G-Science Academies Statement 2016:

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 [*4*]. 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 important 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, risk 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

- 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.
- 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.
- 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

- Recognize that brain disorders constitute a global health crisis and support basic and applied research on their causes, prevention, diagnosis, and therapy including rehabilitation.
- Advance new economic and scientific platforms to develop therapeutics using valid biological models including animals, and promote cooperation between academia and industry.
- 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

- Support multidisciplinary research using theoretical, computational, statistical, and data sciences and mathematics to reveal fundamental principles for developing a unified brain theory.
- Promote international cooperation for sharing neuroscience data to accelerate research and the development of brain-based artificial intelligence and neuro-technologies.
- 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

- Support fundamental and translational research that integrates principles, technologies, methods, and theories of brain science with those in the empirical social sciences.
- 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.
- 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-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 from 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 between scientists, practitioners, 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 contexts 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 [2].
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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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, flexibility, 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 prospects for 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 limited in general. Postdocs often are hired by senior 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 academia 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 institutes would enhance this pattern of mobilization. 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

(1) 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.

(2) 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.

(3) 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.

(4) 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.

(5) 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

(6) 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.

(7) 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.

(8) 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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