the Pontifical Academy of Sciences

Final Statement of the 2018 PAS Plenary Session

Transformative Roles of Science in Society: From Emerging Basic Science toward Solutions for People's Wellbeing

His Holiness Pope Francis has made clear in his Encyclical *Laudato Si'* in 2015 and other comments that the world is facing unprecedented challenges, which threaten the future of civilization. These challenges have been identified and discussed in numerous previous meetings of the Pontifical Academy of Sciences. We refer to the respective statements by the Pontifical Academy, as they remain highly relevant. 1

This statement by the Pontifical Academy of Sciences is based on its plenary conference of 2018 and takes note of some trends in society and science and shares scientific insights on key risks of humanity and science opportunities to address them. Frontiers in main scientific disciplines are highlighted and potential action items emerging from science policy consultations are derived. The purpose of this statement is to stimulate thought and action for more fruitful exchange among science and society. In that context we also embraced the theme of how to foster fruitful relations between the natural sciences, the empirical branches of the social sciences and religion.

I) On science and society

1. People's wellbeing is the goal of the world's longstanding commitment to sustainable development. Achieving it requires coordinated progress on *all* of the UN's recently adopted Sustainable Development Goals. Advances in science are essential to achieving such progress
2. Both **societal change and scientific changes** occur more and more rapidly, and the two are

interlinked. PAS notes that these interlinked changes require responsible engagement by science communities. Science is an integral part of human culture and scientists must not view themselves as a separate community in society.

3. Global change is increasingly impacted by human actions but appropriate and comprehensive **responses to the Anthropocene's risks** for human well-being and planetary health are currently insufficient. Science has progressed with identifying these risks but needs to focus more intensively on working with society and politics to identify and implement solutions that are equitable and just, and that acknowledge the inherent complexities of the tightly coupled inanimate and animate systems of our planet.
4. While acknowledging the limitations of science to predict its own dynamics, let alone the even more complex societal changes**, foresight** into risks and opportunities in the long-term future is needed. Intensified interaction between science and society and trust in science are needed in order to identify large global risks and opportunities and the roles of science and technologies in addressing them rationally, with wisdom and collectively.
5. **Science must constantly earn the trust of society.** Advances in science and changes in society constantly challenge the relationship between science and society. Especially in a time when 'post-truth' sentiments are voiced regularly, the importance and relevance of evidence based insights and solutions must be effectively demonstrated, not just asserted. A loss of trust in science would result in multiple consequences for society, including reduced opportunity for scientific knowledge to inform societal decisions and fewer opportunities for science to have a transformative impact on innovation and technology. Our Academy is particularly sensitive to any such tendencies and therefore seeks ongoing effective dialogue and interaction with science policy leaders and citizens. Transparency and humility are imperative in such exchanges. We seek to strengthen both the ability of science to deliver transformative knowledge as well as the mechanisms to enable society to benefit from new and existing scientific knowledge.
6. We note that **freedom of thought** is fundamental for societal wellbeing - including minorities - and freedom of sciences is fundamental for science to identify new truths and facilitate progress with responsibility. PAS is an independent body within the Holy See and appreciates freedom of research. The PAS has as its goal the promotion of the progress of the sciences, the study of related epistemological questions, the investigation of ethical implications of scientific discoveries and their application as well as the broad dissemination of scientific knowledge for the betterment of human well-being.
7. The discourse between science and society will be endangered if **equality of rights** is not assured, including equal rights of women and men, rights of the poor and most vulnerable, and children's rights. Science must get involved in this discourse, foster understanding of the barriers and drive changes needed to overcome human trafficking, modern slavery and abuse.
8. Progress in achieving the **Sustainable Development Goals** (SDGs) has been sporadic. Many of the targets, including overcoming hunger and high mortality, will not be achieved without major changes in the course of action taken and the integration across the seventeen SDGs.

Pope Francis' Encyclical *Laudato Si'* has made key proposals for accelerating progress. Science is directly relevant to that progress. Scientists need to play a more active role in engaging with society and offering information, assistance and potential solutions at global, national, and local levels. Inclusion of youth is key for the success of these efforts.

II) Selected insights from sciences frontiers to address humanities' challenges

In the 2018 PAS Plenary session we identified emerging insights from both basic science and use-inspired or translational science. We aimed to identify:

1. Groundbreaking developments in the main disciplines of basic science.
2. Evidence-based problem-solving strategies and related research for people's wellbeing, poverty reduction and humanity's current problems of environmental destructions and conflicts.
3. Approaches on how to maintain and foster societies' trust in science.

From the PAS Plenary themes several frontiers in science disciplines may be highlighted

Astronomy, Space: Thanks to improved instruments, in space and on the ground, cosmologists can trace the history of our expanding universe back to the first nanosecond. This progress brings into focus a new set of questions: What generated the observed 'mix' of atoms, dark matter, dark energy and radiation? Was 'our' big bang the only one? And the realization that there are likely to be billions of Earth-sized 'habitable' planets orbiting stars within our Galaxy, has initiated a vibrant new research effort, linking astronomy more closely with biology and environmental science. Due to these novel insights questions on the origin of life seem to have become more approachable.

Physics: Physics continues to expand its reach across scales and contributes tools to many other areas of science, from astrophysics to biochemistry and medicine. At the most fundamental level, physics tries to model the basic constituents of matter and their interactions. Experiments at high particle energies or with extreme precision are probing conceivable limits of the standard model. Precise measurements of fundamental constants are making it possible to redefine the basic units of measurements so that human-made artifacts can be entirely avoided. The laws of quantum physics have led to a far-reaching understanding of atoms, molecules and condensed matter, and they have enabled past transformative inventions such as the transistor, the laser, or magnetic resonance imaging. Quantum physicists are now beginning to harness counter-intuitive quantum phenomena, such as entanglement, to engineer new quantum technology. Envisioned goals include highly sensitive and accurate sensors for forces and fields, secure, unbreakable communication, and quantum information processing. Quantum computers and quantum simulators will enable new approaches to the modeling and understanding of complex systems, such as high-temperature superconductors, that are outside the reach of classical computers.

Biology: Advances have occurred recently in biological sciences that are highly significant towards

improving people's health and wellbeing. Some aspects of these advances have been discussed in this session. Such is the case for the identification of the role of *stem cells* in development, in the process of cell renewal of adult tissues and their potential for regenerative medicine. The production of a drug against multiple sclerosis is a spectacular example of the direct translation of basic research into medicine. Another highlight of the application of research to human health is the progress in cancer treatment by immunotherapy, together with the hope of novel approaches directly derived from recent results in cell biology. The importance of technical improvements in the process of discovery have been underlined. One example is the spectacular development of new microscope technologies allowing the tracking of molecular processes in living cells. Equally spectacular is the progress in genomics, proteomics and metabolomics, all of which profit from the availability of huge databases (big data) and the availability of unprecedented computing power. The project for a "Genome Information-oriented society" paves the way for personalized medicine. Last but not least the enormous potential has been discussed that stem cell engineering has for the regeneration or replacement of injured tissue and organs However, particular attention was drawn to the necessity of an ethical attitude in the application of these spectacular scientific advances in order to respect and protect human dignity.

Medicine, Brain: The past decade has seen major breakthroughs in the therapy and even cure of previously fatal diseases, all of which were the consequence of applications of curiosity-driven scientific discoveries to medical problems. Examples are the treatment of Hepatitis C, the development of vaccines against Ebola, the ability to stabilize and sometimes even cure patients infected with HIV virus, the successes to repress and sometimes even cure cancer by combining immunotherapy and genetic engineering with the classical approaches, the greatly improved success of organ transplantation and the healing of certain genetically determined diseases by genetic engineering and gene therapy.. Much less progress has been made in the treatment of the major psychiatric diseases. The main reason is the still sparse knowledge about the neuronal mechanisms underlying higher cognitive functions. Major challenges are the immense complexity of the nervous system and the fact that its functions are determined not only by genetic but to a large extent also by epigenetic shaping. Here the specific problem is that environmental influences comprise not only biological factors such as nutrition or toxins but to a substantial extent also socio-cultural conditions. Hence, coping with the behavioral and psychological consequences of a diseased brain state requires not only biological interventions but must also consider socio-cultural influences at large. More progress has been made with respect to the substitution of impaired sensory and motor functions using neuronal prostheses or brain-machine interfaces and here is space for promising improvements. To alleviate the symptoms of Parkinson's disease deep brain stimulation with implanted electrodes is now applied in hundreds of thousands of patients and attempts are also underway to use this invasive technique to alleviate psychiatric symptoms. As interference with brain functions, whether with pharmacological, surgical or electrical means often alters not only motor functions but affects also higher cognitive functions and traits of personality, strict ethical control of such interventions is required but not always implemented. Novel ethical challenges are also created by the progress in reproductive medicine (cloning, therapy of

mitochondrial diseases), allo- and xeno-transplantation and with the introduction of the CRISPr/cas technology that permits short cuts to gene editing and gene therapy. As science is international it is an obligation of the scientific community to make this need transparent and to strive for widely accepted international regulations.

Finally, deeper understanding of the brain mechanisms supporting anti- and prosocial behavior (aggression, greed, hate / altruism, empathy, compassion, co-operativity) will hopefully provide the insight required for the development of effective educational regimes and societal incentives to enhance prosocial and constrain antisocial behavior. Substantial progress in this domain is indispensable in order to confine the dual use problem of scientific discoveries. If progress in science and the ensuing increase in power continues to be perverted for the selfish exploitation of the planet´s resources and the design of ever effective weapons, the unquestioned benefits of science are jeopardized.

III) Science addressing large humanities issues and their underlying causes

Climate change, energy, sustainability: The new science of climate extremes has made it possible to link many weather extremes to climate change. During the next 25 years, intensification of weather extremes due to climate change can expose more than 1.5 billion people (20% of the population) to deadly heat stress and other attendant health risks. While the poorest among us (numbering over 3 billion) are most vulnerable, climate change has now the potential to adversely impact the wealthy too in the form of intense fires, floods and droughts. New research has also identified the risk that unabated greenhouse-gas emissions might push the planet into a 'hothouse state', with 5-6°C higher temperatures and up to 60 m sea level rise. Many solutions are still available to avert catastrophic impacts, including mass migrations. The fundamental challenge is to garner massive public support for climate actions. PAS can help immensely by forging an alliance between leaders in science, public health, policy makers and leaders of all faiths. The glue for such an alliance is the knowledge that both science and religion agree on protecting creation (nature) including the 7.5 billion people; and the knowledge that (because of our inaction to mitigate) climate change has become a huge moral ethical issue.

SDGs, health, and wellbeing of population: Healthcare is a universal right as recognized by the United Nations charter. *The economic, social and cultural rights are recognized in articles 22 to 27.* Science develops the data from which the template/protocol/standards of health care are derived. Hence, the process of standardizing protocols to attain the specified goals is a matter of science. Inequalities and lack of capacities in the production and utilization of science, technology and innovation (STI) pose a real challenge to many developing countries, especially the LDCs, in their efforts to solve real life problems and achieve the SDGs. Yet, we also live in a world of unprecedented opportunities. A world in which frontier STI, including digitization, internet of things, artificial intelligence, robotics, drones, 3D printing and genomics hold more promise, than ever

before, in resolving such fundamental problems as energy, food and water securities, as well as controlling biodiversity loss and curbing the impact of climate change and natural disasters in all countries.

Nutrition: Despite recent progress in tackling malnutrition, last year the number of hungry people in the world rose to 821 million – yet it is estimated that one-third of the food produced annually was lost or wasted. We also face huge challenges to address micronutrient deficiencies, which may harm approximately two billion people. Worldwide obesity is rising, having almost tripled to more than 800 million people between 1975 and 2016. This is not just a high income, urban phenomenon, but is increasingly impacting lower income groups and rural populations. Overall, the food system is also placing huge pressures on the environment, as a major contributor to deforestation, air and water pollution, and climate change. Science needs to further identify solutions, but important insights are gained and on that basis we urge governments and the private sector, as well as other stakeholders, to undertake scalable and practical solutions, which reflect the central role of safe foods and healthy diets to the Sustainable Development Goals, and to overcome the particularly large burden of unsafe and unhealthy food for the poor

Ecology and bio-systems (incl. opportunities of genetics): Knowledge about evolution of the universe, of living organisms and of living conditions calls for and offers opportunities to safeguard the very biodiversity that is both our responsibility as stewards of creation as well as the fundamental basis of the life-support systems of the planet. The interdependence of different species of living organisms, highlighted by Pope Francis in *Laudato Si'*, requires more holistic approaches to sustainable development than are currently underway. The biodiversity goals in SDG 14 and 15 underpin most of the other SDGs, enabling humanity, for example, to address poverty, food security, and job creation, and assist with mitigation and adaptation to climate change. Driven by scientific advances, encouraging solutions are now being implemented to help protect biodiversity and enhance the resilience of ocean ecosystems. Specifically, Marine Protected Areas (MPAs) that are fully protected from extractive activities can preserve and restore biodiversity and habitats within their boundaries. Moreover, much of that bounty spills over to adjacent areas outside, helping to restore depleted fisheries. These fully protected areas can also enhance the resilience of ocean ecosystems to climate and other environmental changes. Due to scientific evidence about the benefits of MPAs, there has been an order of magnitude increase in the area of the ocean in MPAs over the last decade. Nonetheless, the area protected is still far less than the international targets set by countries in the SDGs and of the area that scientists calculate is likely needed to maintain the health, productivity and resilience of ocean ecosystems. Hence, in fully protected MPAs, humanity has a powerful, but underutilized tool to help achieve multiple goals.

In parallel to protecting biodiversity and ecosystem functioning through the use of fully protected MPAs, there is new evidence that fisheries can be reformed and restored to greater productivity and resilience to climate change. New science-based approaches to fishery management are

demonstrating that it is possible to use the ocean without using it up. Successes in developed as well as developing countries provide models for ways in which science can assist in achieving food security and job creation through the restoration of productive fisheries that bring economic, environmental and social benefit.

These successes underscore the connections across the SDGs, e.g., between biodiversity, health, food security, jobs and climate change. They also emphasize the importance of science. Moreover, they provide much-needed hope that sustainability is indeed possible when science is used in service to society and when scientists engage with society to tackle big problems.

Another exciting and encouraging development is the availability of cheap miniaturised satellites, enabling monitoring by whole fleets of satellites of land use, urban development, shipping movements etc. These systems can harvest the data needed for an evidence-based management of our biosphere. In addition they can be used to bring the internet to undeveloped and isolated regions, thus enabling the less privileged to also profit from accumulating knowledge.

However, human actions are not only jeopardizing the equilibrium of the geo- and biosphere but also their own biotope. We witness the disproportionate and disorderly growth of large cities, whose number and populations are increasing at a dramatic pace. This creates unhealthy living conditions due to pollution, acceleration and overstimulation, anonymity and loneliness, steep gradients between the wealthy and the poor and the ensuing violence. By contrast, however, big cities also nurture scientific advances, provide a rich cultural environment, professional education and health care and thereby can greatly improve the quality of life of their citizens. Ideally, we should plan new smart cities with a human dimension, containing all the advantages that science can offer, such as clean water, clean environment, connectivity, etc.

IV) Opportunities for consultations among leaders of science organizations, policy makers, religious communities and academicians

Taking note of the transformative roles of science in societies, key science policy issues addressed in the consultations were:

1. Scientific inquiry is constitutive for human culture and has a moral value in itself. As long as humanity actively and intentionally interferes with the world it is a moral obligation to strive for an evidence-based model of the world as this seems to be the only safe way to judge the consequences of actions.
2. As discoveries are per definition hard to anticipate and as many of them are actually serendipitous, it is epistemically questionable to identify priorities for scientific inquiry solely as a function of short-term applicability. A safe investment is to provide conditions that enhance creativity. Science education of the young, literacy, freedom of thought, and

investment in research institutions with flat hierarchies must be priorities. A prerequisite to achieve these goals is the liberation from precarious living conditions. Those struggling for life cannot afford the leisure that nurtures creative thinking.

3. At the same time, science can also provide immediately useful solutions to global problems that require our immediate attention. Investments in both basic and use-inspired (or translational) science are in society's strong interests. Thus, a balance of curiosity-driven and problem-solving science should be encouraged.
4. Ex ante identification of promising fields of science remains difficult, yet science policy and related financing constantly needs to make related decisions. Bold decisions in the face of scientific uncertainties are called for to address uncertain but high risk global changes.
5. Science policy choices' require consideration of moral dimensions. Science communities need to actively engage in shaping and promoting evidence-based worldviews, and in doing so we see synergies between free and responsible natural sciences, the empirical branches of the social sciences and religion. Religion harvests and concentrates the collective experience of populations about rules of moral conduct that are helpful to support peaceful coexistence and thus contributes empirical evidence on the validity of moral rules that is complementary to the evidence provided by science.
6. Religion is also a significant expression of human dignity. It can facilitate understanding of short-term trends within the horizon of the existential and eternal questions of humanity. Thus, it contributes to critical analysis and moral discernment as well as to the expression and experience of meaning-making. The urgent questions of our present time call for a framework of resilience, co-existence and hope, to which religious views and practices contribute a robust grounding.
7. Joint action to preserve and strengthen trust in sound science: scientists and science policymakers need to engage with society to foster trust in science and patiently counter the spread of statements that are grossly distorting realities. Sources of trust and mistrust in science must be understood and opportunities to enhance trust in science identified, including science education and communication.
8. Sharing of science that can help to address global risks across countries for collective action: We note that science itself and its benefits for humanity are not shared sufficiently across nations. As science is fundamental for humanity, this inequality is an ethical issue of growing importance. Developing countries need to be actively included in the advanced international science systems.
9. Science is partly to be viewed as a public good, not only a factor in nations' competitiveness. This especially applies to basic science. The societal and policy demands for short-term translational science need to be critically evaluated and must not marginalize the focus on basic sciences that usually pays off only in the long run. This applies to basic as well as translational (use-inspired) science. Society benefits hugely from the full range of science. Both basic science and translational (use-inspired) science are needed and important.
10. The transformative power of science and technology are obvious (communication, biotechnology, medicine, information processing). However, these goods need to be shared

by all countries. Beyond governments and international organisms such as UNESCO and OAS, National and International Academies, which are independent civil societies, have a particularly important and responsible function to play in the promotion of knowledge and education among the people of the world.

Final remarks

In accordance with the recommendations of His Holiness Pope Francis in his address to the members of the Pontifical Academy of Sciences and guests, we reexamined the potential of science to identify imminent challenges for our geo- and biosphere and to provide solutions. We left the meeting deeply concerned about the state of the world. Not only that old problems like nuclear arms proliferation seem to re-emerge, but contemporary problems, nearly exclusively generated by human action, keep on aggravating. Nevertheless, we put our hope in our ability to overcome the challenges by combining the rational strategies derived from scientific evidence, provided both, by the natural sciences and the empirical disciplines of the social sciences, with the cultural achievements, that define human dignity, are at the basis of our ethical and moral attitudes and roots in normative systems and religion.

Selected Statements by the **Pontifical Academy of Sciences**

- Biological Extinction - How to Save the Natural World on Which We Depend, PAS-PASS Workshop 2017
- Health of People and Planet: Our Responsibility, PAS-PASS Conference 2017, with a focus on climate change
- Science and Sustainability. Impacts of Scientific Knowledge and Technology on Human Society and Environment, 2016
- Sustainable Humanity, Sustainable Nature: Our Responsibility, 2014