. Ideas for future discussion include designing an effective, attractive and interactive STEAM curriculum, methods to introduce effective policies integrating STEAM fields in education, designing systems to assess the effectiveness of such, and considering developing massive open online courses for greater inclusion.

S&T Education
Science Literacy for All

[Chair]

Turekian, Vaughan C., Executive Director, Policy and Global Affairs Division (PGA), National Academy of Sciences; former Science and Technology Adviser to the Secretary of State, Department of State, U.S.A.

[Speakers]

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

Marwala, Tshilidzi, Vice-Chancellor and Principal, University of Johannesburg (UJ), South Africa

Thomsen, Mads Krogsgaard, CEO, Novo Nordisk Foundation, Denmark

Opening Remarks

To start the session, the chair commented that science literacy is an inextricable part of literacy in a broad context as it underpins decision-making through the collection and interpretation of evidence. There is a need to be science literate at an individual, national and global level. A difference in issues faced, existing structures, and the use of knowledge affect how science literacy is considered. University systems, global science organizations, the private sector and governments all have to think about science literacy, and the science community needs to consider cross-disciplinary approaches including collaborating with humanities and the way science training differs for different cultures and communities.

Chair: Turekian, Vaughan C.

The speakers first discussed why science is not just for the scientists. Noting that 2022 is the international year of basic sciences for sustainable development, they emphasized how, on top of basic sciences, cooperation across diverse fields and all stakeholders are also crucial to tackling complex social and global issues. Science literacy can be improved through discourse across disciplines

and among regions, among other areas. The importance of providing incentives and role models for learning science for fun to a wide range of social groups across gender, ethnicity and culture was also pointed out.

The speakers next commented on the barriers to accessibility in science and technology. Inequities in the fields of science, technology, engineering and mathematics (STEM) persist across geographical and gender lines, and there is a need to move from resource extraction economies and close the gap between skills and jobs, particularly in Africa. This requires cooperation among government, industry and society. It was noted that language is also a barrier to scientific literacy.

The speakers then emphasized the importance of science literacy as a prerequisite for solutions that may solve the current crises on energy, food and climate change, and it brings about economic growth. It is also important to each individual and to democratic societies as a whole. Cross-disciplinarity, diversity, public-private partnerships, capacity building in developing countries and scientific input in politics are critical elements.

Discussion

Group discussions were held among the participants. They debated the meaning of science literacy and considered the tensions between compliance, belief in scientific facts, critical thinking and experimentation. There is a need to accept that people think differently, a need to advance scientific communication and journalism, and also to conduct exchanges between the science community and society not just in STEM fields but also in social sciences and the humanities.

The participants also shared experiences in their local contexts and concluded that commitment from the international community and industry is required to motivate students. They spoke of the opportunities and dangers of information and communication technology, a divide in ICT usage and how fake news is related.

The group noted the difficulty of measuring science literacy as it is a methodology to making decisions based on looking for and understanding information. Mechanisms to attaining science literacy may include retaining peoples' childhood interest in science for which the importance of teachers are emphasized. There was also discussion on whether science communication should be a specialized field differentiating science historians and science journalists from other scientists.

In addition, the participants emphasized the urgent need by the scientific community to actively combat misinformation and disinformation around the world. Strategies suggested included a reformation of the education system toward a more interdisciplinary approach to science and an emphasis on science as a methodology for putting knowledge into context; an encouragement of lifelong learning in science; and education of scientists in the importance of communication to the layperson.

To the chair's question of whether science literacy is a genuine need for critical thinking or a selfish want by the scientific community, the participants related their experiences of receiving questions from the public that feeds back into research. The participants also pointed out that the dichotomy of scientists versus non-scientists is an issue. As exampled by citizen science, the layperson is a scientist at some point, so science should be less exclusive.

The speakers concluded that the group discussions have given them food for thought moving forward. Science literacy is at once the knowledge of science, a way of thinking, and communication. There is a need to consider the impediments and incentives to achieving science literacy, and all sectors of society have to be involved to tackle the problem.

S&T Education
New Systems of Learning

[Chair]

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

[Speakers]

Christophers, Chris Francis, Founder & President, iPresence Ltd, Japan

İnan, Umran S., Advisor to the Board of Trustees, President (2009 - 2021), Koç University, Turkey

Giorguli Saucedo, Silvia Elena, President, EL COLEGIO DE MÉXICO, Mexico

Schmidt, Brian P., Vice-Chancellor & President, The Australian National University, Australia [Nobel Laureate 2011 (Physics)]

Papič, Igor, Minister, Ministry of Education, Science and Sport, Slovenia

Opening Remarks

The chair began the session by commenting that we live in an increasingly knowledge- and technologically-intensive economy. Trends like autonomous systems and artificial intelligence (AI) make developing human capital an even higher priority worldwide. Technology and science offer opportunities to make formal and informal learning and training systems more accessible, engaging, personalized and effective. However, to fully leverage such technologies, education providers have to change their ways of providing services. Contrary to their reputation, many educational institutions in fact have a capacity for rapid change as evidenced during the COVID-19 pandemic.

Chair: Evans, Chad

The speakers first noted that cutting-edge technology scares many teachers due to a lack of precedent in implementation and guidelines on their use, and a fear of the responsibility of good usage. They detailed how technology was employed to allow

hospitalized children to participate in class. Technology also aided teachers during the pandemic and enriches education through lowering barriers to inviting overseas speakers. Another issue was student disengagement arising from online education, which remains lost after a return to in-person learning. This issue is common across universities, and raises the need to be careful to not lose the primary purpose of university education, which in the end is an 'appointment between generations' that, if at all possible, needs to take place on university campuses in a face-to-face format. In this appointment, both generations learn/teach one another as there is much that we all need to learn from the students themselves. Solutions to reengage students may include strict attendance rules and/or tailoring classes to their interest, but a balance must be struck between the need to not infringe too much on students' freedom or convenience that the recorded lectures brought about in the case of the former, and the danger of losing touch with or diluting traditional and fundamental disciplines in the case of the latter.

The speakers then moved on to discuss the aspects of current challenges, which include inequal access to technology and connectivity among students and universities, and inadequate home learning environments. Engagement and lifelong learning are also issues. Universities do not just provide the skills necessary for the labor market, but also prepare people for the future through building social skills and cultivating the mind and spirit.

The speakers then commented that education needs to be affordable and scalable to ensure social cohesion and stability. Technology is a solution, but educators have to keep in mind the social aspect of learning systems and the importance of social equity. Education institutions increasingly face competition from the private sector. Integration of teaching and government intervention are possible ways for them to maintain their advantage in knowledge creation.

Finally, the speakers touched on the importance of establishing frameworks on digital education and on student- and teacher-competencies. They shared examples of the use of artificial intelligence in digital education, and emphasized a need for clear definitions. A cross-disciplinary approach is vital in the design of new technologies.

Before transiting to group discussions, the chair posed some questions to the group. In response to what opportunities there may be in new science and technology in learning, comments included analyzing student data to provide better education. Besides implementing new systems of education at the university level, consideration also has to be

made for education at the lower grades. Libraries and other real-life experiences remain important in education.

Discussion

After the opening remarks concluded, the participants held group discussions. The participants shared their thoughts on various topics from the K-12 paradigm and methods to learn and teach with new technology. They also considered the differences between education and skills in relation to university and the notion of academic disciplines – removing the distinction between disciplines may aid research, but may make learning more difficult in a different way. Training for the unemployed who need to be reskilled were also pondered on in relation to the kind of training provided and the provider. There were points made on the ethical obligation of education, and the difference between ethics and values.

In addition, the group understood the need for new systems to adapt to a constantly changing world. Boundaries between teaching and learning have to be crossed so students are involved in the teaching process and the creation of curricula. This enables education to remain culturally relevant and universal. Participants noted that many countries do not have access to technology. In adopting new systems of learning, teachers should be educated

on how to use them, students should receive more guidance on their usage, and such new systems should remain flexible. Practical questions regarding their use were also raised.

The participants also had a discussion on how people, leaders, organizations, and societies define learning. There is a need to understand the resources available and how they should be shared and used, as technology allocation is often done the wrong way. Participants revealed a worry about the future, as leaders are unable to plan the next step in education because they are focused on addressing immediate challenges. Similarly, a misalignment in expectations between the heads of educational institution, staff and students regarding education hinders decisions on the next direction to take. This process is more likely to be evolutionary rather than revolutionary.

The chair concluded by reiterating that the use of technology can be an answer to improving productivity through training skills for the future. Tools can help us but we need to make them widely available. He warned that the issue of student disengagement at all levels of education is a crisis that needs to be addressed immediately as it can potentially cast a shadow over society.

Digital Society

Big Data (Opportunities and Risks)

[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]

Eschermann, Bernhard, CTO, Process Automation, ABB; Member of Innovation Council, Innosuisse - Federal Swiss Innovation Agency, Switzerland

Matsuoka, Satoshi, Director, RIKEN Center for Computational Science (R-CCS), RIKEN; Professor, Department of Mathematical and Computing Sciences, Tokyo Institute of Technology, Japan

Spalding, Kim, CEO, Tradelens, U.S.A.

Mochizuki, Yasunori, NEC Fellow, NEC Corporation, Japan

Mencer, Oskar, CEO, Maxeler Technologies, U.K.

Opening Remarks

Before starting the session, the chair expressed his deep sorrow on the passing of Koji Omi and former Prime Minister Abe. He celebrated the tremendous human contribution made by Koji Omi in establishing the STS *forum* as the single most important science and technology *forum* in the world, in that it discusses scientific and technological issues within a broader moral and ethical framework which promotes and advances a better life in larger freedom for all people of the world.

Chair: Kumar, Ashwani

To open the session, the chair noted that technology and science must be harnessed to achieve goals defined by humanity itself, and that our ability to marshal the path of technology to address the pressing challenges of our times will define the quality of life in years to come.

He pointed out that big data can reinforce prejudice and discrimination, and questioned whether we allow digital technologies to invade our lives and define the nature of our being, and whether technology impacts are reducing human interaction. He cautioned that these profound philosophical aspects will eventually determine the impact of technology on human civilization, and we therefore need to find the right balance between the power of science and the power of philosophy.

The speakers first considered big data use in the industrial context, where data from real-time measurements, other data streams (like from video cameras), and management systems can be used to improve productivity, efficiency, safety, and reduce energy consumption. As an example, early detection of anomalies can avoid negative impacts on production, the plant, and the environment. Obstacles to the use of big data in industrial environments include technical obstacles, such as compartmentalization of plant areas due to cybersecurity concerns, data ownership and access issues, and concerns over whether regulations prevent useful applications of data.

Next, the speakers discussed the bigger picture of the proliferation of simulated AI models driven by supercomputers, as many tech giants now have supercomputers rivaling national supercomputers. Real-time modeling capabilities with AI create huge potential security and privacy concerns, and we are only scratching the surface of understanding the possible bright or less bright future outcomes.

Another topic was how harnessing big data for digital transformation of cities and communities requires data sharing across various domains and across regional boundaries. The Japanese government enacted the Basic Act on the Advancement of Public and Private Sector Data Utilization, and collaborated with stakeholders to develop the Smart City Reference Architecture to facilitate interoperability. Calls by the government to implement specific open APIs are now underway to further improve interoperability. Privacy and transparency are also crucial for social acceptance of digital innovation, and to ensure trust. Such technology governance issues should be addressed through the multistakeholder approach under global harmonization.

Next, the speakers discussed the need for data globalization in the global shipping industry, as highlighted during the recent pandemic, where a lack of standardization had hampered modernization. It was noted that TradeLens provides a common data platform, permissions

framework, and enterprise blockchain for industry partners, with benefits including time savings and optimization of arrivals, contributing to environmental benefits.

The speakers then discussed how the impact of big data on our lives continues to increase. Businesses use big data to provide valuable services that can improve quality of life, and we pay for these services by giving away our data, such as our location. Businesses gain competitive advantage, ultimately driving efficiency. The computation cost involved is a kind of tax on extracting value from data, and we are therefore seeing development of new specialized chips that reduce the cost of extraction.

Discussion

The participants then engaged in a group discussion. First, they touched upon the balance between functional efficiencies and basic human rights, including privacy. Participants noted that there is often a tradeoff of risk to reward, and the need to try instead to reduce risk while increasing the reward. Security breaches can endanger our wellbeing, and in other fields associated with risks to our safety, such as auto manufacturing, we create models and conduct tests to predict the consequences, and then design countermeasures. For big data sharing and regulation, safety measures put in place by authorities are also dependent on citizens' trust in the authorities. One strategy is to show a benefit in exchange for the sharing of data. There are also ethical issues to be considered, as what is good for the nation is not necessarily good for the individual. We need better education to improve understanding and to help individuals make better choices. It was also pointed out that group versus individual rights make this topic even more complicated, such as DNA shared in common with family members, and so the rights on sharing of that data need to be considered. The individual has choice in whether to share our data, but the question is whether mankind remains in charge of its own destiny, or if technology is dehumanizing us. The participants cautioned that human beings may be marginalized in the decision-making process by AI.

The participants discussed privacy concerns related to how much personal information the younger generation are prepared to share in order to use "buy now, pay later" services. It was suggested that legislation should be international since the technology used is international in nature. They also noted that better education is needed for young people to help them make better decisions about the data that they share online.

Discussions also touched upon trust, with people in most countries happy to share their data with the government, but there are greater concerns about big tech companies. It

was suggested that frameworks for safely sharing data are urgently needed to protect consumers, but caution was also expressed that inappropriate or excessive regulation can slow down innovation.

The participants then considered aspects in which we fear AI, such as the negative effects of AI assistance on education, and concerns over the effects that robot assistance will have on us. There are lots of open questions, such as whether we should regulate on which areas AI should not be allowed to enter, and how perfect AI systems need to be, since humans are imperfect, and it is humans that are creating these systems.

The participants also discussed privacy preserving machine learning techniques, noting that advanced machine learning models are very difficult to train and are therefore limited to only a few small groups around the world.

Discussion then touched upon sustainability through improved education standards, and difficulties in achieving the right level of regulation. Parallels were drawn to early development of computers, when there were similar conversations and arguments about the risks.

Fears for the future include loss of choice to opt out of sharing data, fears about wrong decisions made by AI, and concerns about effects on mental health, with the speed of transition making it difficult to be aware of the implications at a personal level.

Finally, the discussion considered differences in the rule of law in different countries, and regulations that trespass borders, creating complexities in what regulations apply where. It was noted that the STS *forum* is a unique space to share this message, but participants stressed the need for more international cooperation and coordination on the use of big data.

The chair wrapped up the session noting that we need to revisit some of our philosophical assumptions, stressing that human emotions are what distinguish our species, and they must not be tamed by technology.

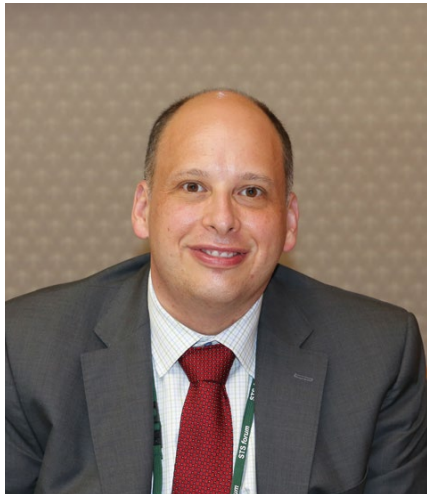
Digital Society
Pandemic of Ransomware

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

[Speakers]
Kudelski, André, President, Innosuisse - Swiss Innovation Agency; Chairman of the Board and Chief Executive Officer, Kudelski Group, Switzerland
Malatras, Apostolos, Team Leader, Knowledge and Information, EU Agency for Cybersecurity ENISA, Greece
Nakatani, Noboru, Executive Vice President, Group Chief Trust & Safety Officer, Z Holdings Corporation, Japan

Opening Remarks

In commencing the session, the chair noted that this topic highlights a number of societal issues facing the world. He pointed out that Chairman Omi would always refer to the lights and shadows, and while the shift in business process towards everything being connected has brought great economic benefits, unfortunately we have also seen that cybercrime is taking advantage of this connectivity to launch remote attacks by holding hostage a company's valuable data and demanding a ransom payment for its safe return. The organizations launching these attacks are extremely professional, and there are now professional ransom negotiators who assist victims with the difficult negotiations to try to resolve these attacks. The chair raised several questions such as how the increasing technology-enablement of society is further enabling these attacks, what lessons from other fields such as medicine, epidemiology and psychology can be applied to tackle ransomware, and whether policies around payments to ransomware attackers or standards around security of key systems could slow attacks or lessen their impact.



Chair: Thompson, Herbert Hugh

The speakers first pointed out the asymmetric nature of cybersecurity, where the target needs to be 100% secure, while the attacker only needs to succeed once. The business model for ransomware is relatively simple, but it can produce large profits, making it a very attractive business for criminal organizations. It was stressed that paying a ransom only makes the business of ransomware more attractive, further increasing the likelihood of attacks. We should also be aware that ransomware could be a cover for something else, such as state-sponsored espionage.

Next, the speakers highlighted that it is likely that only a small proportion of ransomware cases are actually reported, which is a major issue that needs to be tackled, as this reduces the ability to look for commonalities and develop countermeasures. Despite the high number of attacks, the number of threat actor groups is relatively small. The most common initial compromise vector in 2022 is still phishing, highlighting the need for better education. International collaboration presents the best opportunity for society to develop better countermeasures.

The speakers then discussed the complexities of cyber issues, covering national security, espionage, and cybercrime. In many cases it is very difficult to clearly determine the source of attacks, and this challenge of potential misattribution can lead to escalation of international tensions. There is currently no broadly accepted international agreement on how to deal with cyberattacks, mainly because cyberspace is an extension of the broader geopolitical battlefield. Cybersecurity policies therefore need to treat cybercrime in the context of geopolitical issues.

Discussion

Moving to a group discussion, the participants first discussed attacks on banks and financial institutions. It was noted that the world's largest banks spend large amounts on cybersecurity measures, making them less attractive targets. It was pointed out that it is important to think from the perspective of the attackers, who will find and attack the weakest link to maximize their returns for their efforts. It was also pointed out that hijacking messages on the SWIFT system is the most common attack vector against the financial system.

The participants then considered the question of whether money would be better spent on creating a more secure Internet, rather than spend money to defend against attacks. It was noted that the initial success of the Internet was partly due to the simplicity of its protocols, but that it has become so big that it is difficult to fundamentally change at this

point. Instead, we must improve its building blocks piece by piece. One challenge is the need to break backward compatibility to move forward, which is a difficult issue. It was pointed out that most ransomware attacks are not particularly sophisticated, and they could be prevented by appropriate basic IT hygiene, although examples were also presented of very sophisticated human manipulation techniques being used to overcome technical and procedural safeguards.

The discussion among the participants also touched upon the importance of usability of cybersecurity tools and solutions, and how to address the issue of the weakest link being targeted, such as using a kind of human honeypot, and conducting targeted training for those most at risk. There was also some discussion on how to encourage reporting incidents versus the instinct to protect reputation; however, it was pointed out that there are both legal and ethical requirements to inform customers when their data has been compromised.

The participants then considered the systemic causes of the growth in ransomware, noting that many countries have incentives to ignore these activities, since these organizations are bringing capital into the country, which benefits the overall economy. For companies that become victims of an attack, there is in some cases a dilemma of whether to take a

moral stand against paying the ransom to the attackers or fall back on a set of fiduciary responsibilities of the board of directors, such as protecting shareholder value. Participants also discussed what can be done to remove the stigma and shame around falling victim to an attack, and whether we should be treating ransomware in a similar way to a health pandemic with mandatory reporting requirements, and perhaps public insurance infrastructure to support businesses affected by attacks.

Digital Society
Information Authenticity and Governance

[Chair]

Catlow, Richard, Co-President, InterAcademy Partnership, Italy; Professor, Chemistry, University College London, U.K.

[Speakers]

Ataka, Kazuto, Professor, Faculty of Environment and Information Studies, Keio University; Senior Strategist, Z Holdings Corporation, Japan

Schiffrin, Anya, Director of the Technology, Media, and Communications, School of International and Public Affairs, Columbia University, U.S.A.

Verses, Judy, President, Academic and Government Markets, Elsevier, Netherlands

Opening Remarks

Introducing the session, the chair noted that the with the changes in the means and speed of information dissemination, false information or "fake news" also spreads faster than ever before. This is causing significant issues for society's ability to make informed choices and can limit progress on important issues. One critical element of the issue is the difficulty for individuals to identify reliable sources and true experts, with the rise in pseudo-experts and predatory practices in scientific publishing.

Chair: Catlow, Richard

The speakers first considered the various ramifications of the spread of highly-charged misinformation. While messaging apps are the most active channel for the spread of misinformation, they are very difficult to monitor or control. Meanwhile, AI-generated content has become so realistic that it is difficult to distinguish from real content. At the same time, widespread strategic misinformation has grown to become a matter of national security. One countermeasure would

be to limit the number of times the same information can be rebroadcast, at least until it can be verified. Nations should join forces to work on solutions, and nations also need to systematically train white-hat hackers to counteract the influence of state-sponsored disinformation attacks.

The speakers also examined the lights and shadows in the field of research and science publishing, with the lights including how one of founders of BioNTech read an article in the Lancet on January 24, 2020 that revealed the human-to-human transmission of the coronavirus. Learning that one patient was asymptomatic and Wuhan being a major travel hub, he refocused a team working on mRNA vaccines for cancer to work on developing mRNA vaccines targeting the virus. On the other hand, shadows include the "rabbit hole" effect of internet algorithms that reinforce extremist views. It has also been discouraging to see very reputable researchers and scientists being subject to attacks on social media. We must address these critical issues to ensure quality information can be broadly communicated. Trust is the foundation, and growth in open science, making it more inclusive, transparent, and collaborative is one key aspect of ensuring trust in scientific information.

Next, the speakers touched upon the root cause of the issue of misinformation and disinformation as seeking profit or political gain. Policy solutions to counteract misinformation include both demand-side solutions, such as building trust in quality information, the fact-checking movement, and increased journalism exposing misinformation; and also supply-side solutions, such as AI screening of content, lawsuits brought by individuals, funding quality information, and regulation. The Digital Services Act requires big tech companies to do an annual risk assessment and explain what they are doing to address the risks.

Discussion

The participants discussed how to avoid misinformation countermeasures being abused to censor information. They also touched upon how applying friction to misinformation exchange also affects exchange of good information.

The discussion then focused on the fact that some of the points raised in discussions on anti-vaccination are valid questions in many ways, such as whether a research paper may have been influenced by large pharmaceutical company funding, or whether there are flaws in the presentation of the data that undermine the conclusions. It was also pointed out that while in the past we had information presented as facts and opinion, now it seems that we have facts, opinion, and alternative facts. These aspects further highlight

the importance of identifying reputable sources, and of communicating more clearly how papers have been peer-reviewed and presenting trustworthy scientific information in more understandable language.

The participants then discussed the problem of countermeasures against misinformation being repurposed by oppressive or unethical regimes to achieve their own desired outcomes, and the fear that these tools can get turned back upon us. The participants then discussed whether there are any historical examples of successful regulation against major interests, but they also cautioned that breaking up big tech organizations would not necessarily help, since it would likely create even more fragmented channels where this misinformation would continue to spread.

The participants noted that there are many factors contributing to the issue, but we are gradually learning what methods are effective in countering misinformation, such as positive story telling. The participants also cautioned that we should avoid being too focused on science and technology in our approach, noting that the social sciences may have more to contribute to the solutions.

The discussion then focused on the roles of different stakeholders in contributing to solutions, and identifying responsibilities, noting that one of the reasons that disinformation is effective is because it is kept very simple, and people are inclined to believe things that elicit an emotional response; they also questioned how to bring profit-making corporations into the solution process. Again, the participants agreed that to address human aspects, more diverse groups need to be included in the discussions on how to address the issue.

The participants commented that the issue is extremely broad, and even with advanced AI techniques it will be challenging for big technology companies to counter the spread of misinformation.

The participants also pointed out that the right questions must be asked to identify the problem you are trying to solve, and we then need to gather the right broad representation of people together to come up with the correct solution.

The participants pointed out that while it is easy to disseminate misinformation it is very difficult and costly to clean it up. However, the big tech companies have had a lot of time to try to address the issue, and others now must intervene to find a solution, but "big tech" will need to be part of the solution.

Science and Technology in Society *forum* (STS *forum*)
19th Annual Meeting
Kyoto, Japan, October 4, 2022

Statement

1. The 19th Annual Meeting of the Science and Technology in Society *forum* took place from October 2 to 4, 2022 in Kyoto, with the participation of nearly 1,000 global leaders in science and technology, policymaking, business, and media from over 80 countries, regions, and international organizations.

Challenging times:

2. We met in the shadow of conflict and the shifting tectonic plates of the global international order, at a time when humankind faces great and complex global challenges. Science must play a central role to help the world move on beyond the pandemic and get back to the path of sustainable development. This will require that science, government and the private sector, working with communities and within a global-regional-national and local framework of multi-disciplinarity and collaboration to achieve the transformation of our economies to carbon neutrality. We must also keep the human being at the center of our concerns. We must remain committed to human rights and human dignity. Globally, more equality and inclusion are needed for all humans. We also have to understand the complexity of the individual human being, to comprehend a person's mind, not just their brain.

Analysis and Synthesis in Science–The Human Body and Mind

3. Humans are a physical-biological entity whose bodies include the brain with its myriads of neural cells and their connections. But what makes us human is the, apparently, non-physical entity–the mind, which includes our consciousness, way of thinking, and emotions. Many people, including scientists and policymakers, are realizing that a central challenge confronting science in the 21st century is understanding the human mind in biological terms. Biology and neuroscience have generated an astonishing amount of

information, but great effort must still be invested in analyzing and synthesizing that information. Furthermore, we also need to link advances in biology and neuroscience to research in psychology, social sciences and other related fields. This requires a clear vision in policymaking, funding schemes, and training of young scientists.

Breaking Down Silos in Research

4. As the world moves on to the post-pandemic stage, unprecedented challenges are arising. COVID-19 highlighted the presence of many existing global issues, such as the vulnerability of the global supply chain and social inequality between the Global North and South in terms of access to the necessary vaccines and medical treatment. As these issues are by nature interdisciplinary, spanning fields from science and technology to the social sciences and humanities, researchers in various disciplines must collaborate to address them. Effective collaboration between research institutes and the public and private sectors is necessary, as is the creation of an environment that supports interdisciplinary research and fosters communication between researchers in different fields.

Lights and Shadows of AI

5. Rapid advances in computing and robotics are opening new vistas. Artificial Intelligence (AI) is fast developing into one of the most transformative technology advances in history. AI is rapidly increasing in power, precision, and scope of possible applications. It is helping humans undertake many complex tasks from optimizing network traffic to cataloguing images from newspaper archives. But more importantly, it is already helping solve many difficult scientific problems, such as 3D protein folding, which will accelerate the development and deployment of new technologies and increase the speed of scientific advance across a wide range of disciplines. But concerns have increased about the extent to which AI may be amplifying existing human biases and other weaknesses in decision making, and what to do about the risks of autonomous action by AI, especially in the area of weapons. A whole new domain is developing around the ethics of work on and with AI. What AI does must be explainable and understandable. AI is definitely one of the areas where the lights and shadows of science and technology in society is most compelling. Collaboration between governments, policymakers, and researchers is important to ensure that the development of AI is trustworthy, transparent, and responsibly deployed.

Energy and Environment

6. Recent IPCC working group reports point to a future where the likelihood of restraining the global mean temperature to a rise of 1.5 degrees seems increasingly improbable. We need to go from promises to action now. We also need to prepare for unavoidable climate-related impacts and provide concrete analysis of the steps needed to avoid worse outcomes. Climate change and disruptions in the hydrological cycle along with loss of biodiversity, deforestation, and increased pollution as well as densification of human settlements through increasing urbanization constitute converging risks, that require actions at the global, regional, national and local levels. Such programs for adaptation and resilience require adequate funding for the poor countries as well as collaboration between knowledge providers and networks that can take and support action, above all, to avoid suffering due to poverty in Low and Middle Income Countries (LMICs), we also must take special measures to protect women, children, minorities, refugees, and other especially vulnerable groups.

7. With the increasingly rapid advance of the impacts of climate change, we face the urgent global need to shift from our fossil fuel-based energy economy to a new, sustainable system. The time remaining to address this existential problem is frighteningly short, and we need a clear and practical roadmap for this crucial transition. The expansion of renewable energy sources is fundamental. This roadmap could also include the utilization of natural gas and nuclear energy as transitional energy sources. The development of technology should also accompany expansion of novel approaches to clean energy. However, as we monitor CO_2 emissions, we must also look at the inadvertent or even willful release of greenhouse gases, especially methane. Over 100 countries have already decided to slash methane emissions by 30% by 2030.

Food and Water Security

8. The world's food and water supplies are set to face increasing pressure. Climate change, urbanization, and resource scarcity are expected to have severe long-term effects on agriculture production yields and will also put more pressure on global food and water supplies, especially in the arid and semi-arid zones. Food and water security are inextricably linked. Achieving food and water security has always been challenging and will require us to transform our water use and agricultural practices. Food and nutrition security goes beyond adopting technology to taking a systemic approach, from environmentally-sound production by smallholder farms to distribution and outreach. Countries need to consider the synergies across the food, nutrition, water, energy, and

waste nexus while simultaneously doing this in a sustainable way. All this needs strong political will and wide public support.

Preparing for the Next Pandemic

9. While we continue coping with the ongoing COVID pandemic, it is also necessary to prepare for the next. A pandemic affects large parts of the world at the same time, and the world's ability to cope depends on the policies and practices of local, national, and international institutions. Success depends on deeper scientific understanding of everything from virology and immunology to epidemiology and the psychology of human behavior. Collaboration, including expanded public-private partnerships, are needed to develop, produce, and distribute new tests, therapeutics and vaccines in an equitable and efficient manner. Success also depends on maintaining proper monitoring, which requires investment in public health capabilities all around the world. To produce the needed plans and preparations will need political will and public understanding. Success must also avoid inequities in resources, services, access, vulnerabilities, and outcomes arising within and across national borders.

10. By its nature a pandemic is global, and hence the WHO must have a stronger science-based central role in coordinating global monitoring and action. It should also have the means to help those who need help most. Existing health funds should be restructured into a new Global Health Fund, maintaining past programs but adding new funding for financing commodities for disease control, pandemic preparedness and response, and primary health system strengthening in LMICs.

Collaboration

11. Today, some of the biggest challenges affecting innovation and development revolve around coping with post-pandemic effects and redesigning work-life arrangements, supply chains, inclusive growth, rapid demographic change, rural-urban transitions, increasing demand for natural resources, globalization and economic liberalization, climate change, and technological disruption. Academia and the public and private sectors will need to work together nationally and regionally to build and accelerate science and technology and innovation. Collaboration in such endeavors can bring many benefits, including cost savings through sharing administrative expenses, expanding value propositions, improving efficiency, strengthening programs, and making use of compatible skills and abilities.

STEAM Education

12. Addressing real-world problems will require integrating education in arts subjects (including social and economic sciences and business) into STEM education, resulting in what is now commonly known as STEAM education. The use of inquiry-based science education pedagogical platforms for integrated STEAM education promotes the critical thinking, creativity, and problem-solving skills of students and young researchers. International collaboration is essential for building capacity, solving global problems, exchanging best practices, and promoting diversity and inclusion.

Challenges in the Digital Society

13. The revolution in the scale and speed of communication and the massive growth of information and the proliferation of social media platforms have created a new digital society and have changed where and how people access news and information about scientific, political, and societal issues. However, these same attributes have also created a crisis of confidence where misinformation and disinformation spread rapidly, which is extremely detrimental to people and even more seriously, erodes trust in science, institutions, and government. Citizens need to be empowered to protect their privacy and reputation and to exercise critical judgment to recognize fact-based reporting. A properly informed citizenry is necessary for adoption of science-based policies and evidence-based regulations.

Conclusions:

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 societies of the world. And we look forward to convening again next year in Kyoto and have agreed to hold the 20th Annual Meeting of the STS *forum* from Sunday, October 1 to Tuesday, October 3, 2023.

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