SCIENCE AS A GLOBAL PUBLIC GOOD

A POSITION PAPER OF THE INTERNATIONAL SCIENCE COUNCIL

November 2021

International Science Council
The global voice for science

October 2021
Second edition published November 2021

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ACKNOWLEDGEMENTS: The Governing Board members for their reviews and particularly Professor Pearl Dykstra

DOI: 10.24948/2021.09.

REFERENCE: Boulton, G.S. 2021. *Science as a Global Public Good. International Science Council Position Paper*. https://council.science/wp-content/uploads/2020/06/Science-as-a-global-public-good_v041021.pdf

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A. THE VALUE OF SCIENCE

1. The International Science Council (ISC) is committed to a vision of science[1] as a global public good. It is a vision with profound implications for the ways that science is conducted, how it is used and the roles that it plays in society. These implications, the ways they influence the responsibilities of scientists, both individually and collectively, and how they apply in the different settings in which science is practised, are elaborated in this paper.

2. The concept of shared, public goods has been a concern of moral and political philosophers since ancient times and in many cultures. It contrasts pursuit of the good of the many with the pursuit of narrow self-interest. It assumes that citizens stand in a relationship with one another which encourages them to create and maintain facilities or arrangements on the grounds that they serve common interests and produce public value, from which many individually benefit.

1. The word **science** is used to refer to the systematic organization of knowledge that can be rationally explained and reliably applied. It is inclusive of the natural (including physical, mathematical and life) science and social (including behavioural and economic) science domains, which represent the ISC's primary focus, as well as the humanities, medical, health, computer and engineering sciences. It is recognized that there is no single word or phrase in English (though there are in other languages) that adequately describes this knowledge community. It is hoped that this shorthand will be accepted in the sense intended.

3. Knowledge has been amongst the most powerful of public goods. It has been the inspiration, stimulus and agent upon which most human material, social and personal progress has been built. Access to knowledge, and to the education systems that seek to increase the stock of knowledge of individuals, and thereby, in aggregate, of society, are recognized as human rights (UNESCO, n.d.).

4. Science is a special form of knowledge: a formalized approach to knowledge that is rationally explicable, tested against reality, logic and the scrutiny of peers. It has two fundamental attributes that form its bedrock, and which are ultimately the source of its value as a global public good:

   – that knowledge claims and the evidence on which they may be based are made openly available to be tested against reality and logic through the scrutiny of peers;

   – that the results of scientific inquiry are communicated promptly into the public sphere and circulated efficiently to maximize their availability to all who may wish or need to access them.

   The International Science Council regards these as the essential norms of a specific scientific ethic[2]. At the same time, as good citizens, scientists should ensure that they work in ways that are consistent with the highest contemporary societal values of integrity, equity, inclusivity and openness; that as far as possible the results of their work are not used in harmful ways; and that they are responsive to the needs of the societies of which they are part.

> **Knowledge has been amongst the most powerful of public goods. It has been the inspiration, stimulus, and agent upon which most human material, social and personal progress has been built.**

5. Science seeks both explanations that are universally true, as in the behaviour of fundamental units of matter, and ones that are bounded by time or space, as in the past movements of continents or the behaviour of social groups. It seeks to verify what is stable in that very unstable compound that often passes for knowledge.

6. Openness to sceptical scrutiny is the basis of so-called ‘scientific self-correction’, eloquently expressed in words often attributed to Einstein, ‘a thousand

2. They are also the hallmarks of various other forms of serious inquiry that are not regarded as science.

experiments cannot prove me right, but one experiment can prove me wrong'. The word 'scientific' is often, erroneously, used to imply 'correct', 'true' or 'certain'. Science grapples with uncertainty. It can invalidate but cannot validate; 'the aim of science is not to open the door to infinite wisdom, but to set a limit to infinite error' (Brecht, 1939). Although scientists may search for truth, scientific knowledge remains provisional. Although the progress of research may diminish uncertainty, uncertainty will remain.

7. Its disciplined method (para. 4) has made science the most reliable, though provisional, form of systematic human knowledge. It is not a dispensable luxury but has become essential to the advancement of our societies, in responding to their needs, in informing education, strengthening policy, spurring innovation, addressing global sustainability, safeguarding health and wellbeing, and as a stimulus to curiosity, imagination and wonder. It helps all of us to make sense of and navigate the increasingly complex world we live in.

8. These roles illustrate the utility of scientific knowledge as a global public good, a concept usefully defined by economists (Kaul et al., 1999) in a way that is helpful in describing what science should and can be. In economic terms science serves the public good most profoundly through its creation of 'public goods'. Such goods have no market value. They are the basis for most private goods. They include such things as free education, free roads, an honest police force and the rule of law, which we may use for private benefit in, for example, enhancing job prospects, running a road haulage business, safeguarding possessions and protecting investments from corruption. In its specific role as a global public good, science is *a source of beneficial and applicable knowledge that is freely available and accessible worldwide, and where its use by anyone does not prevent or impede its use by others.* Public benefits are of course created from private sector research in many fields, but not generally as public goods.

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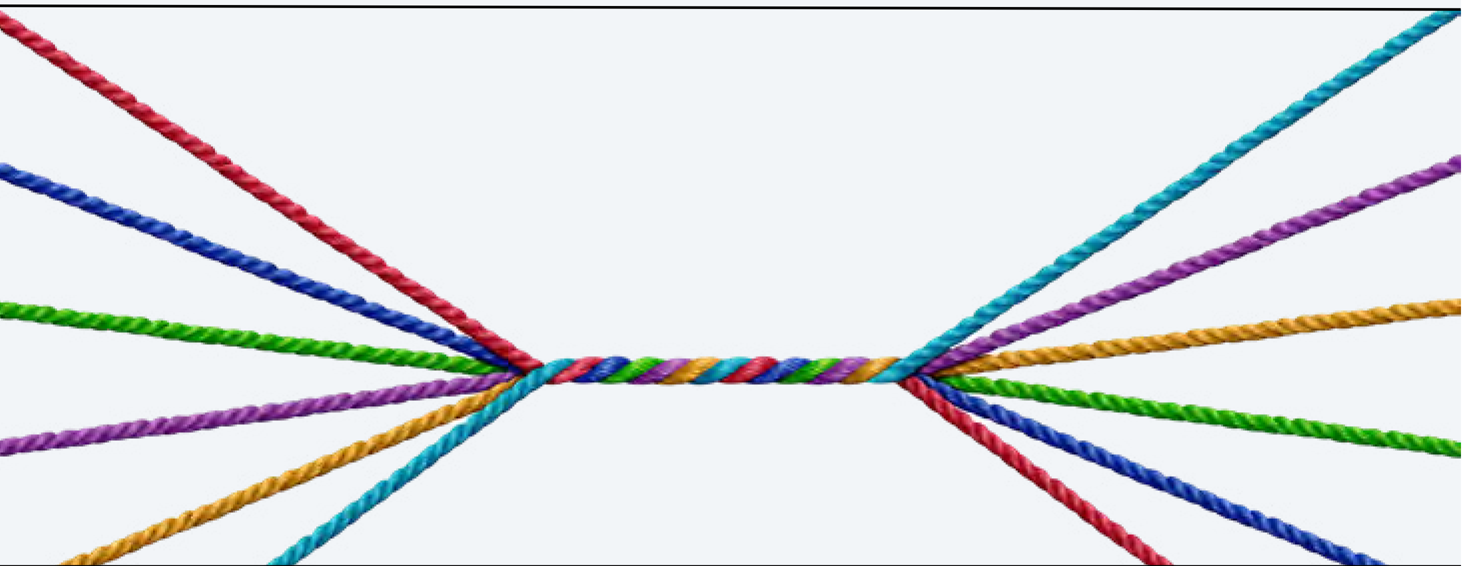
9. In practice, the value of public goods can be obstructed, impeded or withheld by political, philosophical or religious beliefs and practices, by those who withhold or monopolize knowledge for private gain, and by scientists themselves when they choose to communicate their findings in ways that restrict their

dissemination. Such impedances are frequently claimed to be justified by the greater public interest, for example in stemming the flow of knowledge that could be put to malign use, in being essential to competitive commercial innovation, in preserving conventional wisdom, or in protecting the quality of scientific publication.

10. The following discussion seeks to elucidate ways in which the role of science as a global public good is best delivered, how it can be impeded, and the responsibilities of scientists in sustaining its role, both individually and collectively as members of a global community.



B. RESPONSIBILITY FOR MAINTAINING ESSENTIAL ETHICS

11. The ethical stances in paragraph 4 and the public good imperative in paragraph 8 impose three essential responsibilities on scientists: that they should expose the evidence for the truth claims that they make, disseminate their work in the public domain, and act to mitigate significant potential for hazardous use.

EXPOSING EVIDENCE

12. When a published truth claim is based, wholly or partly, on empirical evidence, that evidence must be concurrently available for scrutiny. Otherwise, the claim fails the test that it is ‘scientific’. It is not always a requirement that is easy to satisfy. In the words of Richard Feynman (1974), providing such evidence requires ‘scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty – a kind of leaning over backwards. For example, if you’re doing an

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experiment, you should report everything that you think might make it invalid – not only what you think is right about it'.

13. This responsibility to expose evidential data, no matter how complex it is, has been codified in the 'FAIR' principle, that data, whether big or small, and irrespective of the discipline, should be findable, accessible, interoperable and reuseable (Wilkinson et al., 2016). The failure to observe this principle has contributed to the so-called crisis of replication by making it impossible to test the replicability or even the honesty of some published truth claims (Baker, 2016; Miyukawa, 2020). There is also a failure to recognize that the creativity of much research derives from the inspiration that a particular observation or measurement might reveal a novel insight into reality. Such data is a first-class output of scientific inquiry, and a potentially rich source of inspiration for further analyses or hypotheses. Charles Darwin made the case: 'False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for everyone takes a salutary pleasure in proving their falseness; and when this is done, one path towards error is closed and the road to truth is often at the same time opened' (Darwin, 1871).

COMMUNICATING SCIENCE

14. The communication of science occurs in two principal ways. Firstly, through formal publications that contribute to the 'record of science', the published record of scientific knowledge and understanding from the earliest days of scientific inquiry to the present (ISC, 2021). It is contained in books, monographs, scientific journals, preprints, and the 'grey' literature published in governmental and institutional reports, whether in print or digital formats, or as digital objects. It is continually refreshed, renewed, re-evaluated or rejected across the disciplines of science by new experiments, new observations and new theoretical insights. Secondly, science is communicated in less formal ways as essential contributions to public discourse, debate, problem solving, innovation, education and governmental policy. Although both modes are of great value, the dominance of bibliometric indices as measures of scientific value incentivizes the former, often to the detriment of the latter (para. 24).

COMMUNICATION MODES: THE EXAMPLE OF THE COVID-19 PANDEMIC

The importance of the two basic modes of communication of science has been powerfully exemplified during the COVID-19 pandemic. On the one hand, the rapid transmission of new and emerging knowledge, including by preprints, has been vital to the scientific community's spontaneous response to the pandemic, from first sequencing of the SARS-CoV-2 virus to the vaccine in less than a year. On the other hand, careful, considered and comprehensible scientific presentations in the public media have played essential roles in stimulating public confidence and eliciting the orderly and responsible behaviour of citizens in many societies that have acted to inhibit spread of the virus. Both modes are fundamental to the application of science to a wide variety of problems.

15. There are two major impediments to the formal communication of science as a global public good. The first derives from the business models of many commercial publishers, which are summarized in recent ISC reports (Gatti, 2020; ISC, 2021). The prices charged for many conventional journals, either through subscriptions or 'article processing charges', or as embedded in 'transformative deals', far exceed the necessary costs of production. These prices create barriers to access, either for readers, or authors, or both, particularly for those in poorly funded institutions or low- and middle-income countries, and undermine the full potential of the digital revolution to enhance the penetration and rate of circulation of scientific knowledge, which is not therefore 'freely available worldwide'. The second impediment is the requirement by many journals that authors surrender copyright to their work as a condition of publication, which impedes access to the record of science by modern knowledge-discovery techniques. When such research has been publicly funded, copyright surrender represents a free privatization of a publicly funded asset that should be regarded as a reprehensible transaction.

16. Not only has the digital revolution placed new opportunities in the hands of scientists, but it has also democratized communication in ways that permit individuals and groups to by-pass traditional media gatekeepers of authorized wisdom and to broadcast their views, with minimal restraint, on the web and through social media. Whilst this carries major benefits, it also has a dark side, enabling widespread dissemination of misleading, biased and fake information, exemplified by spurious information during the pandemic that has had damaging

consequences for population health. Ubiquitous digital communication has produced a more complex, crowded communication environment, with more voices vying for attention, some of which overtly attack well founded scientific understanding. It is an environment where the phrase 'alternative facts'[3] undermines the very concept of a fact, and where the brevity imposed by Twitter encourages competing assertions rather than competing arguments. It is an environment in which science needs to articulate its voice with more care and precision and with more attention to education in this new, dynamic world of information if it is to maintain and strengthen its contribution to the global public good.

17. The communication of science is not only an individual responsibility, but sometimes a collective one. There are some urgent issues of profound global societal significance, such as climate change, biodiversity and inequality, where the voice of science needs to be clearly heard in the public domain, but where individual interventions in the restrained and precise tones preferred by scientists are less influential than other, more psychologically persuasive voices, or are drowned by the tumult of global debate. In such circumstances, there is a collective responsibility for the international scientific community to articulate a global voice of 'responsible advocacy' through its representative bodies and the leverage that they command through their networks of influence.

18. But this framing can lead to a paradox that, by advocating a specific policy, scientists risk losing that part of their credibility that comes from their perceived independence, and may, in the heat of public policy debate, even lead to a corruption of evidence and minimization of uncertainty (Goodwin, 2012). The pragmatic view, however, is that if scientists fail to enter important public policy debates, either individually or collectively, the vacuum may be filled by misinformation and lobbying from those with sectional interests. This is a not a soluble problem in the scientific sense, but one where seasoned judgement, sensitive to this dilemma, should inform action, and where the international representative institutions of science have a major responsibility[4].

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3. 'Alternative facts' was a phrase used by a Counsellor to the US President during a public interview on 22 January, 2017, in which she defended the White House Press Secretary's false statement about the attendance numbers of Donald Trump's inauguration as President of the United States.
4. Bodies at the highest level of representation that should promote and support effective processes include the International Science Council, the World Academy of Sciences, the World Federation of Engineering Organizations, the InterAcademy Partnership and the Global Young Academy.

THE DILEMMA OF DUAL USE[5]

19. Most scientific discoveries are ethically neutral. It is the nature of their use that can pose ethical problems. There are some discoveries that yield valuable understanding but have the potential to create significant hazards. It is the nature of scientific discovery that its eventual uses cannot all be foreseen. Einstein, for all his theoretical brilliance, did not foresee the potential power that might be released by the atom and that would give rise to nuclear weapons. Almost any research can have potential risks as well as benefits and cannot necessarily be regulated before all possible uses become apparent. It is unreasonable, however, to extend this concern to all knowledge where there is a mere possibility that this is necessary. Little new knowledge would be able to escape that net, but it is important to focus on those areas where there are actual capacities and a willingness to make use of them in hazardous, damaging or malign ways. Where scientists foresee such uses, they have a responsibility to inform people of it. Recent examples where the scientific community has explored such potentials and advocated ethical and regulatory stances to mitigate possible harms include the use of AI technologies, germline editing, gain-of-function research, and the use of surveillance technologies. Reviewing the potential for harms and advocating ways of avoiding them are important priorities for responsible advocacy by the representative bodies of science (paras 17, 18).

20. These dilemmas apply both to the publication of scientific findings and the release of data. For example, manuscripts about the H5N1 avian flu virus, submitted for publication in 2003, demonstrated how it might be transmitted to humans, knowledge that had the potential to be used for malign purposes. The dilemma was resolved by an agreement between the authors and the editors of the journals involved that the general conclusions should be published, with significant potential benefit to the global influenza surveillance communities, but that details that could enable replication of the experiments by those who might seek to do harm should not be (Science Editorial, 2003). It is important to be aware of the potential for dual use, with the proviso that solutions that optimize the balance between rigour and communication on the one hand and hazard on the other are likely to be case specific. If a scientific discoverer foresees potential for hazardous dual use, it is their responsibility to seek advice from relevant experts as the first stage of an evaluative process.

5. The term *dual use* has primarily been used in the life sciences, particularly in relation to bio-terrorism, but is used here in a more general sense to refer to research, technologies and their artefacts.

C. THE SETTINGS IN WHICH SCIENCE IS PRACTISED

21. The different settings within which science is practised, in universities, institutes, government laboratories, the private sector, and by independent scientists (including citizen scientists) strongly condition the means and the extent to which science serves the public good and how the responsibilities of scientists are exercised. Some settings are unconstrained, where scientists have the freedom to choose the subject of their research and to decide whether and how to communicate it. Others are constrained in these choices.

UNCONSTRAINED SETTINGS AND THE ROLES OF UNIVERSITIES

22. Universities generally uphold a convention of academic freedom, giving academic researchers unconstrained freedom to choose what to study, how to study, how best to communicate their findings, and freedom to express them, including those that are inconvenient to authority. To a great degree, those freedoms have enabled universities to be sources of our most profound understanding of nature and society, as enduring entrepreneurial centres of the modern world and storehouses of anticipatory knowledge for an unknowable future. Fifty years ago, university scientists who studied climate change were regarded as irrelevant, though harmless. But serendipitous investment in their work revealed processes that are now recognized as threatening the future of human society, whilst their successors are playing crucial roles in assessing how it needs to adapt. There is a tendency to see ‘useful research’ only as research directed towards contemporary problems and mobilized by ‘mission-driven’ funding. Whilst mission-driven research is vital for immediate and foreseeable priorities, enlarging the breadth of human understanding through maintenance of curiosity-driven research is a fundamental contribution to humanity’s store of knowledge and understanding. It is a vital role for the universities.

23. Arguably the most important role of universities is in the communication and dissemination of scientific knowledge through the education, generation by generation, of successive cohorts of students in an environment where the boundaries of contemporary understanding are explored and probed through active research. The annual flux of graduates into a great diversity of roles is the dominant vector through which scientific knowledge stimulates social and economic innovation (Boulton and Lucas, 2008).

24. However, competition generated by the rankings that purport to measure the relative excellence of universities, and the bibliometrics that purport to measure individual and institutional scientific contribution are all deemed essential to the 'brand' that attracts students and funding. They powerfully incentivize communication of science through formal publication, with draconian, unrelenting pressures for one form of scientific output, that of publication, to the detriment of other university roles. They have generated a massive demand for publishing outlets, irrespective of any quality checks. They have elicited a large market response in the form of so-called predatory journals that have created a tidal wave of results of dubious value (Grudniewicz et al., 2019). These, and many other perverse outcomes (International Science Council, 2021) are a consequence of the use of inflexible and inappropriate proxy metrics, examples of the axiom that 'you get what you measure', or of Goodhart's law, that 'when a measure becomes a target, it ceases to be a good measure' (Chapman et al., 2019).

25. In some countries and at some times, the convention of academic freedom has been and is constrained by state interests. It is the contention of the International Science Council that untrammelled academic freedom within the law has proven to be of great practical benefit to the societies of which universities are part.

CONSTRAINED SETTINGS

26. Some settings constrain the freedom of scientists because of the purpose that they are designed to serve. Publicly funded research institutes and those funded on a not-for-profit basis tend to serve a specified scientific purpose, so that researchers are generally not free to pursue research outwith that purpose. It is also normally but not exclusively the case that scientific results are institutionally vetted prior to publication in a predetermined form or journal. As a consequence, and in contrast to university practice, such publications tend to be considered as much the product of the institute as they are of the author.

27. There are some publicly funded settings where the imperative to publish remains, but where confidentiality or even strong security is required. Research that involves human subjects, whether undertaken in universities, institutes or

hospitals, quite properly requires that their subjects' identities are not revealed, even though there may be a strong public interest in the results of the study being openly available. In such cases, subject identities must be anonymized, and a pathway for scientists to scrutinize the underlying data must be available if the principle of rigour (para. 4) is to be upheld.

28. Governments also maintain research settings, often for military or state security purpose, where publication of any sort is excluded. The disadvantage to government of this setting is that results are not subject to the scrutiny of external sceptical minds, although given the hazards that are often implicit in the research, intensive, sceptical scrutiny and regulation are essential.

29. How does the issue of science as a global public good relate to private sector companies and corporations? The private research sector has grown enormously in recent decades as the utility of research as a driver of private sector innovation has become increasingly apparent. This trend was epitomized in the work of Peter Drucker (1993), who argued that 'The basic economic resource, the means of production, ... is no longer capital, nor land, nor labour. It is and will be – knowledge.' It is a perspective that has been embraced by governments worldwide, with the consequence that the priorities of science and for science have moved from the periphery to near the centre of governmental concerns and are increasingly taken up by the business sector, with the consequence that over 70% of global investment in science now comes from commercial sources (OECD, 2022).

30. This perspective has also created increasing pressures on universities to commercialize their research through licensing and intellectual property protection, so that many increasingly straddle the public/private interface, with a significant part of their activity becoming constrained by commercial imperatives. Although the capacity to work across the public/private interface is particularly important in facing many major challenges, as exemplified during the COVID-19 pandemic (para. 47), the trend should not be so great as to limit the capacities of academics and universities to speak freely and to contribute a distinctively broad spectrum of research to the scientific enterprise (paras 22 and 40).

> The basic economic resource, the means of production, ... is no longer capital, nor land nor labour. It is and will be – knowledge.

31. Much of the new scientific knowledge created by the business sector is withheld from public scrutiny, at least in the short term, as a private good. Exclusive access to such new knowledge in the form of a patent enables a company to achieve a lucrative short-term market monopoly until it is caught up or overtaken by its competitors. This competitive stimulus lies at the heart of capitalist dynamism, powerfully facilitated by the ability of an innovative idea to attract investment because of the returns generated by a short-term competitive advantage. The patents system permits the underlying concept to filter through to the public domain as a public good, whilst the patent holder retains the knowledge of how best to transform it into marketable products, or to license that knowledge to others. There is little doubt that such a competitive process enhances the rate of innovation, particularly in fields such as pharmaceuticals, energy systems or IT infrastructures, which depend upon major private as well as public investments. Publicly funded knowledge can stimulate private gain that in turn generates public goods of employment and economic wellbeing. At the present time, however, processes are at work that can entrench monopolies, weaken competition and create excessive pricing, and that work against the public good (para. 33).

32. The potential commercial rewards for monopolistic capture of a significant segment of so-called ‘basic’ science and technology are a temptation for private companies. A recent example of such potential capture occurred in the field of genetics (Marshall and Price, 2013). Prior to a case brought before the US Supreme Court in 2013, more than 4,300 human genes had been patented, which could have led to private acquisition of a whole sphere of knowledge. However, the Court decided that because nothing new is created when discovering a gene, there is no intellectual property to protect, so patents cannot be granted. The ruling made all human genes accessible for all publicly and privately funded research and genetic testing in the USA.

33. A major impact of digitalization has been the use of pricing algorithms in digital markets that have helped fuel the growth of so-called technology giants that exercise product monopoly. They are able to offer small or large quantities of a vast range of material, service or information products, giving dominant players exorbitant market power across all sectors[6]. This trend is now also seen amongst commercial publishers of science (ISC, 2021), some of which are transforming themselves from publishing service providers to technology companies, operating

6. Balance sheet data of American publicly traded firms shows that average markups over marginal costs rose from 18% in 1980 to 67% in 2014. De Loecker, J. and Eeckhout, J. 2017. The rise of market power and the macroeconomic implications. Working Paper No. 23687. National Bureau of Economic Research. https://www.nber.org/papers/w23687

service platforms on which they not only maintain their traditional role of publishing the data **of** science but also collect data **about** science from those services, positioning themselves as owners of strategic intelligence vital to scientists, their organizations, their funders, and national governments. They therefore create a strategic position for themselves in controlling access to knowledge, but one in which their accountabilities are to their investors rather than to science. These trends raise concerns about the governance of the scientific enterprise and the extent to which its role in serving the global public good is threatened.

34. A series of questions arise from this analysis of constrained science. To what extent does the specific scientific ethic referred to in paragraph 4 apply to individual scientists working in these settings? How should this ethic influence their relationships, as scientists, to the companies and corporations that employ them? For example, should a company scientist have any responsibility for hyperbole that the company might employ in claiming scientifically demonstrated efficacy for products that they market? How does the evolving dynamic of private sector science relate to science as a global public good as articulated in this paper? Should, for example, the safety cases for commercial activity that may generate public hazards be publicly available (cf para. 19)?

D. RESPONDING TO SOCIETAL NEEDS

35. Science may serve the global public good directly by responding to an expressed need (a challenge), by creating new knowledge that enables activities that have not hitherto been possible (an opportunity), or in new knowledge that lies latent as a knowledge resource that may enable unpredictable future uses.

It is important, however, not to see the utility of knowledge only though the limited lens of supply and demand. Scientific knowledge can enrich human perspectives in ways that cannot be captured on a balance sheet. Knowledge of distant galaxies or of deep time do not contribute to national economies but are profoundly enticing to the human imagination. Such knowledge, for its own sake, is a global public good. The ways that these functions together place important responsibilities on the scientific community and its stakeholders and on national science systems are discussed in the following.

CONFRONTING CHALLENGES AND EXPLOITING OPPORTUNITIES

36. There are growing perceptions of a world faced by convergent crises that threaten the wellbeing of humanity, of the potential of science to contribute to solutions, and therefore of the responsibilities of scientists to seek them. The most challenging perception is the concern for the way that humanity is carelessly destroying the conditions for its collective wellbeing, and casually engineering crises of a magnitude that may be similar to the global disasters of the geological record.

37. At the same time there have been major scientific developments that have profound implications for human society, and where there is an urgent need for science to engage with the fundamental ethical, legal, economic, social and environmental issues that are at stake. Modern data resources deployed by AI technologies offer deeper understanding of complex patterns in nature and society. The biosciences are revolutionizing our capacity to treat disease, and have great potential for improving food systems. These technologies could support a trajectory towards sustainability in sectors that contribute directly to human capital through their greater effectiveness and efficiency. But they could also exacerbate existing environmental damage, deepen inequalities, exclusion and discrimination, undermine privacy, eliminate agency and empowerment on a vast scale, enable cyber-warfare and new forms of criminality, and obfuscate reality in ways that undermine social cohesion and accelerate global crisis.

> The international scientific community must continue to promote broader public understanding of the issues at stake, work to improve the interface between scientists and policy-makers at all levels of governance, and adapt and improve the utility of science systems in supporting beneficial change.

38. The international scientific community is increasingly making its collective voice heard in confronting the challenges (para. 36) and using the opportunities in ways that serve the sustainability imperative, human welfare and the global public good (para. 37). It must continue to promote broader public understanding of the issues at stake, work to improve the interface between scientists and policy-makers at all levels of governance, and adapt and improve the utility of science systems in supporting beneficial change.

39. Global solutions,however, require global involvement. It is crucial that the scientific response is inclusive of diverse values, priorities and approaches. There is a temptation to assume that priorities of the science systems in developed countries are global priorities, leading to the exclusion of knowledge and priorities from other regions, particularly those from the many low- and middle-income countries that are most likely to suffer if current global trends continue or are exacerbated. A global science community has become a greater reality in recent years, but it will not have come of age until it has replaced a unipolar perspective with an inclusive universalism, open to a wider ecology of knowledge and capable of building an authentic global knowledge commons that is able to respond most effectively to contemporary challenges. This must be a priority for the representative bodies of global science if ‘beneficial and applicable knowledge is to be freely available and accessible worldwide’ (para. 8).

A BALANCED PORTFOLIO: RESEARCH FOR THE PRESENT AND FUTURE

40. A perennial human habit has been to sacrifice future opportunities in order to satisfy immediate desires, a trait that has contributed to the current environmental crisis. It is vital that the scientific enterprise does not so concentrate on the immediate that future horizons are narrowed or neglected. Paragraph 22 stresses the role that universities have played in maintaining a broad spectrum of research whilst also contributing to vital mission-oriented research that feeds immediate priorities. Continuing to support a broad spectrum of scientific inquiry that not only serves present needs but also expands the boundaries of knowledge without limitation is a crucial investment in the future. It would be a serious error to suppose that all future needs for scientific knowledge can be effectively anticipated and therefore created through top-down, mission-oriented programmes[7], vital though they are for many contemporary issues.

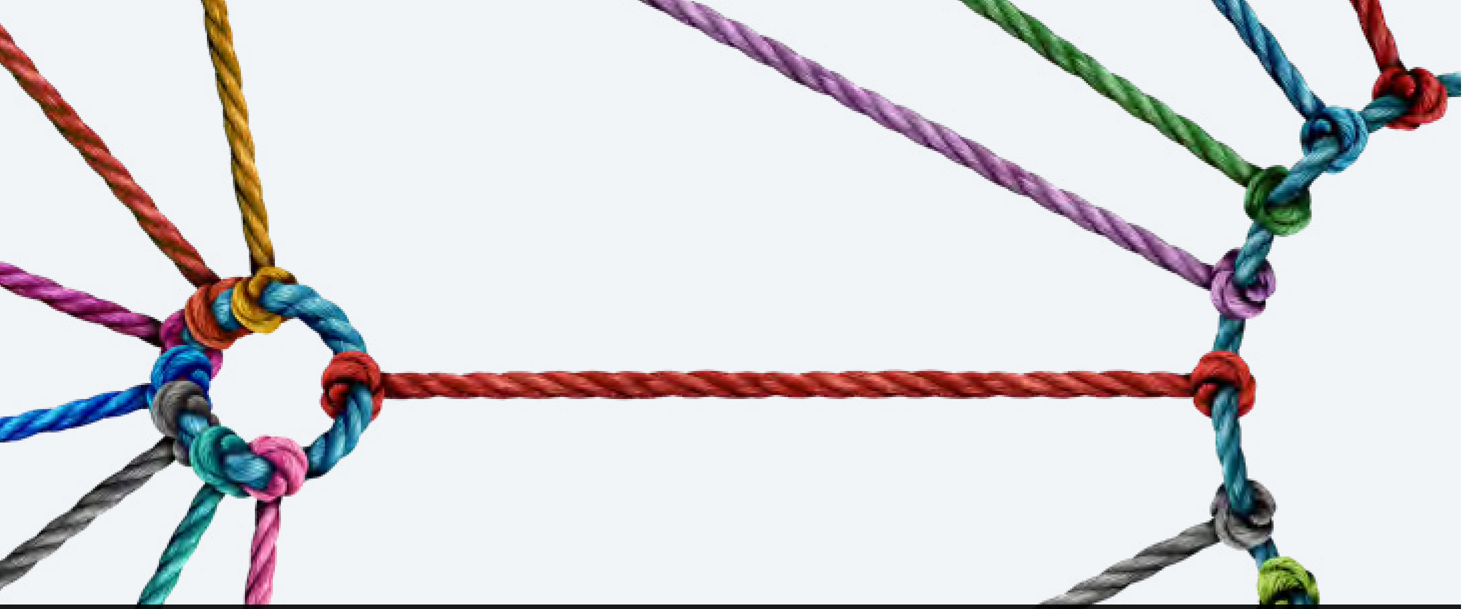
7. This has been most recently exemplified in the scientific response to the COVID-19 pandemic. A large part of the fundamental understanding underlying this response has been the product of decades of public investment, not only in the genomic science that underlies vaccine design and production, but in the many areas of public health, mathematical modelling, psychology and other areas of behavioural science, computer science and beyond that have contributed to the scientific response to the pandemic.

STAKEHOLDER ECOLOGY

41. If science is a global public good, global society is its beneficiary. However, it is national governments that to a large extent determine the means whereby those benefits are realized, through national science systems designed to serve the priorities that they deem to be national priorities. Rather than directly mandating specific research projects to serve these priorities, most countries have developed science systems that have a more consensual architecture. They tend to balance and benefit from the insights of three critical players: government, arm's length funding agencies and, largely, universities (with publicly funded institutes playing a more or less significant role). It is a triad that has been generally successful in creating the balanced portfolio described in paragraph 40, and in adapting to contemporary priorities as these evolve (para. 46). The common premiss has been that whilst government may articulate its priorities and set research budgets for its funding agencies, decisions on how resources are allocated and how research is organized should be the responsibility of researchers, and that giving scientists the freedom to follow their inspiration is the best way to maximize the return on society's investment in research.

PUBLIC/PRIVATE SECTOR RELATIONSHIPS

42. The interface between this public sector system and the private sector is of crucial importance in facing the challenges of human wellbeing. The public/private relationship has often been caricatured as a lumbering, bureaucratic public sector versus a dynamic, innovative private sector. The evidence is rather that the state and public sector have been creative in funding much of the innovative science that has stimulated private sector responses, and that not only has the state shaped and created markets but also corrected their failures (Mazzucato, 2013). The pandemic has illustrated the beneficial potential of public/private synergy, based on creative and effective sharing of ideas, research and data across the public/private interface.



E. AN EVOLVING SOCIAL CONTRACT FOR SCIENCE

43. A key part of that interface has been the link between the business and university sectors, much encouraged by governments in recent decades as a significant source of commercial innovation (para. 30). Tensions naturally occur at this interface, between scientists' desires to publish their work, companies' desires to protect research with commercial potential, universities' desires to be seen to be economically valuable in stimulating innovation and to benefit financially from intellectual property sales and licensing, and governmental policies about the proper roles of the universities that they fund. The tensions in these relationships should be viewed and judged by the spectrum of public value that is generated by their interactions (para. 35) rather than by the sectoral interests of any one player.

44. The priorities of science in serving the global public good must continue to combine exploration of fundamental processes in nature and society and efficient and effective responses to societal priorities as they emerge and evolve. Both influence the relationship between science and the societies of which it is part, the nature of the social contract between them and thereby the social organization of the scientific process. The citizen science movement may be evolving to play a significant role in this, but a countervailing, 'citizen anti-science movement' also appears to be gaining strength[8]. These relationships have and

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8. The COVID-19 pandemic has given a strong impetus to anti-science, anti-state protests (https://euobserver.com/rule-of-law/152647) that are increasingly organized under the mantle of conspiracy theories such as QAnon (https://securingdemocracy.gmfus.org/qanon-and-anti-vax-conspiracy-theories-pose-a-threat-to-democracy-beyond-national-borders/). For example, in Germany, the 'Querdenken' (lateral thinkers) anti-lockdown movement is a coalition that promotes conspiracy theories, such as the idea masks are deadly or that vaccines alter your DNA (https://www.bbc.com/news/blogs-trending-56675874).

will continue to co-evolve, with the international science community having a responsibility to be creative in safeguarding creative systems whilst promoting beneficial change.

45. The implicit social contract between the practitioners of science and the rest of society has its roots in the 1940s and 1950s in the aftermath of a wartime experience of the military benefits of scientific research. It has been expected that in return for public funding, science creates relatively reliable knowledge and that it communicates its discoveries to society (Gibbons, 1999). It is premised by the view that giving autonomy to publicly funded scientists and their disciplines to create new knowledge is the best means of creating innovation for public benefit, with the triadic stakeholder ecology described in paragraph 41 as its appropriate support and its source of effective governance (Bush, 1945).

46. Since that time, priorities for science have successively expanded from an early emphasis on military research, to support of national economies and innovation, to wider social, health and environmental concerns, to the current emphasis on global challenges and social, economic and planetary sustainability. This broad evolution of priorities has been accompanied by changes in the social organization of the scientific effort. It has evolved from one dominantly characterized by the hegemony of disciplinary science, to one where the importance of multi- and interdisciplinary collaboration was recognized as essential in dealing with multi-faceted, coupled systems in society, health and environment, to the contemporary one that recognizes that knowledge production, if it is to be effective in dealing with complex challenges, must be socially distributed, responsive to societal needs, transdisciplinary and subject to multiple accountabilities. The social contract is shifting to one in which science is open to society: transparent and participative.

The social contract is shifting to one in which science is open to society: transparent and participative.

OPEN SCIENCE: SCIENCE AS A PUBLIC ENTERPRISE

47. The open science movement is the contemporary manifestation of this progressive evolution. It seeks to make scientific research and its dissemination accessible to all levels of an inquiring society as part of the co-creation of knowledge for the global public good (Dykstra, 2019). Although the benefits of open science have largely been matters of conjecture, the global scientific

response to the COVID-19 pandemic has been a powerful example of open science in action. A wide variety of scientists have creatively deployed and applied their knowledge, produced databases and websites, short-circuited the cumbersome processes of conventional publication, shared data and ideas with unprecedented openness and across the public/private interface. They have done so in ways that set aside conventional constraints and ruthlessly exposed some of the processes that inhibit the effectiveness of science in contributing to the global public good. The Director of the US National Institute of Health commented: 'I have never seen anything like this' - 'the phenomenal effort will change science – and scientists – for ever' (Sample, 2020). Should this indeed be the new normal? Or should science be allowed to retreat to its old ways and to the more restrictive norms of much conventional scientific inquiry? The unanimous adoption by UNESCO's 193 Member States of its *Recommendation on Open Science* in November 2021 could be a major step in the direction of such a new normal (UNESCO, 2021). Such an inter-governmental agreement could be a powerful lever for change, but the deep engagement of the international scientific community and its representative bodies is vital if the governance of a new era of science is to be well adapted to the service of the global public good.

REFERENCES

Baker, M. 2016. 1,500 scientists lift the lid on reproducibility. *Nature*, Vol. 533, pp. 452–54. https://www.nature.com/articles/533452a (Accessed 15 July 2020).

Boulton, G.S. and Lucas, C. 2008. *What are Universities for?* League of European Research Universities Report. https://www.leru.org/files/What-are-Universities-for-Full-paper.pdf

Brecht, B. 1939. *The Life of Galileo*, p.56. https://www.arvindguptatoys.com/arvindgupta/lifeofgalileo.pdf

Bush, V. 1945. *Science The Endless Frontier*. Washington, United States Government Printing Office. https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm

Chapman, C. A., Júlio César Bicca-Marques, J. C., Calvignac-Spencer, S., Fan, P., Fashing, P. J., Gogarten, J., Guo, S., Hemingway, C. A., Leendertz, F., Li, B., Matsuda, I., Hou, R., Serio-Silva, J. C. and Stenseth, N. C. 2019. Games academics play and their consequences: how authorship, *h*-index and journal impact factors are shaping the future of academia. *Proc. R. Soc. B.*, Vol. 286, No. 1916. https://doi.org/10.1098/rspb.2019.2047

Darwin, C. R. 1871. *The Descent of Man, and Selection in Relation to Sex*, 1st edn, Vol. 1. London, John Murray, p. 385.

Drucker, P. F. 1993. *Post-Capitalist Society*. Oxford, Butterworth-Heinemann. http://pinguet.free.fr/drucker93.pdf

Dykstra, P. A. 2019. Scientific research and social responsibility. M do C. P. Neves (ed.), *(Bio) Ethics, Science, and Society: Challenges for BioPolitics*. Fundacao Luso-Americana, pp. 81–89. https://philarchive.org/archive/MONNHO

Feynman, R. P. 1974. *Cargo Cult Science*. Caltech commencement address. http://calteches.library.caltech.edu/51/2/CargoCult.htm (Accessed 15 February 2021).

Gatti, R. 2020. *Business Models and Market Structure within the Scholarly Communications Sector*. International Science Council Occasional Paper. http://doi.org/10.24948/2020.04

Gibbons, M. 1999. Science's new social contract. *Nature*, Vol. 402, C81–84. https://www.nature.com/articles/35011576

Goodwin, J. 2012. What is "Responsible Advocacy" in Science? Good Advice. Iowa State University, English Conference Papers, Posters and Proceedings. https://dr.lib.iastate.edu/entities/publication/0a882bb5-a4c2-4987-af5c-22e19a221964

Grudniewicz, A., Moher, D., Cobey, K. D., et al. 2019. Predatory journals: no definition, no defence. *Nature*, Vol. 576, pp. 210–12. https://doi.org/10.1038/d41586-019-03759-y

ISC. 2021. *Opening the Record of Science: Making Scholarly Publishing Work for Science in the Digital Era*. Paris, France, International Science Council. https://council.science/wp-content/uploads/2020/06/2020-02-19-Opening-the-record-of-science.pdf

Kaul, I., Grunberg, I. and Stern, M. A. (eds.). 1999. *Global Public Goods: International Cooperation in the 21st Century*. Oxford University Press. https://academic.oup.com/book/25545

Marshall, E. and Price, M. 2013. U.S. Supreme Court strikes down human gene patents. *Science*, 13 June. https://www.science.org/content/article/us-supreme-court-strikes-down-human-gene-patents (Accessed 26 October 2022).

Mazzucato, M. 2013. *The Entrepreneurial State*. London, Anthem Press. https://marianamazzucato.com/books/the-entrepreneurial-state

Miyukawa, T. 2020. No raw data, no science: another possible source of the reproducibility crisis. *Molecular Brain*, Vol. 13, Article No. 24. https://molecularbrain.biomedcentral.com/articles/10.1186/s13041-020-0552-2#auth-Tsuyoshi-Miyakawa

OECD. 2022. Gross domestic spending on R&D (indicator). https://doi.org/10.1787/d8b068b4-en (Accessed 26 October 2022).

Sample, I. 2020. The great project: how Covid changed science for ever. *The Guardian*, 15 December. https://www.theguardian.com/world/2020/dec/15/the-great-project-how-covid-changed-science-for-ever

Science Editorial. 2003. Statement on science publication and security. *Science*, Vol. 299, No. 5610, p. 1149. https://www.science.org/doi/10.1126/science.299.5610.1149

UNESCO, n.d. *UNESCO and the Universal Declaration on Human Rights*. https://en.unesco.org/udhr (Accessed 26 October 2022).

UNESCO, 2021. Draft text of the UNESCO Recommendation on Open Science. https://unesdoc.unesco.org/ark:/48223/pf0000378381.locale=en

Wilkinson, M., Dumontier, M., Aalbersberg, I., et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. *Sci. Data*, Vol. 3, Article No. 160018. https://www.nature.com/articles/sdata201618 (Accessed 21 July 2020).