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TÜRKİYE BİLİMLER AKADEMİSİ
TURKISH ACADEMY OF SCIENCES

G8 & G20

2005-2022

Joint Statements from Science Academies to World Leaders

2022 - Ankara

Compiled by

TÜRKİYE BİLİMLER AKADEMİSİ
TURKISH ACADEMY OF SCIENCES

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from Science Academies to World Leaders
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G8
GLENEAGLES
2005


G8
SUMMIT2006
Saint-Petersburg


G8 Summit 2007
Heiligendamm


HOKKAIDO TOYAKO SUMMIT 2008
G8


FROM LA MADDALENA TO L'AQUILA SUMMIT 2009
G8


MUSKOKA 2010
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FRANCE
2011


G2012
MÉXICO


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Australia 2014


2015
Turkey
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2016
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S20
INDONESIA
2022
SCIENCE

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TURKISH ACADEMY OF SCIENCES

Science Diplomacy and Tools of Academia

Prof. Dr. Muzaffer Şeker[1]

Science is one of the most important elements that contribute to the common civilization of humanity. Scientific ways and methods are guiding in solving the problems faced by humanity. As science academies, it is our duty to search and find solutions to the problems experienced in the world. These problems manifest in many different ways. This can sometimes be natural disasters, sometimes environmental destruction, and sometimes health problems like a pandemic. There are also problems such as educational inequality, pollution, destruction of cultural heritage.

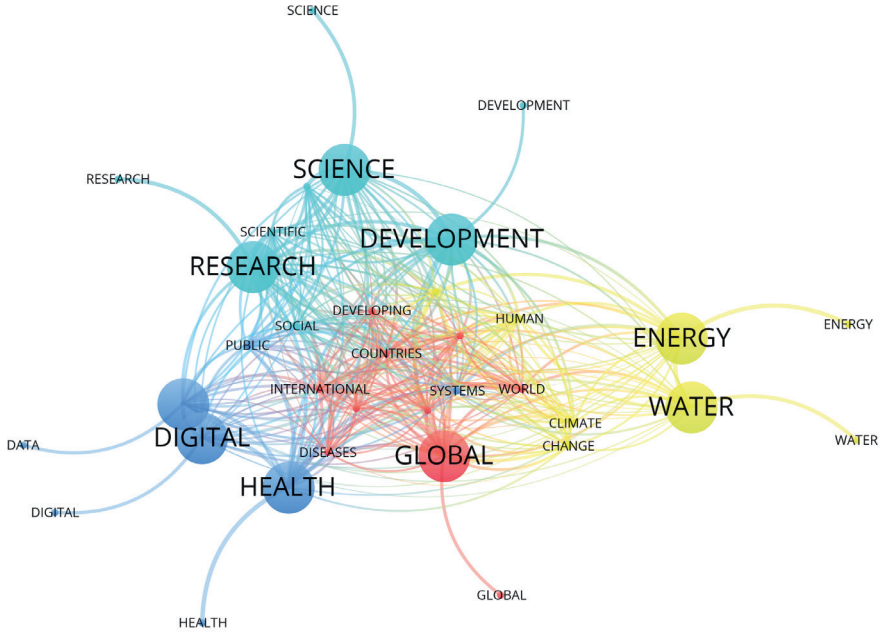


Figure 1. Concept Map (General)

[1] Turkish Academy of Sciences, President

The G8 and G20 are the formations that shape the world. Understanding that the G8 countries cannot solve the problems of the world with such a narrow group of countries has made it necessary for developing countries to participate in the solution of problems that concern all countries. Thus, the formation of the G20 occurred. The G20 summits are more meaningful than the G8 summits in this respect, in terms of the diversity of participation and the expression of different ideas. In addition, the developing countries can express various problems of other developing countries and low-income countries in G20 meetings. Because many developing countries are not involved in decision-making mechanisms in the current economic and political order in the world. Although the G20 platform does not have a decision-making initiative, it is an important opportunity for many developing countries to make their voices heard in the world. In this sense, S20 meetings are also of great importance. We see these meetings as important organizations where the voice of science is conveyed to decision makers.

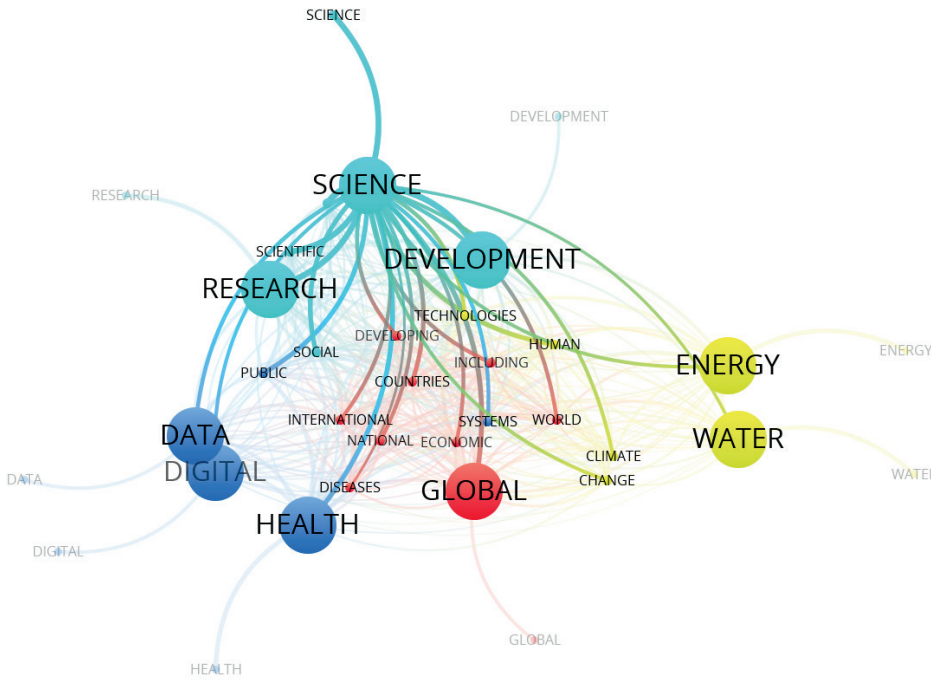


Figure 2. Concept Map (Science Connected)

As in the G20 summit in Türkiye, we declare that it is important to understand that the decisions we make with an eye on global needs rather than just the interests of individual countries prove more efficient and result oriented. We know that the world needs global solutions to address global problems. The decisions we got and the suggestions we made at the S20 meetings are for a more livable world. Leaders should not view them as mere advice. These are homework assignments that will benefit all humanity. Again, in the call at G20 summit in Türkiye, G20 leaders must keep in mind that this organization has the power to improve the life of each and every person in the world.

In this book, we have collected the declarations that we signed or received as science academies at the S8 and S20 meetings in the last two decades. Our aim is to show the findings and solutions offered by science academies to the problems faced by the world in a holistic way. In addition, it is seen that certain concepts are handled intensively. As seen in the Figure 1, the most repetitive and highlighted topics focus on energy and climate/ environment. Moreover, concepts related to the terms as health/diseases, governance, economy and infrastructure have also found their place in the declarations. Again, we see that the terms related to the problems that world and countries frequently encounter are also included in the S20 declarations.

We see that "science" concept is mostly associated with concepts such as energy, climate, world, innovation, change, technology and research. The connections related to science can be seen in detail in the figure 2. The figure shows that the concept of science is associated with almost all terms. This is the most important proof that the S20 declarations offer science-based solutions.

It is certain that S20 declaration are the product of intensive labor and consultation-based meetings. In this respect, each statements offers science-based solutions for the issues on the world agenda. We would like to thank all scientific academies and scientists who signed and contributed to the declarations.

2005
Gleneagles, Scotland / UK
G-8

JOINT SCIENCE ACADEMIES' STATEMENT: GLOBAL RESPONSE TO CLIMATE CHANGE

Climate change is real

There will always be uncertainty in understanding a system as complex as the world's climate. However there is now strong evidence that significant global warming is occurring. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers, and changes to many physical and biological systems. It is likely that most of the warming in recent decades can be attributed to human activities (IPCC 2001). This warming has already led to changes in the Earth's climate.

The existence of greenhouse gases in the atmosphere is vital to life on Earth – in their absence average temperatures would be about 30 centigrade degrees lower than they are today. But human activities are now causing atmospheric concentrations of greenhouse gases – including carbon dioxide, methane, tropospheric ozone, and nitrous oxide – to rise well above pre-industrial levels. Carbon dioxide levels have increased from 280 ppm in 1750 to over 375 ppm today – higher than any previous levels that can be reliably measured (i.e. in the last 420,000 years). Increasing greenhouse gases are causing temperatures to rise; the Earth's surface warmed by approximately 0.6 centigrade degrees over the twentieth century. The Intergovernmental Panel on Climate Change (IPCC) projected that the average global surface temperatures will continue to increase to between 1.4 centigrade degrees and 5.8 centigrade degrees above 1990 levels, by 2100.

Reduce the causes of climate change

The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action. It is vital that all nations identify cost-effective steps that they can take now, to contribute to substantial and long-term reduction in net global greenhouse gas emissions.

Action taken now to reduce significantly the build-up of greenhouse gases in the atmosphere will lessen the magnitude and rate of climate change. As the United Nations Framework Convention on Climate Change (UNFCCC) recognises, a lack of full scientific certainty about some aspects of climate change is not a reason for delaying an immediate response that will, at a reasonable cost, prevent dangerous anthropogenic interference with the climate system.

As nations and economies develop over the next 25 years, world primary energy demand is estimated to increase by almost 60%. Fossil fuels, which are responsible for the majority of carbon dioxide emissions produced by human activities, provide valuable resources for many nations and are projected to provide 85% of this demand (IEA 2004).

Minimising the amount of this carbon dioxide reaching the atmosphere presents a huge challenge. There are many potentially cost-effective technological options that could contribute to stabilising greenhouse gas concentrations. These are at various stages of research and development. However barriers to their broad deployment still need to be overcome.

Carbon dioxide can remain in the atmosphere for many decades. Even with possible lowered emission rates we will be experiencing the impacts of climate change throughout the 21st century and beyond. Failure to implement significant reductions in net greenhouse gas emissions now, will make the job much harder in the future.

Prepare for the consequences of climate change

Major parts of the climate system respond slowly to changes in greenhouse gas concentrations. Even if greenhouse gas emissions were stabilised instantly at today's levels, the climate would still continue to change as it adapts to the increased emission of recent decades.

Further changes in climate are therefore unavoidable. Nations must prepare for them.

The projected changes in climate will have both beneficial and adverse effects at the regional level, for example on water resources, agriculture, natural ecosystems and human health. The larger and faster the changes in climate, the more likely it is that adverse effects will dominate. Increasing temperatures are likely to increase the frequency and severity of weather events such as heat waves and heavy rainfall. Increasing temperatures could lead to large-scale effects such as melting of large ice sheets (with major impacts on low-lying regions throughout the world). The

IPCC estimates that the combined effects of ice melting and sea water expansion from ocean warming are projected to cause the global mean sea-level to rise by between 0.1 and 0.9 metres between 1990 and 2100. In Bangladesh alone, a 0.5 metre sea-level rise would place about 6 million people at risk from flooding.

Developing nations that lack the infrastructure or resources to respond to the impacts of climate change will be particularly affected. It is clear that many of the world's poorest people are likely to suffer the most from climate change. Long-term global efforts to create a more healthy, prosperous and sustainable world may be severely hindered by changes in the climate.

The task of devising and implementing strategies to adapt to the consequences of climate change will require worldwide collaborative inputs from a wide range of experts, including physical and natural scientists, engineers, social scientists, medical scientists, those in the humanities, business leaders and economists.

Conclusion

We urge all nations, in the line with the UNFCCC principles, to take prompt action to reduce the causes of climate change, adapt to its impacts and ensure that the issue is included in all relevant national and international strategies. As national science academies, we commit to working with governments to help develop and implement the national and international response to the challenge of climate change.

G8 nations have been responsible for much of the past greenhouse gas emissions. As parties to the UNFCCC, G8 nations are committed to showing leadership in addressing climate change and assisting developing nations to meet the challenges of adaptation and mitigation.

We call on world leaders, including those meeting at the Gleneagles G8 Summit in July 2005, to:

1. Acknowledge that the threat of climate change is clear and increasing.

2. Launch an international study to explore scientifically- informed targets for atmospheric greenhouse gas concentrations, and their associated emissions scenarios, that will enable nations to avoid impacts deemed unacceptable.

3. Identify cost-effective steps that can be taken now to contribute to substantial and long-term reduction in net global greenhouse gas emissions. Recognise that delayed action will increase the risk of adverse environmental effects and will likely incur a greater cost.

4. Work with developing nations to build a scientific and technological capacity best suited to their circumstances, enabling them to develop innovative solutions to mitigate and adapt to the adverse effects of climate change, while explicitly recognising their legitimate development rights.

5. Show leadership in developing and deploying clean energy technologies and approaches to energy efficiency, and share this knowledge with all other nations.

6. Mobilise the science and technology community to enhance research and development efforts, which can better inform climate change decisions.

JOINT SCIENCE ACADEMIES' STATEMENT: SCIENCE AND TECHNOLOGY FOR AFRICAN DEVELOPMENT

Science, technology and innovation are familiar issues to the G8. In 2000 in Okinawa, G8 leaders established a task force to address the global digital divide, and at the 2003 summit in Evian, G8 leaders endorsed an action plan for science and technology in sustainable development.

There is a clear continuing need for these important initiatives.

We would like to stress, more generally, the fundamental importance of science, technology and innovation in tackling a wide range of problems facing Africa and other developing regions. The goal of securing a sustained improvement in the living standards of nations is highly complex and should be informed by scientists along with economists, social scientists and other experts in the field of development.

At the heart of this endeavour, alongside issues of governance, security and trade, lies the capacity of nations to engage with global science and technology.

We, the national science academies of the G8 nations and the Network of African Science Academies, therefore call on world leaders, including those meeting at the Gleneagles G8 Summit in July 2005, to implement the following recommendations without delay. For our part, we also commit ourselves to working with appropriate partners towards these urgent goals.

1. Recognise that science, technology and innovation underpin success and sustainability in all aspects of international development in Africa, including poverty alleviation and economic growth as well as in areas such as health and agriculture.

2. African countries must be able to develop, adapt and exploit scientific and technological solutions appropriate to their specific needs, otherwise they risk becoming ever more dependent on advice and assistance from the developed world.

3. Recognise that investment in a country's own science capabilities, along with development of merit-based processes and institutions, are essential to the successful use of science, technology and innovation in Africa, and are fundamental to sound policy-making, good governance and industrial development. African countries need to have in place appropriate mechanisms and infrastructure for training and exploitation of knowledge. This will enable them to make meaningful evidence-based policy, in order adequately to address local needs and participate in the international community on science and technology issues.

4. Recognise that for innovation, growth and policy-making in Africa, it is fundamental to promote and develop an environment that encourages knowledge to be produced, communicated and applied to a nation's needs.

5. Sustainable national structures and strategies are needed to provide and maintain a source of well-trained, knowledgeable people, requiring attention at all levels of education from primary to tertiary.

6. Help revitalise African universities and support the development of centres of excellence in science, engineering and technology, including African institutes of technology.

7. The Commission for Africa report in March 2005, for example, stressed the need for investment in higher education and centres of excellence, particularly in science and technology.

8. Explicitly build development of science, technology and innovation capacity into international assistance programmes, including those for specific development sectors, and ensure that these initiatives are African-led and sensitive to social and cultural diversity.

9. Isolated investment in science and technology is not enough – capacity development initiatives should be integrated into programmes in specific sectors. A health programme, for example, should also seek to develop local expertise and resource to enable locals to continue to address the issues long after the specific programme has ended.

10. Encourage the transfer and sharing of scientific, technological and innovation excellence between the developed and developing worlds, as well as among developing world nations.

11. It is critical to ensure appropriate networks are in place to enable all nations to share their experiences and best practice.

12. Identify explicit funds for science, technology and innovation capacity building in Africa.

13. Without adequate funding, nothing will change.

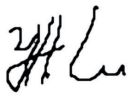
14. Continue to keep the development of science, technology and innovation capacity on the G8 agenda in forthcoming years.

15. Regular updates at annual Summits will help to maintain the momentum for change.

16. Without embedding science, technology and innovation in development we fear that ambitions for Africa will fail.

Academia Brasiliera de Ciências
Brazil

Royal Society of Canada,
Canada



Chinese Academy of Sciences,
China

Academié des Sciences,
France

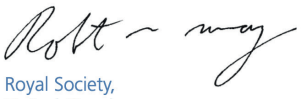
Deutsche Akademie der Naturforscher
Leopoldina, Germany

Indian National Science Academy,
India

Accademia dei Lincei,
Italy

Science Council of Japan,
Japan

Russian Academy of Sciences,
Russia



Royal Society,
United Kingdom

National Academy of Sciences,
United States of America

2006
Saint Petersburg, RUSSIA
G-8

JOINT SCIENCE ACADEMIES' STATEMENT: AVIAN INFLUENZA AND INFECTIOUS DISEASES

At present the world faces a problem caused by the spread of avian influenza. There is a possibility that this could develop into a new human influenza pandemic. Pandemics are rare but can have devastating consequences for public health all over the world. SARS (Severe Acute Respiratory Syndrome) resulted in severe economic losses, estimated as high as thirty billion US dollars. The social and economic consequences of an influenza pandemic would likely be significantly higher.

Avian influenza is only one of many infectious diseases we face globally. It is currently a significant concern for animal health and the poultry trade and has potential for initiating a pandemic in humans. At present, however, it is by no means the most significant disease concern for people globally. While some of the actions currently being taken are only of relevance to avian influenza, some (for example establishing national and international disease surveillance networks) will be useful for other infectious diseases as well. It will be crucially important for the global community not to forget these other diseases whilst tackling the problems of avian influenza. On the other hand, avian influenza could become the catalyst to improve research and response capacity to emerging or re-emerging disease threats globally.

Latest experience has showed that measures to control emerging zoonotic diseases, both to curb their expansion and to diminish economic losses, must be closely coordinated internationally to prevent long-term risks to human health.

Recommendations

All countries of the world should cooperate in addressing the present issues surrounding avian influenza, as well as the long term global strategies to address other major and emerging infectious diseases. This will demand coordinated actions on a global scale by a whole spectrum of stakeholders including governments, scientists, public health experts, veterinary health experts, economists, representatives of the business community, and the general public.

We therefore call on world leaders, particularly those meeting at the G8 Summit in St Petersburg in July 2006, to implement the following recommendations. For our part, we also commit ourselves to working with governments and other appropriate partners in order to achieve these goals.

Support existing international initiatives to monitor and combat avian influenza, in particular those of the World Health Organisation (WHO), the World Organization for Animal Health (OIE), the United Nations Food and Agricultural Organization (FAO), and the World Bank.

The WHO in particular has developed a draft protocol for timely response to and containment of a possible pandemic, including biosecurity aspects of containment, and has made a number of other recommendations.

States should pay particular attention to these recommendations in designing and implementing their own national strategies in anticipation of possible arrival of avian influenza and other pandemic threats within their borders.

Provide support to developing nations in the implementation of their own national strategies to address avian influenza and other infectious diseases, in capacity building of respective infrastructures (particularly for monitoring and detection) and also in helping them to reduce the inevitable social and economic effects of infectious disease outbreaks on the poorest strata of their populations.

Not all countries currently have sufficient capacity to implement measures to combat avian influenza or other infectious diseases. Such infrastructures are crucially important in standing against this threat while maintaining economic growth and sustainable development. A recent international donor conference in Beijing in January 2006 confirmed the readiness of governments and international organizations to support coordinated actions in developing nations in their efforts to counter avian influenza. These actions must be carried out.

Global surveillance is the fundamental instrument for the control of emerging and zoonotic diseases. The current multicomponent and uncoordinated system is not adequate in geographic coverage and human or scientific capacity. The policies for improvement and coordination will involve multiple levels of national and international governmental institutions as well as a variety of scientific, public health and non-governmental organizations as stakeholders in the current and future systems.

G8 governments should therefore seek an independent, evidence-based study (for example by the InterAcademy Council, involving experts from G8 countries and the developing world) to make recommendations for further development of global surveillance capabilities. Such a study would include the appropriate roles, coordination and reporting mechanisms; the human, scientific and technological capacities; and the related costs to improve the world's disease surveillance capability.

Global scientific and medical communities should be mobilised in order to develop new vaccines and drugs, and new more rapid methods for the production of vaccines (the current worldwide capacity for seasonal influenza vaccine production is estimated to be around 300 million doses per annum). More research is also needed to develop a better understanding of the most effective ways to use current vaccines and drugs that are available on the market.

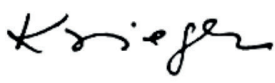
Given the zoonotic origin of avian influenza and several other important infectious diseases, governments and the scientific community should promote international cooperation between human health and veterinary experts to elaborate new methods for detection, diagnosis, prevention and treatment of infectious diseases that take into account the diverse environments and communities that exist globally, with varying capacities to successfully address disease outbreaks.

Governments should be encouraged to collaborate more in the collection of clinical and epidemiological data. The SARS outbreak highlighted problems with the sharing of clinical data from infected patients. Countries should implement strategies that allow clinical data to be accessed and shared, particularly in the early stages of a pandemic, so that information on the disease, those at greatest risk, the best treatment and clinical care can be identified and distributed.

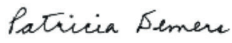
Furthermore, national strategies being developed now should include protocols for the evaluation of interventions before and during possible outbreaks, so that this knowledge can be shared with other countries who have not yet been affected. Collaborative research networks and infrastructure should be established now.

Many of the issues that affect influenza are also relevant to a number of other infectious diseases. It should be noted that, especially in the context of less developed countries, other infectious diseases such as tuberculosis, HIV/AIDS, malaria and ebola cause widespread illness and economic harm. The fight

against these diseases is already under-funded. The world community must ensure that the focus on avian influenza does not compete with, but rather motivates the development of broad-based and sustainable infrastructure with the capacity to address an array of infectious disease threats globally.



Academia Brasileira de Ciéncias,
Brazil



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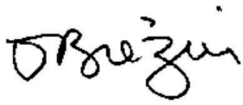

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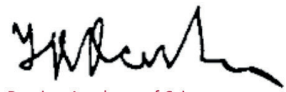
Italy

Science Council of Japan,
Japan



Russian Academy of Sciences,
Russia

Academy of Science of South Africa,
South Africa

Royal Society,
United Kingdom

National Academy of Sciences,
United States of America

2007
Heiligendamm, GERMANY
G-8

JOINT SCIENCE ACADEMIES' STATEMENT ON GROWTH AND RESPONSIBILITY: SUSTAINABILITY, ENERGY EFFICIENCY AND CLIMATE PROTECTION

Introduction

It is important that the 2007 G8 Summit is addressing the linked issues of energy security and climate change. These are defining issues of our time, and bring together the themes of growth and responsibility in a way that highlights our duties to future generations.

In 2005, the Academies issued a statement emphasising that climate change was occurring and could be attributed mostly to human activities, and calling for efforts to tackle both the causes of climate change and the inevitable consequences of past and unavoidable future emissions. Since then the IPCC has published the Working Group 1 part of the Summary for Policymakers of its fourth assessment report, and further reports are expected later this year from IPCC. Recent research strongly reinforces our previous conclusions. It is unequivocal that the climate is changing, and it is very likely that this is predominantly caused by the increasing human interference with the atmosphere. These changes will transform the environmental conditions on Earth unless counter-measures are taken.

Our present energy course is not sustainable. World population is forecast to reach 9 billion by 2050, with the most rapid growth in the poorest countries. Escalating pressures on land will accelerate deforestation. Major increases in demand for energy are inevitable as economies around the world accelerate and peoples justifiably seek to improve their living standards.

Responding to this demand while minimising further climate change will need all the determination and ingenuity we can muster.

The problem is not yet insoluble, but becomes more difficult with each passing day. A goal of confining global warming to an average of 2 centigrade degrees above pre-industrial levels would be very challenging, and even this amount of warming would be likely to have some severe impacts.

Energy, Development and Climate

Many of the world's poorest people, who lack the resources to respond to the impacts of climate change, are likely to suffer the most. The dilemma, however, is that climate protection goals appear to conflict with prosperity targets within the traditional development paradigm.

Access to energy resources and affordability of energy services are key factors for the wealth of nations and the well being of their people.

Last year our academies addressed a further important aspect of the challenges related to energy: the implications for security. We noted then that a key strategic priority will be a diversification of energy sources, as a way to address the wide variety of circumstances and resources, and to decrease vulnerabilities to a wide range of possible disruptions in supply.

Major investments and successful technological and institutional innovation will be needed to achieve better energy efficiency, low- or zero-carbon energy sources and carbon-removing schemes. A clear area for increased investment is energy conservation and efficiency. This has immediate and long-term benefits for local and regional health and environment, security of energy services and climate change, while having potential for local economic development and build-up of local technological capabilities.

Against this background it will be necessary to develop and deploy new sources and systems for energy supply, including clean use of coal, carbon capture and storage, unconventional fossil fuel resources, advanced nuclear systems, advanced renewable energy systems (including solar, wind, biomass and geothermal energy), smart grids and energy storage technologies. Research focused on the energy field must be enlarged significantly. The InterAcademy Council (IAC) is preparing a report on these challenges, which will be available later this year.

Promoting Efficiency: A Key Element

It is urgent to increase efficiency in the global production and use of energy. Energy efficiency has been a major field for the G8 countries since the 2003 Evian Summit.

Concentrating on energy efficiency is an effective contribution towards meeting the global energy challenges.

The implementation of measures to increase energy efficiency will depend to a decisive extent on financing options and technology knowledge. A sound financial and technological framework and improved global investment conditions will therefore be vital.

The common strategic priorities should concentrate on the following points:

Sustainable buildings Around 27 % of final energy is consumed by private households, and much could be done with existing technologies to improve the energy performance of buildings. The energy demands of buildings can be covered to a significant extent by using renewable energies.

Efficient transport and alternative fuels There are around 600 million motor vehicles across the globe. This figure may double by 2020. Here in particular lies a large package of possible measures, like innovative engine concepts with energy efficiency standards, alternative fuels and integrated transport systems.

Modern power technology Fossil fuels will continue to dominate electricity production over the next two decades. The best coal-fired power stations now achieve efficiencies substantially better than the average. Modernisation of old power plants could help to save energy and to reduce carbon emissions.

Electrical appliances are proliferating rapidly. New appliances on the market should be brought in line with the state of the art.

Energy consumption is strongly influenced by human behaviour. It is important to create the conditions and opportunities for energy consumers to use energy more efficiently.

Research and Innovation

Increasing energy efficiency is a first crucial step towards solving the climate-energy problem. An entire portfolio of approaches will be needed, especially the substitution of fossil fuels by renewable energy sources, clean coal technologies, carbon capture and storage and advanced exploitation of nuclear fission and, in the longer term, fusion. This portfolio can be developed only through aggressive investment in research, development and innovation, with the efforts ranging from basic science over strategic analyses to practical applications.

Key research and innovation issues include: overcoming the intermittency problem for renewables, converting biomass (eg lignocellulose) to transport fuels, and coming to grips with the challenges of safety, waste, and non-proliferation in the

nuclear energy domain. A whole-systems approach to energy security needs to be pursued.

Fundamental research is also needed on the climate system, climate impacts, and vulnerability at all scales in order to enhance the adaptive capacities of societies. It is equally vital to promote research on behavioural and other social issues that are central to implementing technological and institutional solutions.

The G8+5 countries should develop national road maps for innovation along with well-defined research agendas. There should be an intense international dialogue about these road maps, agendas and best practices.

Conclusions

We call on all countries of the world to cooperate in identifying common strategic objectives for sustainable, efficient and climate friendly energy systems, and in implementing actions toward them.

G8 countries bear a special responsibility for the current high level of energy consumption and the associated climate change. Newly industrialized countries will share this responsibility in the future.

We call on world leaders, especially those meeting at the G8 Summit in June 2007, to:

1. Set standards and promote economic instruments for efficiency, and commit to promoting energy efficiency for buildings, devices, motors, transportation systems and in the energy sector itself.

2. Promote understanding of climate and energy issues and encourage necessary behavioural changes within our societies.

3. Define and implement measures to reduce global deforestation.

4. Strengthen economic and technological exchange with developing countries, in order to leapfrog to cleaner and more efficient modern technologies.

5. Invest strongly in science and technology related to energy efficiency, zero-carbon energy resources and carbon-removing technologies.

JOINT SCIENCE ACADEMIES' STATEMENT ON GROWTH ANDRESPONSIBILITY: THE PROMOTION AND PROTECTION OF INNOVATION

Promotion

Innovation is the engine that drives economies. Countries support innovation to ensure dynamic economic advancement and prosperity, to gain competitive advantage internationally, and to improve the quality of life of their citizens and those of other nations. The latter is fostered through international collaboration, especially in research and development.

At the very least, global collaboration requires greater promotion and funding, in priority areas such as sustainable energy, climate change adaptation and mitigation, natural hazards, biodiversity, water, and infectious diseases. It is important for governments to invest strongly in a spectrum of basic research, since the greatest benefits often arise from investigations in areas that are not the subject of international focus at a given time.

Innovation faces a fundamental dilemma: the innovator bears the cost, but is not guaranteed the full returns of his or her efforts. Innovators facing immediate imitation are less likely to engage in costly efforts. In addition to their vital responsibilities for education and training, governments have therefore pursued a number of approaches to foster innovation, including the establishment of intellectual property rights such as patents and copyrights, the financial support of R&D and innovation through public funding or subsidies, and the productive use of public procurement. It is critical to establish an appropriate balance between strong government investment and removal of barriers to research and licensing.

The development of long-term international research agendas in priority areas can markedly increase the rate and number of discoveries and inventions, and thus stimulate innovation and commercialization. Such development must include stakeholders from industry, academia and government.

Nations need to activate a culture of entrepreneurship and innovation, and ensure that policies exist to support the translation of such entrepreneurship and innovation into tangible outcomes for societal benefit.

Increasingly, the developing world is focusing on innovation as a route to growth and sustainability. International agencies and the wider donor community should support and encourage nations in the developing world to build their own systems of innovation, including instruments to fund research and development nationally. In particular, investments, including infrastructure, should encourage bringing promising innovations to market (including encouraging venture capital and microfinance, building local manufacturing ability and providing services). Relevant traditional knowledge has a role to play in nurturing discovery and innovation in developing countries.

The developed world should facilitate, where appropriate, the transfer of knowledge and innovative technologies to the developing world, working in partnership so that such technologies can be applied and adapted to local requirements. Such transfers will enable the developing world to leapfrog the conventional route to development. At the same time, the developing world needs to ensure that local infrastructure encourages such transfer of technology, with appropriate tariff, investment and protection regimes.

It is crucial for developing and emerging economies to have people who are skilled at solving complex problems, thus enabling their nations to create and exploit research, development and innovation. The education and training of science, engineering, technology and medical graduates, free of the bias of gender, are essential for success.

Protection

Innovation needs protection, but care should be taken that protective measures do not become impediments to innovation (at all levels, from corporate to individual).

Access to knowledge is critical. Infringing intellectual property rights undermines the long-term progress of innovation. G8 countries should aim to ensure that national and international regimes to protect intellectual property also facilitate and promote access to knowledge.

In order to ensure that the patent system provides the necessary incentives for continued scientific and technological progress, patents need to reveal clearly the key criteria for patentability: utility, novelty, and non- obviousness. G8 countries should provide for harmonised standards to facilitate early dissemination of knowledge by an

adequate "grace period". Such provision protects the inventor from adverse effects of his or her own publications before the filing date.

In order to encourage scientific research, patent laws should also include a properly specified research exemption and permit the use of patented technology for non-commercial research purposes, including improving and further developing the patented subject matter.

A great deal of time and resources are still expended on preparing and filing patents in multiple jurisdictions. Global efforts have been made to harmonise some requirements and share information through the Substantive Patent Law Treaty (SPLT), which is encountering problems. Since the main differences and sharing requirements arise between the jurisdictions of G8 nations, these most industrialised countries of the world could forge an interim agreement among themselves. Such a system should involve best practices and high quality levels in prior art search and examination. Moreover, in the case of patents, quality of the rights issued and thus legal certainty is in urgent need of substantial improvement.

If the application of a newly patented technology from the industrialized nations is needed mainly in the South, an adequate return on investment by the industry in the North is often unlikely under normal conditions. The G8 governments should consider subsidizing development of such patented technology, and then its commercialization in the South. This could be achieved by subsidizing the technology development through a programme tied to the front end of the patent process (e.g. through subsidies, procurement, length of patent term, or by G8 nations paying a fair price for the licence for a developed product on behalf of a country in the South). In return, governments of countries of the South would undertake to enforce the patents, police local manufacturing under licence, etc. This strategy could be beneficial for the commercialization of products needed in the South that might not otherwise be available.

Conclusions

Innovation Promotion

We recommend that the leaders of G8 governments

1. Encourage the development of long-term international research agendas to promote innovation in priority areas.

2. Facilitate the transfer of knowledge and innovation to the commercial realm, especially between universities and industry, and establish tools to activate entrepreneurship.

3. Work with developing countries to build systems of science, technology and innovation for economic and social development, and to promote the education and training of their future leaders particularly in science, engineering, technology, and medicine.

4. Promote global knowledge policies that deal with generation, transmission, use and protection, rather than focusing on just the latter.

Innovation Protection

We recommend that the leaders of G8 governments

1. Encourage global efforts to simplify and enforce intellectual property while making sure that a proper balance is maintained between thoroughly examined formal intellectual property rights and free access to knowledge and information.

2. Develop and implement policies to remove barriers to innovation, in addition to the provision of a fertile infrastructure to foster it.

3. Establish bold initiatives by global financial institutions to facilitate and protect innovation in the developing world.

4. Urge and assist the developing world to have local infrastructure, laws and regulations to catalyse and protect local innovation, thus providing a stimulating environment for the transfer of technology.

Academia Brasileira de Ciéncias, Brazil

Royal Society of Canada, Canada

Chinese Academy of Sciences, China

Académie des Sciences, France

Deutsche Akademie der Naturforscher Leopoldina, Germany

Indian National Science Academy, India

Accademia Nazionale dei Lincei, Italy

Science Council of Japan, Japan

Academia Mexicana de Ciencias, Mexico

Russian Academy of Sciences, Russia

Academy of Science of South Africa, South Africa

Royal Society, United Kingdom

National Academy of Sciences, United States of America

2008
Hokkaido, JAPAN
G-8

JOINT SCIENCE ACADEMIES' STATEMENT: CLIMATE CHANGE ADAPTATION AND THE TRANSITION TO A LOW CARBON SOCIETY

Since 2005, the Academies of Science for the G8+5 countries have called on world leaders to limit the threat of climate change. We have advised prompt action to deal with the causes of climate change and cautioned that some climate impacts are inevitable. However, progress in reducing global greenhouse gas emission has been slow.

In 2007 the Intergovernmental Panel on Climate Change (IPCC) reaffirmed that climate change is happening and that anthropogenic warming is influencing many physical and biological systems. Average global temperatures increased by 0.74°C between 1906-2005 and a further increase of 0.2°C to 0.4°C in the next 20 years is expected. Further consequences are therefore inevitable, for example, from losses of polar ice and sea-level rise.

Key vulnerabilities include water resources, food supply, health, coastal settlements and some ecosystems (particularly arctic, tundra, alpine, and coral reef). The most sensitive regions are likely to include the Arctic, Africa, small islands and the densely populated Asian mega-deltas.

As the concentration of greenhouse gases increases, these impacts become more severe and spread both geographically and sectorally. To stabilize the climate, emissions should eventually be limited to the net absorption capacity of the earth, which is less than half of current emissions. Immediate large-scale mitigation action is required. At the 2007 Heiligendamm Summit, G8 leaders agreed to seriously consider halving global emissions by 2050. We urge G8+5 leaders to make maximum efforts to carry this forward and commit to these emission reductions.

Mitigation policies are essential, but not sufficient. Adaptation is necessary if the worst impacts of climate change, now and in the future, are to be alleviated.

Mitigation and adaptation can complement each other and if pursued together can significantly reduce the risks of climate change impacts.

Adaptation

Climate change is a pressing issue for today. Action on adaptation is needed now and failure to respond poses a significant risk. According to the IPCC:

1. A global mean temperature change of only 2.0°C above 1990 levels will exacerbate existing impacts and trigger others, such as reduced water and food security.

2. Increases of 2.0-4.0°C will result in widespread biodiversity loss, decreasing global agricultural productivity and long-term commitment to several metres of sea-level rise due to ice sheet loss.

3. Increases above 4.0°C will lead to major increases in vulnerability, exceeding the capacity of many physical and human systems to adapt.

In April 2007, the UN Security Council addressed the threat that the aggregate impacts of climate change might cause, in particular the serious environmental, social and economic consequences and the implications for peace and security. All regions will be affected in the long term, but developing countries are likely to be affected most and their vulnerability will be exacerbated by pre-existing stresses.

Humans have been adapting to their environment throughout history. But the rate and scale of climate change means there is no time for complacency. A step-change in our response is needed, with action at global, national and local level. Local actors must be engaged in impact assessment and in identifying solutions. But global and national leadership is also required to manage the macro-scale effects that will accompany widespread efforts to adapt to climate change.

A strategic approach to adaptation must be based on the principle of sustainable development. As an immediate first step, governments can take measures to improve resilience to existing environmental stresses. Such measures will, in turn, reduce exposure to the threat posed by climate change. This involves governments recognizing the role that ecosystems and the natural resource base play in meeting basic needs (water, food and shelter). This strategic approach can be strengthened with more targeted measures once detailed assessments of the impacts and key vulnerabilities have been carried out.

Basic research, technology development and transfer will play a major role in improving the ability of nations to adapt. Understanding the underlying economic, social and environmental causes of vulnerability will enable the development of appropriate policy solutions, and strengthen the ability of the market to respond to the impacts. Governments and businesses can then develop adaptation

solutions and avoid investment in technologies or infrastructure which fail to take climate change into account. This will also contribute to the achievement of other international priorities, including the Millennium Development Goals (MDGs).

Low Carbon Society

The development of a low carbon society means not merely the replacement of energy sources with less carbon intensive ones, but energy conservation as well. Sustainable consumption requires fundamental changes in all sectors and levels of society, including energy- saving housing, low-carbon transportation and more efficient industrial processes.

A movement to a low carbon society will provide the opportunity to mitigate and adapt. Mitigation cannot provide all the answers, but many impacts can be reduced, delayed or avoided by cutting emissions.

There is also an opportunity to promote research on approaches which may contribute towards maintaining a stable climate (including so-called geo-engineering technologies and reforestation), which would complement our greenhouse gas reduction strategies. The G8+5 academies intend to organise a conference to discuss these technologies.

The transition to a low carbon society requires: setting standards; designing economic instruments and promoting energy efficiency across all sectors; encouraging changes in individual behaviour; strengthening technology transfer to enable leapfrogging to cleaner and more efficient technologies; and investing strongly in carbon-removing technologies and low-carbon energy resources: nuclear power, solar energy, hydroelectricity and other renewable energy sources. These points are also stressed in the InterAcademy Council report[1].

Technologies should be developed and deployed for carbon capture, storage and sequestration (CCS), particularly for emissions from coal which will continue to be a primary energy source for the next 50 years for power and other industrial processes. G8+5 economies can take the lead globally to further develop CCS technologies. This will involve governments and industry working collaboratively to develop the financial and regulatory conditions needed to move CCS forward and international coordination in the development of demonstration plants.

Given the time-lags inherent in the global energy system, actions need to be taken now to reach the desired target by 2050. Whilst the developed world should take the lead and encourage technology transfer and collaboration with developing

[1] "Lighting the Way – Toward a sustainable energy future", InterAcademy Council, October 2007 www.interacademycouncil.net

world partners, it is also an issue where the developing and emerging economies can and must make a significant contribution.

Transition to a low carbon society will also require reducing emissions caused by deforestation and degradation of ecosystems, requiring improved agricultural efficiency and sustainable forestry.

Conclusions

1. Responding to climate change requires both mitigation and adaptation to achieve a transition to a low carbon society and our global sustainability objectives. We urge all nations, but particularly those participating in the 2008 G8 Summit in Hokkaido, Japan, to take the following actions:

2. Call on G8+5 governments to agree, by 2009, a timetable, funding, and a coordinated plan for the construction of a significant number of CCS demonstration plants.

3. Prepare for the challenges and risks posed by climate change by improving predictive and adaptive capacities at global, national and local level and supporting the developing world in carrying out vulnerability analyses and addressing their findings.

4. Take appropriate economic and policy measures to accelerate transition to a low carbon society and to encourage and effect changes in individual and national behaviour.

5. Promote science and technology cooperation, innovation and leapfrogging, e.g., by transfer of some basic critical low-carbon and adaptation technologies.

6. Urge governments to support research on greenhouse gas reduction technologies and climate change impacts.

As national science academies, we commit to working with our governments to help implement these actions.

JOINT SCIENCE ACADEMIES' STATEMENT: GLOBAL HEALTH

In 2008, WHO will commemorate the 30th anniversary of the Alma-Ata Declaration which called for "Health for all." The United Nations Millennium Summit in 2000 launched the Millennium Development Goals (MDGs) including three related particularly to health: reducing the infant mortality rate, improving maternal health and halting the expansion of HIV and other infections. The other five MDGs call for action on factors that are also critical for human health.

Diseases - Future Challenges

The world's governments and science communities need to work together to better understand how, where and why infectious diseases emerge and spread. Often these are affected by environmental or social stress. Countries need to cooperate to monitor and contain infectious disease outbreaks.

There also must be greater international focus on, and collaboration to address, lifestyle-linked diseases. A rapidly growing number of people will suffer from heart disease, cancer, diabetes, obesity-related conditions, and neurological and mental disorders.

Smoking is a challenge that has to be addressed in a timely manner.

In order to combat threats to human health globally, education, sharing of information and experience are key. Public health measures which could make a great deal of difference and deserve more attention include:

1. Safe water, basic sanitation, and hygienic measures.

2. Food safety.

3. Equitable access to medical information and treatment.

4. Training and retention of qualified medical and health professionals, and educators.

Nations should ensure that sustainable development plans include measures to share information on, and address and/or prevent, diseases.

Social Capital for Human Health

Because there are many determinants of health, the achievement of good health is not a matter for the health sector alone but also requires, for example, adequate levels of research, human security, education, economic development, nutrition and sanitation.

Therefore, the responsibility for health is shared by all policy-makers in government and international agencies. Although governments remain ultimately responsible for assuring the conditions for health, they must work with civil societies, universities, business, and media among others.

The Way Forward

It is vitally important that we not only focus on the health of individuals, but also strengthen community health systems and the health workforce.

In order to address the challenges for global health, it is necessary to minimize the current obstacles to progress. Our agenda for change requires action across a broad front:

1. Implementing previous funding commitments and encouraging the contribution of additional funding from all sources.

2. Improving provision for public health programs and access to health care.

3. Identifying and advancing research and innovation required to address unmet health and medical needs and support the generation of innovative health care products and services.

4. Building a better evidence base on disease burden and on what interventions work – to assess the present situation and to target prevention and control measures.

5. Meeting skill and infrastructure needs.

6. Developing better coherence and connectivity among all those involved in addressing global health issues.

7. Strengthening of preventive (prophylactic) medicine.

Conclusions

We, the academies of science of the G8+5 nations commit to assist in meeting these health challenges. We will continue to build links within the world scientific community with the objective to strengthen the role of

science in international development. The science academies will do more in the identification of emerging issues and pursuing systematic dialogue with national opinion-leaders, policy-makers and with multilateral organizations.

We urge our governments to:

1. Increase international collaboration, scientific and medical research, locally appropriate capacity building, and technology transfer and sharing to achieve results.

2. Commit to continued global monitoring, communication and sharing of information on all health-related issues. We recommend further concerted effort to identify major challenges in chronic and infectious diseases, as a basis for global collaboration on research and on disease management.

3. Increase their commitment to evidence based health and science policy making.

4. Further strengthen coordination of health related programmes and leading international organizations such as WHO, FAO, and OIE.

5. Promote public-private partnerships to encourage and appropriately protect innovation.

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Russian Academy of Sciences, Russia

Indian National Science Academy, India

Academy of Science of South Africa, South Africa

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Science Council of Japan, Japan

National Academy of Sciences, United States of America

Academia Mexicana de Ciencias, Mexico

2009
L'Aquila, ITALY
G-8+5

CLIMATE CHANGE AND THE TRANSFORMATION OF ENERGY TECHNOLOGIES FOR A LOW CARBON FUTURE

Climate change and sustainable energy supply are crucial challenges for the future of humanity. It is essential that world leaders agree on the emission reductions needed to combat negative consequences of anthropogenic climate change at the UNFCCC negotiations in Copenhagen in December 2009.

At the same time, agreement is needed on actions to ensure basic energy services are available to all of the world's people.

These global challenges require solutions flexible and varied enough to meet the needs of a wide variety of specific energy resources and energy security circumstances.

Reducing The Human Forcing of Climate Change

The IPCC 2007 Fourth Assessment of climate change science concluded that large reductions in the emissions of greenhouse gases, principally $CO_{2,}$ are needed soon to slow the increase of atmospheric concentrations, and avoid reaching unacceptable levels.

However, climate change is happening even faster than previously estimated; global CO2 emissions since 2000 have been higher than even the highest predictions, Arctic sea ice has been melting at rates much faster than predicted, and the rise in the sea level has become more rapid. Feedbacks in the climate system might lead to much more rapid climate changes.

The need for urgent action to address climate change is now indisputable. For example, limiting global warming to 2°C would require a very rapid worldwide implementation of all currently available low carbon technologies. The G8+5 should lead the transition to an energy efficient and low carbon world economy, and foster innovation and research and development for both mitigation and adaptation technologies.

Capitalizing on new technologies will require a major scientific effort and policy initiatives to accelerate adoption of new technologies. The need to find solutions to climate change presents a huge but as yet unrealized opportunity for the creation of new jobs and for the stimulation of new and emerging markets. The role of innovation in delivering energy efficiency and a low carbon world should become a major part of the efforts to rebuild the global economy.

Adaptation To Climate Change

As the impacts of climate change begin to be realized, investment in adaptation technologies is becoming increasingly important and must be increased as a matter of urgency. Knowledge and technology transfer to the developing countries must also be accelerated.

Critical research areas include: increasing the resilience of urban and rural infrastructure and of natural areas (including watersheds and coastal areas); enhancing food and crop production; and water conservation technologies and methods.

The Energy Agenda

Fossil fuel sources remain the predominant energy source for the near future in reducing energy poverty and satisfying growing energy demand, and their exploitation must be consistent with the objective of reducing anthropogenic impact on climate change. Continuous improvement in efficiency and emission standards are needed in the production and use of fossil fuels.

Economically viable low carbon energy technologies may contribute to the recovery and sustainability of the global economy. Diversification of energy sources can also mitigate the volatility of fossil fuel markets and increase energy availability and security.

A low carbon economy will require integrated systems, global collaboration, and concerted actions including:

1. rapid and wide-spread energy conservation measures particularly for industry, transport, and building design, construction and operation. This will require the development and implementation of existing and new technologies, policy tools, monitoring and certification processes, and public education. Energy saving and energy efficiency should be a critical priority in the short term;

2. an agreed international program to develop and deploy CO_2 capture and storage (CCS), and exploration of possible standards for CCS, with the objective of deploying CCS in as many coal power stations as possible;

3. rapidly increased adoption of, and investment in, renewable energy technologies such as wind, geothermal, solar energy, biofuels and wave power. The development of standards and certification for the environmentally sustainable implementation of these technologies is essential;

4. assured access to adequate supplies of natural gas, and promotion of the diffusion of efficient natural gas technologies;

5. development and deployment of an innovative energy generation, transmission, storage and distribution infrastructure;

6. and development of nuclear power plants that are safe and secure, and ensure the secure long-term management and disposal of waste. International collaboration in development of the next generation of nuclear reactors and in reducing the risk of proliferation is essential.

Recommendations

Recognizing the vital role that low carbon energy systems must play in facilitating a sustainable global economy, the G8+5 nations need to seize all opportunities to coordinate our simultaneous work on the climate and economic agendas, and to build global collaboration.

We call on all governments to:

1. agree at the UNFCCC negotiations in Copenhagen to adopt a long-term global goal and near-term emission reduction targets that will deliver an approximately 50% reduction in global emissions from 1990 levels by 2050;

2. significantly increase fundamental international research on the earth's climate, on low carbon and climate resilient technologies, and on ways to protect and enhance the resilience of natural systems to climate change;

3. identify the common strategic priorities for developing and implementing environmentally sustainable technologies for adaptation and mitigation;

4. collaborate in the implementation of low carbon and climate-resilient infrastructure and technologies, and in the implementation of innovative incentives, through the use of economic and regulatory instruments, to accelerate adoption of clean "green" technologies;

5. support and enable developing countries' access to and use of the technologies needed to deliver a sustainable low carbon energy future;

6. pursue the development, demonstration and deployment of economically efficient and technologically safe CCS, and explore the establishment of standards for CCS;

7. pursue international cooperation on safe and secure nuclear power capacity, the safe disposal of nuclear waste, and the reduction of the risk of proliferation;

8. substantially increase investment into the development and deployment of technologies for adaptation, and increase funding specifically for the most vulnerable countries.

Education and public awareness programmes willbe essential as we pursue this agenda. We must build on the current enthusiasm and engagement of a younger generation.


Academia Brasileira de Ciéncias, Brazil


Indian National Science Academy, India


Academy of Science of South Africa, South Africa


Royal Society of Canada, Canada


Accademia Nazionale dei Lincei, Italy


Royal Society, United Kingdom


Chinese Academy of Sciences, China


Science Council of Japan, Japan


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Académie des Sciences, France


Academia Mexicana de Ciencias, Mexico


Deutsche Akademie der Naturforscher Leopoldina, Germany


Russian Academy of Sciences, Russia

2010
Ontario, CANADA
G-8

JOINT G8 SCIENCE ACADEMIES' STATEMENT ON HEALTH OF WOMEN AND CHILDREN

Magnitude and Importance of the Problem

Local Capacity

The health of families, communities and economies is inextricably tied to the health of women – yet every 100 seconds, a woman dies in pregnancy or childbirth somewhere in the world. Mother and child outcomes are closely linked. Reducing maternal mortality is critical and is also a priority for improving child health.

There are less than 6 years left to meet the United Nations Millennium Development Goals (MDGs). The fourth and fifth are critical to this document.

Millennium Development Goals 2015

Goal 4: Reduce under five child mortality by two-thirds

Goal 5: Reduce maternal mortality by three-quarters.

There has been some progress in global child health. Since 1990, deaths of children under five have declined. However it is estimated that 8.8 million children still die each year - more than 1000 every hour.

Progress to reduce deaths in pregnancy and childbirth by 75 per cent by 2015 has been similarly limited and the goal remains a distant target. Over 99% of the women who die do so in the developing world.

Specific Health and Disparity Issues

Maternal Mortality and Morbidity

The risk of a woman dying as a result of pregnancy or childbirth during her lifetime is one in seven in the poorest parts of the world compared with about

one in 30,000 in Northern Europe. Maternal deaths cluster around labour, delivery, and the immediate postpartum period, with hemorrhage being the main medical cause of death; more than 80% are preventable. For every death in pregnancy and childbirth there are 16.5 cases of significant maternal illness or disability; maternal chronic ill-health seriously affects the health and quality of life of surviving children, who often depend on their mothers for food and support.

Perinatal and Neonatal Death

Each year, 3.2 million babies are stillborn and 4 million die in the first month of life – 99% of neonatal deaths occur in developing countries. Neonatal deaths comprise 38% of deaths in those younger than 5 years, and are the main barrier to MDG 4. Major immediate causes of death in the first month of life are preterm birth, asphyxia and infections. Proven, low cost interventions, including prenatal care, skilled care at delivery and community based postnatal care could decrease neonatal mortality by more than one half. Three-quarters of these deaths could be prevented at an additional cost of US$1 per head.

Family Planning

Family planning improves maternal health by reducing unintended pregnancies and abortions, and impacts positively on resource availability. Inadequate spacing of children exacerbates major nutritional disorders and increases child mortality by precluding adequate nutrition during gestation. Provision of effective contraception for approximately 200 million women who have none would prevent 23 million unplanned births, 22 million induced abortions and 14,000 pregnancy-related maternal deaths each year. Quality education for women will improve family planning and child care.

Every year, 42 million pregnancies are terminated, of which about 50% are considered illegal under national legislation, performed by unskilled providers or take place in unhygienic conditions. Severe complications result; there are around 70,000 maternal deaths, more than 3 million reproductive tract infections, and almost 1.7 million cases of secondary infertility. Unsafe abortion accounts for 13% of maternal deaths.

Child Illnesses

Of 8.8 million children under the age of five that die each year, main causes of death from 1 month to five years are pneumonia, diarrhea, malaria, measles and HIV. These deaths are preventable with low-cost, evidence-based public health interventions, such as good nutrition and immunization. Still more deaths would be

prevented by simple treatment when children are sick: for example anti-malarials, antibiotics, oral and rehydration therapy.

Maternal and Child undernutrition

The attribution of about one-half of child deaths and more than 10% of global disease burden to maternal and child undernutrition demonstrates the huge importance of these risk factors to health goals. Malnutrition in mothers accounts for substantial neonatal mortality and intrauterine malnutrition leads to adult disease: diabetes, hypertension, and dyslipidaemia.

HIV and AIDS

AIDS-related deaths remain a leading cause of premature death globally. Untreated pregnant women infected by HIV have a 30% chance of infecting their child. Without treatment, more than 50% of HIV infected children die before two years of age.

Gender Issues and Women's Rights

The failure to meet MDGs 4 & 5 is inextricably linked with poor progress in promoting gender equality and empowerment of women. Regions with high maternal death rates are characterized by disenfranchisement and marginalization of women. Gender inequality is propagated by a lack of access to education (reflected in low literacy rates) and thus an absence of women in positions that set opinion or policy.

Deficiencies in Knowledge Translation

Meaningful progress requires resources in two key areas: knowledge translation and implementation research. Evidence- based policy making has had a limited impact on maternal and child health policy and program development. The reasons for this are many: a lack of highly-qualified national researchers

in the developing countries, a lack of high quality research programs and a severe paucity of research funding in maternal and child health issues. There is also too little research into how interventions or programs can be successfully implemented, and then successfully transferred to other areas.

Recommendations for the G8 Summit

Risks to maternal and child health are not confined to the developing world; vulnerable populations, wherever they exist, need to be targets of interventions that are generally simple and accessible, do not involve specialized technology and are cost-effective.

Intensified effort to improving maternal and child health is essential to attaining Millenium Development Goals 4 & 5.

1. Funding for maternal and child health must increase. Governments and other organizations need to increase resources. Donors need to increase financial contributions in low-income countries to help fill the resource gap. There should be no user fees for basic health services such as delivery care. Immunization of children should be universal. Health facilities and staffing need strengthening. Increased access to prenatal, midwifery, essential obstetric and newborn care must remain the cornerstone of safer motherhood programs. Skilled emergency obstetric care must be accessible to all women who experience complications; research into most effective methods of delivering such care is needed. Support for community facilities should emphasize maternal and child health and also nutrition. Health workforce strategies need to include plans to build a cadre of skilled birth attendants and community health workers to care for pregnant women and children. Developing countries should establish incentive programs to retain clinical staff trained internally and repatriate former staff. Developed countries should be discouraged from actively recruiting trained individuals in healthcare from developing countries and encouraged to form health education partnerships. Strategies to improve maternal health should facilitate access to contraception services and measures to reduce unsafe abortion. Up to 40% of maternal and child deaths could be averted by providing access to these services. The use of modern contraceptives, sex education and appropriate child spacing should be fostered. Greater access to family planning would reduce population growth and impact favorably on resource availability. Accessible family planning services should be integrated with HIV/AIDS prevention services. Governments and inter/ nongovernmental organizations must deal openly with unsafe abortions, and ensure appropriate and accessible treatment of women who develop complications.

2. Initiatives to strengthen the health of women and children should be more effectively coordinated. The community shaping global political priority for the health of Women and Children has been fragmented. G8 Governments should work with international agencies to facilitate regional coordination mechanisms for women and children's health the main focus of which is achievement of MDGs 4 & 5.

3. Policies which protect women and children from all forms of abuse, injury, exploitation and violence must be promoted. Harmful practices such as female genital mutilation should be eradicated. Misuse of technology of prenatal sex determination for aborting female fetuses should be condemned.

4. Maternal and child health research needs strengthening, especially in knowledge translation. There is a lack of research into how interventions or programs including translational and communication strategies can be successfully implemented, and then successfully transferred to other areas. Capacity building including interdisciplinary centres of, health science and innovation should be encouraged in all regions. Health information and education programs are needed to disseminate acquired knowledge; this will require enhanced organizational infrastructure.

JOINT G8 SCIENCE ACADEMIES' STATEMENT ON INNOVATION FOR DEVELOPMENT

The role of Science, Technology and Innovation for Development in Africa and other developing regions

Local Capacity

A substantial fraction of the economic growth of the 20th century derived from advances in science and technology and their application in health, agriculture, information and communication technologies, energy, and many other sectors. The ability of a country to benefit from these advances and to secure a decent standard of living for its people depends on the capacity of its people and its institutions to innovate, i.e. to master the adoption, adaptation, and advancement of existing technologies, as well as the creation of new ones. Innovation refers to the full range of changes, large and small, used to achieve desired outcomes. Innovation often results from basic research that can lead to groundbreaking discoveries and inventions.

In parallel with efforts to promote economic growth and wealth creation, developing countries face an increasing number and range of major challenges, such as emerging or re-emerging diseases, lack of access to safe drinking water and other environmental challenges, and in many cases an unprecedented number of young people who need education, training and opportunities.

Innovation will be essential in meeting all of these goals and challenges.

Human Resource Development

The knowledge, skills, and motivations of people are the ultimate basis for social and economic development. The breadth of the challenges facing developing countries makes it imperative for them to simultaneously address all of the major aspects of human resource development: moving toward universal and effective primary and secondary education; enhancing advanced education and training, especially in areas of national importance, and connecting the content and

experience in the educational and training systems with workforce needs in both the private and public sectors.

Effective teachers, trained beyond secondary level are critical for high quality primary and secondary education. Innovation is essential for the entire human resource development sector: and the need is for people who can continue learning throughout their lives. Primary education can start to develop those skills that the workforce needs to be innovative in all sectors, including the informal sector that is often a major part of developing countries' economies. Innovative approaches are critical to create jobs, rather than just fill jobs that may currently exist.

Partnerships can be especially valuable as developing countries struggle to meet the needs for education, and for educators. In particular, networks of educational institutions in Africa should work together to combine training capacities and information resources, with support from G8 countries and in cooperation with universities in G8 countries. These partnerships could produce increasing numbers of the desperately needed high- quality, up-to-date faculty for African universities and teachers for the elementary and secondary school systems.

Recommendation: G8 and other countries should increase support, both direct, and via partnerships with their educational institutions, for education and training programs in Africa and other developing regions, including:

Innovative primary and secondary science education programs such as inquiry-based education, to improve effectiveness;

1. Regional networks of research and training institutions in developing countries, focusing on priority fields of those countries;

2. Innovative modes of support for faculty and programs of universities of developing countries;

3. Training in entrepreneurial skills and internships relevant to the public and private sectors;

4. New learning technologies adapted to the specific needs of developing countries, such as e-learning in Africa;

5. Merit-based decision making, such as peer review, and competitive approaches for education, training, and technical programs;

6. New strategies to minimize the negative impacts of brain drain.

National Development Strategies, National Innovation Systems and Science and Technology in Africa and other developing regions

National development strategies, reflecting local realities often operate in a changing and challenging global context, and thus must themselves be innovative and adaptive, rather than static. Such national strategies need to be broadly understood and supported by a wide range of individuals and institutions.

National strategies need to develop the right balance between programs driven by government planning for public needs and the dynamic decision-making of the private sector. A successful innovation culture requires a continual process of consultation between public and private sectors to enable them to work together effectively. This is as true for modern service, manufacturing and mining sectors as it is for smallholder agriculture and microenterprise.

National innovation systems need to implement multi-pronged strategies that include education and training, research, development and innovation, as well as supportive government programs and infrastructure. Governments also need to appreciate the fundamental value of basic science in attaining the innovation goals.

Recommendation: G8 and other countries should

1. Act on the principle of basing cooperative and support programs on national development and innovation strategies developed and adopted by developing countries;

2. Align their own cooperative and development assistance programs to build capacities of individuals and institutions in developing countries. Of particular importance is building local capacity for making and

3. implementing informed decisions, and for managing the diverse contributions of official and non-governmental international assistance;

4. Support the strengthening of universities and establishing centres of excellence in basic and applied science, engineering, and in areas of high priority for national innovation systems of developing countries;

5. Assist developing countries in improving access to knowledge resources via ICT to empower citizens to accelerate progress in meeting the goals and objectives of national innovation strategies.

Commercialization of Scientific Discoveries and Inventions to Build Prosperity

Science is a fertile source of discoveries and inventions for commercial innovation. Extensive translational activities are often needed before the benefits of science can

be reaped by societies. In order to strengthen commercialization, many countries have introduced legislation over the last two decades which has given universities and publicly financed research organizations the right and the obligation to manage intellectual property, often via technology transfer offices. Universities and research institutions also support commercialization by establishing entrepreneurship centres and providing seed funds for financing early-stage startups.

Incubators and research parks are commonly found in developed countries, and developing countries are increasingly using these concepts, or experimenting with them.

Developing countries face significant challenges in harnessing the fruits of new knowledge and technologies. Transferring innovations often needs extensive adaptation. Foreign direct investment can serve as a powerful contributor to building national scientific and commercial capabilities. Commercialization models built on entrepreneurial activity are valuable in getting multinational firms to locate in a developing country.

Participation in global networks of entrepreneurship centres, and access to venture capital are key elements that can empower developing countries to build their own innovative capacities.

Recommendation: G8 and other countries should

1. Ensure that policies of intellectual property protection and commercialization reflect the needs of the developing countries;

2. Help developing countries define and develop the regulatory and incentive systems to promote innovation;

3. Encourage the development of collaboration between research institutions and industries for the promotion of technology and knowledge transfer;

4. Support the dissemination of best-practice models. Experimentation will be required to find solutions that best fit local situations.

Royal Society of Canada, Canada

Académie des Sciences, France

Deutsche Akademie der Naturforscher Leopoldina, Germany

Accademia Nazionale dei Lincei, Italy

Science Council of Japan, Japan

Russian Academy of Sciences, Russia

Royal Society, United Kingdom

National Academy of Sciences, United States of America

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Deauville, FRANCE
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JOINT G8+ SCIENCE ACADEMIES' STATEMENT ON EDUCATION FOR A SCIENCE-BASED GLOBAL DEVELOPMENT

Education in science must be targeted
not only to future scientists,
engineers and other specialists
but also to the general population.

Background

Economic growth, provision of food and progress in health – as measured by the spectacular increase in life expectancy during the 20th century and into this first decade of the 21st century – is attributable mostly to advances in science and technology and the expansion of systems of research and education. These advances have impacted our daily lives in many ways including travel, communication and access to new technologies. In the future, science and technology will continue to be key for global development, for example, to meet the need for new and sustainable sources of energy.

Education in science must be targeted not only to future scientists, engineers and other specialists in government and industry but also to the general public, from children in school to adults. This is the only way to make them partners of the scientists and hence to avoid misunderstandings and unfounded fears, and to better understand risks and uncertainties.

Science understanding and practice embody fundamental values such as rigorous reasoning, honesty and tolerance for the opinions of others. The practice of science must be accompanied by a sense of justice and a respect for all human beings.

Education for science-based global development involves three simultaneous challenges: science education for the general public, science education in school, and science education at university and at other national research bodies. This will require innovative approaches and institutions for teaching and research, many of them using modern information and communication tools. It requires also scientific assessment of the outcomes of the education system in order to ensure that the

best state-of-theart tools and educational methods are effectively used. Progress in cognitive sciences and brain research has shed new light on learning processes, especially in very early years of life.

Science Education for the General Public

Science literacy is essential for making adaptive judgments in a modern economy. These judgments involve many choices including, for example, choices about resource scarcity, climate change mitigation,

Education in science must be targeted not only to future scientists, engineers and other specialists but also to the general population.food safety, health decisions, energy futures and many other individual and collective decisions. A democratic society in which only a few scientists and highly educated people understand the bases for major societal decisions is not viable. Accordingly, it is essential that greater efforts be made to disseminate scientific concepts, methods and discoveries to the public. Scientific information must be distributed widely and detailed briefing documents on topical issues must be available for decision-makers and media. Many successful interactions with society have been organised and carried by local and national governments, universities, public and private research institutes and academies. These include public lectures, 'open houses', festivals, pairing with parliamentarians and TV programmes.

We must use all appropriate education tools, including those presented by rapid developments in the electronic media and help people to identify the reliability of the information presented. Finally, the outcomes of all these education practices must constantly be assessed.

Science education in school

Science is taught at school with two goals:

The first goal is to provide the basic knowledge necessary for future citizens in a globalized world. This includes the acquisition of basic knowledge in science as well as the understanding of the very nature of science, the way to pose and then challenge hypotheses. Students must develop a taste for doing experiments, analyze results, make inferences. In short, they must be "curiosity-driven". During the last decades, inquiry-based Science Education (IBSE) has been successfully implemented in developed and less developed countries as well, supported by the Global Network of Science Academies (IAP).

A basic science education for all youngsters in the world is a matter of justice, sharing the beauty of scientific discoveries and the power of scientific methods. Last but not least, learning to reason properly may help protect young minds against intolerance.

The second goal is to recognise talented youngsters and inspire them to become science teachers, researchers, engineers and medical experts. A shortage of good quality mathematics and science teachers in many countries creates a vicious circle that needs to be broken. In many countries even the most developed, there are still huge social inequalities in the opportunities for students to become scientists particularly for young women and low-income groups of society.

The decline of interest in science among youngsters is a serious issue which should be addressed.

Encouragement of young talents could be organized on the basis of different level competitions in different science domains, accompanied by contacts with leading scientists.

To achieve these goals, it is essential to share experiments and pedagogical materials in innovative science education programs and to provide teachers with a significant continued education in Science. In addition, it is advisable to cooperate with the global programs of Education for Sustainable Development (ESD) promoted by UNESCO.

Science Education at University

Universities throughout the world need quality faculty, infrastructure and innovative learning programmes to train and maintain human resources. Databases, electronic libraries, scientific journals and sophisticated software should be widely accessible throughout the world. Access to distant databases creates new opportunities for researchers of all countries particularly in the experimental disciplines. Databases on gene sequences and astronomical objects, for example, can potentially be accessed freely by all researchers, including those from the less-developed countries. Similarly, essential data such as those on biodiversity that are acquired everywhere, can now be exploited by the global community of researchers. The effectiveness of e-learning and its highly positive prospects, however, may be limited by the high cost of implementing and using modern techniques.

Although virtual universities may have considerable potential, research centres remain necessary both to conduct experimental works and to facilitate direct interaction between researchers and between faculty and students.

Conclusion

Data on the comparative effectiveness of educational strategies must be patiently acquired, analyzed and the results disseminated. Rigorous experimental approaches should help to identify which educational strategies are the best, at all levels of educational curricula. This "evidence-based education" could revolutionize the science and practice of education, as "evidence-based medicine" did, to the point that it has become, after just a few decades, the paradigm of modern medical practive.

Recommendations

The Academies of the G8+ countries strongly recommend the following action plan to their Governments:

- Establish the conditions for a true globalization of knowledge in science and technology. Encourage and help governments of developing countries, to give high priority to acquiring and maintaining the necessary infrastructure and human resources for science education, and to facilitate the return of those trained abroad.

- Support international collaboration to set up quality e-learning facilities, accessible to all, including students worldwide, and promote open access to scientific literature and databases.

- Share the growing knowledge derived from brain research, cognitive sciences and human behavioural research to improve learning programs for children, students and the general public.

- Create a network of virtual collaborative research centres at the front line of innovations in education, such as e-learning, inquiry-based and evidence-based education.

- Support and expand existing successful programs which facilitate the two-way interactions between scientists, on the one hand and the general public, media, and decision makers, on the other.

JOINT G8+ SCIENCE ACADEMIES' STATEMENT ON WATER & HEALTH

Access to clean water and sanitation was declared a human right by the United Nations on July 28th, 2010.

Background

The Millennium Development Goal (MDG) 7C states: "Halve, by 2015, the proportion of the population wi- thout sustainable access to safe drinking water and basic sanitation". The Academies of Science of the G8+ countries stress that accessibility, quality and protection of water resources are fundamental to human health in rural and urban areas worldwide. The objectives of MDG7 are imperative in helping to achieve the MDGs on poverty, universal education, food and energy security, gender equality, child and maternal health, most critically, MDG4, reducing child mortality. Diarrhoea-related illnesses kill more children under five years old than AIDS, malaria and measles combined and are the second leading cause of child death. Over 85% of diarrhoea worldwide is due to unsafe water, inadequate sanitation or insuf- ficient hygiene.

A focus on improving sanitation is urgently needed as there has been significantly less progress in this area than in access to safe water. Furthermore, through population growth, increasing pollution and climate change, water as a resource will become scarcer: it is estimated that around 3 billion people will be living in water-scarce countries by 2050. Today, almost 900 million people lack access to a clean water supply, with 2.6 billion people lacking proper sanitation: the direct and indirect effects of a lack of clean water and sanitation are profound.

Within the last decade, more than 1 billion people in the world have now gained access to safe drinking water; much less progress has been made on sani- tation and this has a major impact on human health. It is estimated that the MDG sanitation target will not be met in Sub-Saharan Africa for more than half a century; this is clearly unacceptable. An estimated 16% of the population in Europe, and just under 40% of the world population also lack suitable sanitation.

Nearly 20% of the world population - mainly in rural areas- still practise open defecation, resulting in 300 million tons of untreated human excreta polluting fresh water resources each year. This contributes si- gnificantly to the transmission of more than 20 diffe- rent infectious diseases. In addition, domestic animal populations and their excreta are increasing, as diets change to a higher meat intake. Furthermore, im- proper urban and industrial waste disposal threatens surface and underground water resource quality.

In the absence of improved sanitation, the efficacy of expensive vaccines and chemotherapy to control water-borne infectious diseases is seriously compro- mised. Policy-makers must understand that access to drinking water and sanitation facilities go hand in hand. Solving the lack of water services for tap water supply, treatment, hygiene and sanitation would mi- tigate many other health, economic and social pro- blems. Providing sustainable access to safe water and sanitation is one of the most crucial develop- ment interventions in helping poor people to lift themselves out of poverty. It is also one of the most cost-effective public health measures.

Water and Health Impacts

Major health issues are associated with unsafe water. They include:

- Water-borne infectious diseases - some of animal origin - including cholera, and other diarrhoeal di- seases, hepatitis, amoebiasis.

- Water-related vector-borne diseases such as ma- laria, filariasis, schistosomiasis and dengue, affec- ting more than 500 million people worldwide.

- Diarrhoeal diseases represent one of the major sources of morbidity/mortality in developing coun- tries, accounting for the death of between 1.5 and 2 million children under the age of 5, annually (UNICEF_WHO, 2010). Alarmingly, 50% of hospital beds in the developing world are occupied by pa- tients with water- borne diseases.

- Increasing concentrations of organic pollutants through anthropogenic activity (whether industry, agriculture or groundwater management related) and of naturally occurring arsenic, fluoride and ni- trates in water all constitute human health ha- zards. They require either the development of alternative water resources or appropriate cost¬- effective treatment technologies. Regulations on chemicals need to be improved through better un- derstanding of eco- toxicity and the toxicology of chronic exposure to micro-pollutant mixtures. Tra- ditionally prevalent in industrial countries, chemical pollution is now emerging as a public health concern in developing countries. These countries are now also confronted with massive urbanization. Areas of greatest population density present diffe- rent challenges to rural populations. The re-emer-

gence of cholera is largely due to the spontaneous and burgeoning growth of mega-cities, townships, shanty towns and favelas with no sewage systems or infrastructure. Major improvements have to be made in sewage treatment.

- Water and sanitation issues can be intrinsically lin- ked to land settlement and whilst access to water and sanitation is now recognised as a basic human right, this is often overlooked for displaced people; a problem that will become all the more important with increasing mass migration.

Socio-Economic Impacts of Sanitation and Safer Water

The improvement of sanitation and use of safe water would strongly impact:

- Economical development and lost productivity

Diarrhoeal diseases account for an estimated 4% of the total DALY (Disability Adjusted Life Year) glo- bal burden of diseases, nearly 90% attributable to unsafe water supply, lack of sanitation and hy- giene.

- Education

Approximately half a billion school days are lost each year due to water¬-borne diseases. The lack of adequate facilities in schools is one of the factors that prevent girls from attending school, particu- larly when menstruating. Gender-sensitive sanita- tion, together with education and hygiene, especially handwashing, has significantly reduced the incidence of water-borne and diarrhoeal di- seases, e.g., in Bangladesh and Morocco.

- Public health

Promoting sanitation must be a priority for the de- velopment of public health if we are to attain the MDGs. Achieving the MDGs will depend on the pro- motion of international coordination, community- based cost-effective technologies - such as membrane filtration units - that have dramatically improved access to microbiologically clean water from individual to community scales.

- Integrated Water Management

An integrated approach to managing at watershed level should address the biogeophysical, climatic, social and economic issues related to water mana- gement particularly within river basins.

Recommendations

The Academies of the G8+ countries strongly re- commend the following action plan to their Govern- ments:

1. Develop basic infrastructure for sanitation and maintenance, to achieve acceptable quality water as key priorities and reduce rural/urban disparities. Sanitary facilities in schools, adapted to local, en- vironmental, technological and cultural constraints, are a priority.

2. Promote education, including training of professio- nals and technicians to improve management of water quality, and public information to change the behaviour of populations regarding water supply.

3. Fund research and development for the identifica- tion of pathogens of human and animal origin and the development of simple, low-cost and efficient markers. Further epidemiological studies are nee- ded to develop vaccines against water-borne pa- thogens.

4. Promote capacity-building to improve water mana- gement and hygiene standards; support watershed level community-based actions favouring the key role of women both in rural and peri-urban areas to echo "unheard voices of women".

5. Establish networks of competence at national, re- gional and global levels to improve the efficiency of water use in domestic context, as well as in agri- culture and industry, through research and inno- vative practices that are ecologically oriented.

The benefits of fulfilling these recommendations are so rewarding, both socially and eco- nomically, that the Academies urge the leaders to address this concern and identify methods to meet the financial challenge.

Academia Brasileira das Ciencias, Brazil

Royal Society, Canada

Académie des Sciences, France

Deutsche Akademie der Naturforscher Leopoldina, Germany

Indian National Science Academy, India

Accademia Nazionale dei Lincei, Italy

Science Council of Japan, Japan

Academia Mexicana de Ciencias, Mexicana

Russian Academy of Sciences, Russia

Académie nationale des Sciences et des Techniques, Sénégal

Academy os Sciences, South Africa

Royal Society, United Kingdom

National Academy os Sciences, United States of America

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BUILDING RESILIENCE TO DISASTERS OF NATURAL AND TECHNOLOGICAL ORIGIN

Overview and Background

Disasters impose huge social and economic costs on societies. By reducing exposure and adopting new strategies to increase resilience, these costs can be reduced. While experience from recent disasters provides useful lessons, a more effective guide to building resilience can be based on systematic scientific risk surveillance and ranking. Since a strategy built on this basis is common to a range of disasters, regardless of their cause, implementing these strategies can be an important investment. It is urgent that national governments build resilience strategies into national, as well as international cooperation and development assistance plans.

Disasters

Natural disasters include events such as earthquakes, landslides, hurricanes, floods, typhoons, volcanic eruptions, and disease pandemics. Technological disasters include accidental or human- induced breakdowns in socially critical infrastructures such as dams and levees, energy systems, and information networks.

Disasters are often compounded by cascading effects (e.g., East Japan's earthquake-tsunami-nuclear reactor failure). In this state- ment, we will use the term "disasters" for all of these cases. While some disasters (such as droughts, epidemics, or sinking terrain) may develop gradually, here we focus on disasters that occur on short time scales.

The timing of most disasters cannot be precisely predicted. However, careful scientific study, modeling, and monitoring can improve our understanding of the hazards and exposure, and can often provide valuable early warning. Even for events such as earthquakes, and associated tsunamis, warning of a few minutes can save lives. It is important to reexamine periodically risk expo- sure. For example, extreme weather events (storms, heat waves, wild fire) may become more frequent and intense as a result of climate and other change, and new geophysical and other data may reveal hazards that were previously unrecognized.

Cost of Disasters

Losses and costs of disasters have been increasing. For the first time, global annual losses from natural disasters exceeded $200 billion in 2005, 2008, and 2011. Data on loss of life, on the other hand, has no clear trend—but has been much lower in developed countries, which indicates the value of resilience measures.

The rising cost of disasters is due in part to the continued growth of population and infrastructure in vulnerable locations, aging or compromised infrastructure, and the deferral of needed institu- tional arrangements and investments in warning and protective systems. Sea-level rise and climate change in the future may also increase risks and impacts from disasters. In many cases, natural systems such as coastal mangroves that buffer disasters have been degraded. Society is increasingly dependent on interacting infrastructures that supply energy, food, health care, information, transportation, and finance. Breakdown in one of these can affect many other services.

Coping with disasters can in many cases exceed the capacity of individual countries, and multiple countries may be impacted.

Resilience to Disasters

Resilience can be defined as the ability of a system and its com- ponent parts to anticipate, absorb, accommodate or recover from the effects of a major shock in a timely and efficient manner. Capacity for resilience should be developed in institutions at all levels and sectors of society. In many cases, strengthened resilience has multiple benefits: helping to mitigate immediate deaths, injuries, and economic losses from relatively frequent emergen- cies, while building resilience to future disasters. Elements of building resilience include:

- Systematic assessment and monitoring of disaster risks, con- tinued research to improve understanding of the underlying causes, improved warning systems, and awareness of risks by the public and all levels of governments.

- Establishment of a culture and incentives that lead to the ac- ceptance of responsibility by communities, including private sector and civil organizations, for planning and cooperation in preparation, response, and recovery.

- Long-term planning, investment, and enforcement of mitigat- ing or preventive measures, such as land-use and other zoning and building codes.

- International cooperation in advanced planning and rapid response, as well as research and evaluation on risk factors.

Components of Building Resilience

Important work is underway within the international community, in particular within the Global Platform for Disaster Risk Reduction and the 10-year Hyogo Framework for Action, adopted by 168 countries in 2005. ICSU (the International Council for Science) launched in 2010 a 10-year program of Integrated Research on Disaster Risk. The UN International Strategy for Disaster Reduc- tion is presently consulting on a post-2015 framework. Such efforts produce a wide range of valuable results and recommen- dations which deserve sustained attention and implementation.

The adoption of a systems approach and the identification of multi-dimensional solutions are key elements to building resil- ience. We suggest that particular attention be devoted to these five dimensions, and ask governments to engage the national and international scientific community in this effort:

1. *Repeated Risk Surveillance and Capacity Building for Regular Assessment*. It is hard to prepare for disasters that have not been imagined. Individual regions, nations, and the international community must develop strategies to regularly identify and assess the disaster risks they face and reduce their exposure. Continued monitoring is critical in this regard.

2. *Improvement of Public Health Systems*. Even when an initiat- ing event does not involve public health, large social disruptions can quickly lead to multiple hazards including epidemics. Pub- lic health systems must be strengthened and sustained, both to avoid disaster, and to respond when disasters occur. Capacity to respond to health impacts of disasters, especially for vulnerable populations, should be an integral part of (and an additional incentive for) building strong public health systems. The same considerations apply to crop and animal health systems, with their huge impacts on food security and economies. Govern- ments should regularly assess the adequacy of regional, national and international public health preparedness.

3. *Applications of Advanced Information Technology (IT)*. Information technologies, including geospatial, are important, both to monitor, identify and warn of pending disasters, and to assess the location, nature and extent of damage, deaths and injuries and dispatch, coordinate and allocate relief efforts. Nations should assess the potential advantages of dedicated. IT systems for emergency response versus shared systems that serve multiple roles. Either way, systematic practice (emer- gency response gaming) with all key players, as well as active programs of public involvement and education, are critical to the effective use of these systems.

4. *Planning, Engineering and Implementation of Standards to Minimize Vulnerability.* Losses from disasters can be signifi- cantly decreased by improved standards for buildings, roads, electrical systems, water systems, and other infrastructure, and by zoning to reduce vulnerability. In addition to planning the protection of populations and modern infrastructure, cultural and natural heritage sites require protection, as their loss is irre- versible. Continued research on innovative design, engineering and materials and dissemination of information about available techniques and materials are essential. To be effective, govern- ments must see that standards are enforced.

5. *Integration of Resilience Capacity into Development As- sistance Programs.* Development assistance programs can help countries build their own capacity for resilience, at both local and national levels. For this to be effective, assistance must reach those most in need so that future vulnerability is reduced. Public education and engagement, drawing les- sons from past disasters, and communications capacities are especially important for vulnerable populations and areas. Development assistance, even in crisis situations, should involve institutions and individuals of the afflicted country, to build lo- cal experience and capacity.

Our academies of science are committed to working together with over 100 science, engineering, and medicine counterpart organizations around the world to continue the process of better understanding the causes of disasters, finding ways to make society more resilient, making that information widely available, and helping to implement the many actions needed.

ENERGY AND WATER LINKAGE: CHALLENGE TO A SUSTAINABLE FUTURE

Overview

Needs for affordable and clean energy, for water in adequate quantity and quality, and for food security will increasingly be the central challenges for human- ity: these needs are strongly linked. In some regions, the increasing demands for water in support of energy development and use pose challenges to its availability for food and other human needs and for important eco- logical systems. It is critically important that planning and investment in energy and water infrastructure and associated policies take into account the deep interac- tion between water and energy. A systems approach based on specific regional circumstances and long-term planning is essential. Viewing each factor separately will lead to inefficiencies, added stress on water availability for food production and for critical ecosystems, and a higher risk of major failures or shortages in energy supply. In almost all regions of the world, innovative ways of achieving higher efficiency in use of energy and water will be the key factors that determine whether these linked challenges can be met.

Background

There is widely shared concern over the looming challenge of adequate food for a world population that has grown from 6 to 7 billion in the past 12 years and that will approach 9 billion within 30 years. This concern is based on current and projected needs that will require almost doubling current world food produc- tion, and doing so in situations of increasing demands for water resources. It is widely understood that considering water and energy aspects of food security is necessary, because agriculture is by far the largest user of water in most parts of the world and has enormous energy demands. A key effort in meeting the central challenge of food security will be improving efficiency and reduc- ing waste in energy inputs to agriculture, in agricultural water use, and in post-harvest losses.

However, the direct interaction between meeting energy needs and assuring water availability and quality is less widely recog- nized. Major stresses on availability of energy and water are already being felt in many countries and regions and more are foreseeable. There are widespread deficiencies in existing water energy infrastructure. Continuing population growth and changes in human diets and life styles will increase demand for both energy and water (even apart from demands related to basic nutritional and household water needs). And changes in regional hydrological cycles due to climate change will add to the poten- tial for human development crises.

Energy Requires Water

Energy runs modern society. In most of the world electrical energy depends on large generating plants burning fossil fuel, to a lesser degree on nuclear power, or on hydropower. Fossil-fired and nuclear power plants and solar-thermal systems, as cur- rently operating, require large water withdrawals and some water consumption. Depending on the type of cooling system, these requirements can vary by large amounts. Energy from some renewable sources such as photovoltaic solar and wind, on the other hand, requires very little water.

Fossil fuels provide some 80% of the worlds current energy needs, including most transportation systems. Some fossil fuel sources, including increasingly important "unconventional" sources, such as tar sands, gas hydrates, and gas and oil in tight formations, have substantial implications for quantity and quality of water.

Producing alternative transportation fuels, in particular biofuels, depending on the specific applications, can involve substantial impacts on water resources and water quality.

Water Requires Energy

Providing water quantity and quality requires, in some cases, large amounts of energy. In many countries or regions, where water must be moved long distances from sources to users, consider- able energy is used to pump this water. Where water is available but contamination is extensive, the solutions for improving water quality, including waste- water treatment, depend on energy. The extreme case is desalination, which requires large energy inputs.

Water Stress and Scarcity

Water quantity and quality issues carry serious implications for human welfare, health, and for ecosystems. Current data and a range of projections of demand over the coming few decades (population, demand for water intensive foods, standards of living, sources of energy and end-uses) indicate that a growing number of areas of the world will be in situations of water stress or scarcity, or will not be self-sufficient in food production. Regional-scale projections for the continuation and acceleration of climate changes and impacts on the hydrological cycle indicate intensified water stress and scarcity in some parts of the world, and uncertainty as to exactly where that will occur. While much of the world depends on precipitation, surface water, and rechargeable aquifers, the extensive dependence of some areas on non-renewable ancient aquifers, or on withdrawals that are much greater than recharge rates on other aquifers, presents a special case of foreseeable serious increase in water stress and scarcity.

Recommendations

Water in a sense is both a regional and a global challenge: each country or region has its own specific situation with regard to water quantity and quality, current uses and needs, future projec- tions, and uncertainties in those projections. Food security and water supply for human consumption are local, but also regional and global challenges. The extensively globalized market for food, energy, and other goods constitutes large trade in "virtual water", which globally alleviates but can locally increase, water stresses.

For many, food security alternatives, and better water management and technological alternatives are necessary. Regional water cooperation is, in many cases, essential.

Energy options are a complex mix of local resources (if any), global supply, and available/affordable technological options. The wide range of local circumstances means that the world needs a wide range of clean energy technology options, whose impacts on water need to be well understood and taken into account in the decision processes.

Thus, we Leaders of Academies of Sciences, recommend that governments:

- Ensure that programs in energy and water are fully integrated and that solutions are developed with a systems approach that takes into account their interdependencies. Especially important will be energy efficiency, water efficiency and recycle, and demand management for both. This integration

must also successfully deal with the close linkages to food production and sustainability in land use and maintenance of ecosystems.

- Invest in integrated scientific research and innovation in energy optimization and the sustainable use of water, and in further development of systems analysis approaches for dealing with these challenges.

- Establish effective governance structures and clear policies to facilitate the integrated management of energy, water, and agriculture systems. This may require explicit estimation of indirect costs of energy programs, including consumption or degradation of water, and the reflection of these costs in prices.

- Develop systems, which monitor and make freely available key basic data on water and energy.

Each of these actions requires building local and regional human and institutional capacity for the necessary research, data-gathering, evaluation, planning, governance, technology adaptation, and long-term maintenance. This capacity must be built on a public recognition of the need for long-term planning and the importance of efficiency and conservation. Global cooperation will be essential, including development assistance to many of the most vulnerable countries, building capacity to plan and implement integrated national energy and water programs.

IMPROVING KNOWLEDGE OF EMISSIONS AND SINKS OF GREENHOUSE GASES

Background

Most countries have made commitments to limit human-caused emissions of greenhouse gases. To determine the success of these efforts, we need to use standardized methods that accurately estimate natural and human caused sources and sinks of greenhouse gases—including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)—at a national level. Such estimates are needed to verify an international climate treaty as well as to detect changes in natural green- house gas emissions (such as, large-scale release from methane hydrates) or sinks. Also, better understanding of the global distribution of black carbon (which is soot, rather than a greenhouse gas) would both improve our ability to manage its impact on human health and allow better assessment of its contribution to climate change.

Methods for Estimating Greenhouse Gas Emissions

There are three primary methods for estimating emissions of greenhouse gases, all of which could be improved to reduce uncertainties in emission estimates, by implementing the Rec- ommendations presented in the last section below.

- *National inventories of emissions and sinks*. Countries report emissions to the United Nations Framework Convention on Climate Change using methods developed by the Intergov- ernmental Panel on Climate Change. Emissions are estimated by measuring a human activity (e.g., tons of coal burned) and multiplying by an emissions factor (e.g., CO2 emissions per ton). This method can be applied to achieve different levels of accuracy. Relatively accurate estimates are based on country- specific emissions factors and sophisticated models of emis- sion sources. This method is capable of producing reasonably accurate estimates of fossil-fuel CO2 emissions and sinks, but with larger uncertainties for most other greenhouse gases.

- *Atmospheric methods.* The net sum of human and natural sources and sinks can be estimated using atmospheric and/or oceanic measurements (including remote sensing from satellites) of the gases and state-of-the-art mathematical mod- els of air and water flow. These methods offer an opportunity to provide an independent check on inventory estimates. However, they cannot yet be

used to estimate greenhouse gas emissions and sinks with sufficient accuracy at the national level, because of: transport error; large and incompletely understood background fluctuations of natural emissions; and the small number and uneven geographic distribution of sampling stations. For example, current atmospheric sampling grids largely avoid major emitters like cities, making it difficult to interpret satellite observations. Moreover, air samples are not analyzed for all isotopes of interest: for example, measure- ments of radiocarbon [14C] would enable fossil fuel CO2 emissions to be separated from non fossil fuel sources and sinks). Black carbon, which also influences atmospheric temperatures, is generally monitored as part of air pollution programs.

- *Direct inventories for land use*. Sources and sinks of CO2 can be estimated using time series of measurements at or near ground level (e.g., above- and below-ground change in carbon content of an ecosystem), and satellite measurements of deforestation and reforestation. If all sources and sinks were measured, CO2 from ecosystems could be estimated with sufficient accuracy. Estimates of some greenhouse gas emissions are reasonably good (e.g., methane emissions from cattle), but estimates of other greenhouse gases and sources are poor. N2O emissions vary over space and time, depending on how the land is used (particularly the application of nitrogen fertilizer) and on the local climate, topography, and soil and vegetation properties. Improved fundamental understanding is required before accurate estimates of N2O can be made.

Recommendations

The ability to accurately estimate greenhouse gas sources and sinks is a prerequisite for international agreements or national emission reduction programs to be effective. This ability depends on improved knowledge and understanding of the sources and sinks of greenhouse gases; the coordinated observation of sources and sinks from surface, airborne, and space-based systems; and open access to information from all countries. Key gaps in knowledge could be filled within a few years by refocusing existing measurement programs on greenhouse gas sources and sinks that are important in each country or region. Implementing the first two steps below would yield the capability to accurately estimate and independently verify emissions of CO2 from fossil-fuel use and deforestation, which are responsible for about three-quarters of emissions covered under the UNFCCC. Implementing the third step would improve fundamental understanding of the carbon cycle.

1. Annual measurement and report by all countries of the greenhouse gas emissions and sinks that currently can be estimated accurately, including CO2 emissions from fossil fuel burning and from land use and CH4 emissions from industrial and biogenic sources. The international science community should assist some countries to build the capacity needed to create accurate inventories of these emissions and sinks.

2. International coordination and cooperation to improve the technology and methods for estimating greenhouse gas emissions and sinks and to adopt appropriate new approaches or technologies as they emerge. A concerted effort for sharing state-of-art technologies, deploying cost-effective measurement instruments around the world and in space, and collaborations for combining and analyzing ground and satellite data would speed results and also build science capacity. Such an effort requires exchanges of measurement and analysis methods and established standards for assessing data quality and estimating uncertainty.

3. International and multidisciplinary research programs should be established or enhanced to focus on understanding the possibility of changes resulting in major and/or rapid increases in atmospheric greenhouse gases. The largest risks include the potential release of CO2 and/or CH4 from high latitudes, ocean sediments, changes in ocean biogeochemistry and circulation, and changes in the rain forest carbon budget. It is important to analyze those greenhouse gas fluxes in the framework of global biogeochemical cycles.

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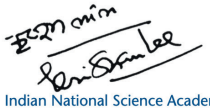

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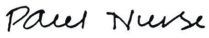

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2013
Lough Erne, Northern Ireland / UK
G-8

DRIVING SUSTAINABLE DEVELOPMENT: THE ROLE OF SCIENCE, TECHNOLOGY AND INNOVATION

Introduction

The framework of Millennium Development Goals has led to several in-depth discussions and debates focused on review of the progress made so far and preparation of strategies for post-2015 era to ensure sustainable development all over the world. At the Rio+20 United Nations Conference on Sustainable Development (June 2012), the world's governments agreed to develop a set of sustainable development goals (SDGs). Discussions at UN level have covered Science, Technology and Innovation and Intellectual Property Rights[1]. Recently, the International Council for Science (ICSU) and the United Nations Department of Social and Economic Affairs (UN-DESA), had jointly a meeting of an Expert Group at the UN Headquarter [2]. The Global Network of Academies (IAP) had issued a statement on Population and Consumption in June 2012. Several Academies and other learned bodies have brought out reports on development issues including US National Academies of Science [3]. Other relevant reports are also available [4].

Academies of Sciences around the world provide evidence and advice to inform their countries' development decisions. For the past eight years, a group of academies have addressed brief statements to governments meeting at summits on global issues. These have included several of the issues related to sustainable development, such as energy, climate change, water, health and infectious disease, and resilience to disasters. This year, the Indian National Science Academy has convened a continuation of this process. During these eight years, there has been immense progress in science and technology, including in information and communications technology and natural resource extraction. However, major global challenges remain, and in important ways have grown, especially as related to continued population growth, climate change, and impact on essential natural systems. So meeting human needs, now and in the future, remains a major challenge. Work is underway in the world community to set Sustainable Development Goals for the coming years. We offer the following perspectives on how science, technology and innovation can play a role in driving sustainable development.

A Still Growing Population

Demographic changes are taking place at a rapid pace all over the world. While a semi- stationary population level might be reached by end of the century, the world population is projected to grow to about 9 billion by 2050, from the present level of about 7 billion. Strategies to slow the population growth rate, such as education, empowerment of women and access to family planning, have yielded positive results in the past, and give hope that, if coherently pursued, it might further reduce the projected rate of growth of growth during the coming decades. The challenge to meet the needs of about 1.6 billion additional people, of which approximately 1 billion will be in Africa, in the next four decades, is enormous. At present, however, there is an urgent priority: bringing the estimated 1.3 billion persons living under extreme poverty condition, out of poverty. The enormity of unsatisfied human needs threatens social cohesion as well as the survival of important living systems of the planet.

Challenges of demographic changes

The demographic structure of many of the less developed areas of the world is still very young, and requires intense investment in order to eliminate illiteracy and improve education at all levels and provide for job opportunities. On the other hand, progress made in healthcare, improved nutrition and healthier lifestyles has led in many other countries to increased survival and increased aging of the population. The wellbeing and social contributions of a growing number of elderly people requires special attention and innovations will be required if we are to provide advanced healthcare and allow valuable societal roles for all.

Challenges of Urbanization

Some cities around the world are demonstrating potential for efficiently meeting human needs. However, unplanned rates of urbanization in developing economies are putting enormous strains on adequate housing and the management of the resources like water and energy and the provision of essential services like sanitation, transport, health care and waste disposal. Also, efforts are needed to ensure and protect essential ecosystems in the process of urbanization. It has assumed urgency as by 2050 there will be ~70% urban dwellers globally against ~50% at the present time. Investments in research and innovative new approaches, as well as behavioural changes, are required if we are to make efficient management of scarce resources, and improvements in other areas such as sanitation.

Providing for nine billion

Water availability is central to agriculture, industrial and energy production and essential for direct human consumption and for critical ecosystems. In view of the current and projected water scarcity and water stress, new ways of increasing the availability of clean water are essential. Therefore, the improvement of water treatment and management systems and technological solutions in recycling and sea water desalination together with other non- technological solutions should be explored. These approaches require the attention and action of governments around the world.

Nutritious food is one of the most basic needs of human society. The level of food production and elimination of malnutrition and hunger has to keep pace with the increasing population, continuing land use change, and the future effects of climate change. This may require more land for food production and certainly improved management of water resources. Newer genetic resources need to be developed, together with other non technological strategies, to meet the challenges of changing climate on crop cycles and yields. Strategies are required to balance the use of synthetic fertilizers and pesticides with more natural equivalents to ensure environment-friendly outcomes. Simultaneous attention is to be paid to the preservation of biodiversity and functioning of ecosystems. Increased food security in part depends on stabilization of international market food prices. Food consumption and production patterns need fresh science, technology and innovation perspectives to promote health, to cut down postharvest losses and reduce waste.

Providing energy without unacceptable environmental impact

Essential aspects of human welfare require energy services. At the same time, fossil fuel combustion has to be implemented within environment and health constraints, and is the predominant driver of climate change, and thus associated impacts including sea level rise, extreme weather events, and ocean acidification. Many studies have identified energy conservation and energy efficiency as essential, multi-benefit, low-cost measures. In addition, a range of clean, renewable energy options are needed to meet the varied needs and circumstances around the world. Systems approaches, including storage, smart grids, conversion of waste and biomass into energy, and in some cases carbon sequestration, will also be necessary and all require further progress in science, engineering and innovation.

Sustainable Consumption

The aspiration for a better quality of life is universal. Yet the resource implications of providing an improved quality of life for all, could jeopardize the future of the coming generations. Levels of material consumption differ enormously between regions of the world and if we hope to raise the aforementioned 1.3 billion persons out of poverty, the most developed and the emerging economies must stabilise and then reduce material consumption levels through: dramatic improvements in resource use efficiency, including reducing waste and employing improved recycling; and investment in sustainable resources, technologies and infrastructures. Systematic decoupling of economic activity from environment is essential. Responsible and inclusive consumption and production are the key elements of sustainability.

Towards universal literacy – including scientific literacy

Universal literacy, especially including women, is well understood to be essential for sustainable and equitable development. But literacy must be better understood to include scientific literacy, since many of the challenges we face will require science and technology solutions. For example, the burden of non-communicable, behavior-related (diet, lack of exercise, substance abuse, etc) disease is rapidly increasing, and evidence-based education is a central tool for addressing such issues. Creative and innovative programs are underway in many countries to further improve learning approaches and to equip teachers with the training and resources necessary. Inquiry based science education is a promising approach on which academies around the world are working in support of improving education

systems, and in many cases with support from the private sector. South-South and North- South cooperation in sharing and implementing effective educational approaches are important to deal with the urgent educational needs of the least developed countries.

Role of Science Academies

Progress in science, technology and innovation is necessary, although not sufficient to solve the many underlying challenges for sustainable development. These include poor governance at all levels from local to global, inadequate education systems, and lack of rural development (access to roads, financing, education, and empowerment of women). Progress also needs trade reform and a transition of the economic system to one from GDP to GDP+, where economic growth is measured in terms of built, natural, human, social and financial capital. Without good governance and a more sustainable economic system the potential gains from advances in science and technology cannot be realized. The Academies

believe that their own promotion of the values of science, including emphasis on evidence, openness, ethical standards, and social responsibility can contribute to good governance. They acknowledge the context within which science and technology exist and pledge to support policy making for sustainable development by:

- Providing a source of independent, objective expertise, bringing scientific rigour to gathering evidence, including what is known and not known, which ultimately underpins progress towards sustainable development;

- Collaborating across academies to raise visibility and capacity to proactively engage with the sustainable development policy community at national, regional and international levels;

- Supporting processes to define, measure and monitor at national, regional and international levels, progress towards sustainable goals;

- Taking actions to help predict and inform policies to prevent adverse effects of development practices and processes;

- Training and supporting the development of human resources in science, technology and innovation – starting at primary and secondary level education, including investments in higher education to help build scientific and absorptive capacity to respond to local challenges;

- Promoting multidisciplinary research for a holistic approach to sustainable development, including engagement with the private sector;

- Improving public awareness of the role of science, technology and innovation can play in promoting sustainable development; and

- Promoting south-south and north-south mobility of researchers.

Reference

[1] Meeting of UN System Task Team on the Post-2015 UN Development Agenda, May 2012

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G-SCIENCE ACADEMIES STATEMENTS 2013: DRUG RESISTANCE IN INFECTIOUS AGENTS A GLOBAL THREAT TO HUMANITY

From the first antibiotic, penicillin introduced in 1940s, which came into wide scale use in the 1950s, anti-infective drugs to prevent mortality and morbidity arising from infections have unarguably been one of the most effective health interventions(besides chlorination of water and sanitation in general) in the history of modern medicine. Whether used to treat bacterial infections, or tuberculosis, malaria or HIV, these drugs have become a legacy arising from meticulous scientific and medical research over many decades that we all wish to pass on to future generations in as healthy a state as possible.

This aim is getting increasingly threatened by the growing problem of drug resistance in infectious disease agents and its spread globally. The pattern of emergence of drug resistance is almost uniform, independent of drug or infectious agent. It starts slowly, but then rises rapidly following a sigmoid shape of frequency change over time. The silent phase may be a decade or even longer, and its existence often lulls observers into a false sense of security post widespread use of a new drug.In recent decades, the rate of discovery of novel compounds, especially antibiotics, has slowed down considerably. From discovery to market it typically takes 10-15 years. The current need, therefore, is not only to extend the life of existing drugs but also to encourage discovery and development of new anti-infective drugs to combat the threat that drug resistance presents to human health.

The current situation is becoming serious with an increasing incidence of detection of resistance to all known drug treatments, especially amongst bacteria. Two examples are as follows. First, the incidence of Multi Drug Resistance (MDR) in Mycobacterium tuberculosis, which can result in untreatable tuberculosis infection, is rising steadily worldwide. According to a recent WHO report, an estimated 440,000 cases of MDR tuberculosis were notified worldwide in 2011[1]. Furthermore, 84 countries have reported untreatable tubercular infection. The second example is that of common bacterial infections caused by Enterobacteria in hospital settings. Carbapenem-resistant Enterobacteriaceae (CRE) infections are on the rise, and have recently become resistant to 'last-resort antibiotics'. These bacteria

are an increasing cause of mortality in many countries (CDC,6th March 2013). According to a WHO report the "…world is heading towards a post-antibiotic era in which many common infections will no longer have a cure and once again kill unabated"[1]. A similar sentiment has been expressed by the Chief Medical Officer of UK who has described antibiotic resistance "as big a risk as terrorism"[2].

The resistant organisms are often very difficult to treat. They impose great health risks to individuals and significant costs to society. Since they are infectious agents they have the potential to spread to others, so that the problem which was initially encountered in hospital settings is now increasingly a community problem as well. More recently the World Economic Forum has included antibiotic resistance in its 2013 Global Risks report[3].

Our aim in making these recommendations is threefold. First, we wish to draw increased attention of the world to this growing problem. Second, we hope to encourage the G20 countries to place the problem of combating the emergence and spread of drug resistant infectious agents high on their health agenda. We urge that the problem of resistance to anti- infective drugs be incorporated in the revised millennium developmental goals. And third, we would like the international community to find ways and means to encourage pharmaceutical companies to invest in the development of novel anti-infective drugs in general, but especially antibiotics.

The emergence of drug resistance is inherent to the basic biology and evolution of microorganisms. In any infection some organisms are likely to be resistant to the used antimicrobial agent as a result of existing spontaneous mutations and genetic exchanges. However, the frequency of such resistant organisms is quite low. The problem arises when the hardy variant gets selected and multiplies by the elimination of sensitive ones by the used antibiotic. The selection pressure exerted by the antibiotic gets intensified with the overuse, misuse or underuse of the antimicrobial agents. This is what happened with the emergence of Methicillin Resistant *Staphylococcus aureus* (MRSA), and now with vancomycin resistant enterococci. Another mechanism of drug resistance is acquisition of drug resistance mediated through plasmids or mobile genetic elements. Such resistance can be horizontally transferred from one organism to another organism, including from animal infectious agents to human pathogens. This is very common with enteric bacteria such as *Escherichia coli, Klebsiella, Acinetobacter, Pseudomonas, Enterobacter* and *Enterococcus.* It occurs not only in bacteria, but also in viruses, fungi and parasites that become resistant to various anti-infective agents.

Varied factors have been identified to be responsible for the emergence and spread of resistant microorganisms. These include: 1) Irrational and self-use of antibiotics; 2) Lack of adherence to a prescribed regimen; and 3) Widespread non-human use of antibiotics and other anti-infective agents as growth promoters in livestock. Problems also arise due to lack of policy for rotation of antibiotics and infection-control in the hospital. Other factors that have aggravated the problem include increasing in use of antibiotics in patients with immune suppression (patients of cancer on chemo/radiotherapy, subjects receiving organ transplants, patients suffering with auto-immune disorders on immune suppressants and patients with HIV/AIDS). The problem is further compounded by poor prescribing habits of doctors and lack of information about changing anti-biotic sensitivity patterns to guide antibiotic rotation. In some parts of the world poor quality of drugs can contribute to the emergence of drug resistance due to exposure to sub therapeutic levels of antibiotics in these preparations. In recent years the use of antibiotics in livestock farming has surpassed the use of these agents in humans. Besides their use for treatment of infections in animals, the agents are commonly used prophylactically to enhance growth rates that increase yields in livestock, poultry and fish farming. This has led to chronic sub-therapeutic consumption of antibiotics by man through eating of the meat from these animals, and also to the emergence of resistant micro-organisms in animals. In one study more than 50% of the bacteria in ground turkey were resistant to three or more classes of antibiotics, while a quarter were resistant to five classes[4]. It is known that resistant zoonotic bacteria may cause human diseases and also pass genetic material to bacteria that infect humans.

Effective surveillance systems have been put in place in some countries to track the emergence and spread of resistance to anti-infectives. Such surveillance has been able to bring about changes in national policies and practices. But there are wide variations between different countries and even within the same country. A country-based analysis is a logical initial step towards establishing a comprehensive open access global drug resistance database. Necessary expertise, information and resources would need to be shared for the purpose. The academies recommend the following actions to reduce the burden of drug resistance to improve global health and to enhance economic well-being.

1. **Promote integrated global surveillance systems**. Determined leadership, additional resource mobilization and strong commitment nationally and internationally is called for to promote cooperation between health agencies, clinicians, epidemiologists, microbiologists, animal husbandry experts, molecular biologists, information scientists and social scientists to prevent the spread of resistant microorganisms.The implementation of these goals would require strengthening of surveillance and laboratory capabilities worldwide.

This will require:

- Monitoring of antibiotic and anti-infective sensitivity patterns in human and zoonotic infections on a regular basis.

- Acquiring of knowledge through surveys of antimicrobial use and environmental impact of antibiotics in water and wildlife.

- Tracking of antimicrobial resistancein real timeat the molecularlevel and creation of global data repository with openaccess.

- Monitoring of drug quality and detection of substandard anti-infective drugs.

2. **Promote Information and Education programs on the rational and responsible use of anti-infective drugs**.This should target medical doctors, patients and other members of society, particularly those involved in animal husbandry and industrial use of antibiotics.

3. **Set up a "drug policy" among member countries** with all necessary regulations for dispensation of vulnerable anti-infective drugs, standard guidelines for anti-infective drug prescriptions, limiting the use of these agents in animal husbandry and assuring availability of quality and appropriate anti-infective therapies.

4. **Enhance prevention and control policies**. This can be achieved by the prevention and control of infections through more systematic use of existing vaccines and in some cases development of new vaccines against problematic infections including bacterial infections acquired in hospital settings, and promotion of universal measures of hygiene and sanitation relevant to prevention of infection.

5. **Encourage pharmaceutical companies, in collaboration with public funded researchers, to develop new antimicrobials**. New scientific approaches using genomics, proteomics and bioinformatics can speed identification of new targets and development of new therapeutic molecules particularly against resistant microorganisms. The policies should include financial and regulatory measures to encourage pharmaceutical industry to develop novel antibiotics expeditiously. There is an urgent need to develop effective drugs against neglected tropical diseases. Development of new diagnostics tests and biomarkers for drug resistance are also important to fight the menace of antimicrobial drug resistance.

6. **Enhancement of R & D capability of developing countries to be a partner in the fight against emerging antimicrobial drug resistance.** The developing countries need to take a lead in all the above endeavours, more so than the developed countries, since the problem of antimicrobial drug resistance more acutely affects them. The cooperation, both amongst scientists and industry, between the North and South should be actively supported to achieve the desired end.

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G20 LEADERS' BRISBANE STATEMENT ON EBOLA

We are deeply concerned about the Ebola outbreak in Guinea, Liberia and Sierra Leone and saddened by the suffering and loss of life it is inflicting. We are mindful of the serious humanitarian, social and economic impacts on those countries, and of the potential for these impacts to spread.

The governments and people of Guinea, Liberia and Sierra Leone are making tremendous efforts to fight the outbreak, with the support of the African Union and other African countries. We commend the brave service of health care and relief workers. We also applaud the contributions of countries worldwide, the United Nations (UN) and its bodies such as the World Health Organization (WHO), international and regional organisations and financial institutions, non-governmental and religious organisations, and the private sector. We fully support the UN Mission for Ebola Emergency Response's ongoing work to harness capacity to stop the outbreak, treat the infected, ensure essential services, preserve stability and prevent further outbreaks and urge that it act swiftly to achieve these objectives.

G20 members are committed to do what is necessary to ensure the international effort can extinguish the outbreak and address its medium-term economic and humanitarian costs. We will work through bilateral, regional and multilateral channels, and in partnership with non-governmental stakeholders. We will share our experiences of successfully fighting Ebola with our partners, including to promote safe conditions and training for health care and relief workers. We will work to expedite the effective and targeted disbursement of funds and other assistance, balancing between emergency and longer-term needs.

We invite those governments that have yet to do so to join in providing financial contributions, appropriately qualified and trained medical teams and personnel, medical and protective equipment, and medicines and treatments. While commending ongoing work, we urge greater efforts by researchers, regulators and pharmaceutical companies to develop safe, effective and affordable diagnostic tools, vaccines and treatments. We call upon international and regional institutions, civil society and the private sector to work with governments to mitigate the impacts of the crisis and ensure the longer-term economic recovery.

In this regard, we urge the World Bank Group (WBG) and International Monetary Fund (IMF) to continue their strong support for the affected countries and welcome the IMF's initiative to make available a further $300 million to stem the Ebola outbreak and ease pressures on Guinea, Liberia and Sierra Leone, through

a combination of concessional loans, debt relief, and grants. We ask the IMF and WBG to explore new, flexible mechanisms to address the economic effects of future comparable crises.

This outbreak illustrates the urgency of addressing longer-term systemic issues and gaps in capability, preparedness and response capacity that expose the global economy to the impacts of infectious disease. G20 members recommit to full implementation of the WHO's International Health Regulations (IHR). To this end, and in the context of our broader efforts to strengthen health systems globally, we commit to support others to implement the IHR and to build capacity to prevent, detect, report early and rapidly respond to infectious diseases like Ebola. We also commit to fight anti-microbial resistance. Interested G20 members are supporting this goal through initiatives to accelerate action across the Economic Community of West African States and other vulnerable regions and will report progress and announce a time frame by May 2015 at the World Health Assembly.

We invite all countries to join us in mobilising resources to strengthen national, regional and global preparedness against the threat posed by infectious diseases to global health and strong, sustainable and balanced growth for all. We will remain vigilant and responsive.

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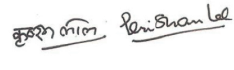

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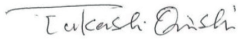

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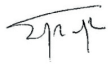

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G20 LEADERS' COMMUNIQUÉ BRISBANE SUMMIT, 15-16 NOVEMBER 2014

1. Raising global growth to deliver better living standards and quality jobs for people across the world is our highest priority. We welcome stronger growth in some key economies. But the global recovery is slow, uneven and not delivering the jobs needed. The global economy is being held back by a shortfall in demand, while addressing supply constraints is key to lifting potential growth. Risks persist, including in financial markets and from geopolitical tensions. We commit to work in partnership to lift growth, boost economic resilience and strengthen global institutions.

2. We are determined to overcome these challenges and step up our efforts to achieve strong, sustainable and balanced growth, and to create jobs. We are implementing structural reforms to lift growth and private sector activity, recognising that well-functioning markets underpin prosperity. We will ensure our macroeconomic policies are appropriate to support growth, strengthen demand and promote global rebalancing. We will continue to implement fiscal strategies flexibly, taking into account near-term economic conditions, while putting debt as a share of GDP on a sustainable path. Our monetary authorities have committed to support the recovery and address deflationary pressures when needed, consistent with their mandates. We will be mindful of the global impacts of our policies and cooperate to manage spillovers. We stand ready to use all policy levers to underpin confidence and the recovery.

3. This year we set an ambitious goal to lift the G20's GDP by at least an additional two per cent by 2018. Analysis by the IMF-OECD indicates that our commitments, if fully implemented, will deliver 2.1 per cent. This will add more than US$2 trillion to the global economy and create millions of jobs. Our measures to lift investment, increase trade and competition, and boost employment, along with our macroeconomic policies, will support development and inclusive growth, and help to reduce inequality and poverty.

4. Our actions to boost growth and create quality jobs are set out in the Brisbane Action Plan and in our comprehensive growth strategies. We will monitor and

hold each other to account for implementing our commitments, and actual progress towards our growth ambition, informed by analysis from international organisations. We will ensure our growth strategies continue to deliver and will review progress at our next meeting.

Acting together to lift growth and create jobs

5. Tackling global investment and infrastructure shortfalls is crucial to lifting growth, job creation and productivity. We endorse the Global Infrastructure Initiative, a multi-year work programme to lift quality public and private infrastructure investment. Our growth strategies contain major investment initiatives, including actions to strengthen public investment and improve our domestic investment and financing climate, which is essential to attract new private sector finance for investment. We have agreed on a set of voluntary leading practices to promote and prioritise quality investment, particularly in infrastructure. To help match investors with projects, we will address data gaps and improve information on project pipelines. We are working to facilitate long-term financing from institutional investors and to encourage market sources of finance, including transparent securitisation, particularly for small and medium-sized enterprises. We will continue to work with multilateral development banks, and encourage national development banks, to optimise use of their balance sheets to provide additional lending and ensure our work on infrastructure benefits low-income countries.

6. To support implementation of the Initiative, we agree to establish a Global Infrastructure Hub with a four-year mandate. The Hub will contribute to developing a knowledge-sharing platform and network between governments, the private sector, development banks and other international organisations. The Hub will foster collaboration among these groups to improve the functioning and financing of infrastructure markets.

7. To strengthen infrastructure and attract more private sector investment in developing countries, we welcome the launch of the World Bank Group's Global Infrastructure Facility, which will complement our work. We support similar initiatives by other development banks and continued cooperation amongst them.

8. Trade and competition are powerful drivers of growth, increased living standards and job creation. In today's world we don't just trade final products. We work together to make things by importing and exporting components and services. We need policies that take full advantage of global value chains and encourage greater participation and value addition by developing

countries. Our growth strategies include reforms to facilitate trade by lowering costs, streamlining customs procedures, reducing regulatory burdens and strengthening trade-enabling services. We are promoting competition, entrepreneurship and innovation, including by lowering barriers to new business entrants and investment. We reaffirm our longstanding standstill and rollback commitments to resist protectionism.

9. Our actions to increase investment, trade and competition will deliver quality jobs. But we must do more to address unemployment, raise participation and create quality jobs. We agree to the goal of reducing the gap in participation rates between men and women in our countries by 25 per cent by 2025, taking into account national circumstances, to bring more than 100 million women into the labour force, significantly increase global growth and reduce poverty and inequality.

10. We are strongly committed to reducing youth unemployment, which is unacceptably high, by acting to ensure young people are in education, training or employment. Our Employment Plans include investments in apprenticeships, education and training, and incentives for hiring young people and encouraging entrepreneurship. We remain focussed on addressing informality, as well as structural and long-term unemployment, by strengthening labour markets and having appropriate social protection systems. Improving workplace safety and health is a priority. We ask our labour and employment ministers, supported by an Employment Working Group, to report to us in 2015.

11. We are committed to poverty eradication and development, and to ensure our actions contribute to inclusive and sustainable growth in low-income and developing countries. We commit to take strong practical measures to reduce the global average cost of transferring remittances to five per cent and to enhance financial inclusion as a priority. The G20 Food Security and Nutrition Framework will strengthen growth by lifting investment in food systems, raising productivity to expand food supply, and increasing incomes and quality jobs. We support efforts in the United Nations to agree an ambitious post-2015 development agenda. The G20 will contribute by strengthening economic growth and resilience.

Building a stronger, more resilient global economy

12. Strengthening the resilience of the global economy and stability of the financial system are crucial to sustaining growth and development. We have delivered key aspects of the core commitments we made in response to the financial crisis. Our reforms to improve banks' capital and liquidity positions and to make derivatives

markets safer will reduce risks in the financial system. We welcome the Financial Stability Board (FSB) proposal as set out in the Annex requiring global systemically important banks to hold additional loss absorbing capacity that would further protect taxpayers if these banks fail. Progress has been made in delivering the shadow banking framework and we endorse an updated roadmap for further work. We have agreed to measures to dampen risk channels between banks and non-banks. But critical work remains to build a stronger, more resilient financial system. The task now is to finalise remaining elements of our policy framework and fully implement agreed financial regulatory reforms, while remaining alert to new risks. We call on regulatory authorities to make further concrete progress in swiftly implementing the agreed G20 derivatives reforms. We encourage jurisdictions to defer to each other when it is justified, in line with the St Petersburg Declaration. We welcome the FSB's plans to report on the implementation and effects of these reforms, and the FSB's future priorities. We welcome the progress made to strengthen the orderliness and predictability of the sovereign debt restructuring process.

13. We are taking actions to ensure the fairness of the international tax system and to secure countries' revenue bases. Profits should be taxed where economic activities deriving the profits are performed and where value is created. We welcome the significant progress on the G20/OECD Base Erosion and Profit Shifting (BEPS) Action Plan to modernise international tax rules. We are committed to finalising this work in 2015, including transparency of taxpayer-specific rulings found to constitute harmful tax practices. We welcome progress being made on taxation of patent boxes. To prevent cross-border tax evasion, we endorse the global Common Reporting Standard for the automatic exchange of tax information (AEOI) on a reciprocal basis. We will begin to exchange information automatically with each other and with other countries by 2017 or end-2018, subject to completing necessary legislative procedures. We welcome financial centres' commitments to do the same and call on all to join us. We welcome deeper engagement of developing countries in the BEPS project to address their concerns. We will work with them to build their tax administration capacity and implement AEOI. We welcome further collaboration by our tax authorities on cross-border compliance activities.

14. We endorse the 2015-16 G20 Anti-Corruption Action Plan that will support growth and resilience. Our actions are building cooperation and networks, including to enhance mutual legal assistance, recovery of the proceeds of corruption and denial of safe haven to corrupt officials. We commit to improve the transparency of the public and private sectors, and of beneficial ownership by implementing the G20 High-Level Principles on Beneficial Ownership Transparency.

Strengthening global institutions

15. The G20 must be at the forefront in helping to address key global economic challenges. Global economic institutions need to be effective and representative, and to reflect the changing world economy. We welcome the increased representation of emerging economies on the FSB and other actions to maintain its effectiveness. We are committed to maintaining a strong, quota-based and adequately resourced International Monetary Fund (IMF). We reaffirm our commitment in St Petersburg and in this light we are deeply disappointed with the continued delay in progressing the IMF quota and governance reforms agreed in 2010 and the 15th General Review of Quotas, including a new quota formula. The implementation of the 2010 reforms remains our highest priority for the IMF and we urge the United States to ratify them. If this does not happen by year-end, we ask the IMF to build on its existing work and stand ready with options for next steps.

16. We need a strong trading system in an open global economy to drive growth and generate jobs. To help business make best use of trade agreements, we will work to ensure our bilateral, regional and plurilateral agreements complement one another, are transparent and contribute to a stronger multilateral trading system under World Trade Organization (WTO) rules. These rules remain the backbone of the global trading system that has delivered economic prosperity. A robust and effective WTO that responds to current and future challenges is essential. We welcome the breakthrough between the United States and India that will help the full and prompt implementation of the Trade Facilitation Agreement and includes provisions on food security. We commit to implement all elements of the Bali package and to swiftly define a WTO work programme on the remaining issues of the Doha Development Agenda to get negotiations back on track. This will be important to restore trust and confidence in the multilateral trading system. We agreed to discuss ways to make the system work better when we meet next year. We will continue to provide aid-for-trade to developing countries in need of assistance.

17. Increased collaboration on energy is a priority. Global energy markets are undergoing significant transformation. Strong and resilient energy markets are critical to economic growth. Today we endorse the G20 Principles on Energy Collaboration. We ask our energy ministers to meet and report to us in 2015 on options to take this work forward. Gas is an increasingly important energy source and we will work to improve the functioning of gas markets.

18. Improving energy efficiency is a cost-effective way to help address the rising demands of sustainable growth and development, as well as energy access and security. It reduces costs for businesses and households. We have agreed an Action Plan for Voluntary Collaboration on Energy Efficiency, including new work on the efficiency and emissions performance of vehicles, particularly heavy duty vehicles; networked devices; buildings; industrial processes; and electricity generation; as well as work on financing for energy efficiency. We reaffirm our commitment to rationalise and phase out inefficient fossil fuel subsidies that encourage wasteful consumption, recognising the need to support the poor.

19. We support strong and effective action to address climate change. Consistent with the United Nations Framework Convention on Climate Change (UNFCCC) and its agreed outcomes, our actions will support sustainable development, economic growth, and certainty for business and investment. We will work together to adopt successfully a protocol, another legal instrument or an agreed outcome with legal force under the UNFCCC that is applicable to all parties at the 21st Conference of the Parties (COP21) in Paris in 2015. We encourage parties that are ready to communicate their intended nationally determined contributions well in advance of COP21 (by the first quarter of 2015 for those parties ready to do so). We reaffirm our support for mobilising finance for adaptation and mitigation, such as the Green Climate Fund.

20. We are deeply concerned with the humanitarian and economic impact of the Ebola outbreak in Guinea, Liberia and Sierra Leone. We support the urgent coordinated international response and have committed to do all we can to contain and respond to this crisis. We call on international financial institutions to assist affected countries in dealing with the economic impacts of this and other humanitarian crises, including in the Middle East.

21. We remain resolute in our commitment to lift economic growth, support job creation, promote development and build global confidence. We thank Australia for its leadership this year. We look forward to working together in 2015 under Turkey's presidency and to discussing progress at our next meeting in Antalya on 15-16 November 2015. We also look forward to meeting in China in 2016.

Annex

Agreed documents

The following documents agreed by the G20 support our communiqué:

- Brisbane Action Plan, November 2014
- G20 Note on the Global Infrastructure Initiative and Hub, November 2014
- 2014 Financial Inclusion Action Plan, November 2014
- G20 Plan to Facilitate Remittance Flows, November 2014
- G20 Food Security and Nutrition Framework, November 2014
- Development Working Group Accountability Framework, November 2014
- 2015-16 G20 Anti-Corruption Action Plan, November 2014
- G20 High-Level Principles on Beneficial Ownership Transparency, November 2014
- G20 Principles on Energy Collaboration, November 2014
- G20 Energy Efficiency Action Plan, November 2014
- The 2015 G20 Accountability Assessment Process, November 2014
- 2014 Accountability Assessment Report, November 2014

Ministerial statements

- Communiqué, Meeting of G20 Finance Ministers and Central Bank Governors, Cairns, 20-21 September 2014

- G20 Labour and Employment Ministerial Declaration, Melbourne, 10-11 September 2014, including G20 Statement on Safer and Healthier Workplaces
- Chairman's Summary, Meeting of G20 Trade Ministers, Sydney, 29 July 2014
- Communiqué, Meeting of G20 Finance Ministers and Central Bank Governors, Washington DC, 10-11 April 2014
- Communiqué, Meeting of G20 Finance Ministers and Central Bank Governors, Sydney, 22-23 February 2014

Supporting documents

We welcome the delivery of the following documents:

- G20 Members' Comprehensive Growth Strategies, November 2014
- G20 Members' Country Employment Plans, November 2014
- IMF Surveillance Note, November 2014
- Quantifying the Impact of G-20 Members' Growth Strategies, OECD/IMF report, November 2014
- Growth Strategies: G20 Emerging Market Economies – World Bank Group Assessment, November 2014
- Global Infrastructure Facility: Update for G20 Leaders, World Bank Group, November 2014
- G20/OECD Report on Effective Approaches to Support Implementation of the G20/OECD High-Level Principles on Long-Term Investment Financing by Institutional Investors, and Annex, November 2014
- Report on G20 Trade and Investment Measures, WTO, OECD, and UNCTAD, November 2014
- G20 Labour Markets: Outlook, Key Challenges and Policy Responses, OECD, ILO and World Bank Group, November 2014
- Opportunities for Economic Growth and Job Creation in Relation to Food Security and Nutrition, FAO and OECD (with inputs from ADB, IFAD, ILO, IFPRI and WTO), September 2014
- Financial Reforms: Completing the Job and Looking Ahead, Financial Stability Board Chairman's Letter to G20 Leaders, November 2014
- Adequacy of loss-absorbing capacity of global systemically important banks in resolution, Financial Stability Board, November, 2014
- Cross-Border Recognition of Resolution Action, Financial Stability Board, September 2014
- Updated G20 Roadmap towards Strengthened Oversight and Regulation of Shadow Banking in 2015, Financial Stability Board, November 2014
- Report to the G20 Brisbane Summit on the FSB's review of the structure of its representation, Financial Stability Board, November 2014
- OECD Secretary-General's Report to G20 Leaders on Tax Matters, November 2014
- International Organisations' proposal for structured dialogue process with developing countries on tax matters, November 2014

These documents are in addition to those delivered to G20 Finance Ministers and Central Bank Governors, Labour and Employment Ministers, and Trade Ministers at their meetings this year.

G20 Working Group reports

- G20 2014 Brisbane Anti-Corruption Update
- 2014 Brisbane Development Update
- G20 Energy Sustainability Working Group 2014 Co-chairs' Report
- G20 Climate Finance Study Group – Report to Ministers, 2014

Issues for further action

- The FSB proposal for an internationally agreed standard requiring global systemically important banks (G-SIBs) to hold additional loss absorbing capacity in resolution will be subject to public consultation, a rigorous quantitative impact assessment and further refinement before any final measure is agreed by the 2015 Summit. The impact analyses will include consideration of the consequences of this requirement on banks in emerging markets, G-SIBs headquartered in EMEs, and state-owned banks.
- Given the challenges litigation poses and in order to strengthen the orderliness and predictability of the sovereign debt restructuring process, we welcome the international work on strengthened collective action and pari passu clauses. We call for their inclusion in international sovereign bonds and encourage the international community and private sector to actively promote their use. We ask our Finance Ministers and Central Bank Governors to discuss the progress achieved on this and related issues.
- If the US does not ratify the 2010 IMF reforms by end-2014, we ask the IMF to discuss options for next steps shortly thereafter and we ask our Finance Ministers and Central Bank Governors to work with the IMFC to schedule a discussion on these options in their next meeting.

Acknowledgements

We thank international organisations, including the IMF, OECD, World Bank Group, WTO, ILO, FSB and UN, for their reports and recommendations, which have provided valuable inputs to G20 discussions.

We thank the Business 20, Civil Society 20, Labour 20, Think 20 and Youth 20 for their important contribution to the G20's work.

Royal Society of Canada
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United States of America

2015
Antalya, TÜRKİYE
G-20

G20 LEADERS' COMMUNIQUÉ
ANTALYA SUMMIT, 15-16 NOVEMBER 2015

Introduction

1. We, the Leaders of the G20, met in Antalya on 15-16 November 2015 to determine further collective actions towards achieving strong, sustainable and balanced growth to raise the prosperity of our people. We are firm in our resolve to ensure growth is robust and inclusive, and delivers more and better quality jobs. We recognize that advancing inclusive growth and entrenching confidence require the use of all policy tools and strong engagement with all stakeholders.
2. In pursuing our objectives, we have adopted a comprehensive agenda this year around the three pillars of decisive implementation of our past commitments to deliver on our promises, boosting investments as a powerful driver of growth and promoting inclusiveness in our actions so that the benefits of growth are shared by all. We have also enhanced our dialogue with low income developing countries as part of our implementation of this agenda.

Strengthening the Recovery and Lifting the Potential

3. Global economic growth is uneven and continues to fall short of our expectations, despite the positive outlook in some major economies. Risks and uncertainties in financial markets remain, and geopolitical challenges are increasingly becoming a global concern. In addition, a shortfall in global demand and structural problems continue to weigh on actual and potential growth.
4. We will continue to implement sound macroeconomic policies in a cooperative manner to achieve strong, sustainable and balanced growth. Our monetary authorities will continue to ensure price stability and support economic activity, consistent with their mandates. We reiterate our commitment to implement fiscal policies flexibly to take into account near-term economic conditions, so as to support growth and job creation, while putting debt as a share of GDP on a sustainable path. We will also consider the composition of our budget expenditures and revenues to support productivity, inclusiveness and growth.

We remain committed to promote global rebalancing. We will carefully calibrate and clearly communicate our actions, especially against the backdrop of major monetary and other policy decisions, to mitigate uncertainty, minimize negative spillovers and promote transparency. Against the background of risks arising from large and volatile capital flows, we will promote financial stability through appropriate frameworks, including by ensuring an adequate global financial safety net, while reaping the benefits of financial globalization. We reaffirm our previous exchange rate commitments and will resist all forms of protectionism.

5. We remain committed to achieving our ambition to lift collective G20 GDP by an additional 2 percent by 2018 as announced in Brisbane last year. Our top priority is timely and effective implementation of our growth strategies that include measures to support demand and structural reforms to lift actual and potential growth, create jobs, promote inclusiveness and reduce inequalities. We have made significant progress towards fulfilling our commitments since last year, implementing half of our multi-year commitments. Analysis by the IMF, OECD and World Bank Group indicates that our implementation so far represents more than one third of our collective growth ambition. Yet we also acknowledge that more needs to be done. We will strive more and take prompt action to expedite implementation of our remaining commitments. Going forward, we will continue to closely monitor the implementation of our commitments through the robust framework we developed this year. We will also continue reviewing and adjusting our growth strategies to ensure that they remain relevant to evolving economic conditions, policy priorities and structural challenges, in particular slow productivity growth, and that they remain consistent with our collective growth ambition. The Antalya Action Plan, comprising our adjusted growth strategies and implementation schedules for key commitments, reflects our determination to overcome global economic challenges.
6. We are committed to ensure that growth is inclusive, job-rich and benefits all segments of our societies. Rising inequalities in many countries may pose risks to social cohesion and the well-being of our citizens and can also have negative economic impact and hinder our objective to lift growth. A comprehensive and balanced set of economic, financial, labour, education and social policies will contribute to reducing inequalities. We endorse the Declaration of our Labour and Employment Ministers and commit to implementing its priorities to make labour markets more inclusive as outlined by the G20 Policy Priorities on Labour Income Share and Inequalities. We ask our Finance, and Labour and Employment Ministers to review our growth strategies and employment plans to strengthen our action against inequality and in support of inclusive growth. Recognizing that social dialogue is essential to advance our goals, we welcome the B20 and L20 joint statement on jobs, growth and decent work.

7. Unemployment, underemployment and informal jobs are significant sources of inequality in many countries and can undermine the future growth prospects of our economies. We are focused on promoting more and better quality jobs in line with our G20 Framework on Promoting Quality Jobs and on improving and investing in skills through our G20 Skills Strategy. We are determined to support the better integration of our young people into the labour market including through the promotion of entrepreneurship. Building on our previous commitments and taking into account our national circumstances, we agree to the G20 goal of reducing the share of young people who are most at risk of being permanently left behind in the labour market by 15% by 2025 in G20 countries. We ask the OECD and the ILO to assist us in monitoring progress in achieving this goal. We will continue monitoring the implementation of our Employment Plans as well as our goals to reduce gender participation gap and to foster safer and healthier workplaces also within sustainable global supply chains.
8. We will address current opportunities and challenges brought into the labour markets through such issues as international labour mobility and the ageing of populations. Domestic labour mobility is an important labour market issue in some G20 countries. We recognize and will further explore the potential of a flourishing silver economy. We further ask our Labour and Employment Ministers to report to us on progress made in 2016.
9. To provide a strong impetus to boost investment, particularly through private sector participation, we have developed ambitious country-specific investment strategies, which bring together concrete policies and actions to improve the investment ecosystem, foster efficient and quality infrastructure, including by the public sector, support small and medium sized enterprises (SMEs), and enhance knowledge sharing. Analysis by the OECD indicates that these strategies would contribute to lifting the aggregate G20 investment to GDP ratio, by an estimated 1 percentage point by 2018.
10. To improve our investment preparation, prioritization and execution processes, we have developed guidelines and best practices for public-private-partnership (PPP) models. We also considered alternative financing structures, including asset-based financing, and simple and transparent securitization to facilitate better intermediation for SMEs and infrastructure investment. Going forward, we call on our Ministers to continue their work to improve the investment ecosystem, promote long-term financing, foster institutional investors' involvement, support the development of alternative capital market instruments and asset-based financing models, and encourage Multilateral Development Banks (MDBs) to mobilize their resources, optimize their balance sheets, and catalyze private sector funding. We are advancing efforts and developing toolkits to unlock the ways and means for countries to better prepare, prioritize and finance infrastructure projects. We expect

the Global Infrastructure Hub to make a significant contribution towards these endeavors. To help ensure a strong corporate governance framework that will support private investment, we endorse the G20/OECD Principles of Corporate Governance. We have placed a special focus on promoting long-term financing for SMEs, and we welcome the Joint Action Plan on SME Financing, the G20/OECD High-Level Principles on SME Financing as guidance, and the establishment of the private sector-led World SME Forum, a new initiative that will serve as a global body to facilitate the contributions of SMEs to growth and employment.

11. Global trade and investment continue to be important engines of economic growth and development, generating employment and contributing to welfare and inclusive growth. We note that global trade growth remains below pre-crisis levels. This is a result of both cyclical and structural factors. We therefore reaffirm our strong commitment to better coordinate our efforts to reinforce trade and investment, including through our Adjusted Growth Strategies. Inclusive Global Value Chains (GVCs) are important drivers of world trade. We support policies that allow firms of all sizes, particularly SMEs, in countries at all levels of economic development to participate in and take full advantage of GVCs and encourage greater participation and value addition by developing countries. We further reaffirm our longstanding commitment to standstill and rollback on protectionist measures and will remain vigilant by monitoring our progress. For this, we ask the WTO, OECD and UNCTAD to continue their reporting on trade and investment restrictive measures. We ask our Trade Ministers to meet on a regular basis and we agree on a supporting working group.
12. The WTO is the backbone of the multilateral trading system and should continue to play a central role in promoting economic growth and development. We remain committed to a strong and efficient multilateral trading system and we reiterate our determination to work together to improve its functioning. We are committed to working together for a successful Nairobi Ministerial Meeting that has a balanced set of outcomes, including on the Doha Development Agenda, and provides clear guidance to post-Nairobi work. We will also need to increase our efforts to implement all the elements of the Bali Package, including those on agriculture, development, public stock holding as well as the prompt ratification and implementation of the Trade Facilitation Agreement. We will continue our efforts to ensure that our bilateral, regional and plurilateral trade agreements complement one another, are transparent and inclusive, are consistent with and contribute to a stronger multilateral trade system under WTO rules. We emphasize the important role of trade in global development efforts and will continue to support mechanisms such as aid for trade in developing countries in need of capacity building assistance.

Enhancing resilience

13. Strengthening the resilience of financial institutions and enhancing stability of the financial system are crucial to sustaining growth and development. To enhance the resilience of the global financial system, we have completed further core elements of the financial reform agenda. In particular, as a key step towards ending too-big-to-fail, we have finalized the common international standard on total loss absorbing capacity (TLAC) for global systemically important banks. We also agreed to the first version of higher loss absorbency requirements for global systemically important insurers.
14. Critical work remains to build a stronger and more resilient financial system. In particular, we look forward to further work on central counterparty resilience, recovery planning and resolvability and ask the FSB to report back to us by our next meeting. We will continue to monitor and, if necessary, address emerging risks and vulnerabilities in the financial system, many of which may arise outside the banking sector. In this regard, we will further strengthen oversight and regulation of shadow banking to ensure resilience of market-based finance, in a manner appropriate to the systemic risks posed. We look forward to further progress in assessing and addressing, as appropriate, the decline in correspondent banking services. We will expedite our efforts to make further progress in implementing the over-the-counter (OTC) derivatives' reforms, including by encouraging jurisdictions to defer to each other, when it is justified in line with the St. Petersburg Declaration. Going forward, we are committed to full and consistent implementation of the global financial regulatory framework in line with the agreed timelines, and will continue to monitor and address uneven implementation across jurisdictions. We welcome the FSB's first annual report on the implementation of reforms and their effects. We will continue to review the robustness of the global regulatory framework and to monitor and assess the implementation and effects of reforms and their continued consistency with our overall objectives, including by addressing any material unintended consequences, particularly for emerging markets and developing economies (EMDEs).
15. To reach a globally fair and modern international tax system, we endorse the package of measures developed under the ambitious G20/OECD Base Erosion and Profit Shifting (BEPS) project. Widespread and consistent implementation will be critical in the effectiveness of the project, in particular as regards the exchange of information on cross-border tax rulings. We, therefore, strongly urge the timely implementation of the project and encourage all countries and jurisdictions, including developing ones, to participate. To monitor the implementation of the BEPS project globally, we call on the OECD to develop an inclusive framework by early 2016 with the involvement of interested non-G20 countries and jurisdictions which commit to implement the BEPS project,

including developing economies, on an equal footing. We welcome the efforts by the IMF, OECD, UN and WBG to provide appropriate technical assistance to interested developing economies in tackling the domestic resource mobilization challenges they face, including from BEPS. We acknowledge that interested non-G20 developing countries' timing of implementation may differ from other countries and expect the OECD and other international organizations to ensure that their circumstances are appropriately addressed in the framework. We are progressing towards enhancing the transparency of our tax systems and we reaffirm our previous commitments to information exchange on-request as well as to automatic exchange of information by 2017 or end-2018. We invite other jurisdictions to join us. We support the efforts for strengthening developing economies' engagement in the international tax agenda.

16. In support of our growth and resilience agenda, we remain committed to building a global culture of intolerance towards corruption through effectively implementing the 2015-2016 G20 Anti-Corruption Action Plan. We endorse the G20 High-Level Principles on Integrity and Transparency in the Private Sector which will help our companies comply with global standards on ethics and anti-corruption. Ensuring the integrity and transparency of our public sectors is essential. In this regard, we endorse the G20 Anti-Corruption Open Data Principles and the G20 Principles for Promoting Integrity in Public Procurement, and we welcome the ongoing work on asset disclosure frameworks. We will further work to strengthen international cooperation, including where appropriate and consistent with domestic legal systems, on civil and administrative procedures, as an important tool to effectively combat bribery and to support asset recovery and the denial of safe haven to corrupt officials and those who corrupt them. We welcome the publication of our Implementation Plans on beneficial ownership transparency and will continue our efforts in this regard.
17. We remain deeply disappointed with the continued delay in implementing the IMF quota and governance reforms agreed in 2010. The 2010 reforms remain our highest priority for the IMF and we urge the United States to ratify these reforms as soon as possible. Mindful of the aims of the 2010 reforms, we ask the IMF to complete its work on an interim solution that will meaningfully converge quota shares as soon as and to the extent possible to the levels agreed under the 14th General Review of Quotas. The 14th Review should be used as a basis for work on the 15th Review, including a new quota formula. We reaffirm our commitment to maintaining a strong, quota-based and adequately resourced IMF. We reaffirm our agreement that the heads and senior leadership of all international financial institutions should be appointed through an open, transparent and merit-based process and we reiterate the importance of enhancing staff diversity in these organizations. We reaffirm

that the Special Drawing Rights (SDR) basket composition should continue to reflect the role of currencies in the global trading and financial system and look forward to the completion of the review of the method of valuation of the SDR.

18. We welcome the progress achieved on the implementation of strengthened collective action and pari passu clauses in international sovereign bond contracts, which will contribute to the orderliness and predictability of sovereign debt restructuring processes. We ask the IMF, in consultation with other parties, to continue promoting the use of such clauses and to further explore market-based ways to speed up their incorporation in the outstanding stock of international sovereign debt. We look forward to the upcoming review of the IMF-WB Debt Sustainability Framework for Low-Income Countries. We acknowledge the existing initiatives aimed at improving sustainable financing practices, as stressed in the Addis Ababa Action Agenda. We also take note of the Paris Forum initiative, which contributes to further the inclusiveness by fostering dialogue between sovereign debtors and creditors.

Buttressing Sustainability

19. 2015 is a crucial year for sustainable development and we remain committed to ensuring our actions contribute to inclusive and sustainable growth, including in low income developing countries. The 2030 Agenda, including the Sustainable Development Goals (SDGs) and the Addis Ababa Action Agenda, sets a transformative, universal and ambitious framework for global development efforts. We are strongly committed to implementing its outcomes to ensure that no-one is left behind in our efforts to eradicate poverty and build an inclusive and sustainable future for all. We adopt the G20 and Low Income Developing Countries Framework to strengthen our dialogue and engagement on development. We will develop an action plan in 2016 to further align our work with the 2030 Agenda.
20. Our work this year supports key areas for sustainable development such as energy access, food security and nutrition, human resource development, quality infrastructure, financial inclusion and domestic resource mobilization. We endorse the G20 Action Plan on Food Security and Sustainable Food Systems, which underlines our commitment to improve global food security and nutrition and ensure the way we produce, consume and sell food is economically, socially and environmentally sustainable. We remain focused on promoting responsible investment in agriculture and food systems, improving market transparency, increasing incomes and quality jobs, and fostering sustainable productivity growth. We will pay particular attention to the needs of smallholder and family farmers, rural women and youth. We also commit to reducing food loss and waste globally. We welcome Expo Milano with the theme "Feeding the Planet-Energy for Life". We also welcome our Agriculture

Ministers´ decision to establish a new platform to improve the way we and other countries can measure and reduce food loss and waste.

21. The private sector has a strong role to play in development and poverty eradication. Through our G20 Call on Inclusive Business we stress the need of all stakeholders to work together in order to promote opportunities for low income people and communities to participate in markets as buyers, suppliers and consumers. Our G20 National Remittance Plans developed this year include concrete actions towards our commitment to reduce the global average cost of transferring remittances to five percent with a view to align with the SDGs and Addis Ababa Action Agenda. We are promoting financial inclusion by helping to open up access to payments, savings, credit and other services. We welcome the continued work on financial inclusion within the Global Partnership for Financial Inclusion (GPFI).
22. We remain focused on the G20 Principles on Energy Collaboration and welcome our Energy Ministers´ first meeting ever. Recognizing that globally over 1.1 billion people lack access to electricity and 2.9 billion rely on the traditional use of biomass for cooking, we endorse the G20 Energy Access Action Plan: Voluntary Collaboration on Energy Access, the first phase of which focuses on enhancing electricity access in Sub-Saharan Africa where the problem is most acute. The Plan aims to strengthen G20 coordination and establishes a long-term voluntary cooperation framework that can be applied to other regions over time, recognising that energy access is a critical factor to foster development. In this first phase, we will cooperate and collaborate with African countries and relevant regional and international organizations on policy and regulatory environments, technology development and deployment, investment and finance, capacity building, regional integration and cooperation, taking into consideration national needs and contexts.
23. We recognize that actions on energy, including improving energy efficiency, increasing investments in clean energy technologies and supporting related research and development activities will be important in tackling climate change and its effects. We endorse the G20 Toolkit of Voluntary Options for Renewable Energy Deployment. We also highlight the progress made this year by participating countries in taking forward our collaboration on energy efficiency and agree to further support on a voluntary basis the 2015 outcomes of existing work streams on efficiency and emissions performance of vehicles, particularly heavy duty vehicles, networked devices, buildings, industrial processes and electricity generation, as well as financing for energy efficiency. We will continue to promote transparent, competitive and well-functioning energy markets, including gas markets. We stress the importance of diversification of energy sources and continued investments for increased energy security. We reaffirm our commitment to rationalise and phase-out inefficient fossil fuel subsidies that encourage wasteful consumption, over the

medium term, recognising the need to support the poor. We will endeavour to make enhanced progress in moving forward this commitment. We ask our Energy Ministers to report back on energy collaboration again in 2016 on the continued implementation of the G20 Principles on Energy Collaboration.

24. Climate change is one of the greatest challenges of our time. We recognize that 2015 is a critical year that requires effective, strong and collective action on climate change and its effects. We reaffirm the below 20C goal as stated in the Lima Call for Action. We affirm our determination to adopt a protocol, another legal instrument or an agreed outcome with legal force under the UNFCCC that is applicable to all Parties. Our actions will support growth and sustainable development. We affirm that the Paris agreement should be fair, balanced, ambitious, durable and dynamic. We underscore our commitment to reaching an ambitious agreement in Paris that reflects the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances. We reaffirm that UNFCCC is the primary international intergovernmental body for negotiating climate change. We welcome that over 160 Parties including all G20 countries have submitted their Intended Nationally Determined Contributions (INDCs) to the UNFCCC, and encourage others to do so in advance of the Paris Conference. We are prepared to implement our INDCs. We will instruct our negotiators to engage constructively and flexibly in the coming days to discuss key issues, among other things, mitigation, adaptation, finance, technology development and transfer and transparency in order to arrive at Paris with a way forward. We commit to work together for a successful outcome of the COP21.
25. The scale of the ongoing refugee crisis is a global concern with major humanitarian, political, social and economic consequences. There is a need for a coordinated and comprehensive response to tackle this crisis, as well as its long term consequences. We commit to continue further strengthening our support for all efforts to provide protection and assistance and to find durable solutions for the unprecedented numbers of refugees and internally displaced persons in various parts of the world. We call upon all states to contribute to responding to this crisis, and share in the burdens associated with it, including through refugee resettlement, other forms of humanitarian admission, humanitarian aid and efforts to ensure that refugees can access services, education and livelihood opportunities. We underline the need to address the root causes of displacement. We highlight, in this regard, the importance of political solutions to conflicts and increased cooperation for development. We also recognize the importance of creating conditions to enable refugees and internally displaced persons to safely and voluntarily return to their homes. We will work with other states to strengthen our long term preparedness and capacity to manage migration and refugee flows. We invite all states according to their individual capacities to scale up their assistance

to relevant international organizations in order to enhance their capabilities to assist affected countries in dealing with this crisis. We encourage the private sector and individuals to also join in the international efforts to respond to the refugee crisis.

26. We are living in an age of Internet economy that brings both opportunities and challenges to global growth. We acknowledge that threats to the security of and in the use of ICTs, risk undermining our collective ability to use the Internet to bolster economic growth and development around the world. We commit ourselves to bridge the digital divide. In the ICT environment, just as elsewhere, states have a special responsibility to promote security, stability, and economic ties with other nations. In support of that objective, we affirm that no country should conduct or support ICT-enabled theft of intellectual property, including trade secrets or other confidential business information, with the intent of providing competitive advantages to companies or commercial sectors. All states in ensuring the secure use of ICTs, should respect and protect the principles of freedom from unlawful and arbitrary interference of privacy, including in the context of digital communications. We also note the key role played by the United Nations in developing norms and in this context we welcome the 2015 report of the UN Group of Governmental Experts in the Field of Information and Telecommunications in the Context of International Security, affirm that international law, and in particular the UN Charter, is applicable to state conduct in the use of ICTs and commit ourselves to the view that all states should abide by norms of responsible state behaviour in the use of ICTs in accordance with UN resolution A/C.1/70/L.45. We are committed to help ensure an environment in which all actors are able to enjoy the benefits of secure use of ICTs.

Conclusion

27. We remain resolute to continue our collective action to lift actual and potential growth of our economies, support job creation, strengthen resilience, promote development and enhance inclusiveness of our policies. We thank Turkey for its G20 Presidency and hosting a successful Antalya Summit this year. We look forward to our next meeting in Hangzhou in September 2016 under the Chinese Presidency. We also look forward to meeting in Germany in 2017.

G7 SCIENCE ACADEMIES' STATEMENT 2015: FUTURE OF THE OCEAN: IMPACT OF HUMAN ACTIVITIES ON MARINE SYSTEMS

Human activities are driving major changes in the oceans of the world. One key driver of changes is elevated carbon dioxide (CO2) concentration in the atmosphere caused by human activities. This leads to ocean acidification, warming and deoxygenation, changes in ocean circulation, continued sea level rise, and an altered marine productivity and biodiversity. Other key drivers are pollution with nutrients, chemicals and plastic, overfishing and spreading of invasive species. All of the changes in the ocean have profound effects on human wellbeing and human societies in many regions of the Earth. The G7 Academies of Sciences call for: (1) changing the course of nations' CO2 emissions, (2) reducing and further regulating man-made pollution of the sea, (3) ending overfishing and pre- serving marine biodiversity and ecosystem function through research-based management and (4) enhancing international scientific cooperation to better predict, manage and mitigate future changes in the ocean, and their impacts on human societies and the environment.

The ocean covers over two-thirds of the earth's surface, plays a vital role in global biogeochemical cycles and supports much of the planet's biodiversity. It provides a livelihood for millions of people and makes an increasing contribution to feeding a rapidly growing population. It now faces two categories of threat:

1. Threats related primarily to greenhouse gas emissions, including ocean temperature and sea level rise, ocean acidifi- cation, stratification and changes in ocean circulation, which will alter the productivity of the ocean as a whole.

2. Other threats that are regional to global, including flooding, chemical, nutrient and plastic pollution that ends up in the ocean, overfishing, extraction of resources such as oil, gas and minerals, habitat destruction and other human activity such as construction of large coastal infrastructures.

These and other changes are already imposing increasingly severe effects on biodiversity, marine productivity as well as on human populations and activities, especially in coastal zones and islands.

The ocean has a very large heat capacity and is currently storing more than 90 % of the additional heat associated with global warming, which it redistributes from one region to another on time scales ranging from years to several decades. The ocean is also currently absorbing one quarter to one-third of emitted fossil fuel CO2. Net carbon uptake by the ocean will occur as long as human activities are adding CO2 to the atmosphere and until the equilibrium between the atmosphere and ocean is re-established. Accordingly, the ultimate fate for most CO2 derived from fossil fuel will be its dissolution in the world's surface waters, followed by its transfer into the deep ocean, where much of it will be neutralised by reaction with sedimentary carbonate on the deep sea floor. However, as this process takes tens of thou- sands of years, it is too slow to dampen the consequences of CO2 increase for the coming generations.

The uptake of CO2 into surface waters is causing a number of interrelated changes in ocean chemistry, including an increase in ocean acidity. The full impacts of these changes on key marine ecosystems are only beginning to be understood but include impacts on energy balance, physiology, behavior and survival of many marine organisms. Of particular concern is the ability of marine plants and animals to construct their calcium carbonate shells or skeletons. Thus the ocean's uptake of CO2 comes with potentially serious impacts on biodiversity, food webs and marine ecosystem services, including fisheries.

Global warming itself is altering surface water temperatures and thus changing the solubility of CO2 and oxygen (O2) in ocean water, as well as altering the ocean's density stratification and circulation patterns. Global warming induces changes in ocean circulation especially in polar regions. This is highlighted by the retreat of summer sea ice in the Arctic Ocean and dramatic trends in climate and marine life in the coastal waters of the Antarctic Peninsula. These polar changes may lead to further changes in weather, climate and ecosystems throughout the world, as is already evident on a regional scale in the form of droughts and other weather extremes.

The global mean sea level is currently rising in response to ocean warming and the melting of land ice, and will continue to rise at an accelerated rate in the coming decades and centuries. By 2100, a global mean rise of at least 1 m above the present level and up to 1.4 m in some regions is likely. Societal impacts are likely to include shoreline recession, changes in extreme sea levels (e.g. flooding from storm surge), and loss of coastal infrastructure, natural resources and biodiversity.

These impacts will lead eventually to increased costs, the displacement of people and the migration of environmental refugees.

The circulation and mixing of the ocean supplies oxygen and nutrients essential for growth of marine organisms. The expected physical changes will therefore impact ocean productivity, biodiversity, ecosystem functions and fisheries. Human activities on land are injecting pollutants into coastal marine environments, including nutrients that lead to excessive algae blooms, which sink and decay, further lowering oxygen and creating "dead zones" in coastal waters. Waste products such as non-biodegradable marine litter and toxic chemicals can accumulate in the food chain with yet unknown consequences for the health of consumers of ocean products, including humans. Plastic debris accumulates in the ocean at all depths with detrimental consequences for marine life. Introduction of non-native species can disrupt ecosystems and impact fisheries and tourism.

Overfishing is a serious global problem that damages biodiversity and productivity, hence the future of fisheries as well as resilience of ocean ecosystems. Recent evidence suggests it is possible to end overfishing and recover many depleted fisheries resulting in economic, social and environmental benefits. Illegal, unreported and unregulated fishing undermines fishery management and threatens food security and ocean resilience. Human activities in coastal areas, including coastline alteration and aquaculture, also play a role in damaging marine ecosystems, increasing their vulnerability and exacerbating the often combined impacts of warming, ocean acidification, pollution and nutrient enrichment.

In order to avoid the most serious adverse impacts that are foreseen, the following actions are necessary:

1. *Change the course of nations' CO2 emissions*

- Accelerate the transformation to a carbon-free economy by reducing emissions at a national level.

- Include the ocean in environmental policies, including sustainability concepts for the use of materials and goods.

- Enforce the goals of the UN Framework Convention on Climate Change (UNFCCC), overcoming short-term economic considerations that ignore short- and long-term costs of climate and ocean changes.

2. *Take actions to reduce and further regulate man-made pollution of the sea*

- Reduce the use of fertilisers, the discharge of human and animal sewage, the generation of nutrients from aquaculture. Improve wastewater management in watersheds.

- Halt the dumping and regulate the discharge of waste and toxic materials. Take urgent action to reduce the input of plastic debris from all sources into the marine system.

- Reduce inadvertent transport of non-native species via global shipping and aquaculture. Strengthen the regulation of ballast water release.

- Implement high global standards in all aspects of maritime activities by national and international regulations, and improve the coordination of maritime surveillance and scientific ocean observation.

3. *End overfishing and protect marine biodiversity and ecosystem function through research-based responsible management*

- Conserve and restore natural fish populations and the ecosystems on which they depend and establish networks of marine protected areas, including the high seas.

- Manage fisheries in a sustainable way and strive to eliminate illegal, unregulated and unreported fishing.

4. *Enhance international scientific cooperation to better predict, manage and mitigate future changes in the ocean and their impacts on human societies and the environment*

- Provide leadership in strengthening and catalysing interna- tional collaborations. Improve access to study sites, and to data and models, to enhance our knowledge of the ocean's physical, chemical and biological dynamics and interactions between human wellbeing and ocean ecosystems.

- Increase international coordination and provide required infrastructure and capacity building for sustained ocean observation.

G7 SCIENCE ACADEMIES' STATEMENT 2015: INFECTIOUS DISEASES AND ANTIMICROBIAL RESISTANCE: THREATS AND NECESSARY ACTIONS

Emerging infectious diseases and antimicrobial resistance seriously endanger individual and global health. A comprehensive strategy is needed to tackle health threats from infectious diseases – one that requires a much more visible political and public profile and a cross-sectoral approach, involving health, agriculture, development, economy and other policy areas. The G7 Academies of Sciences call for: (1) accelerating research and production of new antimicrobial agents, vaccines and diagnostics, (2) prioritising the research agenda to fill knowledge gaps for key diseases, (3) installing global surveillance programmes, (4) raising awareness in society, and (5) a coordinated rapid response in the face of major epidemics. Only then can the necessary resources be generated to ensure optimal prevention, diagnosis, and treatment for all.

The recent Ebola outbreak shows that emerging and re-emerging infectious diseases continue to pose a serious international threat despite major research advances in recent years. At the same time, there is an alarming global trend towards resistance to antimicrobial drugs. In our increasingly interconnected world, pathogens spread quickly and across borders, posing a growing threat to global health and prosperity.

The current situation is serious and untenable. There is a strong need for new classes of antimicrobials, vaccines, and diagnostics for infectious diseases. However, industry alone will not solve this problem because of a perceived low return of investment. Therefore, there is an urgent need to stimulate research and development for novel approaches to disease prevention and treatment.

The rise of resistance to antimicrobial agents and the resurgence of significant communicable diseases such as tuberculosis are putting at risk the achievements of modern medicine, the health of societies, and the realisation of the Millennium Development Goals. The underlying scientific basis of this resurgence is often well understood, and there has been considerable international work on antimicrobial resistance in the past year [1]. But international coordination is urgently needed to control outbreaks that stretch beyond geographic borders.

The statement signed by the G8 Science Ministers after discussion with the G8 Science Academies' Presidents in 2013 was a significant contribution to this issue [2].However, much more needs to be done to tackle the devastating human health problems caused by infectious diseases.

The G7 Academies have identified critical actions needed to address the immediate threats of infectious diseases. They emphasise the importance of international collaboration that integrates both the scientific community and industry.

The following actions are necessary:

1. *Accelerate the discovery, registration and production of new antimicrobial agents, vaccines and diagnostics*

1. Identify and implement new sources of support, including public-private partnerships to enhance the likelihood that interventions will reach the proof-of-principle stage.

2. Develop novel antimicrobials and vaccines for key diseases and evaluate ways to keep them in reserves until they are needed. Antibiotics that have not been previously released are less likely to encounter resistance from disease-causing organisms. Vaccines developed for novel diseases will be ready for efficacy testing during an epidemic. Establishing reserves for future use could create new business models for pharmaceutical companies.

3. Develop attractive business models and other incentives to increase efforts in academia and revive commercial interest.

Accelerate the development of diagnostics, vaccines and therapeutics to better meet the threat from highly dangerous pathogens.

2. *Fill knowledge gaps and prioritise the research agenda*

a. Identify and fill the gaps in basic research and ensure that results from applied research are transformed into effective interventions (and thus survive the "valley of death").

b. Identify microbes from diverse habitats as a source of new antimicrobial agents also on the basis of genetic inventories. In addition, identify and validate new biological targets and elucidate novel modes of action.

c. Study and elucidate the ecological and evolutionary dynamics of microbial

communities to prevent and understand mechanisms of resistance. This will require scaling up laboratory experiments to real-life situations as found in farms, hospitals and the community.

Develop innovative strategies for prevention and rapid diagnosis of infection.

3. *Conduct global infectious disease surveillance programmes*

a. Invest in and enhance global infectious disease surveillance of both humans and animals to improve timely prediction and rapid response to outbreaks.

b. Harmonise national programmes and define global action plans for the surveillance of particularly threatening pathogens.

c. Support implementation of the World Health Organization's Global Action Plans, e.g., the Plan on Antimicrobial Resistance.

4. *Organise and sustain joint efforts in society*

a. Commit to improving and sustaining health care systems in vulnerable populations accompanied with capacity building for health and health research at regional, national and international levels. Regulate the use of antibiotics in medicine and agriculture.

b. Continue to develop tailored public outreach efforts for educating the public on the development of resistance, prevention and effective management of infections. Establishing such outreach activities will raise the public's awareness of health threats and the importance of innovation.

c. Continue to increase support for global application of infection prevention and control programmes (such as vaccination, hygiene and sanitation), and ensure access for all – including high-risk groups such as migrant populations – in community care and hospital settings.

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G7 SCIENCE ACADEMIES' STATEMENT 2015: NEGLECTED TROPICAL DISEASES

Neglected Tropical Diseases (NTDs) are a group of infections that affect mainly the poorest and place an economic burden on low- and middle-income countries. In principle, NTDs are preventable, treatable, controllable and some even eradicable. Moreover, most interventions against NTDs are highly cost-effective. To make progress toward preventing, controlling and eliminating NTDs, the G7 Academies of Sciences call for: (1) increasing efforts to empower and build capacity in affected countries to deal with these diseases, (2) intensifying research on NTDs, (3) developing and delivering affordable and accessible treatments, and (4) NTDs to be fully accounted for in the Sustainable Development Goals.

Neglected Tropical Diseases are a group of parasitic, bacterial, and viral infections that cause immense suffering in more than a billion people. These diseases are characterised by insufficient treatment and care. Of the more than 30 NTDs (including Ebola), WHO prioritises 17 diseases with greatest impact including schistosomiasis, lymphatic filariasis, river blindness, dengue and leprosy. NTDs are endemic in 149 countries of the world, most of them low- and middle-income countries. Most NTDs are chronic and can significantly disable particularly the poorest and most vulnerable individuals, households and communities. NTDs place substantial burden on the health and economic systems in affected countries. Although at present no NTD has been controlled, eliminated, or eradicated, progress on many of the most important of these diseases would be a major step towards alleviating poverty[1], [2]. Still, for many NTDs there are too few effective drugs and some mainstream treatments can have severe side effects.

Some progress has been achieved over the past decade: WHO has increased its commitment to NTDs and a recent report[3] calls for increasing domestic investments to reach WHO's Roadmap targets for 17 NTDs by 2020[4].These targets are supported by a specific resolution at the World Health Assembly in May 2013[5].In addition, private and public sector organisations have committed themselves to controlling, eliminating or eradicating 10 NTDs by 2020, by making long-term donations for drugs (with an annual value of US$ 2 billion), by advancing R&D, enhancing collaboration and cooperation at national and

international levels and enabling funding and monitoring programmes[6], [7], [8]. Affected countries now place NTDs higher on their agenda and develop national NTD plans[9], [10]. However, resources for research and/or implementation are still insufficient: NTDs receive only 0.6 % of Official Development Assistance for Health.

Much more needs to be done with a much greater urgency to reach the 2020 targets for all major NTDs. The specificity of diseases as well as the likely adverse impacts of severe climate events, risks of conflicts, increasing mobility/migration, and political instability need to be taken into account when developing strategies for tackling the NTD challenges. NTDs should be fully accounted for in the Sustainable Development Goals.

The following actions are necessary:

1. *Increase efforts to empower and build capacity in affected countries*

a. Invest in empowering national health systems in affected countries, particularly with regard to improving access to treatments and diagnostics to reach universal health coverage. Help the governments of endemic countries in their efforts to inform and raise peoples' awareness on risk factors and prevention of NTDs, taking into account specific cultural practices as well as local and indigenous knowledge.

b. Invest in increasing the capacity in endemic countries for surveillance of patients, vectors, pathogens and animal reservoirs. In particular, foster the One Health-approach to address zoonotic NTDs such as leishmaniasis, and African trypanoso- miasis (sleeping sickness).

c. Promote research cooperation and technology transfer between industrialised and low- and middle-income countries, particularly with the aim to establish research capacities in endemic countries.

2. *Intensify research on NTDs*

a. For progress on prevention, control, treatment, and where possible eradication of NTDs, strengthen basic research, particularly on the biology of infectious agents, the host response and the cross-effects with other diseases. Intensify research on transmitting vectors and intermediate hosts and develop new measures for their control. Study animals as a reservoir for pathogens and assess the importance of closely related pathogens in livestock production.

b. Study how new technologies can be implemented and increase applied and programme-oriented research for diseases targeted for elimination or eradication.

c. Study the full economic effects of NTDs on individuals, house holds and nations to provide more effective and equitable targeting of interventions. Develop an agreed-upon metric to measure the effect of interventions.

3. *Develop and deliver affordable and accessible treatments*

a. Create new and strengthen existing incentives for industry and academia that decouple costs of R&D from the price of products to make treatments for NTDs affordable and accessible.

b. Further develop easily usable and affordable point-of-care technologies. For this purpose, strengthen product development partnerships especially with and in endemic countries.

c. Support the sustainable delivery of treatments and diagnostics by strengthening supply chains of WHO prequalified products.

d. Identify behaviour and conditions that increase the risk of acquiring or exacerbating NTDs. Based on this, develop and provide training and information to the general population.

e. Consider as well nonprioritised NTDs and develop clear metrics to measure the effect of interventions.

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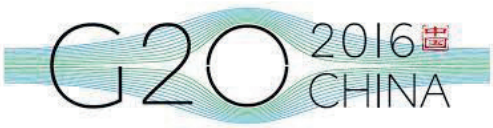

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G-SCIENCE ACADEMIES STATEMENT 2016: NURTURING FUTURE SCIENTISTS

Science is a human endeavor driven by an innate desire to acquire an ever-deeper understanding of the workings of nature and to meet human needs. Throughout history, scientists have continuously increased our knowledge of the world, and their innovations and inventions have immensely improved the human condition. Present-day society relies heavily upon science-based discovery, technology, and policies – whether in information systems, energy management, or disease control. Thus, nurturing future generations of scientists is important for the development of society. How can nations best develop future generations of scientists? The major issues, outlined below, include improving education and career paths in science, encouraging social values in scientists to interact with society, and promoting a diverse workforce with opportunity for women, minorities, and scientists in developing countries. How these fundamental questions are addressed will have an enormous global impact on the future of science in and for society.

Connecting Scientists and Society

Promoting Science Education and Outreach

Science is an essential subject at all educational levels. Exposure to science at the pre-primary, primary and secondary levels is important for learning the values of evidence-based inquiry and for nurturing scientific thinking. This requires training of high-quality science teachers for all school levels and the design of attractive programs and innovative teaching methods. In higher education, students can learn to conduct research, explore specialized disciplines, and establish scientific integrity and professional principles to become responsible scientists in society. The study of science is beneficial for all students whether or not they continue on to scientific careers. Critical thinking and the scientific method should form the core of science curricula at all levels. Inquiry-Based Science Education requires active pedagogy where students become "young researchers" investigating nature and society. Interdisciplinary approaches to education instill versatility, f lexibility, and creativity important for research and other careers.

A key part of science education is learning the value and means of communicating science to the general public and policymakers. Education for Sustainable Development (ESD) [1] aims to provide benefits for society. In ESD, science education is a form of public outreach, improving scientific literacy and understanding of basic concepts related to human wellbeing (e.g. nutrition and public health), and increasing trust in science and scientists among citizens. This and similar efforts can promote the active involvement of non-scientists in scientific activities where appropriate and even accelerate open innovation. At the same time, science outreach experiences offer opportunities for scientists, particularly those in younger generations, to be conscious of "science in society" and learn to instill science as a way of life. A societal attitude favorable to science is also essential for stakeholders outside of the scientific community to be willing to contribute support for science.

Supporting Scientific Career Development

The future of science depends on education and support for younger scientists. However, in academia the prospectsfor their career development are challenging. The post-doctoral research (postdoc) stage is often a bottleneck for career advancement in developed countries due to insufficient principal investigator positions, while in developing countries such positions remain l imite d in ge ne r a l . Postdo c s of te n a re hire d by se nio r research- grant awardees to work on specific projects on a short-term basis, resulting in significant risk for their career choices. With limited academic career opportunities, the pressure to "publish or perish" for all researchers can create an adverse environment for career development, leading to dropout, or even misconduct.

Specific training and career paths need to be developed for doctoral-level researchers in economic sectors outside of academia, including industry, commerce, service, education, media, government and non-government organizations. Given diverse career paths, scientists can contribute to sectors of knowledge-based economies that place a high value on critical thinking, evidence-based decision-making, and technological and conceptual innovation. To enable alternate career paths, universities can provide young scientists with opportunities for self-assessment, learning transferable skills, and engagement with other sectors of society.

The evaluation of research productivity based on publications constitutes a series of crucial checkpoints in the career development of young scientists. The widespread indiscriminate use of single metrics (e.g. number of peer-reviewed publications or a journal's impact factor) is inappropriate for evaluation of scientists. Instead, balanced rigorous reviews by scientific experts assessing scientific production are

recommended. Assessment should be based on multi-faceted criteria and research evaluation guidelines such as DORA [2] as well as research-related activities such as societal involvement. This would ensure scientists' productivity, creativity, and ability to take scientific risks and pursue interdisciplinary and transdisciplinary research.

Scientists' Roles and Responsibilities in Society

While the primary mission of scientists is to develop and critically examine new knowledge, and pursue innovation and social progress, they also are expected to learn, perform, and take leadership positions in other important roles and responsibilities in and for society. First, scientists certify and systematize the acquired body of scientific knowledge and transmit it to the next generation. Second, scientists educate and mentor younger colleagues of successive generations and diverse backgrounds, to ensure the propagation of scientific values including critical inquiry and thinking, broad perspectives, and high ethical standards. Third, scientists get involved in outreach activities, communicate scientific developments to the general public, and engage citizens and young people who wish to improve their understanding of science [3]. The implementation of science and technology by policy makers also depends on a dialogue with

stakeholders in society, so that scientists can know the concerns, perspectives, and priorities of society, and contribute to policy-making by offering evidence-based information related to policy choice. A critical aspect of these exchanges is that public stakeholders must be able to trust the validity of scientific results, whereas scientists bear the responsibility of meeting these expectations. The support for science and scientists in society is based on this trust/responsibility relationship, and the scientific community is responsible for training and enforcing appropriate ethical research standards.

Creating a Diverse Global Workforce

Inclusion of Women and Minorities in Science

The healthy development of science and research communities is impossible without the participation of scientists from diverse backgrounds. Although the proportion of women scientists and those from minority groups, in terms of ethnicity, physical disabilities and other groupings, varies among countries, they are rarely represented in fair proportion, especially at higher levels within organizations and in terms of equitable compensation. This under-representation is both a pervasive social injustice and a massive loss of potential contributions to science and society. Women are in some cases better represented among younger generations of scientists, but

still face severe challenges in their later career development. Among these concerns is that the critical age range for childbearing overlaps with the traditional period for career development from junior to senior positions. To mitigate this issue, parental duties can be handled by both men and women, and additional flexibility within the workplace can be promoted. The availability of child- care facilities is also important. A second problem is that more women researchers work in academia than in business enterprises [4] despite the increasing employment of scientists in business at a faster rate than academian in the global competition for building knowledge-based economies. Given this unfavorable situation, improvements in the working conditions for diverse researchers in both academia and industry is essential so that high-quality scientists can compete in a fair way for jobs regardless of gender or other backgrounds. Toward this goal, developing and exposing young scientists to successful peer role models for women and minorities is critical. Finally, training in cultural sensitivity is required in the scientific community along with policymaking that mitigates unconscious biases, ensures flexible timing in promotion decisions at all career stages, and protects work-life balance for all.

Supporting Scientists in Developing Countries

Science is a borderless activity and has long served as a role model for international cooperation. Many global issues remain, particularly with respect to capacity building and researcher mobility and training in developing countries, which can be adequately addressed only through effective collaboration between developed and developing countries. Bilateral and multilateral cooperative programs and partnerships between developing and developed countries, and their research universities and institutes, are strongly encouraged and can be better supported and incentivized by governments, to move from the directional depletion of human scientific resources called "brain drain" to the more equitable model of "brain connectivity and circulation". Such exchange-focused collaborations should aim at strengthening the capacity of institutions to reach a critical mass of researchers in developing countries. This should span all levels from pre-doctoral, doctoral, and post-doctoral training to independent research, to expand careers and

opportunities. The formation of bilateral and multilateral programs for researcher exchange and new international institute s would e nha nce this pat te r n of mobiliz ation. International funding and awards would also encourage younger scientists to "circulate and connect" and support for programs that enable this are needed.

Ensuring Access to Scientific Information

All researchers worldwide should have access to the academic scientific literature and opportunity to publish their own research based on its quality irrespective of

their financial means. Scientific societies, research organizations, publishers and governments should collectively strive to establish a sustainable economic model to mitigate the disparities in access to scientific information and to publication opportunities in different research environments. Various ideas have been proposed for the future of academic publication that go beyond the traditional model based on journal subscriptions levied by the publishing industry. This "Open Access" principle supports free access to scientific publications by all researchers and by the public. While the merits of open access policies are appreciated, concerns remain with quality control of the peer review and publication process that can be prone to malpractice (e.g. predatory publishing) and these must be resolved. An alternate business model involves public subsidy of journal subscription fees. For scientific publications to be sustainable and beneficial to scientists, a solution to cost sharing among journals publishers, journal subscribers, authors of journal articles, and the public sector must be viable and equitable.

Recommendations by the G-Science Academies Connecting Scientists and Society

Science Education

The scientific community, policy makers and society can better promote science education and prepare future scientists, and all students, with inquiring minds, critical thinking, broad perspectives and ethical integrity.

Career Development

Providing positive research environments and creating opportunities for doctoral students and post-docs to learn wider subjects and skills to pursue careers in broader sectors of industry, government and education is recommended.

Scientists' Assessment

The use of single metrics for scientist evaluation, such as number of publications, citations, or journal impact factor should be replaced by those reflecting the quality and importance of the science and the diverse activities of scientists.

Public Communication

Prioritizing public education and communication to the public and children on scientific developments, and engaging citizens to improve their understanding of science is needed.

Resource for Policy

Evidence-based advice of scientists on issues in social choice and policymaking is critically important. Policymakers can seek scientists' input on these issues, and training scientists for such purposes is necessary.

Creating a Diverse Global Workforce

Women and Minority Groups

Working conditions for scientists and practices that enable diverse representation and career prospects of women and minorities in a discrimination-free environment are essential.

Developing Scientific Capacity

Developed and developing countries can collaborate to strengthen global scientific capacity and mutual mobility at pre-doctoral, post-doctoral, and investigator stages.

Access to Scientific Information

All scientists should have access to academic literatures and opportunities to publish their research results. Sustainable publication systems with appropriate cost-sharing should be developed.

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G-SCIENCE ACADEMIES STATEMENT 2016: STRENGTHENING DISASTER RESILIENCE IS ESSENTIAL TO SUSTAINABLE DEVELOPMENT

Present Status

In the decade between 2005 and 2014, more than 6,000 natural and technological disasters occurred around the world, which killed more than 0.8 million people, displaced millions more, and cost more than 1 trillion USD[1]. Losses due to disasters are increasing in both developed and developing countries. Human factors that increase exposure and vulnerability, such as poverty, rapid population growth, disorderly urbanization, corruption, conflict and changes in land use, poor infrastructure including non-engineered housing, together with effects of climate change on weather patterns with increased extreme events, aggravate the negative consequences of natural and technological hazards. Disasters derail sustainable development, particularly in developing countries. Consequently, the need to embed disaster risk reduction into sustainable development goals is paramount.

In the globalized 21st century, a disaster in one country creates disruptions in others: the 2011 Thailand floods cut off car component factories and adversely affected car production in Europe; the 2004 Indian Ocean tsunami inundating the beaches of Thailand and killing more than 5,000 people including tourists caused the largest numbers of deaths from a natural hazard in Sweden's history; the 2006 drought in Syria was one of several contributing conditions that led to the current humanitarian crisis; and the Great East Japan Earthquake in 2011 led to a tsunami, a nuclear facility malfunction, and economic effects worldwide. International events like these show the connection between disaster resilience and sustainable development.

Decision makers need better tools to understand impacts of these types of crises, cope with natural hazards, respond to technological breakdown, and apply lessons f rom past experiences to improve emergency preparedness and capacities to manage crises. Science can contribute by deepening the understanding of hazards and improve ability to anticipate future emergencies and quantify impacts. Innovative engineering can decrease impacts and provide critical information for

planning, rapid response and recovery. Furthermore, cascading effects of disasters require better understanding of connections, and strong international cooperation; at present, international collaboration in disaster risk reduction is not sufficient.

Key Direction

In 2015, the international community agreed on three major accords: the Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework), the Sustainable Development Goals (SDGs), and the Paris Agreement on Climate Change (Paris Agreement). These agreements collectively present an urgent need and opportunity for action in 2016 and beyond. There are important connections among these agreements. For example, the SDGs and Paris Agreement identify actions that can build resilience against both meteorological and geophysical hazards. Also, the Sendai Framework embeds disaster risk reduction as an indispensable part of sustainable development through four of its priorities:

Priority 1: understanding disaster risk

Priority 2: strengthening disaster risk governance to manage disaster risk

Priority 3: investing in disaster risk reduction for resilience

Priority 4: enhancing disaster preparedness for effective response and to "build back better" in recovery, rehabilitation, and reconstruction.

Increasing disaster resilience involves many stakeholders. To realize these priorities and to build resilient societies, we need to maximize the use of existing knowledge and create new types of science and technology that serve broad and collective societal needs. Building this new approach requires interdisciplinary research, collaboration, and cooperation among natural sciences; engineering; medical, social and political sciences; and the humanities. Transdisciplinary collaboration and excellent communication bet ween scientists, practitioner s, and policy-makers are essential.

With the increased scientific knowledge, innovation and technology, the scientific community can identify risks, evaluate system vulnerabilities, and become more effective in communicating the interconnected nature of disaster risk. Efforts are needed to strengthen national platforms for disaster risk reduction, and encourage or enable scientists and practitioners to work closely with relevant stakeholders in locally relevant contexs and language. Common, compatible, or even standardized disaster information resources and indices should be developed for easier exchange among different countries and regions. Integrated analysis of disaster data and information should be promoted to accelerate international cooperation and help

countries identify the most impactful ways for bringing resources to a disaster, its risk reduction, or a response. These efforts will ensure interoperability among countries during multi-national responses, lead to better data on the costs of disasters, and greatly reduce losses through mitigation and resilience-building efforts.

Actions that Build Disaster Resilience and Sustainable Development

The following six actions are recommended for policymakers to increase resilience capacities applicable to a wide range of disasters, their cascading effects, and implications for foreign aid, assistance, or economic impacts.

1. Develop metrics and indicators for evaluating exposure, vulnerability and resilience. Metrics and indicators can be used to:

    - identify, visualize, and evaluate under-recognized disaster risks that hinder sustainable development by taking a holistic view of the changes in hazards, vulnerabilities and exposures arising from societal and environmental problems.

    - anticipate, prepare for, and reduce the consequent disaster risks effectively or in consistent ways

    - ascertain ways to evaluate level of risks.

    - make informed investment decisions and to understand value returns on investments

2. Advance scientific and technical knowledge and improve assessment of disaster risk, including building relevant data infrastructure that advances ability to anticipate future events with greater accuracy, developing disaster damage data archives, and expanding understanding of how disasters unfold across different regions and sectors.

3. Improve understanding of natural and human-made hazards, by developing new technologies and applying effective and innovative engineering for disaster prevention, by constantly raising political and public awareness and through effective emergency response and recovery including mental and physical health management.

4. Strengthen inter and trans-disciplinary collaborative efforts in cooperation through a major international research platform, such as Future Earth[2], providing the knowledge and support to accelerate our transformations to a sustainable world[3].

5. Engage the investor community. Investors, from both the private and public sectors, are important players in disaster risk reduction. It is important to find

ways to engage them more fully in disaster resilience decision making, as investments will drive the future of sustainable development.

6. Promote sharing information, initiate a forum to share best practices and lessons learned in disaster risk reduction and provide practical solutions to implement the Sendai Framework, focusing on community of practices with relevant stakeholders including the private sectors.

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UNDERSTANDING, PROTECTING, AND DEVELOPING GLOBAL BRAIN RESOURCES

The human brain is civilization's most precious resource. Investment in brain science is, therefore, an investment in the future of society, and nations must cooperate to understand, protect, and foster optimal development of the brain. To cultivate global brain resources, the G-Science Academies propose four Objectives, to be pursued in parallel, where strategic support for neuroscience will benefit society. (1) Fundamental research with international collaboration; (2) Global programs for the diagnosis, prevention and treatment of brain disorders; (3) Theoretical modeling of the brain and the development of brain-based artificial intelligence (AI); and (4) Integration of neuroscience with the social and behavioral sciences to improve education and life management as components of a brain-aware society.

Understanding the brain and how its functions are expressed in behavior is a complex scientific endeavor rivaling the search for the origin of the universe. The path to treating brain disorders, developing brain-based AI, and promoting a brain-aware society cannot bypass the difficult challenge of fundamental research on brain structure and function. Basic brain science has made spectacular recent progress built upon advances in genomics and protein chemistry to identify genes and molecules, optical and transgenic tools to observe and manipulate neural circuits, and multimodal functional brain imaging to study human cognition. However, a remaining bottleneck is the lack of technologies to study the brain at a resolution sufficient to enable understanding of its complex neuronal network in animal models and humans. Such technologies, in association with computational tools, would enable a clearer view of brain functions to facilitate a deeper understanding of cognition and reveal the core mechanisms of brain disorders. To achieve this goal, systematic approaches are needed to complement and extend research in single laboratories. Large-scale brain science projects are being initiated in many countries along with other biomedical research initiatives (e.g. next-generation sequencing, precision medicine, and biobanking) to develop new technologies, perform brain network mapping and recording, and establish neuroinformatics platforms[1]. However, these projects require extensive international coordination of technology, personnel, and data to economize and accelerate scientific progress. A successful example of a multilateral global

research organization is the Human Frontier Science Program (HFSP) founded by the initiative of Japan.

Brain disorders represent a global threat to individual well-being, economic productivity, and intellectual capital[2]. Owing to pervasive social stigmas and therefore a lack of data, however, the adverse impact of brain disorders is often hidden. These disorders can be classified into five groups: [A] Neurodevelopmental disorders (e.g. mental retardation, epilepsy, and autism spectrum disorders); [B] Mental illnesses in adolescence and adulthood (e.g. major depression, bipolar disorder, and schizophrenia); [C] Degenerative diseases (e.g. Alzheimer's and Parkinson's diseases); [D] Brain injuries (e.g. stroke, traumatic brain injury, brain infection, and brain tumors); and [E] Chronic conditions (e.g. stress, addiction, malnutrition, headache, and sleep disorders). Eight million deaths each year are attributable to brain disorders[3]. In the last 20 years, their incidence has increased 41% and accounts for 1 in 10 years of lost health. Brain disorders account for 36% of disability-adjusted life years (DALYs) in high-income countries (HICs) and 29% in low- and middle-income countries (LMICs) [4]. In particular, dementia (including Alzheimer's disease) and depression are urgent public health issues with enormous economic and societal costs. In order to produce successful therapies, new economic approaches to drug development are needed, including the use of cellular and animal models with predictive validity, and trilateral cooperation of government, academia and industry. Brain illnesses overburden society: in LMICs there is insufficient access to infrastructure, resources and funding, while in HICs research and clinical stakeholders are often fragmented. Addressing this problem will require international programs and centers that tightly integrate medical research, diagnosis, treatment, rehabilitation, and caregiving to combat the global epidemic of brain disorders.

The brain is the most complex biological system in the known universe. For example, the human central nervous system can easily perform complex decision-making after minimal learning, a feat surpassing the capability of the most efficient computers. Theoretical studies are essential for understanding the computational principles of brain function and for creating quantitative mathematical models. A fundamental understanding of brain circuits and their functions in behavior will require an approach that incorporates theory, experimentation, and computation as peer methodologies. Success will depend on a multidisciplinary quantitative approach that includes mathematics, statistics, information science, and computer science, as well as biological disciplines. An impor tant component will be the acquisition and analysis of large data sets. The principles of open data, particularly as these apply to publicly funded research, should be recognized, in order to promote the widest possible sharing and analysis of data sets. Fundamental brain theories will also be essential for the development of applications in brain-based computing, AI, and information/communication technologies (ICT). While AI originated in computer science, recent

advances in deep learning have been based on brain theory[5] and future AI will benefit from algorithms based on further brain research, which will also be useful for the design of brain-machine interfaces and brain activity-decoding machines. However, like other rapidly advancing technologies, AI raises concerns that need to be addressed by establishing a globally coordinated investigation of its social, ethical, and philosophical implications in the context of neuroscience and society.

Human culture is a dynamic concept that is created and renewed by diverse brain functions. Therefore, the role of neuroscience in the development of future society depends not only on studying the physical, biological, and computational basis of brain functions, but also on opening major research interfaces with the empirical social sciences. Collectively, these interactions will orient neuroscience toward a greater impact in the global society and economy. Integration of the neurobiological, behavioral and social sciences will also create paths for the use of brain-based information in human applications with everyday use. A key example of this potential interdisciplinary convergence is in the science of learning. Emerging knowledge on how the brain acquires new information from biological, cognitive, and computational approaches could greatly improve the design of evidence-based education programs for children and adults[6]. Such knowledge also could provide a scientific basis for regulation of those approaches along with those based on pseudo-scientific claims. Likewise, the integration of brain science and the behavioral and social sciences will enable better predictive models of human behavior that will be useful for individuals in areas as diverse as economic decision-making, r i sk assessment, and social interactions. Collectively, evidence-based understanding of brain functions will transform the theory and practice of life management for individuals and brain-informed policies for organizations with broad utility for developing a sustainable, innovative global society. The integration of brain, behavioral and social sciences will provide a path for the science-based development of global brain resources.

In accord, the G-Science Academies recommend four Objectives:

1. *Support Fundamental Research on Brain Principles and Technologies*

a. Support fundamental brain research from the molecular and genomic landscape of brain cells to neural circuit development and functional mapping to brain networks and behavior.

b. Prioritize the development of novel brain recording and imaging technologies for high-resolution and large-scale analyses of brain structure and function, especially for human studies.

c. Facilitate the international collaboration of large-scale brain and biomedical projects in technology development, data management, researcher training/ mobility, and coordinated funding.

2. *Address Brain Disorders with Next-Generation Integrative Programs*

a. Recognize that brain disorders constitute a global health crisis and support basic and applied research on their causes, prevention, diagnosis, and therapy including rehabilitation.

b. Advance new economic and scientific platforms to develop therapeutics using valid biological models including animals, and promote cooperation between academia and industry.

c. Support partnerships between higher and lower-middle income countries to strengthen research and clinical capacity for the study and treatment of brain disorders, and enhance public education.

3. *Promote Theoretical Neuroscience for Creating Brain-Based Applications*

a. Suppor t multidisciplinar y research using theoretical, computational, statistical, and data sciences and mathematics to reveal fundamental principles for developing a unified brain theory.

b. Promote international cooperation for sharing neuroscience data to accelerate research and the development of brain-based artificial intelligence and neuro-technologies.

c. Launch a global dialogue on neuroethics spanning scientific, policy, regulation, and governance spheres to address the safety and efficacy of brain-based technologies and applications.

4. *Integrate Brain, Behavioral, and Social Sciences for Education and Life Management*

a. Support fundamental and translational research that integrates principles, technologies, methods, and theories of brain science with those in the empirical social sciences.

b. Promote multidisciplinary research on the biological and cognitive foundations of human learning for the creation of scientific programs and tools for child and lifelong education.

c. Launch research and international cooperation on the development of programs and guidelines for brain-based life-management and social function for individuals and organizations.

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G-20

IMPROVING GLOBAL HEALTH: STRATEGIES AND TOOLS TO COMBAT COMMUNICABLE AND NON-COMMUNICABLE DISEASES

Executive Summary

Communicable (infectious) and non-communicable (non-infectious) diseases seriously endanger individual wellbeing and global health, and threaten the global economy. Strong short- and long-term evidence-based strategies are needed. The G20 Academies of Sciences call for the strengthening of healthcare and public health systems, applying existing and emerging knowledge, addressing the broader social and environmental determinants of health, reducing serious risk factors for disease through education and promotion of healthy life styles, ensuring access to health resources globally, and enhancing and extending robust strategies for surveillance and information-sharing. Furthering research is a prerequisite for providing knowledge and new tools to meet these challenges.

Communicable diseases (CDs) and non- communicable diseases (NCDs) continue to burden all nations and require urgent action. Around the globe, their impact is devastating, leading not only to individual and family suffering, but also to tremendous healthcare costs, loss of workforce, and declines in productivity and prosperity. Together these present a serious and continuously growing threat to healthcare and public health systems, economic growth, social cohesion and equity, and even to international security.

The recent Ebola and Zika epidemics have shown that a disease in one country can have serious effects on other countries around the globe. Preparedness for future outbreaks of emerging and re-emerging diseases urgently needs improvement. In addition, the interrelationship between CDs and NCDs can no longer be ignored: at least 15 percent of all new cancer cases worldwide (17.5 million in 2015) are caused by infectious agents[1, 2]. In turn, NCDs may also increase an individual's risk of certain infectious diseases: for example, 15 percent of the tuberculosis burden may be linked to type II diabetes[3].

Scientific research continues to improve the understanding of the causes and contexts of different diseases and how they are interrelated. This knowledge leads to more effective measures for prevention, medical interventions and disease control.

Application of existing knowledge has been inadequate, however.

In order to reduce the burden of disease, the following areas require particular attention: public health and living conditions, risk factors and healthy lifestyles, interactions between CDs and NCDs.

Public health measures such as vaccination, sanitation, water treatment and supply, and waste management have improved the lives of billions of people, but their implementation is still not adequate. In addition, there are many challenges that interfere with good living conditions and good health, and these must be addressed: e.g. poverty and inequality, population growth, climate change, armed conflicts, population displacement, natural and man-made disasters, megacities, violence, traffic and other injuries, environmental degradation and pollution, as well as loss of biodiversity.

Scientific research has shown the overarching and growing importance of risk factors associated with major NCDs (e.g. cancer, cardiovascular diseases, mental illnesses). Treatable or preventable risk factors include overweight, malnutrition, frailty, abuse of substances such as tobacco, alcohol and drugs, lack of physical activity, dysfunctional microbiota, and infectious agents. One single risk factor can be linked to various diseases: for example, smoking is a major risk factor associated with cancer, cardiovascular diseases, asthma and chronic obstructive pulmonary disease (COPD).

Measures to reduce CDs will also reduce NCD based mortality: highly effective strategies already exist for the diagnosis, therapy and prevention of most infections that are known to increase the risk of cancer. These strategies include vaccination programmes as well as treatments using antimicrobials against infectious agents such as Helicobacter pylori, human papillomavirus, hepatitis B virus or hepatitis C virus*.

In view of these challenges, the Science20 network recommends actions in the following areas:

1. Provide reliable and resilient health systems

a- Ensure strong systems for health that include

- robust public health services encompassing disease surveillance, epidemiology, laboratory capacity, prevention, education and risk reduction programmes.
- accessible, appropriate and comprehensive primary and other medical care, including quality vaccination.

b- Apply existing knowledge to prevent

* For some cancer-associated viruses (e.g. Epstein-Barr virus) treatment or preventive vaccine is not yet available.

- infection-associated cancer (e.g. cervical carcinoma, hepatoma and stomach cancer) by preventive vaccination (human papillomavirus and hepatitis B virus) or other treatment (hepatitis C virus and Helicobacter pylori).

- diseases related to alcohol or tobacco by regulation and education.

- diseases such as type II diabetes or cardiovascular diseases by treating hypertension and reducing obesity.

2. Address social, environmental and economic determinants of health

- Ensure clean air and water (including wastewater treatment and waste management), sanitation, adequate and safe housing, and liveable healthy cities.

- Beginning in early childhood, promote health literacy and knowledge about risk factors and adequate hygiene.

- Facilitate programmes to empower and educate multipliers such as family heads, peers, health workers, employers and teachers.

- Eliminate malnutrition and improve dietary education, e.g. in schools, by raising awareness about nutrition and food quality, as well as support access to appropriate diets.

3. Strategic instruments

- Implementing global access to quality vaccines, diagnostics, medical devices and therapeutic drugs at affordable prices. This would also help to reduce the misuse of antibiotics and, consequently, antimicrobial resistance.

- Educating on the evidence-based safety and the benefits of vaccinations to increase confidence in vaccines.

- Developing of combined strategies for global surveillance to detect, track and control CDs and NCDs. This includes strengthening and extending disease reporting, laboratory capacity, syndromic surveillance, and innovative data mining strategies, as well as information sharing. Better coordination of human, animal and environmental health systems ("One Health concept") is important, especially with respect to early detection of and response to threats.

- Support of robust, active surveillance networks and facilitating of prompt reporting about outbreaks:

  - Provide incentives for immediate response and access to financial support.

- Ensure that evidence-based scientific data and sound public health policies define actions taken by countries directly and indirectly affected by outbreaks.

- Support basic and applied research, within and among countries, because research is vital for providing knowledge and new tools for current and future challenges.

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G7 ACADEMIES' JOINT STATEMENTS 2017

THE CHALLENGE OF NEURODEGENERATIVE DISEASES IN AN AGING POPULATION

Demographic and socio-economic scenario

World population growth has been accompanied by a progressive increase in the number of older people. Government-supported medical research and scientific discoveries as well as improved education and living conditions have greatly reduced the chances of pandemics caused by infectious pathogens. in developed countries, life expectancy is now rising well above 80 years. Although in older people the prevailing causes of death are still cardiovascular diseases and cancer, Alzheimer's and Parkinson's diseases, Amyotrophic Lateral Sclerosis and other neurodege nerative disorders that are known to be strongly age related are among the top ten illnesses ending with death that cannot yet be cured or slowed significantly.

The increase in the frequency of disabling, currently incurable neurodegenerative disorders is likely to have a devastating impact on individuals, families and societies, unless effective means to reduce the incidence and progression of these diseases are discovered. Alzheimer's disease alone will affect between one-third and one-half of people above 85 years of age; thus, the number of people affected, estimated at 40 million worldwide in 2015, is anticipated to increase to 135 million by 2050[1], [2]. As life expectancy in developed countries increases, the individual, social and financial burden of assisting these disabled patients surely will grow. in 2050 the economic toll is expected to rise to about one trillion US$ per year in the USA alone[1]. Moreover, in low- and middle-income countries the number of afflicted per sons will increase in parallel with life expectancy, with serious negative impacts on their economies unless affordable healthcare and treatments become available.

These diseases currently have no cure but only care. Specific and effective treatments for them are urgently needed. Because of the heavy personal and economic impact of neurodegenerative diseases, and since pharmaceutical companies are unlikely to invest in the kind of fundamental research necessary

to crack the problem, a significant expansion of public funding is vital to sustain a worldwide effort against the growing burden of these brain diseases. Based on recent progress, a global effort may have a realistic chance to address the problem effectively. Now is the time for political action given that the unrestrained aging of the population forebodes a depressing future for the next generations.

Scientific Outlook

Neurodegenerative disease are variable, with symptoms ranging progressive dysfunction of motor control to mood disorders and cognitive deficits eventually expressed as full-blown dementia. When cognitive problems first begin and before they are sufficiently severe to impair markedly a subject's ability to carry out daily activities, the pathology results in mild cognitive impairment that may progress to a full fledged dementia. With time, disabilities impair normal, autonomous life, and eventually these patients require total assistance.

Today the primary goal is understanding the causes, mechanisms and progression of these disa bling diseases. in spite of the evident clinical differences among them, neurodegenerative diseases have some fundamental commonalities. Pathology studies have revealed that the brain, spinal cord or peripheral nervous tissue harbor a number of abnormal nerve cells containing aggregates of damaged proteins that are characteristic of each clinical disorder.

Vascular and inflammatory processes contribute to the progression of many neurodegenerative diseases. Nevertheless, the discovery that protein damage is likely to be a unifying molecular mechanism shared by different neurodegenerative diseases has been an important step forward. A sensible strategy is to discover methods and drugs that either prevent or interfere with the formation and accumulation of these damaged proteins. Further research aimed at understanding the underlying molecular and cellular bases of these diseases would offer great hope for the future.

Challenges and Strategies

Important research initiatives are underway[3], but the magnitude of this problem calls for much broader efforts as no effective and specific cure is currently available. Medical care and social assistance far afflicted patients and their families are essential, and some successes in terms of caring and improvements in quality of life have been achieved, even though such services are often overburdened. Moreover, education, diet, physical exercise, cognitive stimulation, and treatment of diabetes, hypertension, obesity, might improve cognitive status. These effects, however, are small[4] and have to be confirmed, which calls for well-controlled, large and randomized clinical trials.

In order to identify molecular targets far novel therapeutic interventions, the underlying physiological and molecular mechanisms leading to neurodegenerative disorders must be unveiled through innovative basic research. A rational strategy addresthe problem of these neurogenerative diseases demands an aggressive international initiative aimed at (i) rescuing talented and committed scientists to study in depth the mechanisms implicated in the onset of the neurodegenerative process and (ii) working toward minimizing the crisis by accelerating properly designed and conducted clinical studies. Based on the example of previously successful initiatives to combat cancer and AIDS, responsible policy makers should declare their equally strong commitment to support and encourage a concerted programme to combat and minimize this looming neurological disaster.

A delay in the onset of dementia by just five years would reduce the burden of Alzheimer's disease by 50%. Such a limited delay would be beneficial, yielding improved autonomy of the patient and relief to the commitment of the family and the public health bill.

Large-scale public funding for fundamental rese arch is urgently needed to sustain a worldwide effort against this neurological challenge, in partnership with industry. The time for a political decision is now, given that population aging is proceeding rapidly and, with it, a predicted increase in neurodegenerative disorders.

High-priority actins to be considered:

- Encourage and support new research directions toward the goals of clarifying the different categories of neurodegenerative diseases, of identifying new markers that predict neural degeneration, and of finding new targets for development of novel therapies to prevent or cure these diseases;

- Uncover the molecular, genetic and cellular com monalities of neurodegenerative disorders and develop new and valid cellular and animal models specific for the different diseases;

- Improve clinical trials and cognitive tests and make them more accessible, in order to signifi cantly advance early diagnosis and enroll more people in both prevention and treatment;

- Design and implement better programs that inte grate medical care with social and technological services, taking into account the challenges for caregivers.

Academies may play an important role in supporting all of the above recommendations by promoting the importance of peer-reviewed science in the field; by developing prediction and prevention activities; by providing a continuous forum to discuss scientific pro¬gress; and by providing multidisciplinary advice to governments, agencies and scientific institutions.

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CULTURAL HERITAGE: BUILDING RESILIENCE TO NATURAL DISASTERS

Background

This statement focuses on the resilience of cultural heritage to natural disasters. Man-made disasters are excluded from consideration, although the devastation they induce is often comparable ar even greater than the effects of natural catastrophes, as shown by recent and less recent wars ar terrorist attacks. Howe ver, as man-made disasters invariably have societal causes, responses to them need strategies distinct from those dealing with natural disasters and need to be addressed separately.

In spite of numerous declarations concerning the protection of cultural heritage (see Annex A), national governments have been slow in taking effective actions. This is of serious concern since the list of recent catastrophic events that have severely affected the cultural heritage worldwide is extensive. Cultural heritage has suffered from the devastating effects of earthquakes, floods, hurricanes, landslides, debris flows, volcanic eruptions, tsunamis and fires. Unfortunately, for the most part, little has been learnt from these catastrophic events. A striking example in this respect is the case of Florence; an assessment of an independent International Committee has ascertained that, after 50 years, insufficient action has been taken to reduce the risk that an event analogous to the 1966 floods would lead to a similar tragedy today.

This situation is likely to worsen, as the risk of natural disasters will increase due to climate change, sea level rise, urban development and population growth and their impact on ageing, culturally significant infrastructure.

Protecting cultural heritage: a special challenge

Cultural heritage can be better protected from natural hazards via the developments and practices in the general field of disaster risk reduction. Heritage conservation must therefore be integrated into existing disaster reduction policies. We note three key aspects of cultural heritage.

First, the willingness of people and governments to protect their cultural heritage derives from the unique aesthetic, historic, educational, social, symbolic, scientific, and spiritual values placed on tangible heritage, all of which add significantly to the economic value of these cultural assets. But those values, re sources, and responsibilities for action, may be different at the local, national, and global levels.

Cultural heritage and natural resources share common challenges and concerns. Far example, they both require careful management by present generations in order to assure access and enjoyment of these resources by future generations. There is a distinction between the two: damage to natural re sources can sometimes be 'repaired' through human intervention (except in cases such as biodiversity), whilst cultural assets are unique and once lost they are lost forever. This 'uniqueness' should prompt na tional governments, international institutions and non-governmental institutions to address the special aspects of cultural heritage when seeking resilience to natural catastrophes.

Second, risk assessment for heritage sites, a prerequisite to devising appropriate strategies for disaster risk reduction, raises a number of issues, notably: what is the level of residual vulnerability that may be allowed when dealing with the protection of heritage sites and collections? What indicators of resilience ought to be employed when planning mitigation measures for a city of art, a monumental site or a museum? it is clearly difficult to value the nan-market nature of many cultural heritage objects and to deter mine the replacement price for them, but measures should be further developed and the estimates obtained should inform the allocation of mitigation re sources.

Third, technical and engineering efforts are needed to help historic buildings and heritage collections withstand the impact of major disasters: is such work economically feasible? Past and recent devastating earthquakes are dramatic examples of the immense effort required to protect the enormous and fragile artistic and architectural heritage of a great number of historic towns throughout the world.

In addition, measures and strategies for building resilience, for example urban planning regulations and structural measures for risk mitigation, must be designed to minimize impact on the authenticity and integrity of the cultural assets to be protected. This obvious constraint makes mitigation efforts even more challenging, especially when the heritage to be protected contributes to determining the risk that one seeks to mitigate: e.g. the risk of flooding is often increased by the presence of historical bridges which cannot be simply removed ar significantly modified.

Effective pre-disaster planning should allow far the prompt intervention of experts following a major catastrophe. This action is most often crucial to allow for the stabilization and ultimate survival of masterpieces, as the great work of the Florence restoration community demonstrated in 1966.

However, providing assistance to people in urgent danger is the top priority that should never be postponed nor hindered by first aid to cultural assets.

General actions

Enhance public awareness

Public engagement with the significance and vulnerability of cultural heritage should be increased, especially within the younger generations, by enhancing educational efforts to instill a greater understanding of the unique values of cultural heritage as crucial elements of the identity of communities. Both the public and private sectors should be encouraged to embrace the responsibilities, shared with societies local and worldwide, to preserve tangible and intangible cultural heritage for future generations. This responsibility is reflected in the concept of intergenerational equity.

Pursue research

Much effort is still required to reach a broad scientific consensus on appropriate procedures to map geo physical and weather-related hazards and identify the catastrophic events to be considered at each specific site when implementing mitigation measures. International research networks and practitioner training pro grams should be enhanced. The development of ap propriate damage mitigation measures, including traditional knowledge on disaster mitigation developed at the local level, through the long history of disasters, should then be focused upon if, or when, the hazards are defined. Dynamic (time-dependent) modelling is also needed to capture the impacts of ageing building stock and the repeated cycles of natural hazards such as floods, cyclones, earthquakes and tsunamis.

Establish and implement protocols

Protocols defining the appropriate measures to be implemented after a catastrophic event are crucial. These protocols should be updated periodically and approved by all the relevant institutions and agencies. They should be made available to the entity responsible for the coordination of rescue efforts. Affordable and effective mitigation steps available for any kind of cultural heritage should be widely shared and implemented.

Recommendations for decision makers

Acknowledge the uniqueness of cultural heritage

Governments and international institutions must be aware that the protection of cultural heritage, both tangible and intangible, from the impact of natural catastrophes requires greater and more focused attention in the near future. They should also acknowledge that heritage sites, historic urban fabrics and collections, deserve a special status, with a higher and more sophisticated level of protection than that assigned to common buildings and artifacts on display in those buildings.

Develop assessments, plans and protocols

The "Build Back Better" paradigm proposed in the Sendai Framework includes pre-disaster plans as well as post-event emergency phases to assure safe and timely recovery of damaged cultural assets. ünce protocols are identified, their implementation will re quire trained emergency crews as well as sufficient human resources at the national level.

Support research and skills transfer at national and international level

Critical issues related to the protection of cultural heritage from natural hazards require additional rese arch, which should be promoted and funded at both national and international levels. in addition to continued research efforts, it is essential to provide adequate support and funding to the major schools of conservation/ restoration, where unique knowledge and skills are taught and handed down to new gene rations. These schools benefit from the interaction with advanced research centers where innovative technologies for the diagnosis, stabilization and treatment of damaged works are developed.

Pursue innovative participatory funding policies

Clear and preventive assessments of the social costs and benefits associated with risk-reducing in vestments (including social and economic costs of inaction) should be integrated into public policies and planning. Beyond traditional tax payer funded mechanisms, new funding streams related to social capital generation could be developed in favor of specific cultural projects. People and industries (e.g. tourism) could be actively involved in responsible decision-making processes through appropriate funding schemes.

Enhance international cooperation

Consideration should be given to the establishment of an international Heritage Task Force to enhance the emergency response efforts of existing national and international institutions.

Academies may play an important role in supporting all of the above recommendations by promoting the importance of peer-reviewed science, engineering and technology in risk mitigation; developing prediction and prevention activities; providing a continuing forum to discuss scientific developments; and providing multidisciplinary advice to professional heritage preservation bodies, government agencies and scientific institutions.

Annex

The protection of cultural heritage has been the subject of general declarations issued by international institutions:

- the Hague Convention, adopted by UNESCO in 1954, aimed at protecting cultural heritage in the context of war;
- the Convention on the Protection, at a National Level, of the Cultural and Natural Heritage, adopted in 1972 by the General Conference of UNESCO, ratified by 192 states;
- the Sendai Framework for Disaster Risk Reduc tion 2015-2030, adopted in 2015 at the Third UN World Conference on Disaster Risk Reduction. The renewed international commitment to this framework included, for the first time, the protection of cultural heritage as a major objective.

Institutions have been established to protect cultural heritage from the damaging effects of natural disasters or other catastrophic events. in the USA, the Federal Emergency Management Agency (FEMA) and the Smithsonian institution are currently co-sponsoring the Heritage Emergency National Task Force (HENTF), a partnership comprising 42 national service organizations and federal agencies. in 1997, ICOMOS, a international NGO dedicated towards the protection and management of cultural heritage, established the international Scientific Committee on Risk Preparedness (ICORP). ICOM is responsible for similar programs for museums and collections. in 1998 The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) created by UNESCO, issued a Management Manual on Risk Preparedness for World Cultural Heritage. Blue Shield International (formerly the International Committee of the Blue Shield), coordinates preparations to respond to emergency situations as well as to provide post-crisis support.

Finally, in 2006, the European Parliament issued the Report en titled Protecting the cultural heritage from natural disasters.

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FOOD AND NUTRITION SECURITY: IMPROVING SOILS AND INCREASING PRODUCTIVITY

Executive Summary

Soils, water and energy are essential resources for ensuring food security in the world. Human pressures on soil resources are reaching critical limits. Main threats are erosion, loss of organic carbon, nutrient imbalances, salinization and sodification, loss of biodiversity, contamination, acidification, compaction and urbanization. In this context, the S20 affinity group makes the following specific recommendations for the sustainable management of soils:

1. Promoting good soil governance. Priorities should be given to limiting urban sprawl and devising adaptive strategies of soil management to climate change. Soil monitoring based on benchmark sites and/or permanent observatories is necessary to assess soil restoration programs and detect tipping points in soil degradation. Integration of soil, water and crop data into scientifically based models allows for building scenarios and supporting decisions. Science is needed to inform policy actions by governments and civil society, particularly legislation concerning soil conservation and protection. It is necessary to promote education (schools and media) as a means to increase public awareness of the essential role of soils. Programs aimed at educating farmers in sustainable soil management are strongly needed.

2. Promoting soil knowledge in specific areas. Comprehensive 3D high-resolution (30-m) digital mapping is necessary to generate knowledge of soil properties and its relevance to research and management. Integrating 3D digital soil properties with weather monitoring and crop suitability will improve water and fertilizer efficiency, and define best practices adapted to local and regional conditions. These soil and crop suitability maps should be complemented by methods of proximate soil sensing employing real- time big data to hasten digital agriculture. The research agenda on soils must include the following: a) Deciphering the mechanistic functions of the soil microbiome and its biodiversity on soil function and on plant and human health; b) Studying the efficiency and the effective recycling of fertilizers, a critical global constraint to achieving yields; c) Studying the short- and long-term sequestration of carbon, the preservation of soil organic matter and the rehabilitation of degraded soils; d) Developing strategies to decrease the toxicological aspects of agrochemicals including combatting pests by ecological procedures, using less-toxic and rapidly- decomposing pesticides, and applying highly targeted treatments.

3. Increasing international scientific cooperation programs in the sustainable management of soil. Doctoral and post-doctoral programs that enhance professionals and scientists of less developed countries should be specifically established and promoted.

Soils are fragile surface formations that are responsive to human activities. As the World Soil Charter states: "Soils are fundamental to life on Earth but human pressures on soil resources are reaching critical limits" (FAO, 2015a). Knowledge and protection of soils is essential to sustain human civilization.

The list of soil-related issues on the agricultural agenda has increased greatly in recent years. The 2015 Status of the World's Soil Resources identifies the main threats to soils as soil erosion, loss of organic carbon, and nutrient imbalances. Other threats include soil salinization and sodification, loss of soil biodiversity, soil contamination, acidification, and compaction (FAO, 2015b). Additionally, high quality soil is being lost to urbanization and industrial development. According to the FAO (2015b), 33 percent of the world's soils are moderately to highly degraded due to these threats.

Soils, water and energy are essential resources for ensuring food security in the world. FAO (2015c) estimates that approximately 95 percent of global food production comes directly or indirectly from soils. At the current population growth rate, and projected changes in diets, it is estimated that the world will need to produce 60 percent more food by 2050, which necessitates prioritization of the preservation of functional soils for a food-secure world.

The management of soil needs to encompass sustainable agriculture as well as the broader functions of soils for the maintenance of natural ecosystems and for climate regulation. A multidisciplinary concept of global soil sustainability is needed to quantify biophysical, economic, social and policy dimensions.

Soil sustainability requires knowledge, legislation and education in good agricultural practices of a natural resource that is often privately owned and yet is an important public commodity. Broad access to the information generated is imperative.

A diversity of sustainable soil management approaches is described in reports by UN organizations, for example, FAO (2015b) and UNCCD (2017). These aim to combat soil erosion, increase soil organic matter and promote soil carbon sequestration, limit soil sealing, enhance soil biodiversity, and long-term physical and chemical fertility. They all share the premise that sustainable soil management, using scientific, evidence-based and local knowledge can maintain or increase nutritious food supply, while also contributing to climate mitigation and safeguarding of ecosystem services (FAO 2015b).

In this context, the S20 affinity group makes the following specific recommendations aimed at improving evidence base for the sustainable management of soils and increasing productivity:

1. Promoting good soil governance implies soil protection against the threats mentioned above. Priorities should be given to limiting urban sprawl and devising adaptive strategies of soil management to climate change.

   Soil monitoring based on benchmark sites and/or permanent observatories is necessary to assess soil restoration programs and detect tipping points in soil degradation. Indicators must be defined according to regional and local conditions to generate relevant information for policy makers and stakeholders. Integration of soil, water and crop data into scientifically based models allows for building scenarios and supporting decisions. Science is needed to inform policy actions by governments and civil society, particularly legislation concerning soil conservation and protection. It is necessary to promote education (schools and media) as a means to increase public awareness of the essential role of soils. Programs aimed at educating farmers in sustainable soil management are strongly needed.

2. Substantial progress in soil knowledge of soil properties and it relevance to research and management. This effort must be extended to all geographical regions of the world in order to identify soil deficiencies, and to underpin new practices which can improve soils. Integrating 3D digital soil properties with weather monitoring and crop suitability will improve water and fertilizer efficiency, and define best practices adapted to local and regional conditions. These soil and crop suitability maps should be complemented by methods of proximate soil sensing employing real-time big data to hasten digital agriculture. This will reduce inputs and improves environmental outcomes while maintaining or improving productivity.

The research agenda on soils must include the following:

a) Deciphering the mechanistic functions of the soil microbiome and its biodiversity on soil function and on plant and human health, is one of the more interesting challenges in modern biology. Modern high-throughput sequencing will be the basis for quantifying the genetics and enzymatic controls on an array of soil processes fundamental to agriculture, climate and medicine. Although this complex research area is at its infancy, these studies can eventually be useful to increase soil productivity and for decontamination by microbial remediation.

b) Research on the efficiency and the effective recycling of fertilizers, a critical global constraint to achieving yields.

c) The study of the short- and long-term sequestration of carbon, the preservation of soil organic matter and the rehabilitation of degraded soils.

d) Programs aimed at reducing and eventually avoiding soil contamination should be encouraged, focusing on the toxicology and environmental aspects of agrochemicals and on sustainable practices. Examples include the combat of pests by ecological procedures, the use of less-toxic and rapidly-decomposing pesticides, and highly targeted treatments.

3. Increasing international scientific cooperation programs in sustainably managing soil. Doctoral and post-doctoral programs that enhance professionals and scientists of less developed countries should be specifically established and promoted.

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G7 ACADEMIES' JOINT STATEMENTS 2018

REALIZING OUR DIGITAL FUTURE AND SHAPING ITS IMPACT ON KNOWLEDGE, INDUSTRY, AND THE WORKFORCE

Executive Summary

Digital technologies are transforming the early 21st century, leading to the creation of entirely new industries based upon machine learning and artificial intelligence and lowering barriers to participation in and access to data, education, and communication tools for citizens around the world. It is believed that international cooperation will be essential in key areas of security, accessibility, and regulation to secure a digital future that is inclusive, democratically governed and ethically minded in which open data and reliable information can circulate. With these objectives, the Academies propose the following principles of action:

- Inclusion and access with the goal of equal opportunity to participate in and gain from the digital transformation, to channel gains equitably and eliminate digital divides.

- Information literacy relying on a comprehensive educational plan for all age groups with the objective of providing skills and tools allowing citizens to critically interpret, verify and validate the quality of information circulating in the digital infrastructure.

- Quality of tools and standards through robust mechanisms for production, validation, access and dissemination of open data, information and machine learning systems, to strengthen reliability and security, preventing tampering, manipulation and privatizing use of data and ensuring that machine learning algorithms are interpretable by non-specialists.

- Democratic governance in the form of regulatory frameworks to set up an oversight of internet service providers, social media and other entities and prevent private monopolistic or oligopolistic power in the digital economy and to ensure open and neutral internet, protection of digital data and respect for norms of individual privacy.

- Employment and training policies to encourage new economic activities, foster emerging technological sectors and ensure that the benefits of new technologies also be distributed to workers and that schemes be available for their training and reemployment.

- Ethics and human values should guide the development of digital technologies, artificial intelligence and big data analytics and intervene in all stages of digital innovations to preserve values of freedom, democracy, justice and trust.

The promises and challenges of the digital revolution continue to expand and change, making the precise character of our digital future profoundly uncertain. We must urgently focus on key policy challenges and principles for action in order to make optimal decisions and choices for realizing our digital future and shaping its impact on knowledge, industry and the workforce. This statement highlights these challenges and principles by drawing upon insights and evidence from across scientific and scholarly fields.

Civil society groups, governments, businesses and individuals have been embracing information and communication technologies (ICTs) in digital tools that drive innovation, economic growth, and social prosperity. These tools support the capturing of data to drive insight and knowledge creation while facilitating access to information, collaboration, learning, discovery, and sharing across geographical distances and national borders. Technologies such as artificial intelligence, machine learning, crowdsourcing, big data analytics, blockchain, digital transactions, and automation increase efficiencies in production and service delivery, change the nature of work, and make new business models possible. Future developments, including quantum computing, may accelerate these changes. New ways of conducting science, learning and collaboration across all research fields emerge from increasing insights from data.

At the same time, potential vulnerabilities and perils expand and change with the increasing importance of the digital revolution. Digital technologies disrupt existing business practices, social structures, and economic relationships. Such technologies reshape economies, changing the boundaries between market and non-market activities, disrupting jobs, reducing individual agency in decision-making, diminishing control over personal data, and devaluing labour. The rate and scale of change brought about by the digital revolution magnify the challenges for those unable to take advantage of its opportunities or disproportionately affected by rapid transformations. As ICT developments increasingly affect individual and collective decision-making and understandings of the world, those without adequate digital literacy are seriously disadvantaged.

Accordingly, a central challenge of our time consists of harnessing this wave of widespread disruption to ensure that benefits are distributed equitably, that deleterious effects and vulnerabilities are addressed, and that increasing risks are contained.

Governments around the world have been preparing for the digital future, working in partnership with international organizations, national scientific academies, and other agencies. Initiatives are underway to better reflect social needs as tomorrow's digital technologies and information resources are developed. Strategies to enable universal access to the tools and networks that power digital economies and support social inclusion are being implemented, albeit unevenly. Individuals, businesses, civil society, and governments are now positioned to reap massive benefits from the adoption of digital technologies by collectively recognizing, critically reflecting upon, and addressing five policy challenges.

Policy Challenges

1. **Inclusion and Equity of Access:** The digital revolution presents tremendous opportunities to reduce socio-economic inequalities within and among countries. At the same time, accessibility gaps and forms of polarization are intensifying existing stratification between 'winning' and 'losing' economic sectors, businesses, social groups, and even societies-thereby potentially excluding significant parts of humankind from the gains of this revolution. Educational and infrastructure programs to grant all citizens access to digital skills needed for jobs of the future; to high-speed internet; and to media and information literacy remain underfunded or underdeveloped. Digital inequities are particularly evident in remote, rural, and poor communities. Social media platforms and online forums, valued for enabling the free exchange of ideas and networked social interaction, have also become spaces in which some citizens (disproportionately women, Indigenous peoples, racialized communities, and diverse vulnerable groups) experience harassment and abuse. Technological interfaces designed for some groups of users but not others can curtail the ability and willingness of citizens to participate in digitally-mediated public debate.

2. **Information Quality, Security, and Resilience:** The quantity of data produced and disseminated through digital technologies and platforms has not yet been matched by a corresponding bolstering of procedures and norms to verify and validate the sources, quality, diversity, and technical accuracy of the data, nor by policies to protect the security and ensure the resilience of digital infrastructure. All major infrastructure systems have become digitally-based and have major cyber vulnerabilities. Public understanding of key issues

and problems may be stagnating in some areas (such as climate change or vaccinations) as information bubbles have proliferated. The potential for subtle or covert manipulation of public opinion is growing, while public confidence and trust in traditional sources of information and knowledge (such as scientific bodies and media of record) erodes. As dependence on data, ICTs and their related systems grows, so does the significance of their vulnerabilities and potential failures.

3. **Transparency, Openness, and Interoperability:** Many recent technological transformations have appropriated personal data, fostered proprietary standards, or utilized "black boxed" algorithms. Examples include social scoring to quantify individual risk, shortlisting of job candidates, setting of prices for online transactions, and the selection of optimized and suppressed information in social media. The lack of regulatory structures to ensure oversight, transparency, interoperability, interpretability, and scrutiny of digital data and its uses presents a challenge to democratic principles of openness and accountability. Where the complexity of some systems, such as those based on deep learning, makes their outputs difficult to explain, new approaches to ensuring openness and accountability may be required, based on understanding how these systems work in practice.

4. **The Future of Work:** Driven by developments in artificial intelligence and machine learning, digital technologies and business strategies are leading to the automation or replacement of jobs across various skills and economic sectors, while creating a variety of new jobs and augmenting the abilities of workers to perform in existing and emerging industries. The ultimate effects of these changes depend on the direction of technological innovation, and how workers, employers, and policy makers respond to it. The evidence thus far shows that the resulting disruption is producing an uneven distribution of work-related gains and losses within and between societies, in terms of job security, wages, working time, or entrepreneurial opportunities.

5. **Ethics:** Digital capacities have outpaced the institutional arrangements and public understanding on which normative frameworks can be based to ensure that innovation respects principles of public good and human welfare. The fact that something can be done does not necessarily imply that it should be done, notably in the absence of clearly defined ethical guidelines (in the cases of autonomous systems and weaponized artificial intelligence, for instance). The shift from analogue to digital life demands new ethical frameworks to address new fundamental questions regarding the reconciliation of digital technologies to human values, the consequences of human interactions with intelligent machines, and the meaning of responsible innovation.

Principles for Action

Broad engagement across civil society, industry and governments will be essential to collectively address the five policy challenges noted above, and thereby to realize the potential of the digital revolution to enhance quality of life for everyone. Equity, inclusion, security, and prosperity in our digital world is the responsibility of all. We suggest the following principles for action.

1. **Inclusion and Access:** The goal of equal opportunity for all to participate in and gain from digital transformations requires consultative design and continuing public dialogue and public programs. Public programs should aim to disseminate technical skills and make data and digital infrastructure accessible to citizens regardless of geographical location or socio-economic status. It is essential to measure and monitor inclusivity in emerging technological areas. Public programs are essential to channel the gains of technological disruption equitably across societies, while preventing disruption from disproportionately affecting vulnerable segments of the population and workforce. While progress has been made on this front, digital divides persist and must be eliminated as a matter of priority.

2. **Information Literacy:** In addition to access to data, citizens need general digital skills and tools. Citizens now require increasing familiarity with ethical issues surrounding the uses and applications of ICTs, and critical literacy to interpret and validate the quality of information. Among multiple benefits, such capacity can help guard against false claims and coordinated disinformation campaigns. Citizens should be able and encouraged to participate in online interaction through which they can express their opinions and disseminate information. In this way, digital public spaces such as social media platforms can better find a balance between two fundamental democratic norms-protecting freedom of expression and eliminating hate speech. Comprehensive education to develop such digital literacy skills is required for all ages.

3. **Quality of Tools and Standards:** Robust mechanisms, procedures, and standards for the production, validation, and dissemination of data and information are needed to strengthen data reliability, infrastructure security and resilience, interoperability, accessibility, transparency, and factual accuracy. This could include new standards or guidance to create trustworthy and resilient cybersecurity systems. At the same time, action is required to prevent tampering, manipulation, and arbitrary or privatizing uses of data and digital infrastructure. Quality control measures and open standards are essential for effective evidence-based scientific research and societal decision-making, and to secure citizens' trust in democratic institutions. Long-term

preservation and curation of data resources are essential. Such measures and standards must be co-designed, implemented and enforced by stakeholders within governmental and international organizations, the private sector, and civil society. Developers should ensure that machine learning methods and algorithms are interpretable by non-specialists and thus open to public scrutiny.

4. **Democratic Governance:** Regulatory frameworks and policies are needed to provide democratically governed oversight of internet service providers, social media corporations and other entities that serve as gatekeepers and data stewards. The emergence of private monopolistic or oligopolistic power in the digital economy should be prevented in order to safeguard the principles of an open and neutral internet. It is vital to ensure service neutrality and to ensure the protection of digital data to respect norms of individual privacy and safety while preserving data in the public domain. Patterns of data use in the 21st century have led to a reflection on ownership and control of personal data and information by the individual; humans and their digital selves must enjoy rights to dignity and respect. International cooperation will be essential to the implementation of this principle.

5. **Employment and Training:** Appropriate public policies and private investment models must encourage new economic activities and employment opportunities, and foster the growth of smalland medium-sized players, as well as fund and support-through tax incentives or targeted strategic investments-training and re-employment opportunities for workers. Education, training, and mentoring are needed to complement technical knowledge. Such opportunities should also address creativity, innovation, adaptability, and interpersonal skills to adjust to changing labour markets. Policies should ensure that the benefits of new technologies be distributed to workers in the form of reduced or more flexible working hours, higher wages, and better working conditions. These benefits should also contribute to societal needs via appropriate tax policies.

6. **Ethics and Human Values:** Appropriate ethical models must guide the development of digital and computationally-based technologies, artificial intelligence and the use of big data. Innovation should be pursued within a framework of ethical considerations regarding human welfare and ecological preservation. Shared social norms, moral frameworks, and technical principles-such as open data standards, responsible technological development, and the protection of nature-are essential to our global digital future.

Conclusion

The digital revolution is transforming the early 21st century, leading to the creation of entirely new industries based upon artificial intelligence and machine learning, and lowering barriers to participation in and access to data, education, and communication tools for citizens around the world. By drawing upon insights and evidence from across scientific and scholarly fields to address specific policy challenges and guided by the principles highlighted in this statement, we believe that significant gains can be harnessed and optimized, via national and regional governments and institutions,

civil society and private sector actors. International cooperation will be essential in key areas of security, accessibility, and regulation. Our Academies intend to continue our efforts to inform this process and contribute to ongoing communication and international collaboration amongst all stakeholders. Together, we can secure a digital future that is inclusive, democratically governed, ethically minded, and in which open data and reliable information can circulate-that is, a future in which all citizens will be equipped to respond to challenges and take advantages of emerging opportunities.

G7 ACADEMIES' JOINT STATEMENTS 2018

THE GLOBAL ARCTIC: THE SUSTAINABILITY OF COMMUNITIES IN THE CONTEXT OF CHANGING OCEAN SYSTEMS

Executive Summary

The Arctic is being profoundly transformed by climate change. This has implications on terrestrial and marine ecosystems, affecting those who live on and from them. It is time to develop a shared scientific vision to protect these vital ecosystems as best we can, produce science for evidencebased decision-making and enhance collaborative scientific investigations of these issues. The G7 Academies propose the following:

- Research cooperation relying on augmented interdisciplinary research supported by large scale international science initiatives in combination with cooperative decision-making among Arctic nations;
- Training individuals from a diversity of fields and backgrounds, including those residing in the Arctic, to ensure the necessary scientific capacity to address global and local issues;
- Accessible, usable and timely science databases that can be shared among all stakeholders and decision makers;
- Programs on remote sensing linked with in-situ monitoring activities integrating sustained highinclination satellite missions, new technologies for underwater measurements and regionallyintegrated in-situ monitoring that incorporates local knowledge.

A Changing Arctic Ocean and Ecosystems

Arctic air temperature is increasing at twice the rate of the global average, equating to an approximate 2°C increase over the course of the 20th century. Since satellite measurements began in 1979, Arctic sea ice extent has declined in all months of the year and at an astonishing rate of 13.2% per decade for the month of September (or 86,100 square kilometers per year). These changes have global consequences for ocean temperatures, salinity, water circulation and acidification. Particularly

significant is the Greenland ice sheet, which has been losing about 270 billion tons of ice every year since the early 2000s, and as a result now contributes to around 25% of global mean sea level rise. Fresh water increases in the Arctic due to sea ice melting, Greenland ice mass loss, and Siberian river runoff alter Arctic ocean circulation patterns, and impact air-sea interactions and related chemical exchange processes that can have consequences on a global scale.

Changes to the Arctic climate system have resulted in less predictable weather patterns; sea ice formation occurring later, earlier sea ice break-up; melting of glaciers; thawing permafrost, with the potential increase of methane release; increased coastal and soil erosion. Most researchers expect that, due to climate change, the Arctic will become largely free of sea ice (i.e. less than 1 million km2 in extent) during the summer months sometime between 2030 and 2070, profoundly transforming regional and global environmental processes. All of these factors will result in profound changes to important feedback loops such as when sea ice, which reflects light, turns to open water that absorbs heat – meaning that climate change will continue in the region and at an accelerated rate. Furthermore, there will be a significant shift in the abundance of species, their seasonal occurrence and geographic distribution, thereby affecting Arctic food webs and local food security.

Healthy Oceans, Healthy Communities, and Healthy Peoples

The Arctic is being significantly impacted by climate change. Biophysical impacts related to changing temperature, precipitation, extreme weather events, sea ice, and permafrost will have implications for terrestrial and marine ecosystems, which in turn have consequences for the health and well-being of the numerous coastal communities in the region. All communities in the Arctic will be affected as they rely on the services of healthy ecosystems for hunting, fishing, local economic enterprises, as well as for physical and mental health. The seaways enable bulk maritime re-supply with essential north/south and international economic connections that are fundamental to domestic and international trade. There is also a strong and vibrant Indigenous presence in many communities across the Arctic where cultural networks transcend national borders, where travel over water and importantly over sea ice has occurred for thousands of years, and where connections to a healthy ocean are entwined in the cultural fabric and well-being of local society.

Sovereignty, Security and Sustainability

The changing Arctic Ocean also has major implications for global security, national sovereignty, and international trade related to: increased access to new global marine trade and transportation routes; lengthened ice-free shipping seasons; and increased opportunities and pressures related to Arctic tourism, Arctic fisheries and natural resource development. It is predicted that climate-related changes to

the Arctic regions could stimulate investments ranging from US$ 85-265bn over the next decade, offering the potential for significant and long-term sustainability opportunities for communities and governments in the region. However, with these largely climate change-induced socio-economic changes come increased potential risks such as: oil spills, shipping disasters and environmental contamination with subsequent public health risks, as well as the potential for the introduction of invasive species. There are also ramifications for search and rescue operations, human safety, mortality, and morbidity, together with impacts to infrastructure and livelihoods in the North. There are also risks related to local capacity, whereby larger global forces may overwhelm and impede locally led initiatives.

While the Arctic marine environment sustains unique and globally important ecosystems, it remains among the least-understood basins and bodies of water in the world. This lack of scientific understanding is concerning, as changes to the Arctic Ocean have complex and wide-reaching biophysical implications for local and global environmental processes. They also have significant repercussions for the health and well-being of local communities, and they could influence the future of global maritime trade, and with it, the potential for altered global power relations.

Sharing a Scientific Vision for Peoples and Marine Environments

The G7 Academies stress the critical need to support and enhance basic Arctic research endeavours and cooperation that promote healthy and thriving coastal communities in the context of changing ocean systems. To address this need, the G7 Academies propose a vision of broad international collaboration that includes natural, social, and health sciences, engineering, humanities, and Indigenous knowledge in order to:

- Understand how climate change and human activities impact vital Arctic ecosystems;
- Develop innovative and interdisciplinary approaches and technologies to address these challenges;
- Use this knowledge to enable rich and robust evidence-based decision-making to inform decisions and manage and minimize environmental and sociological impacts.

The G7 Academies recommend:

1. Research Cooperation

- Funding considerably more international and interdisciplinary research, including Indigenous knowledge, in both natural and social sciences to ensure that sound scientific, environmental and societal decisions are made for future development and the well-being of all;

- Developing innovative conservation and governance approaches to support the health and well-being of Arctic ecosystems.

2. Building Science Capacity

- Training individuals from a diversity of fields and backgrounds that will ensure the necessary expertise is available internationally;

- Training those residing in the Arctic is essential: this will incorporate locally-driven science questions and foster development of circumpolar research infrastructure.

3. Accessibility of Information

- Develop interoperable and open data-sharing platforms and sample-archiving systems;

- Provide appropriate communication infrastructure that enables information sharing in a timely manner and is usable by diverse communities.

4. Enhanced and Linked Remote Sensing and insitu Monitoring Programs

- Continue high-inclination satellite missions dedicated to monitoring long term changes in terrestrial ecosystems, as well as in ice and ocean conditions; this would also ensure safe and optimal navigation across the Arctic;

- Extend the development of research vessels, and autonomous vehicles, platforms, cabled observatories and sensors that operate in open water, under the sea ice and on the ocean floor;

- Integrate these broader scale systems with regionally-integrated in-situ monitoring programs that incorporate local knowledge.

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THREATS TO COASTAL AND MARINE ECOSYSTEMS, AND CONSERVATION OF THE OCEAN ENVIRONMENT – WITH SPECIAL ATTENTION TO CLIMATE CHANGE AND MARINE PLASTIC WASTE

Executive Summary

A healthy coastal and marine environment is essential for the ongoing sustainable development of human society. The ocean is a large absorber of atmospheric heat and carbon dioxide, and provides a vital buffer against anthropogenic climate change. The ocean contributes to human well-being in many ways, such as providing protein from fisheries, maintaining various natural cycles and is also a source of recreation and spiritual comfort. However, coastal and marine ecosystems are also facing serious threats. There are major environmental concerns on a global scale, which include acidification, deoxygenation, warming and its associated sea level rise as well as frequent extreme weather conditions. High nutrient inputs and inflow of pollutants such as heavy metals and organic toxic materials deteriorate coastal environments. Accumulation of plastic waste in the ocean originating from both land and ocean is an emerging problem. Damaging fishing practices, including Illegal, Unregulated and Unreported (IUU), affect coastal and marine ecosystems. The role of science in minimizing these impacts upon nature and society should not be understated.

The G20 Academies of Sciences calls for:

1. use of expert, evidence-based advice and assessment using an ecosystem-based approach during further development of marine resources so as to minimize undesirable impacts on the marine environment;

2. redoubling actions aiming to reduce stressors on coastal and marine ecosystems such as climate change, overfishing and pollution;

3. establishment of more recycling and energy efficient practices at national, city and local levels, through stakeholder collaboration and science-based target setting and its follow-up;

4. capacity building for both essential research infrastructures (including research vessels and remote and autonomous observation and survey capabilities) and human capital through education;

5. establishment of an improved data storage and management system that ensures open access by scientists globally;

6. and sharing of information gained through research activities carried out under extensive and multinational collaboration, to expedite a comprehensive understanding of the global ocean and its dynamics.

The ocean is a key component of our global ecosystem. As the main heat reservoir in the climate system, it has contributed greatly to stabilizing atmospheric climate. The ocean's ongoing uptake of heat and carbon dioxide represents the single-most important natural buffer against man-made changes to the atmosphere.

The ocean also houses rich biological communities, encompassing more biological diversity than is found on land, providing a variety of contributions to human well-being. These benefits include 17~20% of food protein (FAO, 2018), approximately half of the annual oxygen production on Earth, as well as over 20,000 substances of pharmacological interest, while also being a source of recreation and spiritual inspiration.

Coastal and marine ecosystems, however, face serious and escalating threats from human activity. Climate change caused by an increase of atmospheric carbon dioxide concentration is warming, acidifying and deoxygenating the ocean. Plastic waste is now a widespread pollutant and the ocean is an accumulation point for other contaminants.

These crises have already been well recognized by various forums, and to overcome these threats, action targets have been set under various UN systems, such as the Aichi Biodiversity Targets in the Convention on Biological Diversity and Sustainable Development Goals (SDGs), especially SDG 14 focusing on conservation of the oceans and sustainable utilization of marine resources. To promote achievement of these targets, the General Assembly of the UN has designated the years 2021-2030 as the Decade of Ocean Science for Sustainable Development, based on the proposal prepared by the Intergovernmental Oceanographic Commission of UNESCO.

The ocean is one integrated global system, so collaboration across all nations and sectors is needed to accomplish the targets and to safeguard this vital ecosystem. The role for science in meeting them cannot be overstated.

1. *Global warming, ocean acidification, and ocean deoxygenation – three threats to the ocean associated with human activity and global environmental change*

The geographic distribution of marine species is rapidly changing in response to global warming and human activity. Species that fail to adapt or change their distributions and life cycles rapidly enough to cope with these changes may be at risk of extinction. Such disruptions to coastal and marine ecosystems may have as yet unknown consequences for the ecosystem processes upon which humans depend. Sea level rise caused by global warming also poses a serious threat to coastal and shallow-water ecosystems, such as coral reefs, mangrove swamps, salt marshes, macroalgal and seagrass beds, because intense human development in the coastal zone prevents landward migration of these valuable habitats. Furthermore, occasional extreme weather phenomena such as super-typhoons have frequently wreaked serious damage on local communities including fishing facilities. In polar regions, especially the Arctic, the rapid warming and loss of sea ice have already considerably reduced the habitat for marine mammals and other species.

The increase in the atmospheric concentration of carbon dioxide is acidifying ocean waters, which has been recognized as one of major causes of deleterious effects for life on the planet. The impact of ocean acidification may prove to be severe for marine calcifying organisms, such as reef-building corals, snails, oysters, mussels, sea urchins, crabs, lobsters, and others. The impact is especially severe for cold-water species, such as deep-sea corals and shell building planktonic animals. These and related ocean changes may transform the globally expansive open ocean plankton community, with attendant effects on the marine food web and also the exchange with the atmosphere of trace gases, including carbon dioxide.

Ocean warming is seriously affecting the world's coral reefs, which are the largest biodiversity hotspots in the oceans. When seawater temperature exceeds a critical threshold, the symbiosis between corals and their algal symbionts breaks down, causing coral "bleaching" events. In conjunction with the influence of ocean acidification, coral reefs are projected to decline by a further 70–90% at 1.5°C increase (high confidence) with larger losses (>99%) at 2°C increase (very high confidence) by the end of this century (IPCC, 2018).

Ocean deoxygenation is also a threat to marine animals that respire aerobically. A number of animals pass through areas of low oxygen daily to feed at the surface. Any increase in thickness of this area, or further decrease in oxygen levels caused by climate change-induced stratification of the ocean surface increases risk.

Land-based human activity impacts on coastal and marine ecosystems through riverine discharge and nonpoint source pollution. Nutrient over-enrichment caused by high concentrations of nutrients such as nitrogen and phosphate, and contamination of rivers by toxic materials such as organic mercury, heavy metals, pesticides, drugs (e.g. antibiotics, contraceptives, and psychiatric drugs) and PCBs, can cause serious pollution and deoxygenation in brackish and other coastal environments near river mouths and estuaries. For rivers with large flows (e.g. the Mississippi), the area of the ocean impacted may be hundreds of square kilometers.

2. *Marine plastic debris – an emerging new threat*

Marine plastic debris is a growing concern with regard to pollution of the marine environment. Large sized plastic debris such as plastic bottles, shopping bags etc. can kill marine animals through accidental ingestion; unintended mortality is also caused by discarded fishing nets (Gall and Thompson, 2015). Small sized (<5 mm) plastic particles - so-called microplastics - are also harmful to marine animals. Furthermore, laboratory experiments suggest that microplastics can transfer to marine organisms any toxic organic pollutants that are easily adsorbed on their relatively large surface areas (de Sa et al., 2018). There is a risk that seafoods may become contaminated by such pollutants through biological concentration into the upper trophic levels (Setälä et al., 2014). Marine debris also carries alien species over long distances, which may dramatically modify regional ecosystems (Barnes, 2002).

More than 80% of the plastic debris in the ocean originates from the terrestrial wastes of human society (Ribic, 1998; Nakashima et al., 2011; Hardesty et al., 2017), driven by increasing human plastic consumption without adequate infrastructure for waste processing, and consequently degrading the marine environment. More active studies are necessary for quantitative understanding of the impact of plastic debris on ecosystems in ocean surface waters, in the water column and at the seafloor.

Besides the reduction of single-use plastics, an overall industrial innovation of the chemical composition of plastics is needed, avoiding any materials that may accumulate for centuries in the environment.

3. Need for enhanced fundamental research and cooperation between science and policy.

Fishing activities have been seriously impacting the marine environment for many years. To promote sustainable fishing, the need is greater than ever for science-based national and international management of fisheries activities, including

better enforcement and elimination of IUU (Illegal, Unregulated and Unreported) fishing as defined by FAO.

Establishment of fully and highly protected areas in the ocean can help preserve biodiversity, habitats, and in some cases also create jobs; such areas also store carbon, allow recovery of depleted fisheries and enhance resilience to climate change. Marine Protected Areas (MPAs) are a powerful but underutilized tool to help protect ocean ecosystems and ensure sustainable development (e.g. through the Aichi and SDG targets). International and interdisciplinary efforts are needed to better understand and incorporate use of MPAs – especially fully and highly protected areas that permit none or minimal extractive activity – into climate change mitigation and adaptation planning, fishery management, and marine spatial planning.

Besides global warming, any increase in atmospheric carbon dioxide concentrations inevitably causes ocean acidification. Ocean acidification will not naturally reverse on timescales in excess of tens of thousands of years. Therefore, international efforts to reduce carbon dioxide emissions should be supported and enacted even more proactively.

The problems concerning coastal pollution in addition to plastic waste-based impacts - such as excessive nutrient inputs from land-based runoff - can be significantly reduced if basic infrastructure such as sewage treatment facilities are constructed as necessary and the use of fertilizers in agriculture is optimized by improving fertilization techniques and planting of more nutrient efficient cultivars. Fertilizer runoff can be reduced by using plantings to absorb these nutrients; this could include vegetation buffers along streams and rivers, and wetlands in estuaries and bays. However, understanding the impact of global climate change on pollutant remobilization is an urgent research priority.

In light of the increase of plastic debris pollution on a global scale, research on a variety of plastic waste-related topics should be carried out through collaboration among international scientists with diverse backgrounds, and with harmonized methodologies. More research is needed on the origin and transport of plastic waste to the ocean, its distribution once it reaches the ocean, prediction of future amounts of plastic debris and particularly its impact on ocean ecosystems, as well as methods to mitigate harmful effects on the ocean.

To realize an innovative society with minimal plastic waste pollution, new materials are needed that are degradable and which cannot accumulate in the environment. Capacity building in the collection, processing as well as recycling systems for plastic waste is necessary, thereby enhancing the cooperation of

researchers, industry engineers and policy makers. Also necessary are research and development activities on designs for environmentally friendly plastic products, as well as developing materials to replace plastics in order to expedite solutions to the plastic waste problem. Progress in this issue will require a change in the attitudes and behaviors of citizens and the private and public sectors through collaboration between governments, companies, researchers and citizens. In this regard, establishment of reuse, recycling and energy efficient practices at national, city and local levels is a key approach for tackling plastic waste pollution. It is vital to enhance the capacity at city and local levels to help curtail the use of single-use plastics, implementing the 3Rs (Reduce, Reuse, Recycle) and proper waste management through stakeholder collaboration, science-based target setting and monitoring to assess effectiveness. Enhanced collaboration and further understanding between developed and developing economies are indispensable for the effective management of the currently alarming high amount of plastic waste pollution globally.

In the future, human impacts on the marine environment are likely to increase through offshore wind farm construction, deep-sea mining and mineral resource development, the opening of the Arctic passage to shipping due to global warming, coastal development and tourism. It is the paramount role of science to serve society by providing expert, evidence-based advice before and during the development of these activities so that they do not cause unwanted impacts on the marine environment. It is also important to redouble efforts aiming to reduce stressors on coastal and marine ecosystems - such as overfishing, pollution and marine noise - in order to increase resilience to ocean impacts from these new activities as well as to changes in the global environment more generally.

Strong international collaboration among researchers will help ensure that scientific advice incorporates the information gained through research activities carried out under solid international collaboration. Capacity building, both through education and in the form of research infrastructure, will be necessary to advance global ocean science. Infrastructure such as research vessels, remote and autonomous observation and survey platforms and techniques to provide more precise and cost-effective data, and data storage and management systems to ensure open access by scientists globally will be the keys to realizing a comprehensive understanding of the ocean ecosystem under the spirit of reciprocity.

The ongoing rise in atmospheric carbon dioxide is impacting the ocean not only through warming but also through the biogeochemical effects of ocean acidification. From this perspective, ocean acidification represents an important extra impetus for international efforts to mitigate carbon dioxide emissions. Human impacts on the ocean, from fishing to coastal pollution, are pressing issues.

Without discounting these challenges, the rise in the atmospheric concentration of carbon dioxide due to fossil fuel burning is an overwhelming concern for the future of the ocean and indeed affects all of Earth's habitats. If our central goal is to improve the prospects for humanity on our planet for decades and centuries into the future, then ambitious steps must be taken to limit the atmospheric accumulation of greenhouse gases.

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EXECUTIVE SUMMARY

The primary conclusion of the 2020 Science 20 (S20), representing the National Academies of Science of G20 nations, is that issues of planet and people must be viewed holistically and with full appreciation of their complexity and interconnectedness. This lesson was learned from a systematic examination of emerging critical global transitions in health, environment, and technology, punctuated by a real-time example of a globally disruptive event, the COVID-19 pandemic. This viral pandemic laid bare the health, economic, social, and educational vulnerabilities of societies and exposed the lack of foresight that resulted in ill-equipped responses on multiple fronts.

The world's leading economies, represented by the G20 countries, must have the foresight to alleviate the system- level economic and social disruptions that will be brought by the next pandemic and other future Critical Transitions. As such the G20 Academies of Sciences recommend the following actions:

1. Advance existing pandemic preparedness towards an internationally collaborative framework to monitor and respond rapidly to emerging diseases and handle future pandemics.

2. Promote advanced therapy and precision medicine research to enhance personalized care, with a view to concurrently improve technology, cost, and accessibility.

3. Deploy policies and interventions to address the challenges arising from demographic shifts.

4. Develop an integrated and efficient closed-loop systems approach to natural resource extraction, distribution, consumption, disposal, and recycling.

5. Promote circular design of materials and energy systems through advancing the 3Rs (Reduce, Reuse, Recycle) plus Renewables aimed at net zero carbon emission.

6. Bridge the emerging digital divide to ensure that all people on the planet have access and capability to use digital technologies and the internet, while ensuring privacy, resilience, and security of digital networks and devices.

7. Improve the sustainability of the digital infrastructure, including end-user devices, and improve opportunities for smart city technologies to contribute towards a cleaner environment.

8. Adopt a multi-disciplinary approach to plan for a human-centric, digitally enabled society of the future, in which the digital infrastructure is fully embedded in the entire social, educational, political, business, and cultural landscape.

9. Support foresight research that is based on robust science, repeatable methods, and open sharing, and incorporates recent advances in complex systems analysis.

10. Establish a platform upon which to implement and foster international collaboration and to build trust in foresight research and activities.

Critical Transitions : Abrupt Shifts in the State of Ecosystems

In 2008, the world experienced a global financial crisis, a critical transition that warranted the G20 discussions to be elevated to include G20 leaders[1]. Twelve years later, we are faced with another critical transition of far-reaching impact in COVID-19. These transitions are abrupt shifts in the state of our ecosystems[2] and become critical when they have global or far reaching impacts. The global impacts of these Critical Transitions could be negative and avoidable, negative and unavoidable, or positive and desired. Several Critical Transitions have been identified across health, environment, and digital sectors, and are now occurring at an unprecedented pace and magnitude. The world's leading economies, represented by the G20 countries, must have the capacity to alleviate system-level economic and societal disruptions that can happen during and from such Critical Transitions. The science and engineering community must help governments identify impending risks and opportunities, but they must also provide evidence-based advice to policymakers to explore the "solution space" for addressing these risks or optimizing the opportunities.

COVID-19 is the latest in a long line of infectious disease outbreaks that have increased both in frequency and diversity over the past several decades, a period coinciding with population doubling, urbanization, globalization, and climate change[3]. Repeated outbreaks and prolonged pandemics will probably become

more common in the future and will demand sustained and data-driven foresight research. Holistic approaches, such as 'One Health', must be contextually understood as complementary to the basic provision of access to healthcare and to broad support for the United Nations Sustainable Development Goals (SDGs). Another health and socio-economic related Critical Transition is due to the significant demographic shifts many countries are facing due to changing birth rates, aging populations, migration, and urbanization. Aging represents a significant demographic shift affecting many developed nations. The potential implications include increased vulnerability to infectious diseases, rising healthcare expenditures, and increased demands for healthcare services for the elderly including mental health. Furthermore, the way healthcare is practiced is going through a transition. Conventional therapeutic approaches face several challenges, mainly related to their lack of specificity and associated toxicity. Multiple approaches have recently emerged to overcome these limitations such as multi-omics technology, tailored cellular therapy, specific immunotherapy, gene therapy, and nanomedicine. However, inadequacy of talent, institutions, regulations, and funding have hampered progress in these areas. While the COVID-19 pandemic has accelerated the application of telehealth and other digital health applications, it has also revealed serious gaps in digital infrastructures and digital literacy especially among vulnerable populations. This is further exacerbated by the lack of uniform regulatory and legislative structures as well as the absence of real-time data sharing mechanisms that also maintain data privacy and security.

The disruptions caused by the COVID-19 pandemic seem to have temporarily slowed many environmental impacts caused by human activity. Yet, we continue to damage the environment by following the traditional linear economic model based on 'take-make-consume-throw away' practices. This has created a situation where we are using our natural resources unsustainably and generating enormous waste. The traditional linear economic model and associated downsides could be mitigated through a circular economy that is based on 'reduce, reuse, repair, refurbish, and recycle', while maintaining focus on economic development that includes green jobs. However, technological challenges and insufficient incentives for upscaling and adoption have been barriers to the swift transition to circular economic designs. Moving towards a more circular economy would seamlessly complement existing global climate and environmental efforts to deliver opportunities including reduced pressures on the environment, enhanced security of the supply of raw materials, and increased numbers of jobs. These will further contribute to the attainment of multiple SDGs. Increasing greenhouse gas emissions are driving a critical transition of climate change and consequent damage to land and marine ecosystems, which in turn pose threats to human health and lives. Efforts to reduce emissions and enable carbon circularity will support global commitments for responsible development while also reducing

environmental pressures from hyper growth and urbanization. Limited awareness of available approaches and of opportunities to reduce emissions and to adopt carbon circularity continues along with a lack of economic and regulatory incentives to drive change. The need for such change is central to attaining SDGs related to making cities resilient and sustainable, combating climate change and its impacts, and conserving oceans and marine resources.

The COVID-19 pandemic has underscored the divide in our society between those who have capability and access to digital technology, especially the internet and services enabled by it, and those with limited or no access. The present pandemic has further reinforced the notion that internet accessibility must be considered a basic or fundamental right of every citizen. Furthermore, the existing telecom infrastructure is vulnerable to disruptions by Critical Transitions such as climatic disasters, cyberattacks, and pandemics. Despite the strong need for resilience, most nations are economically and politically constrained from investing in the network redundancy that provides resilience. These vulnerabilities in connectivity and data are shaking trust in digital technology. This mistrust has been compounded recently by the emergence of deep fakes, misinformation, and fake news. We are witnessing a changing societal landscape across multiple domains. Digital technology is disrupting traditional industries and giving rise to novel ones. In turn, this disruption is changing the professional landscape via job elimination and outsourcing and is particularly affecting vulnerable groups including women. Geopolitical factors, involuntary human migration, and climate change are resulting in increased urbanization. By 2050, two- thirds of the world's population are expected to live in urban areas, causing a heavy load on cities' operations and resources. While smart city technologies could offset this, we are not able to harness their full potential due to the lack of interoperability between competing proprietary technologies. Furthermore, global digital infrastructure and the associated billions of end-user devices consume vast amounts of energy and significantly contribute to global greenhouse gas emissions. More needs to be done in helping to reduce energy consumption and e-waste.

Foresight: Connecting the Dots

The current pandemic crisis has highlighted that Critical Transitions can have far-reaching impacts across the globe and that global challenges transcend societal, economic, political, and technological domains. The growing complexity and interconnectedness of systems make it increasingly difficult for policymakers to understand the impact of their decisions as they navigate the Critical Transitions we will face. The pathway to better government, policy, and action should be built on a whole-system approach.

"Foresight is a purposeful process of developing knowledge about the future of a given unit or system of actors, which is aimed at action in the form of public or private policy making, strategizing and planning."[4] Yet, the on-going COVID-19 pandemic clearly shows that pandemic foresight was and still is a challenge requiring the convergence of medical, public health, socio-economic, and complementary disciplines. Up to this point in history, exercises for navigating the future have largely been conducted by policy analysts in think tanks, corporations, multilateral organizations, and governments. Science has been an ad hoc resource for most foresight studies. However, profound global challenges and Critical Transitions require insightful leadership and vision to transform these traditional foresight exercises through evidence-based foresight research.

Foresight research would propel the science and engineering community into a needed central role to develop deeper, more accurate, and more comprehensive foresight methods to drive effective policymaking. There is a need for foresight research that can connect the dots, allowing the assessment of the impact and unintended consequences of decision options and leading to visionary actions at an international level.

International cooperation and collaboration are needed for better foresight research. The pandemic has provided the central incentive to break silos for healthcare professionals, engineers, scientists, policy and decision-makers, and leaders worldwide. In fact, given the wide disparities among developed and developing nations in terms of research capabilities and financing, international collaboration on foresight scientific research, innovation, and funding is needed. International collaboration on foresight research naturally flows from the growing interconnectedness of the world and resonates with SDG 17, 'Revitalizing the global partnership for sustainable development'. Advancing foresight research and international collaboration in foresight activities holds the promise of fulfilling the potential of our best minds to avoid and mitigate future suffering and achieve greater health, stability, and prosperity.

The G20 Academies of Sciences seek to:

1. Advance existing pandemic preparedness towards an internationally collaborative framework to monitor and respond rapidly to emerging diseases and handle future pandemics.

Establish an international research agenda to study the superposition of pandemic scenarios on existing health conditions, lifestyles, health impacts from environmental changes such as climate change, and social interactions using contemporary research methods. Such research will build on and work with existing global

efforts to strengthen the response to a pandemic or similar health emergencies. The impact and feedback from social and behavioral research, mental health, and frontline-community interactions must be considered. To enable the application of foresight, data must be collected, shared, and analyzed, with results transparently communicated in a manner that ensures peer review, continuous knowledge sharing, data assimilation, and continuous quality improvement.

2. Promote advanced therapies and precision medicine research to enhance personalized care, with a view to concurrently improve technology, cost, and accessibility.

Enhance the development of techniques such as multi-omics technology, tailored cellular therapy, specific immunotherapy, gene therapy, and nanomedicine to complement the traditional healthcare industry. Promote vertical integration of multidisciplinary basic, translational, clinical, and ethical outcomes research, cutting across silo-based activities and taking into account the need for facilitating trans-national mobility and accessibility of scientists and clinicians through better exchange policies. Patients must be empowered to actively participate and collaborate in health research programs. The agenda must also incorporate development of low-cost and high-precision digital health solutions, leveraging predictive models to profoundly understand pathogenesis, identify new drug targets, and develop more personalized diagnostic and therapeutic modalities. Investments in research and training programs are needed to enhance human capital to support the development of and access to innovative diagnostics and therapeutics including vaccines.

3. Deploy policies and interventions to address the challenges arising from demographic shifts.

Account for global demographic, ethnic, and socioeconomic differences in health-related data analyses to allow more accurate data interpretation and decision-making, especially among vulnerable populations and systems with growing inequities. Similarly, conduct a comparative analysis of epidemic data collected from different countries using an agreed framework and appropriate samples in population surveys to provide added value. Among older adults, mental health issues resulting from social isolation, as well as other challenges related to higher risk of contracting diseases, limited digital literacy, and inadequate access to testing and treatment must be addressed.

4. Develop an integrated and efficient closed-loop systems approach to natural resource extraction, distribution, consumption, disposal, and recycling.

Establish the required legal and economic structure to promote large-scale acceptance and application of closed-loop systems and use of recycled and recovered products by businesses and consumers. Steps to encourage the development and adoption of closed-loop systems, especially among key sectors such as mining, manufacturing, construction, services, agriculture, and urban dwellings, should be undertaken. This will in turn stimulate research, development, and use of innovative waste reduction technologies. The design of circular economy systems should create new jobs and encourage community participation at the local level to reduce the use of virgin materials and to promote responsible consumption. Develop educational materials and programs on the circular economy to be included at all educational levels to raise awareness and open career paths to innovation, startups, and jobs in all aspects of the circular economy. Leveraging advanced digital technologies such as IoT, AI, big data, and blockchain will improve the efficiency, resilience, and circularity of natural resource use as well as enhance synergies of circularity in energy, water, materials, and food. Progress towards circularity and waste minimization must use standardized circular economy indicators to support establishment of targets for transitioning towards the circular economy.

5. Promote circular design of materials and energy systems through advancing the 3Rs (Reduce, Reuse, Recycle) plus Renewables aimed at net zero carbon emission.

Promote renewable energy along with affordable and sustainable energy systems including storage, through market-based approaches and awareness programs, that will reduce societal dependence on fossil fuels. Conduct techno-economic feasibility studies and lifecycle assessment to determine the optimal mix of alternative energy technologies coupled with 3R related technologies in integrated societal systems that will best meet carbon neutrality goals. Assessment and promotion of emerging Carbon Capture, Utilization, and Storage (CCUS) technologies such as Bio-Energy Carbon Capture and Storage (BECCS), and conversion of CO2 into products, including tests at test bed sites, will be required to clarify their upscaling and implementation opportunities. Encouraging forest and marine ecology recovery and restoration as methods for carbon sequestration will simultaneously help restore biodiversity.

6. Bridge the emerging digital divide to ensure that all people on the planet have access and capability to use digital technologies and the internet, while ensuring privacy, resilience, and security of digital networks and devices.

Develop strategies to encourage funding of the digital infrastructure and development of communications technologies and devices suited for deployment

and use in poor communities and remote locations with limited infrastructure. Inclusive education and literacy programs are required for all to ensure digital education opportunities, especially among women, minority groups and disadvantaged communities. Leverage the scientific community in digital infrastructure planning to upgrade current systems for improved resilience and increased network traffic demands. Dedicate more resources to promote data science for the public good, research and development for robust and resilient AI algorithms, stronger cryptographic protocols, and expanded regulations to prevent threats from random failures and malicious cyber-attacks.

7. Improve the sustainability of the digital infrastructure, including end-user devices, and improve opportunities for smart city technologies to contribute towards a cleaner environment.

Accelerate initiatives aimed at reducing the environmental impact of digital technologies, including designing for energy efficiency, developing less intensive computational methods, and using renewable energy sources in place of non-renewables. Develop standardized tools and frameworks to maximize efficacy in the use of digital technologies and maximize their useful lifetime to reduce e-waste. Design smart cities and smart communities to be inclusive, optimize resource sharing, embrace interoperability, and reduce the emission of greenhouse gases and other pollutants. Promote collaboration and knowledge-sharing of best practices and experiences among policymakers, industry, community stakeholders, and the scientific community. Enhance public awareness of the environmental impact associated with use of digital technologies.

8. Adopt a multi-disciplinary approach to plan for a human-centric, digitally enabled society of the future, in which the digital infrastructure is fully embedded in the entire social, educational, political, business, and cultural landscape.

Strengthen focus on multidisciplinary education and research, interlinking science and engineering, social sciences, the humanities, and ethics, and enhancing the quality of digital education for all. Initiate a broad scientific and public discourse related to the societal and health impacts of digital technologies and engage in public education based on scientific evidence. Support the development of technologies and human-managed processes that allow for rapid detection and blocking of deep fakes, fake news, and disinformation, and empower users to identify and handle false and misleading information. Increase investment in research and development of trustworthy and explainable AI in high-stakes domains such as finance and healthcare and develop methodologies and protocols for the incorporation of ethical behavior into robots and related autonomous technologies.

9. Support foresight research that is based on robust science, repeatable methods, and open sharing, and incorporates recent advances in complex systems analysis.

Transform foresight research given recent major advances in network and complexity science, AI, machine learning, big data analytics, and advanced computing (e.g. quantum computing). Ensure that foresight research is based on robust science and repeatable methods that are openly shared. Such research would involve the intersection, interaction, and/or combination of scientific and engineering methods, technologies, trends and drivers, as well as the contexts in which these are embedded. Such enhancement would strengthen the reliability of foresight research and would promote trust in the use of and outcomes from these applications.

10. Establish a platform upon which to implement and foster international collaboration and to build trust in foresight research and activities.

Encourage international organizations (such as the UN) to establish a global clearinghouse and knowledge-sharing platform, as well as a global scientific advisory body to strengthen scientific foresight research, to foster international collaboration and collective exchange of foresight reports, data, best practices, and information on foresight initiatives conducted around the world. This will complement and leverage existing (mostly) regional foresight efforts by encouraging international dialogue on the need for foresight research and capabilities to understand the complexity and interconnectivity of global systems. Challenges that are global in nature often involve different pathways in different regional, national, or local contexts, and effective intervention options are also likely to vary according to context. International cooperation must foster acceptance and tolerance of various cultures and social norms. Global cooperation offers a rich collaborative space for developing appropriate methods that use cutting-edge developments in network and complexity sciences, AI, and big data with the goal of promoting foresight research. Such efforts should also help to develop protocols, technologies, and regulations to ease data sharing, both locally and cross-border, to allow open access to data among relevant stakeholders. These efforts should also help to prioritize programs that heighten the awareness of foresight to the broader society and policymakers and to establish strategies for communicating different futures to diverse audiences.

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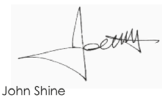

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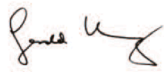

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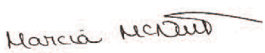

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2020 G-SCIENCE ACADEMIES' STATEMENT: BASIC RESEARCH

EXECUTIVE SUMMARY

Expanding fundamental knowledge has made enormous contributions to solving global challenges and sustaining healthy and prosperous societies. Investment by the public in basic research creates essential human and intellectual capital and enriches society in unexpected ways, including new treatments and technologies that spawn new industries, elevating the global standard of living.

Yet, there are many current cases of inadequate or decreasing investment in basic research. And investments and policies for education, capacity building, cooperation and openness are necessary to realize the benefits of basic research and to distribute them throughout society.

- Our central recommendation is to restore and sustain long-term public funding of basic research, pursuing new frontiers of knowledge, providing the basic fuel for successfully meeting current and future challenges

It is also important to:

- Strengthen investment in cultivating inquiry and innovation through early and ongoing science, technology, engineering, and mathematics (STEM) education, integrated with the humanities and arts

- Foster global cooperation and information sharing to accelerate discovery and spread benefits and to reduce knowledge-based inequities

- Support interdisciplinary collaboration among and between fields, including engineering and social sciences

- Openly publish research, to increase scientific knowledge, foster curiosity, and benefit all publics

Background

"Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science. Today, it is truer than ever that basic research is the pacemaker of technological progress."

—Vannevar Bush, (Science, The Endless Frontier, 1945)

Seventy-five years ago, Vannevar Bush laid out the case for government support of basic research—that is, research pursued for the advancement of fundamental knowledge without preconceived application in mind. His report drew the connection between the pursuit of fundamental knowledge and technological progress, elucidated by several examples from his time—from the discovery of penicillin and use of vaccines to the development of synthetic materials and radio communications. In cases of such leaps in scientific understanding, the benefits to the global community have been enormous. Advances in biomedicine have enhanced and saved untold numbers of lives. Scientific breakthroughs have created new industries and jobs, and advances in agriculture freed billions of people from hunger.

The challenges of the present are daunting—including the need to address climate change and mitigate the impact of natural disasters, fight new and re-emerging agents that cause disease, address chronic health issues, provide robust technological systems and cybersecurity, reverse environmental degradation, and provide sustainable sources of energy, food, and water. Basic research is more important now than at any stage in human history, a crucial, long-term investment in the future to meet these challenges and produce game-changing ideas essential to the progress and endurance of society.

Why Basic Research?

It is a paradox of science that the road to revolutionary breakthrough is often an indirect, inquiry-driven approach that yields increased understanding of the natural world and ourselves, and enables transformative discoveries for real-world challenges. For example, cancer could not seriously be addressed before fundamental breakthroughs were made in genetics and molecular biology.

Basic research across disciplines is necessary for responding to our common challenges. Human activity has a large impact on the planet, its resources and its climate, and accelerating technological developments provide unanticipated social and ethical implications. These challenges inequitably affect the most vulnerable populations in society. Thus, it is essential to understand human decisions, behavior, culture, political processes, migration, and conflict. These questions can be addressed by basic research in fields including engineering, social sciences, and humanities. Science is intrinsically an international endeavor beyond national borders and cultures, and its benefits should be distributed equitably and globally. It can contribute to cross-cultural dialogues, international understanding, and to peace.

Basic research is an essential complement to mission- oriented research and development, which target specific problems or commercial objectives. Applied activities supply advanced tools needed for basic research, and those tools provide other direct benefits to society. Young scientists and scholars are drawn to the deep intellectual challenges of inquiry-driven basic research and are trained in, or create, new questions and ways of thinking. As these skills are applied to societal priorities, they can have transformative effects, enabling the growth of R&D-intensive industries and formation of start-ups.

While the rate of return on investments in basic research is difficult to estimate, historical experience and specific examples indicate that it is very high. Economists have estimated the social rate of return for all research and development investments to range up to as much as 100 percent. Continued contribution of basic research to global well-being depends on adequate, steady, long-term public funding. Public funding promotes the scientific values of objectivity, honesty, fairness, and accountability, thereby fostering science of the highest quality, rigor, and transparency.

Basic Research, Its Application And Benefits

Apart from the immediate scientific results, basic research often generates indirect benefits. Most of modern technology is a consequence of basic research. Some illuminating examples:

Most modern electronic devices including microprocessors, lasers, and nanotechnology are dependent on classical and quantum theory, first conceived in 1900 by physicist Max Planck, resulting in almost a third of the gross national product of leading economies. With the advent of quantum computers, the quantum internet, and quantum sensors, this percentage may increase.

Modern biomedical applications are based on discoveries in molecular biology, starting with the structure of DNA by Crick, Watson, and Wilkins. In the 1960s, microbiologist Hamilton Smith and colleagues showed how an enzyme is capable of slicing DNA at specific sites, which in turn sparked the growth of the biotechnology industry. Basic research beginning in 1987 by Ishino Yoshizumi discovered unique repetitive DNA sequences in bacteria, the function of which was later elucidated in 1989 by Francisco Mojica, whose work led to tools for gene editing. These gene-editing tools are being applied in agriculture and have the potential to revolutionize medicine.

While studying ultra-cold temperatures, physicist Heike Onnes discovered the phenomenon of superconductivity that can be used to create powerful magnets. This knowledge has been applied in contexts from maglev transport to magnetic resonance imaging (MRI) in healthcare, but later basic research also benefited from these advances. The CERN particle accelerator used superconductivity to confirm the existence of the Higgs particle. Further, the development of functional magnetic resonance imaging (MRI) provides new opportunity for understanding the brain's role in human behavior, fostering breakthroughs in basic research by social scientists in economics, sociology, anthropology, psychology, and communication.

Basic research may require significant time for advancements to be applied. An example is the many fields researching artificial intelligence (AI). The first attempt at a computerized neural network was built by Minsky in 1951. Then neural networks were written off for decades. Recently, the incredible yield of basic research on AI was driven by the information explosion, with mass

storage of data and extraordinary improvement in computing capacity. Continued research on AI and its ethical and social challenges is essential.

The common thread among these (and numerous other) breakthroughs is that basic research provides enduring potential for long-term and evolving applications. Basic research can lead to paradigm shifts, opening up entirely new fields of industry, technology, and understanding of the human condition. Public investment in basic research often encourages important private sector research and innovation.

Challenges

Because of the exploratory nature of basic research, and the need for healthy and stable funding, government is the key funding source in the advancement of new knowledge. Since much of the knowledge developed by basic research is publicly accessible and benefits global society as a whole, it is a public good that cannot easily be owned or restricted by individuals, institutions, or nations. Of course, not

every basic research project will develop into immediately practical applications, yet those that do have a vast impact on humanity.

In many countries, however, public funding for basic sciences is inadequate, has stagnated, or is declining. Economic and political uncertainties, along with a research climate driven by short-term results and the hunt for scarce funding, have undermined investment in transformative ideas. Yet, now more than ever, the scale and complexity of global challenges demands revitalized investment in basic research to leverage the full spectrum of human ingenuity in devising insight and solutions.

The chief concerns of government include full employment, public health and national security, whereas businesses are inherently focused on shareholder returns. Corporate and philanthropic funding of basic research is valuable and reaffirms the importance of cultivating new knowledge, yet its incentives remain different and do not provide a stable substitute for public funding of basic research. Public funding is unique in that it is more apt to ensure both open, creative inquiry and resource stability, as is needed for effective basic research.

Recommendations

1. Most importantly, restore and sustain long-term public funding of basic research

Governments have proven to be the most natural and reliable funder of basic research. Investment in basic research, including in engineering and social science, provides the knowledge basis on which applied research can build to address major current and long-term challenges.

2. Build capacity via STEM education

It is vital to cultivate student creativity, imagination, and a scientific approach from the earliest stages of education, through robust investment in STEM education, integrated with humanistic, social, and artistic perspectives. Funding of scholarships for undergraduate and postgraduate studies is also essential. Special effort and support for education and basic research in less-developed countries and regions is of particular urgency to harness intellectual potential and address urgent needs while improving access to the benefits of science.

3. Cooperate globally

Open cooperation is key to the pursuit of new knowledge on the fundamental laws of nature. It is essential for governments to support scholarly exchange and

visa programs. Basic research, when pursued with integrity in open cooperation among a global community, additionally serves to enhance international relations and mutual trust. Ensuring that basic research data, opportunities to present and partake in cutting-edge research, and scholarly publications are globally accessible is essential to scientific advancement and an equitable world.

4. Collaborate across disciplines

Investment in basic science must take into account all research disciplines, including engineering, social sciences, and humanities. All should be pursued to engage in understanding the social, cultural, and ethical implications of advancing technologies.

5. Openly publish research results

Results of research funded by the public should be made available and accessible to the public at no further cost. This requires innovative science communication and publishing models.

2020 G-SCIENCE ACADEMIES' STATEMENT

DIGITAL HEALTH AND THE LEARNING HEALTH SYSTEM

Executive Summary

With the enormous progress in digital technologies, it is possible to envision high functioning and continuously learning health systems that can improve resource allocation and lower costs while advancing research, healthcare, and patient experience and outcomes.

Health systems positioned for continuous learning and improvement are increasingly able to gather and apply evidence routinely and systematically in real-time; ensure that care delivery is optimized for the individual, including end of life; address barriers to health equity; manage the health of populations; identify and control emerging diseases; and assess outcomes to improve processes and training. Biomedical science will soon be able to draw upon vastly larger databases to generate new scientific knowledge and reduce impediments to healthcare for individuals and populations.

While digital health technology—e.g. bioinformatics and medical informatics—already makes these advances feasible, their realization will require extensive individual, organizational, national, and international collaboration. Action is required to ensure that actors across the world develop trustworthy technologies for deployment in applications to the benefits of people at all stages of their lives. Careful stewardship is required to ensure that the benefits of these technologies are shared across society.

Priorities requiring global cooperation include:

1) cybersecurity, safety, and privacy; 2) interoperability; 3) availability of reliable data and information; 4) secure virtual data repositories; 5) integrative analytics and predictive modeling; 6) mathematics of learning; 7) knowledge representation and management; and 8) IT literacy, public understanding, and ethics.

Dependence of Health on Reliable Information Flow: Applications of Digital Health

Health progress depends on the optimal generation and flow of reliable knowledge and information. Digital health is a broad term applied to a range of digital tools to record, organize, store, analyze, link, and share information—text, images, signals—for use in observing, assessing, learning, managing, and improving the healthcare of individuals and populations (Figure 1).

With the development and rapid growth of these digital

the health effects of their interplay, as well as our abilities to share information across domains in operations and learning processes.

Health care. Movement of patient health records onto digital platforms offers enhanced prospects for more effective care for individuals, both within and among care sites, as well as for greater individual and family involvement and control in the care process. Diagnostic tools are increasingly developed on digital platforms, with imaging systems, lab on a chip (blood and serum chemistry tools, we now have profound opportunities to generate new health-related knowledge, monitor its application, predict results, and guide courses of action. The application of these tools has transformative implications for each of the domains that determine the health of individuals and populations: genetics, behaviors, social circumstances,

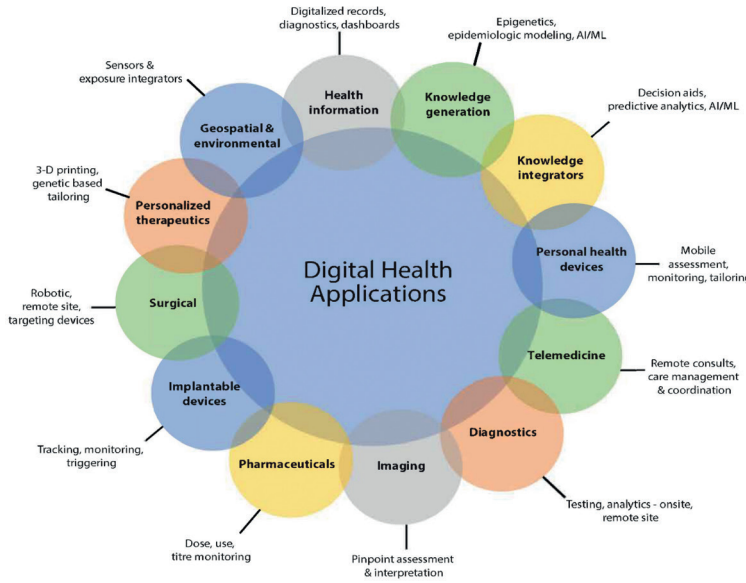

Figure 1. Evolving applications of digital technology in health
Source: National Academy of Medicine, Digital Health Action Collaborative, 2019.

physical environments, and health care. Improving health depends on our ability to understand the nature of those domains, their causal relationships, and analyzers), monitors (e.g. cardio-pulmonary), and many others functioning through digital signals that generate data with the potential for more integrated insights, and for better and faster integration in individual care.

Application in medical treatment includes use of decision aids, predictive modeling, care coordination, dose regulators, and 3D printing of organic matrices treating conditions such as burns or joint damage. Genomic data assume an increasing role for cancer prevention, diagnosis, and targeted treatment. Digital monitoring technologies allow real-time assessment in settings ranging from intensive-care units to daily activities through wearable devices. Cardiovascular diseases and medication adherence are examples in which monitoring can be improved. A basic application of digital technology is for patient safety. Harm to patients can result not only from human factors but also from system technical incompatibilities, disjointed communication, or breakdowns. All applications can benefit from digitally based safeguards. Digital health technology carries the potential to support continuity of care among providers as well as during care location transitions.

Remote site care access. Digital remote-site health monitors, including cell phones, smartwatches, implantable devices, and signal enabled clothing, are now used in the real-time assessment of a patient's condition. Telemedicine advances provide consultation outside customary healthcare-organization care sites. Rapidly evolving remote-site treatment, even for acute management, now includes wearable and implantable sensors and medical devices, e.g. cardioverter defibrillators. Remote robotic surgery, using wireless networking, allows surgeons the prospect of performing operative procedures at a distance. The hospital-in-the- home is an increasingly accepted practice.

Promotion and protection of health. Digital health has enabled enhanced personal risk identification, which can better pinpoint and predict individual vulnerabilities. Digital health has improved the ability of individuals to monitor their own exercise, diet, pulse, blood pressure, weight management, menstruation, sleep patterns, and stress management, meaning increased engagement and control over one's personal health.

On a population-wide scale, disease and injury surveillance draws directly on digital health capacity. Electronic case reporting automates the flow of data between providers and public health agencies about disease and preventable conditions (e.g. through immunizations). Geospatial and environmental sensors provide insights into factors such as environmental exposure, neighborhood risks related to social determinants of health, and impacts of the built environment, such as inaccessible

sidewalks leading to sedentary habits. Geo-trackers embedded in inhalers, for example, can help pinpoint sites and conditions endangering asthma patients.

Discovery, innovation, and knowledge development. As very large data sets and exploration tools evolve, more structured and systematic generation of hypotheses and virtual testing will be enabled. This will accelerate developments in arenas such as genomics (understanding the nature and function of genomic factors that shape health, including gene mutations, differential gene expression, and epigenetics); integrative analytics and predictive modeling, through artificial intelligence, with expert systems natural language processing, and machine learning; and protocols for data repositories.

Requirements for Progress: Secure and Reliable Digital Health Infrastructure

With potential applications of digital health technology of the breadth noted above, certain operational preconditions must be met, both to facilitate attainment of the potential and to safeguard against possible risks. Figure 2 offers a graphic representation of the facilitative and governing infrastructure required to steward the development and application processes.

Cybersecurity and privacy. There are many challenges, and risks to achieving the potential benefits from advances in digital health. Sustained multi-sector, multi-site, and multinational collaborative efforts are required to develop and apply creative solutions. A major priority for nations and health organizations is the collaborative development and implementation of system security protocols. Technical and process safeguards are essential to ensure that individual privacy is protected in accordance with individual wishes. Approaches are needed to share immutable records of transactions among network participants. Blockchain may offer one such approach. trusts. A basic, related need is development and cultivation of the digital health workforce, which is acute in most countries. This is especially critical for developing countries that have limited infrastructure, digitized records, weak data security systems, and often lose the few trained workers they have. The training challenge for leveraging digital health is vast—in health care, public health, and biomedical science.

Interoperability. Just as the flow of information among care sites is a basic requirement, the connectivity and communication among devices is an essential prerequisite for patient safety. Incompatible interfaces can and have had catastrophic consequences. Health Level Seven International (HL7), a non-profit standards organization for the exchange, integration, sharing and retrieval of electronic health information, has created a promising set of international interoperability standards

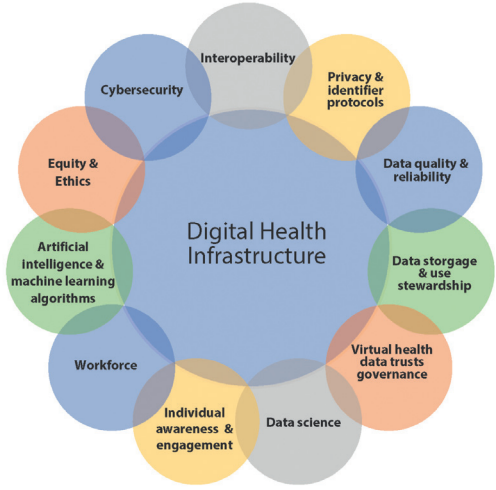

Figure 2. Infrastructure requirements for progress in digital health

(e.g. HL7 on Fast Healthcare Interoperability Resources). Such standards allow information to be shared and processed in a consistent manner. Full functionality will require action by all health care providers, as well as international collaboration.

Data reliability, storage, and access. The most basic determinant of the utility of digital health is data availability, quality and reliability. This requires standards and curation protocols for data and information (e.g. FAIR principles) to ensure their seamless utility across institutions, languages, and jurisdictions. Structure and maintenance guidelines as well as international cooperation is essential. Equally important are protocols for data storage, access, control, sharing, and use. In principle, authority over individual data lies with the individual from whom they derive, and access to and control of use belongs to the individual or their designee. Every step in the use of information, however, generally requires an element of ceding control, as well as the potential for value to be added. Economic, legal, philosophical and practical issues must be addressed. The differences that exist among nations concerning data access, control, and monetization clearly present limiting circumstances for the contributions of digital health. Thus, mechanisms for ongoing cooperative exchange are needed.

Data science and artificial intelligence. There is a clear need to invest in the capacity and cooperation necessary to foster advances in data science and artificial intelligence. This will require developing data-science tools as well as developing the pathways, agreements, and protocols for establishing curated virtual health-data Equity, ethics, and public engagement. Health data are intensely personal. Capturing the full potential from digital health will require a much deeper understanding and appreciation at the individual level. Responding to the public demand for progress

and participation in building the digital health frontier is a compelling priority. The rapid development and application of digital health is also accompanied by the need for vigilance on ethical issues ranging from unauthorized access to misuse of personal information. Capacity building remains an essential component of global progress in health. In a data centric approach, developing countries may suffer from lack of digital data to make intelligent decisions. Careful stewardship is needed to ensure that the benefits of digital health are shared across society and the globe.

Broad Priorities

To realize the benefits that digital health offers to enhance the human condition, individually and collectively, systemic and dedicated collaboration is required across fields, sectors, and nations. The following are identified as key priorities in this respect.

1. *Cybersecurity, safety, and privacy:* technical, governance, and legal protocols and standards, as well as inter-governmental agreements for the safety, security, and privacy of the digital health infrastructure, ensuring proper ownership of personal data.
2. *Interoperability:* standards to ensure seamless device interfaces and reliable information exchanges.
3. *Availability of reliable data & information:* standards and curation protocols for data and information, including tools to track provenance, and improvements in the amounts and quality of open data.
4. *Secure virtual data repositories:* structure and maintenance guidelines, as well as storage, access, and release requirements to safeguard the operational integrity and security necessary for the virtual functionality of data repositories.
5. *Integrative analytics and predictive modeling:* artificial intelligence tools (including machine learning and deep learning) that are transparent to clinicians and patients, to mine large and heterogeneous databases for insights for individuals and populations as well as to serve in digital decision support systems.
6. *Mathematics of learning:* computational algorithms and mathematical models are foundational to the application of machine learning approaches to biologic processes that highly variable, introducing epistemic uncertainty and requiring novel adaptive mathematical concepts and appropriate context sensitivity.
7. *Knowledge representation & management:* information management software and tools for access, vetting, and delivery of information
8. *IT literacy, public understanding, and ethics:* public dialogue about digital health, bringing a range of stakeholders into the policy process as part of a governance system that builds trust and maintains vigilance and safeguards against abuses and unintended consequences, and in which the public can have confidence.

2020 G-SCIENCE ACADEMIES' STATEMENT

GLOBAL INSECT DECLINES AND THE POTENTIAL EROSION OF VITAL ECOSYSTEM SERVICES

Executive Summary

A great majority of insects provide unique and irreplaceable ecosystem services, including pollination, recycling, and nutrient provisioning. Striking declines in diversity and abundance, in some cases upwards of 75% in less than 30 years, have been documented in insect communities. Because loss and degradation of habitats and other contributing factors usually cross political boundaries, international cooperation is essential to mitigate or reverse such declines.

Human activities clearly are the major causes of declines in the abundance and diversity of animals, including insects[1]. Insects occupy virtually all terrestrial habitats. Their spectacular diversity reflects their small size and short life cycles, which allow them to partition habitats and resources and adopt specialized lifestyles. Their specialization, however, makes insects vulnerable to changing environmental conditions. Hence, it is important to assess and ideally to predict where and how anthropic pressure affects insects, in order to support policy measures for their conservation and sustainable ecosystem services.

Joining with others[1] who have argued for specific measures to protect insect biodiversity, our academies urge implementation and public support of actions outlined at the end of this statement.

The "Insect Apocalypse" -Is It Real?

Long-term studies have documented declines in the abundance and biodiversity of insects around the world, including a 75% decline in the total biomass of flying insects in Germany [3], [4] and a 35% decline in global abundance of butterflies and moths[5] over 27-year and 40-year periods, respectively. These reports have raised concerns about a so-called "insect apocalypse" and generated dire predictions of global ecological collapse, while some other publications on this topic have been criticized for methodological irregularities or limitations[6]. Long-term

datasets derived from standardized sampling methods are essential for detecting declines, especially species with boom-and-bust population fluctuations[7].

Extinction risks have been evaluated for fewer than 1% of the described insect species[8]. Carrying out such evaluations is complicated by the vast numbers and diversity, small size, concealed habits, and complex life cycles of insects. Moreover, there is a critical shortage of taxonomists and of support for their work[9]. Consequently, the roughly one million known insect species likely represent less than 20% of all extant species[10]. Moreover, whereas most insect diversity resides in the tropics, most documented declines have been recorded in northern temperate regions. Thus, the existing estimates may not reflect global threat levels.

Consequences of Decline And Extinction

The impact of an overall global decline in insect numbers on human health and well-being is obscured by widespread misperceptions that insects are generally harmful. Indeed, only about 1% of all known insect species cause crop losses of 20-80% globally, enough food to feed a billion people, and fewer than 1% of mosquito species transmit diseases that kill at least 750,000 people annually.

An overwhelming majority of insect species contribute positively to ecosystem services and goods that are of tremendous value to humans. These benefits include provisioning services (food, raw materials, medicines), regulating services (pollination, decomposition, nutrient cycling, water purification, pest control, soil stability and fertility), and cultural services (recreation, education, scientific research). Nearly 90% of flowering plant species, including almost 75% of the world's major crops, benefit from pollinators to reproduce via fruit and seed production, and most of these pollinators are insects[11]. The annual global value of insect pollination services, provided not only by bees but also by other insects[12], has been estimated to exceed $200 billion[13], and the demand for resources that require insect pollination is expected to increase.

Insect antagonists (e.g. predators and parasitoids) of plant-feeding insects play a critical role in sustaining plant communities, and their judicious use for biological control has been key in reducing dependence on insecticides for pest management. Nutrient cycling, soil formation, and even water purification are also influenced by insects. In many regions, termites break down dead wood and dung, thereby promoting soil fertility by recycling nutrients. In Nordic lakes, billions of midges emerging from their larval habitats link aquatic and terrestrial energy and nutrient cycles, moving vast amounts of nitrogen and phosphorus to fertilize terrestrial habitats. Insects are also major prey for freshwater fishes, amphibians, birds, and bats throughout the world. The 40% decline in the abundance of North American birds documented between 1966 and 2013 has been attributed in part to declines in the abundance of the insects on which they prey[14].

Human Causes of Insect Decline

Among the most consequential human impacts affecting insect populations are habitat loss and degradation associated with agriculture, urbanization and residential development, as well as resource extraction. Habitat losses through land conversion are occurring in areas where insect diversity is highest[15]. Habitat quality is further affected by the use of agrochemicals, particularly insecticides. Agrochemical residues that retain insecticidal activity have adverse impacts on non-target insect species. Furthermore, the conversion of natural communities for agriculture reduces species diversity, including that of insects, and threatens adjacent ecosystems by creating barriers to dispersal and exposing insects to pesticides, invasive species, heavy metals, and light pollution.

Human-mediated redistribution of insect species, both deliberate and accidental, has led to the decline of many native species through competition with, and/or displacement by, invasive species. For example, the accidental introduction of an Argentine ant species into the unique vegetational community of the Cape provinces of South Africa led to the decline of indigenous ant species adapted to disperse the seeds of many plants.

Changing patterns of temperature and rainfall, caused by rising levels of greenhouse gases, are altering species distributions. For some species, populations have increased and ranges have expanded. For example, bark beetles in North America have become more abundant because of warmer winters, resulting in defoliation of coniferous forests. For many other species, climate change directly or indirectly can cause declines. Thus, Alpine and Arctic bumblebees are experiencing range compression, a result of decreasing suitability of habitats. Moreover, the increased frequency, intensity, and duration of extreme weather events have disrupted food-webs, producing seasonal mismatches between specialized insect pollinators and the plants that cannot reproduce without them.

Inappropriate use of pesticide applications can result in massive mortality of non-target insects, many of which are beneficial, often outside the treated area. And electrocution devices ("bug-zappers"), which are extremely inefficient at killing their target species (primarily mosquitoes), kill millions of non-target, beneficial species.

Finally, indirect drivers (e.g. markets, policies and societal awareness) are influencing ecosystems. Global markets for agricultural commodities, food, fiber or wood benefit human societies, but they also incentivize intensive production at the cost of insect populations and ecosystem services[16]. Agricultural and forest policies are not focusing enough on halting declines in biodiversity[17].

A Call to Action

Insect declines are global challenges that require international collaboration, as (i) the geographic distributions of threatened species often cross international borders and (ii) the globalization of trade has resulted in an increase in the number of accidentally introduced invasive species that may displace important native species. The planet is undergoing a massive urbanization, the conversion of wildlands to agriculture, and other human activities that degrade or destroy unique habitats. These changes alter food webs, resulting in the displacement or elimination of plants and animals, including insect communities. It is essential to protect threatened habitats, because when they disappear or become degraded, their insect inhabitants may be lost. Other major challenges to addressing insect declines are the paucity of data for documenting trends, the difficulty of identifying the various causal factors, and insufficient numbers of knowledgeable entomologists and ecologists. There is an urgent need to identify species at greatest risk, factors that threaten their survival, and consequences of their loss.

Protecting insect biodiversity is critically important for maintaining the integrity of managed and natural ecosystems, which are essential for water supplies, global agriculture and food security and safety. Finding solutions requires coordinated effort among many groups, including scientists and scientific societies, nongovernmental conservation organizations, policymakers at many levels, federal funding and regulatory agencies, science communicators, corporations, and private citizens around the world.

Recommendations

Actions recommended by our Academies include the following:

1. Encourage and support long-term monitoring of insect species and biomass to identify stressors by means of (i) new technologies such as artificial intelligence, environmental DNA analysis and rapid whole-genome sequencing for species identification and monitoring and (ii) museum datamining.

2. Promote citizen science through support for (i) environmental and conservation movements and education of citizens to identify and monitor insects and (ii) informing the public, including farmers, about the importance of insects and necessary changes in human behavior.

3. Identify and protect critical habitats at risk, in order to maintain communities of insect species in well- functioning food webs. Protected habitats should be large enough to withstand adverse influences of adjacent lands; declines have already been documented in many reserves designed before the importance of adjacent lands was recognized. Designs of reserves must also anticipate changes in habitat suitability associated with changing climatic conditions, and frequency of extreme weather events.

4. Adopt mitigation and adaptation strategies to address climate change and its effects, which are predicted to be severe drivers of insect shifts and declines in the future.

5. Regulate and incentivize changes in human activities that exact excessive tolls on insect communities and/or internalize the costs of non-target effects and other environmental degradation, especially for actions that do not appreciably improve human well-being. Develop and support eco-friendly (and thus insect-friendly) land-use systems.

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G-20

PANDEMIC PREPAREDNESS AND THE ROLE OF SCIENCE

Executive Summary

Based on consideration by the Scientific Academies of the G20 countries of how the experience of the response to COVID-19 might inform pandemic preparedness in the future, the governments of G20 are urged to undertake the following actions:

1. Promote the creation of a global network of surveillance, with agreed criteria to:

- Detect emerging unusual clusters of morbidity and mortality that may be the harbingers of a potential new pandemic by:

- building on existing infrastructures including the global alert and response system for disease outbreaks;

- promoting enhanced support for systems such as the Epidemic Intelligence from Open Sources initiative (EIOS); developing robust policies and platforms for collating and sharing detailed data - for example on pathogen genomics.

- Provide molecular epidemiological surveillance for directly transmitted respiratory infections (the most dangerous in terms of rapid spread) and bacterial infections in the context of the spread of antibiotic resistance genes.

- Strengthen the system for worldwide antimicrobial resistance surveillance.

- Advertise, educate and promote support for these, and build capacity and skills for their use.

The network should be underpinned by the governance, infrastructure and skills to interpret, analyse and connect across countries, and to learn from international data.

2. *Promote the distributed manufacture and delivery of diagnostics, drugs, vaccines, medical supplies and equipment for:*

- Increased technology and manufacturing capability worldwide, but especially in low and middle-income countries.

- Streamlined regulatory processes for novel diagnostics, drugs and vaccines.

- International regulatory agencies to look at the lessons learned from swift development of vaccines in the COVID-19 pandemic and ensure new regulatory processes can be implemented in a timely fashion.

- Provide an international structure to compile and advise on the sensitivity and specificity of different diagnostic tools.

- Enhance access to new technologies, accounting for intellectual property, patenting and pricing mechanisms.

3. Launch an Intergovernmental Convention that should:

- Pave the way to the formulation of an International Agreement on Pandemic Preparedness and Management, as recently proposed by more than 20 world leaders.

- Provide a unique forum to assess the experience of COVID-19 for successes and failures in global cooperation.

- Discuss the need for incentives and mechanisms to reinforce the International Health Regulations (2005) that must become a sharper instrument for action and more timely reporting of potential outbreaks.

Introduction

A pandemic is the worldwide spread of a new disease. Achieving protection against a pandemic is a public good. Like mitigation of climate change, it is a supranational issue that cannot be left only to national governments. Achieving global health security (including prevention of pandemics) requires reinforced international collaboration to deliver decisions about allocation of limited resources.

Lessons From Covid-19 And Previous Pandemics

The first lesson of pandemic preparedness is that this needs to start long before a new pandemic starts. Countries with recent experience of zoonotic infections that might have become pandemic, such as avian influenza, SARS-1 and MERS, have tended to manage the current pandemic more effectively than those whose public health systems were less experienced and that had received less investment in pandemic preparedness.

Pandemic preparedness starts with rapid and transparent sharing of information and samples, it requires research at great speed and scale, and involves the production and distribution of necessary public health commodities such as vaccines and drugs, protective equipment, and the infrastructure for iden- tification, testing, tracing, isolating, treating and preventing cases, especially considering the routes of disease transmission. Aware of the heavy economic, societal and human impact of pandemics, recommendations aimed at enhancing preparedness have been put forward in the recent past[1], [4]. However, it is clear from the COVID-19 pandemic experience that the recommendations have not been sufficient to mitigate the effects of the pandemic, nor have they been ade- quately implemented in most countries. Indeed, a major problem in the response to COVID-19 has not been just one of resources, except for drug and vaccine shortages, but also misinformation and unsuccessful global coordination of resource deployment at scale, resulting in a multiplication of parallel efforts.

Preparing for unexpected and difficult-to-predict infectious

diseases to prevent or control outbreaks can be very challenging. Nonetheless, the world has accumulated substantial knowledge and experience from past infectious disease epidemics and pandemics. Great strides have been achieved towards ensuring preparedness and response capacity for potential emerging infectious diseases particularly in high income countries. This was achieved by developing and implementing comprehensive approaches and proactive systems including resource prioritization, substantial investment in scientific research and improvement of research infrastructures, efficient national and international cooperation; effective networks of infectious disease epidemiology and surveillance, research collaboration and enablement of data sharing, therapeutics and vaccine clinical trials, dedicated and committed scientific, medical and political leadership. Unfortunately, progress towards meeting such minimal preparedness, especially in low and middle income countries, is lagging in terms of public health surveillance and outbreak response causing high risk and vulnerability.

Lessons on pandemic prevention and early detection

A) Preventing the onset of epidemics

Control of infectious diseases depends on preventing new cases of infection. It requires the ability to detect any new or re-emerging pathogens including drug-resistant microbes that represent a challenge for global health. Interactions between humans, domestic and wild animals are important predisposing factors that are influenced, not only by their immediate environment, but also by agricultural practices and cultural attitudes. The frequency of zoonoses will likely increase due to a growing and increasingly mobile human population, climate change, inappropriate use and scarcity of water, consumption of wildlife products, legal and illegal trades of wild animals, and loss of biodiversity. The international community is confronted with two interlinked major challenges, namely *mitigating human vulnerability to pandemics and developing approaches to minimize spill overs from animals and their associated environment to humans.*

Presently, our ability to predict the emergence of a disease in areas and populations identified as being at high risk is poor and is constrained by knowledge and technological asymmetries, infrastructure, culture, and politics.

Epidemiological surveillance includes the systematic collection, recording, analysis, interpretation, and dissemination of data on communicable diseases that can lead to early war-ning signals and promote an adequate response. Surveillance must be enhanced in high-risk areas and populations, which may be identified with the support of epidemiological models and experience, including emerging local information and scientific findings on infectiousness of pathogens, information on international trade, mobility, transport, animal breeding, agricultural practices, and loss of biodiversity. The capacity for continuous genetic sequencing, molecular surveillance, structured data and terminology for the use of artificial intelligence must be integrated to enhance the detection of novel pathogens, predict risk, and identify of potential therapeutics.

B) Early detection of the pathogen in animals and humans and predictive models, immediately after an outbreak

Early detection is essential and relies on clinical recognition, mathematical modelling, the rapid availability of trained personnel, and an infrastructure for widespread and rapid testing and tracing. Establishing the capability for contact tracing is particularly important at the beginning of a pandemic. International data sharing must occur rapidly. Early detection can be based on passive surveillance of cases, or on active surveillance of sentinel sites or on new technologies capturing

specific symptoms in the population[5]. Models based on previous information should be improved by incorporating emerging local information.

Rapid data and sample collection and then their international sharing is key to fighting a pandemic. A global network of clinical and epidemiological surveillance, coupled with the capability for genomic analysis, needs to be managed by highly qualified personnel according to principles of complete transparency of communication. In some countries, essential information to make decisions during the COVID-19 pandemic was provided by large cooperative data platforms, with ethics (including consent) and administrative procedures developed in advance.

C) Preventing the spread of epidemics

Containment measures are crucial. Non-pharmaceutical interventions (e.g. testing, quarantine and isolation, physical distancing, masking, handwashing, ventilation hygiene) have proven to be highly effective. To implement such measures better, we need to increase the understanding of infection control, leading to its implementation in a coherent public health response. The refinement of early epidemiological models with the help of data assimilation, filtering via actual observations, and sensitivity analysis may help guide the choice of the most appropriate containment strategies. This needs to be done within the global network mentioned above and detailed below, including a repository of raw data, terminology and procedures for supervision.

Many of the world's epidemics, particularly those transmitted by intermediate hosts, are known to be highly sensitive to longterm changes in climate and short-term fluctuations in the weather. Predictive models should apply environmental data to test for any relationship between local environmental conditions and spread of diseases.

Experts in communication of public health messaging need to be trained in advance and messaging coordinated both nationally and internationally. Variable and inconsistent messaging have undermined compliance with public health precautions and fed scepticism about the safety and effectiveness of vaccines, social distancing and the use of masks. Curtailing the spread of misinformation via social media platforms requires global cyber regulations and enhanced cyber-security. The striking progress made in the accelerated development of vaccines for COVID-19 (months rather than years) shows that vaccines can be deployed to prevent recurrent surges of infection in a pandemic, especially when appropriate interventions are taken to delay the reappearance of the disease. This is also true of vaccine adaptation to the emergence of novel strains, which evade protective immunity.

D) Identifying the vulnerable population and determining preventive or mitigating measures

The COVID-19 pandemic has revealed high variability in outcomes based on age, gender, ethnicity, and comorbidities that need to be better understood.

Lessons on interventions

Various challenges have become apparent in the COVID-19 pandemic.

Firstly, a striking variability has emerged in the response to infection and in the usefulness of interventions dependent on the stage of the disease. The detection of treatments that worked relied on randomized clinical trials (RCTs) asking simple questions in complex situations. By contrast, small trials, often performed at a single site, were often underpowered and not uusefu[6].

Parsing and predicting variability of response to the infection has relied on global alliances and pipelines that might be repositioned to gather scientific information across the lifespan of the disease, provide information on the timing of interventions, and accelerate the discovery of novel diagnostic and therapeutic opportunities. Such a coordinated mechanism must align with manufacturing, procurement, distribution, and delivery.

Secondly, the sensitivity of the global supply chain of essential drugs and vaccines to disruption has become evident. International coordination is necessary to address this complex problem that is impacted by funding, distribution infrastructure and politics.

The management of such challenges could be organized by the WHO, leveraging its unique role in establishing norms for global behavior (e.g., data sharing, material transfer agreements, common protocols, and ethics reviews). However, the governance of this complex enterprise would strongly benefit also from the involvement of medical and scientific organizations worldwide as, in its present configuration, WHO is not an operational body and is responsible to its member states. We suggest that this issue be thoroughly analyzed in the light of the COVID-19 experience.

Proposal of Actions

General Actions

Science alone cannot abolish the contribution of poverty and inequality to pandemic vulnerability, as well as to the health, social and economic costs of a pandemic, which have emerged dramatically during COVID-19. However, a scientific assessment of the latter costs would show conclusively that addressing poverty and inequality is now, more than ever, a global priority. Pursuing this challenging goal does require strengthening of national science, technology and innovation systems especially in low and middle income countries. A global effort to narrow the widened income gap caused by COVID-19 is urgently required.

The G20 governments should recognize the need to:

- Provide secure funding to National and International Health Institutions to allow for the provision of transparent, independent and accessible public health information to the global community as well as for the best allocation of available resources. This would include investment in basic, translational and implementation research, analysis of public health strategies such as lockdowns and travel restrictions to identify the best sustainable practices that could be harmonized and applied in the future. It should also include a source of current information on the safety and efficacy of new vaccines and drugs and the sharing of sequencing capability to monitor genomic variations in pathogens that may alter infectivity and virulence or change the effectiveness of vaccines or confer resistance to therapeutic drugs. Genomic sequencing allows the rapid development of tools to monitor the spread of the pandemic and the evolution of new strains.

- Improve communication as well as health and scientific education among the public, addressing areas of misinformation, public scepticism and concern related to the required interventions necessary to control a pandemic, including those that are embedded in culture (e.g. vaccine hesitancy, the wearing of face masks, trust in pharmaceutical companies).

- Promote research to discover new antimicrobials, promote the reduction in use and more rational deployment of existing antimicrobials, for both human treatment and animal breeding and exclude antimicrobials from use in healthy humans and animals.

- Extend the deployment of technological innovations (e.g. telemedicine) that may help to provide health assistance and guide resource allocation in the course of pandemics.

- Pay attention to psychological stress associated with pandemics that affect the mental and emotional health of global populations and health care providers.

- Invest the relatively small amounts of resource necessary to reach a minimum level of preparedness such as to improve outcomes for vulnerable populations when an outbreak occurs.

3.2. Specific actions to improve prevention and early detection

International collaboration of the G20 governments is especially needed to reach the following goals:

i. Improve regulation and enforce biosecurity of farmed animals (good husbandry practices) as well as documentation and control of legal and illegal trading of wild animals.

ii. Promote the study of emerging infectious diseases under a "One Health" approach. This requires cooperation between medical, veterinary, agricultural and environmental sciences, as well as the establishment of specific research institutions where integrated research can be performed. There should be a reflection on the measures needed to improve the degree of success of the joint efforts of the current WHO, World Organization for Animal Health [formerly the International Epizootic Office (OIE)], Food and Agriculture Organization of the United Nations (FAO), and UN Environmental Programme (7).

iii. Propose the creation of an international network of National Institutes for Infectious Diseases and Infection Control. This would update open-access databases and repositories of relevant epidemiological, clinical, and other scientific data collected in each country through the involvement of reference hospitals and other networks in member countries. Real time surveillance would be a key part of data sharing. Transparency of national and local health organizations for the realtime availability and sharing of comprehensive clinical and scientific standardized datasets to WHO to facilitate the work of international experts is necessary.

Specific areas for data collection and sharing include:

- Biology, pathology, and ecology of new microbial pathogens, with special emphasis on rapidly-mutating RNA viruses; ecology of animal carriers and reservoirs; mechanisms of pathogen transmission within and amongst animal species and from animals to humans;

- Determinants of the onset and spread of zoonoses; information systems on epidemiological surveillance, increasing their interoperability;

- Strengthening joint activities to enhance biosafety and biosecurity at the global level;

- Studies to explain the variability of response to infection.

iv. Enhance coordination on research in the following areas:

- Mechanisms of contagion, assessment of the risk of contagion under different environmental conditions (humidity, temperature, ventilation, distancing), technological innovations of protective equipment.

- Study of the relationships between climate change and the emergence of microorganisms, including the risk of the appearance of pathogens presently buried in the cryosphere.

- Innovative technologies to allow for the accelerated development and dissemination of new drugs and vaccines.

- Development of and global access to a distributed network of vaccine manufacturing facilities, to control infections. More than ever, vaccines must be considered as a global good for which each country must be the guarantor.

- Development of rapid, simple, efficient, and inexpensive diagnostics and establishment of clear diagnostic criteria.

- Genomics platforms for systematic assessment of pathogen evolution and host genomics, and development of multiomics and immunophenotyping pipelines with standardized approaches to sample analysis.

- Analysis of basic aspects of antigen immunogenicity and immune memory.

- Transnational platforms for integration of structured data and terminology from questionnaires and electronic health records.

- Development of animal models using the 3Rs (replacement, reduction and refinement) that can mimic human diseases for pathogenesis study and for drug screening.

v. Develop comprehensive industry enabling biotechnology platforms. Industry led initiatives might include building multiple antibody libraries, biobanking of microorganisms, development of viral vector platforms, screening of products and formulations and a facility to achieve good manufacturing practice (GMP) process development, manufacturing scale up and stockpiling of materials for preclinical and clinical trials.

3.3 Specific actions to improve the control of new pandemic diseases

i. Refine approaches to screening for new drugs, integrating novel laboratory technologies and preclinical models with experimental medicine approaches and innovative exploratory trial designs. This should be planned on a global basis.

ii. Establish several international networks designed to activate rapidly observational cohort studies and large RCTs incorporating digital screening methods and rapid response evidence- and consensus-based frameworks for immediate treatment. Put in place a funding mechanism - a research preparedness - response fund - for vaccine and drug development and the rapid design and implementation of such studies and trials.

iii. Establish a streamlined international consultation mechanism for medical professionals to recommend rapidly only those new or repurposed drugs proven to be effective and safe.

iv. Increase sequencing capacity to detect viral evolution that may impact the effectiveness of diagnostics, small molecule drugs, immunotherapies and vaccines, and integrate evidence on genotypic evolution with strategies to determine phenotypic properties such as incubation periods, infectiousness, transmissibility and pathogenicity as measured by mortality and morbidity requiring hospitalization.

v. Collect pathogen samples where genome data can be linked to location and epidemiological and demographic information about the patient from which the sample was collected. A well curated, interoperable database of

such information should be designed and made operational for emerging infections.

vi. Establish a global monitoring system to record the longterm sequelae of infection and the comparative safety and duration of efficacy of vaccines and pharmaceuticals.

4. The Need For An International Agreement On Pandemic Preparedness And Management

In view of the above recommendations, we support the launch of an Intergovernmental Convention that should pave the way to formulation of an International Agreement on Pandemic Preparedness and Management, as recently proposed by more than 20 world leaders[8] and affirmed at the G7[9]. The Intergovernmental Convention should provide a unique forum to discuss success and failures emerged from the experience of COVID-19 and the need for incentives and mechanisms to reinforce the International Health Regulations (2005) that must become a sharper instrument for action and more timely reporting of potential outbreaks. The International Agreement should be subject to an annual review of the implementation of the commitments and policies agreed upon. While there is great uncertainty about the future threats of infectious diseases, there is much that governments and policymakers can do to prepare. Many of the key choices for governance and regulation are about recognizing the need for a globally integrated approach to tackling infectious diseases. A true "One Health" approach in close cooperation with the WHO, the FAO, the OIE and the UN Environmental Program (UNEP) as well as similar organizations [10], is essential.

While the structuring of an International Agreement on Pandemic Preparedness is left to the governments, it should aim

i. to facilitate rapid and efficient implementation of practices based on the best available science and technology and

ii. to de-politicize and integrate public health messaging from a widely accepted source.

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CRISES: ECONOMY, SOCIETY, LAW, AND CULTURE TOWARDS A LESS VULNERABLE HUMANKIND

Introduction

The current COVID-19 pandemic, and systemic crises such as climate change, reveal deep-seated structural fragilities and criticalities in the material and cultural spheres of world societies. However, crises entail opportunities if they induce awareness of the challenges confronting humankind as a whole and stimulate the transformations needed to achieve less vulnerable societies. This statement focuses on present-day fragilities and challenges and aims to highlight and strengthen the role of coordination between local, national, and international actors to increase resilience at a global scale.

1. Global Challenges And Opportunities

The increased interdependence between countries, cultures, and economies has been a distinctive feature of the last decades. Achieved through the expansion of communication, trade, international division of labour, international education, increased cultural sharing, and financial linkages, this interdependence has vastly increased opportunities for the countries, regions and sectors that could benefit from it. However, many could not reap those advantages or were negatively impacted.

The COVID-19 pandemic and climate change disruptions have shown that interdependence makes crises arising in some countries or regions to quickly spill over, destabilising vast areas and potentially the way of living worldwide. The fragility of interdependent economies and societies has been exposed, for example, in financial markets instability and increased indebtedness, struggle for resources, large-scale reduction or misuse of common goods, supply-chain challenges, and uncontrolled migrations, particularly severe in those countries most affected by this phenomenon.

However, increased interdependence can become a powerful instrument for controlling and mitigating systemic vulnerability, provided that countries are able

to coordinate their actions acknowledging that vital conditions for human survival and well-being are at stake. No single country, however large and powerful, can effectively implement solutions to global crises, such as the COVID-19 pandemic, future pandemic outbreaks, climate change disruptions, and widespread food shortages. The G20 states have a major responsibility to lead a response to systemic challenges that urgently require measures reducing vulnerability and increasing resilience at the world scale.

2. Fragilities And Resilience: Towards A Less Vulnerable Humankind

The impact of the COVID-19 pandemic has shown that worldwide interdependence by itself does not guarantee resilience: parts of the world fully integrated in global networks of communication and trade have not been less affected than areas at the margin of globalisation. In many cases, the crisis has brought to light fragilities that have built up over time. Inequality in the distribution of income and wealth has greatly increased, leading to a weakening of social cohesion. Public and political responsibility has been reduced under the influence of narrowly identified economic and political objectives. In many cases the provision of, or access to, public goods has declined, and the sustainability of human interaction with the natural environment has greatly suffered. In several cases, compliance to uniform cultural standards worldwide, not mediated by a thorough knowledge of and adaptation to local contexts, has hampered the mutual understanding of different traditions. Respect for cultural diversity, including for indigenous peoples, together with respect for fundamental human rights, must be seen as a necessary condition for maximising the resilience of world societies.

Global interdependence can provide a stepping-stone to greater resilience if fragilities are addressed through coordinated actions. Primary instruments are those that reduce social and economic inequality, increase the provision of public goods, improve environmental and health protection, enhance education and the reciprocal awareness and respect of different cultures, thereby building a community of shared future for humankind.

Actions in the above-mentioned areas require coordinated efforts by high-level public actors to achieve global resilience. The G20 states have the opportunity and the duty to lead humankind through the structural transformations needed to face global crises.

An Action Map: Global Coordination for Systemic Crises

An integrated set of concerted actions are proposed in the cultural, social, economic, and legal fields, to promote mutual awareness of different historical trajectories and cultural traditions, counteract inequality, and promote social cohesion, foster the coordination of legal frameworks, and implement resilienceoriented economic and social policies.

3.1 Education and research

- Practices that ensure equal opportunities in education between countries should be promoted.

- Education should foster the integration of local history, national history, and global history, and promote demonstrative reasoning and scientific validation as critical tools against dissemination of false or unverified news. The study of history in a broad and anthropological perspective, far from being an irrelevant comparison of local events and narratives, has a key role in understanding past, present, and future crises, as well as in exploring sustainable ways to meet the challenges confronting humankind.

- Research and research evaluation systems should promote a much-needed integration between natural and technological sciences, humanities, and social sciences: as the COVID-19 and climate change crises are showing, interdisciplinarity has a fundamental role to play in determining the effectiveness of research to deal with systemic crises and support policy actions tackling global challenges.

- Fundamental research in all fields of knowledge should be promoted and mainly supported by sufficient public funding to advance all areas of enquiry, and to enhance scientific creativity and innovation. The substantial involvement of Humanities, Arts, and Social Sciences is necessary to properly address societal, environmental, climate, and health challenges. Special attention must be given to the advancement of both theoretical and applied knowledge of the structural transformations and policies needed to achieve less vulnerable and more resilient social and economic systems.

3.2 Cultural heritage

- Knowledge, mutual understanding, and respect of cultural heritage should be a priority of national governments and intergovernmental cooperation.

- National and regional policies should foster local communities' awareness of their heritage and the active participation of citizens in its enhancement and protection. A recommendation to G20 governments is to promote education and dissemination of cultural heritage knowledge in all its forms (historical and archaeological heritage, indigenous, cultural and linguistic traditions, as well as live creative practices, such as performing arts) as a tool to make people aware of and involved in their own histories and traditions, material and immaterial. This can be achieved through schools and universities, museums, and other public institutions, and will enhance the contribution of cultural diversity to an enriching and sustainable development of human societies. Learning and respecting other histories, cultures, and languages can reduce intolerance and give people the tools to interact with each other as world citizens, mitigating racial and ethnic antagonism.

- The development of digital technologies, and fostering widespread access to them, should be enhanced to enable universal awareness and sharing of world heritage, even in times of crises.

3.3 Social policy and legal harmonisation

- National policies should promote social cohesion by tackling educational gaps between socioeconomic groups, genders, age groups, and territories; implementing urban and regional policies aimed at addressing problems arising from rural poverty and rapid urbanisation, especially in mega cities; opposing social and territorial marginalisation, including the digital divide, particularly in the vast rural areas of developing countries; integrating culturally different groups and fostering inclusiveness. International aid in the social policy field should acknowledge that uniform solutions are unlikely to successfully address the needs of vulnerable groups across the world, and that effective policies often require a contextualised approach.

- Fundamental human rights to make lives sustainable in a healthy, equitable and secure social and natural environment should be universally recognized and pursued at local, national, and international levels.

- International coordination should promote research efforts and policy measures aimed at increasing social preparedness to pandemic outbreaks and other world-scale crises. An international research initiative aimed at investigating the comparative social and economic impact of the COVID-19 crisis and responses to it is strongly recommended to better understand the conditions for a mature and well-planned social and cultural policy to deal with current and future crises.

- International coordination should promote universal, free, and timely availability of vaccines as public goods and other life-saving medical devices and means of protection from pandemics. Measures should be taken to increase the effectiveness of the global health architecture in which the World Health Organization (WHO) must play a central role.

- Intergovernmental coordination should reduce excessive differentiation of taxation regimes. Measures should be taken to ensure that taxation of corporate incomes is kept within an internationally agreed range, with special reference to the digital economy.

- A global normative framework must be promoted to achieve broader internet access and public governance of communication worldwide, enhancing cybersecurity to prevent unlawful cyberspace activity. This measure is essential for global connectivity to increase the resilience of world society.

- Intergovernmental cooperation should identify and implement effective legal protection of global commons and essential resources.

3.4 Economic actions

- In international trade, countries should avoid policies protecting their domestic economies at the expense of other countries, while acknowledging that different opportunities are afforded to countries as a consequence of the different timings, conditions, and historical contexts of their development processes. The World Trade Organization (WTO) should act according to these principles and its dispute settlement mechanism should be strengthened.

- International coordination to reduce the vulnerability of supply platforms that are essential for resilience is strongly recommended.

- International coordination should promote economic policies that focus not only on growth of gross domestic product (GDP) but also on material and social resilience, universal access to credit facilities, and equity across genders, social groups, and generations.

- A global crisis platform based on international participation and governance should be explored, as a means to provide the liquidity needed to support and coordinate the emergency measures needed to address systemic crises.

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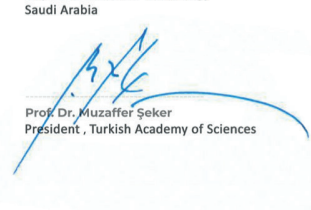

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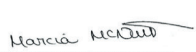

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2022
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G-20

Executive Summary

The Science20 (S20) recommends that the G20 governments tackle challenges in the priority issues that cover: building resilient health systems, enhancing adaptive capacity of health systems to climate change, bolstering multi-disciplinary science and technology for pandemic preparedness and climate change, guaranteeing that people are at the center, and strengthening the nexus between data-research-policy- practice for climate change, pandemic preparedness and economic recovery. The S20 recommends the following action measures:

1. WHO should globally coordinate the implementation of the proposed actions, to ensure alignment with relevant global health initiatives.

2. Mitigate health care contributions to greenhouse gases (GHGs) and climate change, while at the same time, improving health care quality and resilience.

3. Improve the path to a more sustainable, resilient and effective health system that should include development of country-driven adaptation actions for strong and equitable health systems aligned with national priorities, and engagement of local and international communities.

4. Leverage technical advancements, in particular information and communication technology (ICT), supported by clean/renewable energy systems adapted to local conditions, including developing preventive medicine, tele-health care and community health literacy to avoid overloading critical health systems and meet consumer needs.

5. Enhance technological development that significantly contribute to achieving sustainable development targets in utilizing renewable energy resources, building urban water systems and sustainable public infrastructure, sustainable management of natural resources, increasing healthy diet from sustainable food production, and producing environmentally-friendly materials and products.

6. Increase the currently minimal financial support for health adaptation, expand multilateral climate finance projects, and develop appropriate financial incentives.

7. Enhance multi-disciplinary collaborative work with more research on pandemic preparedness and climate change among multiple stakeholders for the benefit of the people, the planet, and the prosperity for all parties.

8. Encourage Open Data practices to enhance knowledge collaboration and transfer among G20 members, that should be accompanied by a strong data policy and ethics.

9. Encourage mutual partnership to support climate action, recognize the importance of a just transition to a low-carbon economy enabling a fair and just energy transition for many countries, supported by proper energy policy and financial incentives through market-based approaches.

10. Require the commitment of G20 members to support the science and technology cooperation and expand access across member countries. Sharing financial support, knowledge and technology among G20 members is argued as a mechanism to achieve those commitments, so that no one is left behind.

11. Ensure the sustainability and resilience of our societies and planet, by guaranteeing that all people are at the center, especially people in vulnerable situations in the Global Health Architecture (GHA) and the Digital Economy Transformation (DET).

12. Equalize disparate access and powers, increase efforts to integrate the Social Sciences and Humanities into all public policy decisions affecting people, thereby guaranteeing that people are at the center.

13. Bolster the adoption of evidence-based policy to strengthen political will and leadership and establish institutional design to facilitate the exchange of scientific information for decision makers.

14. Involve all stakeholders including the public and local communities, ensure transparency and access to data availability and translatability, local as well as global, in various forms, including digital, to monitor and evaluate scientific-based policymaking.

The Ways Forward for Tackling Current and Emerging Challenges

1. We note that Climate change and the COVID-19 pandemic are existential threats with complex interacting causes. Both lead to unpredictable and unprecedented consequences. There are parallels between the scale and scope of their impacts and the responses they evoke. Understanding shared drivers, coupled vulnerabilities, and criteria for effective responses, will help societies worldwide to prepare for future threats from climate change and unpredictable pandemics.

2. Despite warnings from the scientific community about the risks of the pandemic, the world has largely remained unprepared for the current crisis, and insufficient action has been taken against climate change. There are plenty of reasons for the multitude in handling the pandemic at a local level. Citizens' resilience and their capacity to withstand and respond to unpredicted crises must be improved, by reforming social protection schemes and policies to be more adaptable, anticipative, and adjustable. This can be done through adaptive social protection and adaptive policy. It is necessary for governments, with strong support from the private sectors, to give the necessary support. In order to increase the motivation of the private sector, public incentives and corporate social responsibility activities can be accelerated. Nevertheless, the political system and ability to deal properly with the pandemic, public policies and decisions are highly dependent on the availability of science-based data analyses.

3. In rebuilding G20 economies after the COVID-19 pandemic, we are required to have the ability and willingness to reconsider the type of global economic activities we need for a sustainable future. A workable and affordable green transition that is attentive to ways of living and practices specific or unique to different local situations is essential to mitigate climate change and alleviate environmental crises. A high-quality partnership for a new era of global development should also be strengthened for stronger, greener and healthier global development. Such systemic recovery can go forward only if policy makers are guided by a clear vision, policy and strategy, involving both the public and private sectors in: boosting productivity; investing in infrastructure; reaching net-zero greenhouse gas emissions; and implementing the Paris Agreement and the 2030 Agenda for Sustainable Development Goals.

4. In the education sector, re-imagining and re-designing to build forward better are essential. The principles in the UNESCO Futures of Education initiative highlight the importance for post COVID-19 recovery. The pandemic has revealed many potential problem areas and opportunity gaps. Governments and communities can improve the education and knowledge base for young generations, from elementary school students to university students, and people from all ages and segments of society. Addressing educational challenges must emphasize multidimensional, interconnected, and holistic approaches.

5. The 2022 G20 Summit promotes the theme of "Recover Together, Recover Stronger", with the intent of developing concrete action plans for green, inclusive, resilient, and sustainable global economic recovery after the COVID-19 pandemic. Three pillars of the G20 summit that are aimed at achieving the goals to an optimal future for humankind are: Global Health Architecture, Digital Economy Transformation, and Energy Transition.

6. We, the Science20 (S20), recommend that the G20 governments strive toward achieving sustainable and inclusive growth across the world, and to contribute toward enhancing the quality of life. The recommendations related to tackling challenges in the priority issues cover: building resilient health systems, enhancing adaptive capacity of health systems to climate change, bolstering multi-disciplinary science and technology for pandemic preparedness and climate change, guaranteeing that people are at the center, and strengthening the nexus between data- research-policy-practice for climate change, pandemic preparedness and economic recovery.

BUILDING RESILIENT HEALTH SYSTEMS

7. The COVID-19 pandemic has had wide-ranging impacts on all areas of society, leading to setbacks in health gains and efforts to achieve universal health coverage. The diversion of health system resources to address COVID-19 care has led to a disruption of essential health services. New barriers to healthcare access, such as movement restrictions, reduced ability to pay and fear of infection, have posed additional and unprecedented challenges. As the first major pandemic in both the digital information and communication age and the era of molecular medicine, COVID- 19 provides major lessons that we must take on board. We need to be proactive on the policy, communications, education and science fronts. Past overreliance on reacting to events as they occur, rather than on prevention and preparedness, has left countries unprepared to timely address a global crisis of this speed and magnitude. Unfortunately, the pandemic has also hit vulnerable populations hardest and further exacerbated pre-existing inequalities. That we can, and must, change if, in our interlinked and interdependent world, humanity is to have a bright future. The COVID-19 experience is a wake-up call that health systems and all essential infrastructures at the global, regional and national levels need to be substantially improved to provide a safety net for imminent existential threats. Obvious challenges are pandemics and climate change. Recovery from the pandemic and preparation for the next provides an opportunity to make changes in health and other systems that help to address problems related to climate change. The health system transformation would be a part of enhancing global preparedness and response that benefits every layer of society. Health, social, education and economic infrastructures are irreversibly intertwined.

8. We, the Science20 (S20), recommend the following action measures with regard to this issue.

9. WHO should globally coordinate the implementation of the proposed actions, to ensure alignment with relevant global health initiatives, such as the 'One

Health' Joint Plan of Action. Essential institutional arrangements should be promoted, such as: networks of international centers of excellence fostering faster responses for interlinked global crises; increasing the flow and speed of information and data sharing within and among countries; increasing the flow and speed of information and data sharing within and among countries; and increasing response capacity within countries to tackle emerging crises. The health sector can itself do more to mitigate its contributions to greenhouse gases (GHGs) and climate change while, at the same time, improving health care quality and resilience. Tackling the pandemic and climate change and improving preparedness by producing a suitable strategy which could include:

1. A pandemic alert system that provides all research institutions and authorities with immediate access to relevant information, following strict data sharing policy and ethics;

2. Facilities for the production of vaccines and drugs on all continents that can be rapidly brought into production in the event of a pandemic;

3. Secure supply chains for medicine-relevant materials and production at multiple locations worldwide;

4. A well-trained medical workforce, a global education program curriculum for health units and measures for burnout of the medical workforce in response to a pandemic; and

5. Expansion of public health monitoring network and utilization of information and communication technology (ICT) to overcome the limitations of epidemiologic investigations.

ENHANCING ADAPTIVE CAPACITY OF HEALTH SYSTEMS TO CLIMATE CHANGE

10. Climate change will increasingly impact human and ecological health and well-being. Changing conditions will expand favorable habitats for vectors of parasites and other pathogens, exacerbate antimicrobial resistance, and increase the risk of zoonosis, making the implementation of the 'One Health' approach even more urgent. They will also cause disruptions in food production and distribution, exacerbating food insecurity and all forms of malnutrition. This will increase health care burden related to communicable and non-communicable diseases, including mental health. Failing to recognize and address this issue will make the recovery more painful and expensive. Therefore, climate change mitigation and adaptation need to be embedded in all pandemic recovery plans, including in the health sector.

11. All populations are vulnerable; however, the impacts tend to be most severe for the poor, who often already suffer from poor sanitation and limited access to safe drinking water, healthy food, energy and transport. Furthermore, few countries currently include weather and climate-informed information in their health in surveillance systems for climate-sensitive diseases or health-related early warning systems.

12. A wide array of technologies can be leveraged to create, expand and monitor the effectiveness of health care and the contribution of the health sector to advancing socially and ecologically sustainable development, including enhancing and ensuring compliance with environmental adaptation and mitigation measures within the health system. In order to realize this potential, there is a need to build greater acceptance of, and capacity for, using information and communications technology (ICT) in healthcare.

13. We, the Science20 (S20), recommend the following action measures.

14. The path to a more sustainable, resilient and effective health system should include development of country-driven adaptation actions for strong and equitable health systems aligned with national priorities, engaging local and international communities. Improving access to sanitation and safe drinking water, healthy diets from sustainable food systems, clean/sustainable energy, and transport, can substantially reduce poverty and improve health and wellbeing. Measures such as appropriate urban/spatial planning, universal health coverage and social safety nets can further reduce the burden of avoidable disease, thereby enabling health systems to respond to the increased burden of disease related to climate change. Specific ways to enhance the adaptive capacity of health systems include but are not limited to:

- Leverage technical advancements, in particular information and communications technology (ICT), supported by clean/renewable energy systems adapted to local conditions, including to develop preventive medicine, tele-health care and community health literacy to avoid overloading critical health systems and meet consumer needs;

- Improve early warning systems and readiness of health services and medical supply logistics to react to emergency cases, especially in remote areas;

- Increase multi-sectoral/multi-level collaboration on health and climate change policy; and

- Increase the currently minimal financial support for health adaptation, expand multilateral climate finance projects, and develop appropriate financial incentives.

BOLSTERING MULTI-DISCIPLINARY SCIENCE AND TECHNOLOGY FOR PANDEMIC PREPAREDNESS AND CLIMATE CHANGE

15. Preventing, preparing for, and responding to a global health crisis such as pandemics and climate change require multi-sectoral and multi-disciplinary approaches that engage different sectors and actors such as governments, business, and civil society along with researchers and scientific bodies to work together on a common agenda of prevention, adaptation, and mitigation of risks and impact. This necessitates that pandemic and climate risk reduction be an integral part of national health and economic policies to strengthen the resilience of societies at large.

16. Research dependent on multi-disciplinary approaches across spatial and temporal scales is needed to identify effective policy and governance solutions to such complex challenges as pandemics and climate change. However, research funding agencies do not currently allocate sufficient funding for cross-disciplinary and multilateral research initiatives. Institutional fragmentation further exacerbates the effectiveness of various research efforts and makes it more challenging for science to contribute effectively to policy making. To promote sustainable transitions, multi-disciplinary science should embrace inclusivity, equity, co-production, and scientific rigor.

17. Furthermore, partnership and collaborative processes from all stakeholders are required to enhance the acceleration and adoption of technologies for environmental regeneration and quality of life improvement. In this context, policy makers, business practitioners, scientists, researchers and societies should be working together to add sustainable value and reinforce the positive aspects of technology's effect on the environment. As technology changes the way we live, it will continue to have a profound impact on the way we regenerate and protect our environment's sustainability. Therefore, we suggest that technology transfer be conducted among G20 members.

18. We, the Science20 (S20), recommend the following action measures.

19. Enhancing multi-disciplinary collaborative work with multiple stakeholders for the benefit of people, the planet, and prosperity for all parties.

20. Technological development in utilizing renewable energy resources, building

urban water systems and sustainable public infrastructure, sustainable management of natural resources, increasing sustainable food production, and producing environmentally-friendly materials and products are among the pathways by which technology policy will significantly contribute to achieving sustainable development targets. Furthermore, as the need for robust scientific research increases, Open Data practices could be encouraged to enhance knowledge collaboration and transfer among G20 members. The adoption of Open Data should be accompanied by a strong data policy and ethics.

21. We strongly suggest that more research on pandemic preparedness and climate change be carried out, for example, research towards energy transition. The energy system is experiencing rapid transitions that are triggered by the latest developments of science and technology, updated regulations, consumer preferences, and the growing global demand for affordable and clean energy. Yet, many countries face different energy challenges in their pursuit of a low-carbon economy. Utilization of renewable energy sources and energy system digitalization to create more intelligent and flexible energy systems is key to ensuring a smooth energy transition process. A shift towards decentralized energy systems will ensure that everyone can have stable and affordable energy. Mutual partnership to support climate action is required, recognizing the importance of a just transition to a low-carbon economy enabling a fair and just energy transition for many countries. The energy transition system will be efficient and effective if it provides proper energy policy support and financial incentives through market-based approaches.

22. The G20 members need to commit to supporting the science and technology process and expanding access across member countries. Sharing financial support, knowledge and technology among G20 members is argued as a mechanism to achieve those commitments. The G20 needs to strengthen cooperation in order to overcome the pandemic and to mitigate climate change, and enhance research science and technology contribution, so that no one is left behind.

GUARANTEE THAT PEOPLE ARE AT THE CENTER

23. Rapid social and economic transformations are related to rising global temperature and have accelerated the changing conditions for communicable diseases. We have been building economies and communities in ways that have negatively impacted human health and well-being. We need to leverage science, technology, and innovation to involve people in building an interconnected health system and digital economy that benefit and create safety nets for all. We believe that ignoring the needs of peoples has made our societies and global structure more vulnerable to shocks.

24. Thus, we propose recommendations to ensure the sustainability and resilience of our societies and planet. Such is done by guaranteeing that all people are at the center, especially people in vulnerable situations in the Global Health Architecture (GHA) and the Digital Economy Transformation (DET).

25. To equalize disparate access and powers, we must increase efforts to integrate the Social Sciences and Humanities into all public policy decisions affecting people, thereby guaranteeing that people are at the center. Thus we should:

- Establish commitment from all nations, governments, and all segments of society alike down to local communities and to the individual level to build meaningful, collective effort and deep participation at all levels with the aim to tackle global challenges;

- Increase society's resilience in the face of various forms of crises;

- Convey common global values based on necessary and appropriate research in the social sciences and humanities;

- Improve people's lives, livelihoods, and life chances in facing multi-dimensional human-made disruptions (i.e. geopolitical armed conflicts, social dislocations, conflicts), which cause other disasters (health, climate, energy disasters);

- Reduce barriers so all people can benefit from universal health, education, and global social economic access to all;

- Increase commitments from all participating governments down to local levels to cooperate in the global fundraising and harmonizing standards endeavor in realizing the GHA and DET;

- Strengthen resilience and adaptability appropriate in dealing with the prevailing diversity among nations, communities down to the individual levels within the GHA and DET;

- Ensure just, inclusive and affordable GHA and DET services for all so that no one is marginalized;

- Pool expertise, knowledge, imagination, and values of the Humanities and Social Sciences so that it is central to public and policy conversations about the GHA and DET around the world;

- Pursue these goals within all our fields, our contributions, our teaching/ education, and our forms of public engagements so that the GHA and DET can benefit as many people as possible;

- Overcome difficulties in human solidarity and pursue common development in harmony; and

- Keep moving toward a community with a shared future for humankind, and jointly create a better future.

STRENGTHENING THE NEXUS BETWEEN DATA- RESEARCH-POLICY-PRACTICE FOR CLIMATE CHANGE, PANDEMIC PREPAREDNESS AND ECONOMIC RECOVERY

26. The experiences of handling, and coping with, the consequences of COVID-19 have taught us the value of evidence-based-policy-making. Serious problems exist, however, in countries where data are insufficient and lack precision to generate evidence-based-policy. In fact, addressing intersectional and complex health, climate change and socio-political-cultural problems, as well as moving towards just energy transition and economic digitization depends on hard numbers and evidence. Evidence-based-policy deriving from valid and reliable data not only provides short-term solutions, but also generates good practices of inclusion and interconnectivity of various parties and diverse sectors of human life for a sustainable future.

27. The COVID-19 pandemic and the transformed ecological, economic, and techno-socio- cultural environment mark a turning point for establishing a solid nexus of data – research - policy and practice for evidence-informed-policy and decision-making. Multi-stakeholders faced major challenges in translating a rapidly evolving body of new data and evidence stored in documents and digital devices into tangible response efforts on global-health, climate change, energy transition, and economic digitization. Both the pandemic and climate change also create situations, where health and environmental policy decisions receive unprecedented public attention through the use of various media and digital platforms.

28. Trusted relationships and dedicated governance structures for agile knowledge translation often play a key role for promoting the use of best available data and evidence for responsive and timely decision-making. In too many countries, however, siloed mentality within governmental institutions still poses a major technical and political challenge for efforts to incorporate insights from the latest global evidence into coordinated national policy and programs. Another problem is the uncertainty and incomplete information that can be presented in

a cloud of misinformation. The lack of data integration between diverse sectors leads to inappropriate policy decisions which miss the target of achieving equal access to economic resources. This has to change if we are to have robust evidence-based policy, along with better regional sharing of available data, monitoring and evaluation of implementation that is essential for scientific knowledge to achieve its full potential for impacting positively on people's lives.

29. We, the Science20 (S20), recommend the following action measures.

30. In building resilience against global-health and climate-change threats, policymaking should:

- Bolster the adoption of evidence-based policy to strengthen political will and leadership;

- Establish institutional design to facilitate the exchange of scientific information for decision makers.

31. Since pandemics, climate change, and the need to develop a just energy transition and economic digitization are interrelated, advocacy to policymakers should:

- Incorporate the inter-connectivity and inclusion of diverse bodies of knowledge and communities;

- Provide space for engaging with youth, civil society, and politicians in advancing the scientific evidence-to-policy ecosystem at the global, regional and national levels;

- Implement intersectoral solutions through high quality data analysis and evidence based, people-centered approach, informed by inter-, multi-, transdisciplinary and collaborative research; and

- Support mitigation pathways and adaptation policies.

32. In monitoring and evaluating scientific-based policymaking on climate change, just energy transition, pandemics and economic digitization, we should:

- Involve all stakeholders, including the public and local communities; and

- Ensure transparency, and access to data availability and translatability, local as well as global, in various forms, including digital.

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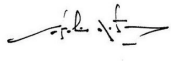

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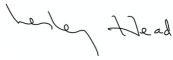

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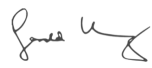

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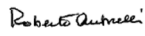

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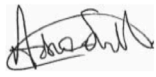

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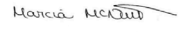

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