WORKSHOP REPORT

Career Pathways in Multidisciplinary Research: How to Assess the Contributions of Single Authors in Large Teams

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WORKSHOP ORGANISED BY THE SCIENCE EUROPE SCIENTIFIC COMMITTEE FOR THE LIFE, ENVIRONMENTAL AND GEO SCIENCES

Table of Contents

Executive Summary

Over the past two decades, scientific research has made increasing use of integrated 'big science' approaches, relying on large collaborative, multi-disciplinary and interdisciplinary research teams – often working across borders and across sectors – to address the big societal questions. This trend is set to continue and this changing scientific environment has presented the research community with new challenges that need to be addressed.

Modern technology and advances in computers, software, data and modelling underpins progress across all research disciplines. The number of authors on multidisciplinary research papers is increasing, and disorganised lists of author names are proving inadequate for the purposes of attribution and credit.

The former Science Europe Scientific Committee for the Life, Environmental and Geo Sciences[1] published an Opinion Paper in June 2014 entitled 'Career Paths in Multidisciplinary Research',[2] in which it made recommendations for the development of an appropriate framework to better evaluate the contribution of individual scientists in large multidisciplinary teams.

As a follow-up to that Opinion Paper and to seek solutions for updating methods and traditions for assessing multidisciplinary science with extended stakeholders, the Committee organised a workshop in Brussels on 1 and 2 December 2015. Representatives from Science Europe Member Organisations (both research funding and research performing organisations), the publishing community, various research organisations and universities, evaluators and researchers, were invited to share their diverse perspectives and to brainstorm the issue (full programme is at Annex 1).

The 'state of the art' in terms of crediting multidisciplinary research, the needs of various stakeholders, solutions, bottlenecks and recommendations for funders, researchers, policy makers and publishers were discussed in-depth. It was universally agreed that systems such as crediting appropriately, supporting data re-use and rewarding multidisciplinary science need updating. There is a need to determine standardised criteria for evaluating multidisciplinary science, and a need to apply them successfully in evaluation panels and in recruitment. In order to achieve this, guidelines should be provided for researchers, funders, evaluation panels and publishers on how to credit and to cite specific contributions, data, tools and software in an improved way. Data and tools were especially highlighted; informal mentions of software and datasets should end and proper citation should be used in the future. Individual researchers should take steps themselves to ensure that they highlight all of their contributions. In addition to the typical peer-reviewed publications, researchers should disseminate their 'other research outputs', such as collaborative work, shared data, new methods or techniques, software, media outputs and other such contributions. These should in turn be evaluated along with the traditional outputs.

The full list of recommendations are listed at the end of the report, and include further suggestions about how to more accurately credit and better evaluate multidisciplinary research. Some of the promising new tools and methods being developed, were presented and discussed. The benefits of applying new methods for assessing the specific contributions of researchers and accurately awarding them for their scholarly input to the data-driven multidisciplinary research of the current and future scientific landscape would be wide-ranging. Collectively, such new approaches will foster multidisciplinary science and support research-driven innovation.

Introduction

Background

The way that scientific research is performed is evolving rapidly. While some traditional approaches continue, modern science is shifting towards large-scale approaches, requiring multidisciplinary consortia, international collaborations and networks, and the accessibility of high-quality datasets and software tools has become an essential requirement for success. For example, in the life, environmental and geoscience research fields, advances in high-throughput technologies and computational science are providing increasing possibilities for data collection and processing, and are catalysing the advancement of knowledge. This changing scientific environment has presented the research community with new challenges that need to be addressed, and novel approaches to evaluate and reward the new types of research are needed.

Allocating appropriate credit for research input has a huge impact on funding and employment, and greatly influences the choices made by researchers in their projects and careers. The traditional evaluation method of relying on authorship of articles in peer-reviewed journals for ranking candidates is becoming increasingly deficient and is not adequate to cope with the increasing diversification and specialisation of multidisciplinary research teams.

An increasing number of talented, early- and mid-career stage researchers struggle with the problem of visibility and recognition for their work when applying for grants or positions, and this can negatively affect advancement in their careers as researchers. Their contribution of valuable datasets or analytical software tools, for example, are often not adequately recognised, because they are neither appropriately cited within texts, nor credited in authors' lists for research articles. How often a software tool is used or downloaded can go unreported. Evaluation methods for selecting candidates for grants and for positions in research institutions are still traditionally applied and modern indicators that track real contribution to large team outputs are not routinely embedded into the evaluation system. This creates disadvantages for researchers who provide a non-traditional, yet invaluable, input to a large team and does not encourage participation in multidisciplinary science.

Emerging research disciplines are often at the interface of several disciplines, for example computer and data sciences, informatics, modelling, physics, chemistry, and engineering. This workshop presented case studies about life sciences merging with geosciences and computer science, but similar challenges arise when social sciences and humanities transcend the traditional boundaries of their fields too. The merging of disciplines brings both social and technology-driven innovation. Supporting multidisciplinary researchers will further sustain multidisciplinary research in the future, which will continue to be central to finding the answers to society's challenging questions.

A fundamental change in the methods and indicators for recognising and rewarding non-traditional contributions to multidisciplinary research and for evaluating an individual researcher's contribution to such teamwork, as well as their knowledge, and professional competence, is needed. Change is needed in order to adapt research-career evaluation systems and to retain the talent of early-career researchers. Recognising the inadequacies of the present system, the former Science Europe Scientific Committee for the Life, Environmental and Geo Sciences[1] published an Opinion Paper in June 2014 entitled 'Career Paths in Multidisciplinary Research',[2] in which it proposed four recommendations to improve the situation. As a follow-up to that Paper and to seek further solutions for updating traditions in multidisciplinary science, the Committee organised this workshop in Brussels on 1 and 2 December 2015.

Workshop Aims and Format

The presentations and discussions at the workshop aimed to further reflect on, expand and refine the four recommendations from the Opinion Paper, as appropriate, based on the input of the additional stakeholders present. How to implement new strategies and approaches within the scientific community, and how the workshop's recommendations could be translated into practice, were also explored.

Researchers performing multidisciplinary sciences within the life sciences and geosciences presented approaches to citing and crediting work that are currently applied in their fields. This was followed by three sessions, entitled 'Look to the Future', 'Bottlenecks' and 'Practical Approaches', where speakers highlighted new models and ideas. This was followed by a session wherein the publishing community (as 'Influencers') shared their experiences with new models.

To finish the workshop, breakout groups and a final round table discussion of various 'Decision Makers' (within the evaluation processes associated with scientific research) analysed specifically the four recommendations from the 2014 Opinion Paper (**Recommendations 2–4** for the breakout groups and **Recommendation 1** for the round table discussion), which are in summary:

- **Recommendation 1:** Applicants for a job, promotion, fellowship, grant and tenure are required to submit a **contribution list**, together with the relevant publications, to evaluators, employers and funding organisations. The contribution list should be considered a mandatory document for the various evaluation procedures.

- **Recommendation 2:** Various evaluation and promotion committees should include the number of co-publications, co-patents, networking efforts and research collaborations, as indicators of an individual scientist's capacity to cross the boundaries of a single discipline, and as demonstration of active engagement in multidisciplinary research. This should be universal to better capture the added **value of collaborative research**.

- **Recommendation 3: Data should be made available** to the scientific community at large through freely available data access models, repositories and web metrics. Such output should be considered equal in importance to scientific publications.

- **Recommendation 4:** Recognise the **development of enabling tools** such as methods, algorithms and software as a significant contribution to knowledge creation and management. The success of such endeavours should be measured by for example, the number of users/downloaded applications by users relying on such valuable research tools.

The Kick-off

Amanda Crowfoot (Director of Science Europe) welcomed participants and introduced Science Europe to the audience, explaining how the organisation uniquely bridges science research across Europe with science research policy. **Dr Bonnie Wolff-Boenisch** (Head of Research Affairs, Science Europe) then introduced the workshop and its concept. Specifically, the objectives were to:

- use the recommendations in the 2014 Opinion Paper as a starting point for discussions with an extended group of stakeholders and to validate and/or challenge them within this broader audience;

- present case studies from multidisciplinary research fields in the life, environmental and geo sciences, with emphasis on new emerging research, where the field blends with computer sciences and informatics;

- produce refined recommendations and recommend new criteria for crediting work, which could be translated into policy recommendations and potentially policies (at a later stage); and

- contribute to the establishment of an appropriate recognition, reward and evaluation framework for early- and mid-career researchers, or researchers in new fields at the evolving intersection of innovative technologies (such as ICT and biotechnology) and society.

Presentations

What Can We Learn From Other Research Disciplines?

The Solid-Earth Science Perspective

In the first presentation, **Professor Rinus Wortel** (Utrecht University, The Netherlands), explained that "solid-earth science (such as geophysics and geology), is by its nature highly multidisciplinary, and historically this has tended to be valued by most funding agencies – indeed it can sometimes be over-emphasised by the agencies." Similarly, journals covering the geosciences have no problem with the multidisciplinary nature of the field and the editors of these journals are usually experienced in handling manuscripts that cross several disciplines. When listing authors on a paper, the trend in other fields, such as in the life sciences, of giving most weight to the last (anchor position) and first authors (majority of work and writing), does not generally apply in this field. Rather there are a range of systems, for example one whereby authors are listed according to the weight of the individual contribution, or in alphabetical order. He noted that "in the absence of any explicit description of an individual's contribution, it is difficult to ascertain actual contribution information, so it is recommended that individual contributions are made clear universally, as is currently done in only some journals. When considering a candidate's suitability for a grant, promotion, and so forth, it is important to take into account more than a publications list, and other factors such as personal qualities and actual research contributions – particularly in innovation – must be taken into account."

The Climate Modelling Perspective

In her presentation, **Professor Ina Tegen** (Leibniz Institute for Tropospheric Research, Germany) informed participants that climate science is also highly multidisciplinary, and that the social sciences are increasingly becoming involved in projects. A key feature of climate science is its reliance on the use of mathematical models. "Obtaining appropriate credit for developing models remains a challenge and publishing a team's work within this field is not straightforward. Often, journals want to see the results that arise from the use of a model and not just the model itself," she said. Nevertheless, there is a trend towards recognising model development recently and 'model making' is starting to be recognised as a discipline in its own right, with dedicated journals that will publish details of model development. Two notable programmes have impacted significantly on the global climate modelling community: first, the Intergovernmental Panel on Climate Change (IPCC) assessment reports, which represent high-level publications, contributions to which are recognised as evidence of an individual's high standing; and second, the World Climate Research Programme's 'Coupled Model Intercomparison Project' (CMIP). Both represent highly valuable resources for climate output data. While being an author of an IPCC report is considered very prestigious, the reports are not taken into account when calculating one's H-Index (see Annex 2).

The Oceanic and Atmospheric Sciences Perspective

"The nature of publishing and authorship has changed markedly within ocean and atmospheric sciences over the past decades, reflecting the way that this science has also moved," stated **Professor Peter Liss** (University of East Anglia, United Kingdom). He reminisced how "thirty years ago, PhD research could result in a single paper with the PhD student as its sole author. Now, things are more complex. Take for example, an experiment to examine the effects that seeding the ocean with iron has on the growth of phytoplankton. This type of study involves a research vessel with potentially 30 people, made up of experienced scientists, technicians, graduate students, people involved with remote sensing, and meteorologists, etc. Devising an appropriate way to acknowledge these people's

individual contributions in such a setting is a challenge." The trend to list more details about authors' individual contributions to a paper is welcome and is workable where the number of authors is relatively small. Where there are 30, or 40, or up to 1,000 authors – which is not uncommon in large research infrastructures – things become more challenging and this requires agreed rules. Also, it is important to ensure that recognition goes to the right person in terms of key input and not automatically by hierarchy, for example.

A View of the Future of Multidisciplinary Teams in Life Sciences

Crediting from the Biological Perspective

Professor Barend Mons (Leiden University Medical Centre, Netherlands Bioinformatics Centre, Dutch ELIXIR Node, and Chair of the High-Level Expert Group on the European Open Science Cloud) said that "although data is supposed to be 'the new oil', we are generating vast amounts of it, at an ever-accelerating rate, but we lack the ability to deal with it properly." Data loss is real and significant, while data growth is staggering. Substantial resources are required to capture, store and curate data in a way that makes it useable and useful. "Why do we bury it first and then mine it?" he asked. "We are seeing very significant hurdles in accessing data from publications, from paywalls and problems with data mining, to broken links and lost raw data files. In most cases we can find only five percent of the data that we know should be there in scientific journals." Professor Mons thinks that "the traditional way of presenting scientific results in the form of a journal article, with an abstract, tables, figures, and links to supplementary data, is archaic and increasingly redundant. Supplementary data should be published in its own right, and people who understand data stewardship are needed to manage databanks; currently, there is little incentive for data experts to remain in academia and many turn to industry for a more rewarding career. Obstruction of tenure of data experts impairs knowledge sharing and innovation."

The People behind Research Software – Crediting from the Informatics/Technical Point of View

Professor Carole Goble (University of Manchester, United Kingdom) emphasised that much of the research performed across all disciplines, including the life sciences, would not be possible without the development of software that underpins research infrastructures, even though use of the software can sometimes not be seen. Too often the people responsible for developing this software are seen as merely providing a service for researchers and are not given appropriate credit for their work or creations. She informed participants that the software community has its own impact and credit models, with publishing environments and code and curation tracking mechanisms, and that they would like these to be recognised and valued by the wider research community. Data archives and software increasingly form important elements of the objects built by multi-part teams; large numbers of experts are involved in this infrastructure and these people need to be given acknowledgement for their contribution. Professor Goble proposed that "there should be jam for everyone." Software and data resources are often used, but authorship is not awarded, or the work is not cited in a paper, and is only acknowledged informally in a way that is not measureable by evaluators. This is unsatisfactory when panels evaluate and rank individuals solely on publications and citations for employment, promotions or funding. "Informal mentions should end; credit and authorship should not be conflated. There needs to be new forms of credit, based on use and impact, not just authorship, and papers should be abandoned as the sole unit of research credit," said Professor Goble. What is often not taken into account in discussions about this topic, is the social component and the need for cultural change from an 'egosystem' to a 'team science system', and one which has appropriate rewards.

Current Bottlenecks in Multidisciplinary Research Teams in Life Science

Irreconcilable Differences: the Need for Bioinformatics and Bioinformaticians in Academia

Professor Jeffrey Chang (University of Texas Health Science Centre, United States) re-emphasised to participants that the production of data in the life sciences is unrelenting and is creating a growing demand for experts in bioinformatics. In 2012, the University of Texas set up an innovative bioinformatics services centre, focusing on data analysis. In its first 18 months, the centre accumulated 2,500 hours of service with up to three full-time personnel. Originally the idea was to develop pre-packaged services: scientists would send across their data and the centre would send back the analysis. This turned out to be a challenging task, because either no standard solutions existed, or they were often found to be insufficient: projects would start out on one track and then take a turn, based on complex results. Research input for the development or adaptation of analytical approaches to deliver an appropriate solution was required. As a result, bioinformaticians who were supposed to only provide services, were now adding new knowledge and therefore became contributors of expertise. The centre thus changed, and now more closely resembles a research partner, requiring staff with PhD-level training in bioinformatics who can formulate research questions and understand how to carry out detailed and complex analyses. The contribution of these high-grade people to the overall research effort is key and should be recognised, and an appropriate career structure that recognises team-based scientific contributions needs to be developed to support and sustain them.

The Problem of Authorship and Recognition in Systems Biology – Maintaining the Dew Point

"In the life sciences, current methods of evaluating researchers are inadequate, irrational and often arbitrary," stated **Dr Nicolas le Novère** (Babraham Institute, United Kingdom). Usually, only peer-reviewed articles are used for evaluation, only the first or last position in the author list counts, and the name of the journal and its impact factor are of key importance to a selection panel. He noted that "bizarre criteria can appear: three citations in a 'mediocre' journal equate to one citation in a 'top' journal." Experimentalists invariably get top billing, while very good bioinformaticians may be buried in the middle of a long list of authors and thus receive effectively no credit for their work. Systems such as the H- and M-indexes (see Annex 2) are a slight improvement, but also consist of evaluation by publications alone. Indeed, peer-reviewed journal publications alone as a measured output is not the case in all fields of research; in the social sciences, for example, books can count as a measure for evaluation, while in computing, peer-reviewed conference proceedings are acceptable. Dr le Novère summarised that "there is a consensus that the current evaluation system is broken within the life sciences. But who makes these nonsensical rules and who applies them? We do: policy makers, grant panels, science officers, editorial boards, recruitment panels – all are made up of researchers, still using these outdated metrics."

Practical Approaches

The Project CRediT and Mozilla Badges

Dr Liz Allen (F1000, Project CRediT, United Kingdom) said that specific author contributions should be routinely included in all articles. A simple and standardised way of doing this is being developed by the Consortia Advancing Standards in Research Administration Information (CASRAI) CRediT project (Contributor Roles Taxonomy,[3] see also Annex 2). CASRAI is an international non-profit organisation dedicated to reducing administrative burden and improving impact measurement for researchers. Their CRediT project brings together a diverse set of stakeholders with a common interest in better understanding and communicating the different kinds of contributor roles in research outputs. It

proposes a way of listing contributions (that is, a taxonomy), which includes 14 roles intended to capture the various contributions that can go into scholarly works. Dr Allen said that if a system such as the CRediT taxonomy is to be adopted widely by publishers, it is important that it has widespread support and is put in place at an early stage so that multiple and diverse taxonomies do not start popping up *ad hoc*, bringing confusion rather than clarity.

The 'Mozilla badges' concept is an initiative that uses the web and coloured badges to denote authors' contributions, utilising the same taxonomy as the CRediT project. Their idea is to "enhance the experience surrounding an academic article." Badges can serve as a standardised digital credential for the work done by each author. It is hoped that such badges and schemes will help to provide incentives for researchers and will show the diversity of roles involved in a piece of research, as well as increasing recognition for the researchers in question. In other developments, researchers can sign up to the unique digital identifier ORCID[4] (a registry) or to Vivo,[5] both open-source tools connecting data regarding scholarship, linked together with one identifier number per researcher (see Annex 2). ORCID is working on building CRediT into its registry as well.

Best Practices at a University

In his presentation, **Professor Bert Overlaet** (KU Leuven, Belgium; LERU representative) emphasised that a key aspect of decision making regarding the evaluation of a researcher or a research project is centred on the dynamics of the committee or panel making the decision. It is important that the selection committee is made up of people with a diversity of expertise, so that all the relevant aspects of a proposal can be judged fairly, something that is especially vital for multidisciplinary proposals. In some cases, evaluation panels are selected for a specific call; experts from varied backgrounds can be selected for such multidisciplinary panels, but this is not always the case. Training committee members to deal with diversity and conflicts of perspectives on a proposal is very important. He suggested that "committees need to be broader minded than they currently often are, and not just populated with people at an advanced stage of their career who are set in their ways. In our institution we value multidisciplinarity, and proposals that involve a consortium across disciplines are given a bonus score. When evaluating individuals, we ask them to list their five most important 'publications or other output', rather than simply 'papers', and try to establish why they have chosen these, and ask them to include details of their contribution to each study."

Professor Overlaet closed the session by stating that the transformation of crediting work within the life sciences is a challenge that needs to, and will be, tackled in the near future.

Discussions of Different Stakeholders

Influencers

After the presentations in the introductory session, a series of round table discussions were held. The first one was one with a panel of 'influencers': invited representatives from publishing houses that are experimenting with new formats for publishing multidisciplinary and data science, and those with new methods of peer review, designed to cope with both the increasing amount of publications and the changing needs of authorship recognition within different research communities. The publishers are called 'influencers', because the successful acceptance of a paper in a journal has influence on the decisions of funders, evaluation panels, and human resources departments. However, at the same time, publishers are also 'influenced' by the changes in the science system and society.

Dr Mark Patterson (eLife) informed participants that the journal eLife assigns all components of a paper – figures, tables, videos, supplementary data and so forth – DOI numbers (Digital Object Identifier; see Annex 2). In this way, papers move from having a fixed format and layout towards being a collection of research objects. This opens the way towards providing more flexibility and granularity, enabling individual researchers to be given credit for specific aspects of the work. eLife has established

a consultative editorial process, which involves discussion amongst the editors and reviewers, which is proving to be a good model for the evaluation of multidisciplinary research.

Dr Bahar Mehmani (RELX Group) said that Elsevier is operating a pilot project to open up the peer-review process to make it more transparent, for example by publishing peer reviews alongside the article. Access to peer reviews can help early-stage researchers to get a better idea of what is required when reviewing and in order to be successful (with both their reviewing and applications). In addition, credit is being given to scientists for carrying out peer review and people are allowed to volunteer to become reviewers. Elsevier have started efforts to credit researchers who make their data available and are working on new ways to support the posting, publishing and citation of research data with the 'Force 11' group (see Annex 2). This will encourage the re-use of research data and enable the reproducibility of published research.

Dr Kamila Markram (Frontiers) informed participants that "a key element of the Frontiers concept is to publish on the basis of sound research and not to make judgements on issues such as impact or novelty." Rather, the importance of the study is gauged by the number of views and downloads it receives – so effectively, in the Frontiers open science platform model, the community seek, share and generate the knowledge and make the judgements. Frontiers has also experimented with a variety of other novel publication formats, and created Loop – a research network intended to foster and support Open Science (see Annex 2).

Dr Catriona MacCallum (PLOS) said that "one of the problems with multidisciplinary peer review, is that we do not have data on what does and what does not work. We need a process to allow many more than the usual two or three reviewers to look at such papers." There needs to be a way to find more experts and the right experts for reviewing multidisciplinary science. There is a problem with reviewing data: often it is not reviewed adequately (or at all) and we then only find out if the data is reliable afterwards, when other people try to use it. "We also need to remove subjective evaluation about whether a paper is 'interesting' and concentrate on whether it is sound," said Dr MacCallum. "How interesting or important a paper is should be decided by the community after the research output is published," she concluded.

Dr Thomas Lemberger (EMBO Press) informed participants that EMBO Press is moving towards a much more transparent system of peer review, publishing peer reviews alongside papers. Few people object to this, or decline to act as reviewers on this basis. It is an excellent tool for early-stage researchers to learn what makes a good review. For early-stage researchers working in multidisciplinary research, the most important thing is for journals and funders to consider multidisciplinary research favourably; this means a change in mind-set. He said that "there are difficulties in reaching consensus among the myriad reviewers of multidisciplinary research and a strong editorial hand can be needed to integrate information from the different reviewers."

Conclusions from this Session

The panel members from the publishing domain discussed with all participants their challenges and what their future roles could be in the changing science-publishing environment. Different types of peer-review methods were elaborated, such as open, collaborative or traditional peer review, and their current experiences with them were reflected on. It was found that publishers of open-access journals often integrate new tools more easily and, in some cases, are already testing new formats on the research community.

Organising the peer-review process and assuring its quality control is a key contribution of the majority of the publishers. Some publishers predicted that that the peer-review process would be entirely organised by the research community in the future, not only because of the technical developments and the creation of new tools and concepts, but also because of a changing mind-set across the research community to 'take matters into their own hands'; other publishers foresaw that the 'traditional' method of peer review would remain, albeit enriched by modern technology. Based upon

the discussions, the breadth of approaches was apparent and no single trend was evident – aside from the increasing use of, and need for, modern technologies.

Whatever model will be successful, or whichever business models may work in parallel, there was agreement between all stakeholders that common standards have to be clarified in collaboration with publishers, research funders, and the research community to better assess new forms of scientific collaboration. A system to reward scientists for openness, and willingness to share their data and to build a career upon it, needs to be put in place. Alongside this, a new way to routinely credit and incentivise reviewers for their review work is needed.

It will be important to consider how acceptance and recognition of a new paradigm across the whole science system, including funders, publishers, reviewers, committees and researchers, can be ensured.

Breakout Group Discussions

After the round-table discussions with the publishers, participants took part in two parallel breakout group discussions, framed around the recommendations made in the 2014 Opinion Paper of the Science Europe Scientific Committee for the Life, Environmental and Geo Sciences. One breakout group discussed recommendations 3 and 4, respectively on 'making data available to the scientific community through data access models, repositories and web metrics' and 'recognition of the development of enabling tools (methods, algorithms and software) as a significant contribution to knowledge creation and management'. The second breakout group discussed recommendation 2 on 'capturing the added value of collaborative research', and whether evaluation committees should include the number of co-publications, co-patents, networking efforts and other research collaborations as indicators of an individual scientist's capacity to cross the boundaries from a single discipline, and as demonstration of active engagement in multidisciplinary research.

Breakout Group Discussion on Recommendations 3 and 4: Data and Tools

There were strong views that the 'currency' of science is moving away from written articles, towards data, and that the concept of a manuscript as it has previously been known is fading into history. A modern research paper is a complex entity, consisting of many discrete objects: images, data files, external resources, and so on. There have been moves to provide raw source data behind the figures in molecular biology and other disciplines, and this will continue. A dataset in itself should be considered as a *bona fide* research outcome. In order to acknowledge and recognise the endeavour of making data fully and openly available for its possible reuse, there is a requirement for a change in the mind-set of funders and publishers and by the scientific community at large.

Alongside new crediting and incentive systems for scientists, all such 'Open Science' moves require an appropriate and properly resourced infrastructure for data deposition and curation, as well as funding for data management, quality control, and sustainability. One such solution proposed is the European Open Science Cloud (EOSC), launched by the European Commission, which aims to create a trusted environment for hosting and processing research data to support science. The EOSC would offer European researchers and professionals in science and technology a virtual environment with open and seamless services for storage, management, analysis and re-use of the data that are linked to their research activities, freely, across borders and scientific disciplines. ELIXIR and other infrastructures also host valuable data hubs across Europe (see Annex 2).

Regarding possible best practices for the deposition of datasets and models, it has been suggested both at this workshop and by others, to identify datasets by all of the names of the people responsible for creating them. A dataset is currently often annotated only with the name of the person who uploaded it, which does not recognise the important contributions of the other individuals involved in creating it. Alongside this anonymity, a source of frustration for computer scientists is that resources are often used or downloaded, but rarely cited correctly. Within many journals, the citation of software

is still informal, for example through a URL only (http://example.com), or by using the common name of the software. The community feels that informal mentions of software and datasets should end, and proper citation of work and workers should be put into the workflow. There are publishers who have already started to reflect on the development of standards for proper citation of data, tools and software. Scientists, funders and decision makers increasingly acknowledge this, and the need to become more proactive in defining such standards has arrived.

Breakout Group Discussion on Recommendation 2: Collaborative Research Evaluation

Evaluation committees need to be equipped to deal with multidisciplinary proposals. Some funding bodies have approached this issue by having standing committees for multidisciplinary proposals. For consideration of such proposals, it is important to have people on the reviewing panel who are themselves directly experienced in multidisciplinary research.

A weakness of many evaluation systems is that the members of the panel communicate remotely, sometimes simply forwarding their comments or verdict on a proposal without any discussion. Anonymously distributed peer review was considered by participants as an unsatisfactory way to reach a decision on a proposal. Panel members should sit around a table and openly discuss and debate the merits of a proposal together in person.

Reviewers need guidance on the expectations of funders and on the selection criteria to be met when they evaluate multidisciplinary proposals (either papers or candidates). Especially in the case of proposal evaluation, there needs to be transparent, open dialogue between expert reviewers and with the funding body. Furthermore, the same assessment criteria must be clearly stated in the documentation for proposal applicants, in order to provide guidance and clarity for them on the expectations of the funding body that provides support and peer reviewers, or of the evaluation panels which assess the proposal and decide to recommend them for funding or not.

In general, the framing of adequate questions to a candidate or proposal submitter is important. These questions should be framed in a way that is appropriate to the particular stage of the applicant's research career. Applicants should not be evaluated only on metrics such as publication records, but on questions about other more qualitative types of output and achievement, including those pertinent to multidisciplinary science, such as: will this proposal involve multidisciplinary and other collaborative approaches; does the candidate have a track record of working openly with people from other disciplines; and is this research transcending the traditional boundaries of a discipline? Especially regarding the last questions, members of such a panel must understand that in a multidisciplinary proposal the innovation is often realised by the merging of disciplines. Proposals are often rejected because one discipline is not at the cutting edge or because the right expertise is not represented in the panel and thus the proposal might not be judged on its own merit. Therefore, it is recommended to add these types of question into evaluations and to move away from relying solely on questions about lists of publications or articles. Although the track record in peer-reviewed publications or review articles is important, it should not be the sole criterion for assessing a researcher's excellence and/or potential, and it is strongly recommended to focus more on other contributions, achievements and accomplishments (such as generation of datasets, software and materials or methods, outreach activities, media and social media interactions, number of downloads, contribution to peer review, publication of other national reports, evidence of collaborative and networking activities, and evidence of influencing policy and practice).

If 'team science' and the willingness to be part of a team effort becomes an important trend in recruitment or funding selection criteria (for selection and evaluation panels), there will be a need for more appropriate criteria and indexes to measure this and to determine how to best select this type of researcher or the best proposal. The same reflection is required when it comes to rewarding engagement with the public, or making the raw data of scientific publications fully available and reusable for peers working in the same, or other, research disciplines.

A selection of potential questions that could be asked (when recruiting, and also in relation to proposal selection) were identified within the Collaborative Research Evaluation breakout group:

- What is/are your most important paper(s) (not necessarily those with the highest impact factor) and why?
- What is your essential contribution to the proposal, which could make it successful, or how did you bring new insight?
- Describe how you have been an effective and team-playing collaborator; have you proactively initiated new collaborations?
- Do you have any experience working across the boundary of your discipline?
- How has your work been used by others, and how open have you been to facilitating this?
- How effectively have you communicated your work to a broader audience?

Decision Makers

The closing discussion was with a panel of decision makers from research funding and research evaluating organisations, to whom the question 'what's next?' was posed. **Dr Annalisa Montesanti** (Health Research Board, Ireland and member of the Science Europe Working Group on Research Careers), chaired this session, which was moderated by **Dr Iain Cameron** (RCUK and Chair of the Science Europe Working Group on Research Careers) and **Professor Dirk Inzé** (Chair of the Science Europe Scientific Committee for the Life, Environmental and Geo Sciences). The workshop's main topics were revisited by the panel and discussed from the perspective of early- and mid-career researchers and applicants for jobs, promotions, fellowships, grants and tenure, as well as in terms of what is currently being done in that regard by this set of decision-making stakeholders.

The European Research Council (ERC) targets early-career researchers specifically through its 'Starting Grants' funding scheme, said **Dr Mike Mugabushaka** (Head of Sector, Support to Monitoring and Evaluation of ERC Activities). This supports high-calibre researchers who have between two and seven years post-PhD experience. There is wide scope for multidisciplinary research, given that proposals are investigator-driven and that the sole criterion for selection of a proposal is scientific excellence. The ERC is currently establishing a framework for studies on multidisciplinary careers, based on ERC funding grants.

Professor Bernard Rentier (European University Association) stated that "institutional repositories are having an increasingly important role in the dissemination of research and are particularly popular with the younger 'Facebook generation' of scientists. Incentives should be given to encourage all researchers to use such institutional repositories." He also reminded participants of the DORA initiative[6] (Declaration of Research Assessment, see Annex 2), which was signed by many universities, but which is not being followed robustly. He said "unfortunately, the journal impact factor remains the widely used tool for the quality assessment of research and researchers, even though it is widely acknowledged as a very inadequate measurement. Persisting to use this tool may be strongly misleading the evaluation of scientific careers."

"There is no one-size-fits-all approach in the assessment of multidisciplinary research proposals and a number of diverse mechanisms are needed," said **Dr Chonnettia Jones** (Wellcome Trust). The Wellcome Trust, for example, does not use journal-based metrics for reaching funding decisions, but rather provides specific guidance to funding committees, so that an application is assessed on the merit of the work, and a range of criteria are taken into account to assess achievements appropriate to the stage of the applicant's career and experience.

"For Marie Skłodowska-Curie research fellowships, the excellence of the researcher is based on the person's track record, appropriate to his or her career stage and involves assessment criteria that move beyond simple publication record," said **Mr Paul Harris** (European Commission, DG Education and Culture, Unit for Innovation in Education, EIT and MSCA). The degree of multidisciplinarity in a proposal is something that should be chosen by the researcher, and around 30% of proposals are deemed multidisciplinary.

Conclusions from this Session

The decision makers took note of the new requirements to go beyond the traditional methods of evaluating scientific contributions. Though things are not yet ideal, there is a clear trend emerging: systems such as crediting and rewarding data, its re-use and supporting data research infrastructures need to be revised in order to integrate modern science successfully in evaluation panels and in recruitment. There is a need to determine standardised criteria for evaluating multidisciplinarity and to recognise how they influence career pathways. Also, there is the recognition that the science system is not broken per se, but is in need of radical new and/or more consistent methods and indicators to better capture the actual current research landscape, whilst boosting new knowledge.

Workshop Summary and Conclusions

To tackle the grand societal challenges faced globally today, the need to work collaboratively across disciplines and across sectors will increase, and multi- and interdisciplinary science will have more impact. Early-career researchers should be incentivised to train in working across the boundary of single disciplines and to learn the additional skills and competencies needed to succeed. Accurate means of acknowledging and rewarding the work performed in multidisciplinary teams should be applied. Hence, new identifiers for collaborative work, and criteria to guide and train panel members to evaluate the more collaborative proposals and researchers, will need to be put in place consistently across research funding and related organisations.

Traditional indicators were developed in the past for the assessment of projects carried out in small research teams, which were historically composed of one student and one supervisor. In these cases, authorship on a peer-reviewed publication clearly indicated the role and involvement of each contributor. However, in the life sciences today, the scientific output of an individual continues to be mostly measured by the number and impact of papers, where the crucial first authorship (leading effort) or last authorship (guidance of the project) is still perceived as the key indicator of the intellectual contribution. Being a listed author on a paper and contributing to it are two distinct, yet related, things, and this warrants clarification and requires clear guidelines.

In the increasingly collaborative and digital arena of modern scientific research, the standard author list often fails to fully represent the diverse contributions that go into the work. Researchers should be accurately and fairly recognised for the work they do, especially when that work is factored into decisions about funding, hiring, and careers. Crediting and rewarding specific contributions to published research would encourage collaboration and increase the sharing of raw and complete data, code and software for further application.

Since the data component is increasingly replacing text components, particular identifiers for data production, analysis, curation, and accessibility need to be developed. Regarding data citation, crediting and reward systems, new infrastructures (such as repositories) and their funding, curation, and support need to be developed in parallel. This will support the careers of the vital contributors to multidisciplinary work and will protect the resources (of data and skilled researchers) and drive innovation. Innovative new publications are starting to treat all components of a paper as individual entities in their own right, with their own DOI numbers – text, data, tables, figures, videos and so forth. This opens up a way of crediting specific individuals for a particular piece of work within an overall study.

In addition, via ORCID (see Annex 2) the development of identifiers for the linked and centralised contributions of authors (a taxonomy of all of their details, outputs and categories) aids a standardised, more accurate and fair evaluation, for proposals or recruitment. Other useful tools, for example FAIRDOM[7] and the FAIR guiding principles,[8] Depsy,[9] Researchobject,[10] CASRAI, Vivo and Loop (also see Annex 2) are paving the way forward as well.

Alongside the crediting of specific pieces of work in a team paper, the shift towards multidisciplinary and interdisciplinary research has resulted in the crucial need to establish indicators that acknowledge the value of this approach and the value of the individual's engagement in this process. The Science Europe Scientific Committee for the Life, Environmental and Geo Sciences wanted to alert academic employers, promotion and appointment committees and European and national research funding organisations to the lack of clear evaluation metrics for researchers working in multidisciplinary teams, as well as metrics across the whole data pipeline. The absence of such metrics has a negative impact on career pathways, as many researchers are reluctant to participate in multidisciplinary research. Therefore, in 2014, the Committee devised concrete recommendations to contribute to the elaboration of a more appropriate evaluation framework, which were expanded upon at this workshop with the perspectives of key players and stakeholders and are grouped and listed in the chapter 'Recommendations', below.

The sharing and reusability of data could be additional criteria in the track record of researchers' achievements and contributions. It is essential to support the career development of researchers in changing research environments by establishing clear and standardised sets of indicators that facilitate the evaluation of their work and demonstrate their achievements in a multidisciplinary environment.

Failure to establish and implement such an updated evaluation framework will act as a strong deterrent for the most talented individuals to embark upon career paths in domains of science that require a multidisciplinary effort. Hence, the workshop participants would like to urge academic employers, publishers, evaluators, and European and national research funding organisations to adopt the following recommendations, as they encompass a wide range of outputs, contributions and activities. This is intended to facilitate the advancement of career pathways of researchers engaged in multidisciplinary and collaborative endeavours and to boost scientific progress.

Recommendations

Crediting and Rewarding Scientific Contributions

Recommendations for Funders (Proposal Submissions) and Publishers (Paper Submissions)

- Researchers should be encouraged to include more information about their personal contribution to datasets, new methods, or software in their applications/submissions, for example by the inclusion of a checklist (in the same way that people are given a checklist to ensure that all the references are in place).

- It should be made more attractive for researchers to participate in peer reviewing (proposals and papers). This could be based on non-monetary incentives (such as for example the possibility to acknowledge review work on CVs).

- Organisations can sign up to the San Francisco Declaration on Research Assessment (DORA), which specifies new and better ways to assess research. More important than simply signing up, is ensuring that the principles are actually implemented in practice.

Recommendations for Researchers

- Individual researchers should take steps themselves to ensure that they highlight all their contributions, in addition to the typical peer-reviewed publications, for example by ensuring that 'other research outputs', such as collaborative work, data, methods or techniques, media output and other such contributions are present on the person's institutional profile, in the same way that publication lists are a key component of such profiles.

Crediting, Rewarding and Funding Along the Whole Pipeline of Data and Software Creation, Management and Use

Recommendations for all Stakeholders

- Informal mentions of software and datasets should end; instead proper citation should be used. In order to achieve this, the following should be done:
    - A framework for data and software citation should be developed, starting with the elaboration of standard guidelines; such standard citation guidelines should be further developed based on existing material or roadmaps, such as FORCE11 or the Ten Simple Rules approach (see Annex 2).
    - Publishers should be part of the process, to ensure that guidelines are mirrored universally in all publishers' guidelines.
    - Funders should be part of the process, to ensure that guidelines are mirrored universally in all proposal guidelines.
    - Guidelines should be provided for researchers on how to cite data/tools/software.
    - Guidelines should be provided for evaluation panels on how to credit data work.
- When datasets and models are deposited they should be registered with the names of all of the contributors responsible for creating the dataset or model.
- Career pathways should be developed for people involved in developing data and software infrastructure.
- A framework for stewardship of standardised data should include incentives to further encourage the open publication of data/tools/software, (in order to encourage the scientific community to adopt such a paradigm shift and to share their information and raw data), in parallel with the development and management of an infrastructure to safely store it.
- Researchers, publishers and funders should ensure that data can be re-used by the communities; hence, an agreement between, and commitment of, funders, publishers and scientists is needed to actually implement such a system, and to credit scientific contributions, especially for data, tools and software re-use.

Recommendations for Funders

- Funding should be made available for data and software management and repositories, for the purpose of sustainability, to harness the full potential of data and software in the long term and for reasons of quality control.

Recommendations for Funders Setting up Evaluation Panels for Collaborative Work

- Reviewers should be provided with guidance on the important criteria that should be applied to evaluate a researcher, and/or a proposal, within multidisciplinary research.
- Applicants should not be evaluated on metrics such as publication record only, but also on criteria that reflect multidisciplinarity and collaborations, and additional contribution to knowledge such as data sharing, or other related criteria (engagement with the public, contribution to innovation, team-fitness, and so on).
- If 'team science' and willingness to be part of a team effort become important trends in recruitment and in funding, and if they become selection criteria for panels, then appropriate indexes on how to select this new type of researcher should be established. The same reflection is needed when it comes to rewarding engagement with the public, or to making scientific publications more accessible for peers working in other research disciplines.
- In fellowships and career development awards that are focused on training and career progression, funders/panels should consider framing their evaluation criteria in a way that is appropriate to the career stage of the applicant.
- Members of multidisciplinary evaluation panels should sit around the same table and openly discuss and debate the merits of a proposal in person, as opposed to sending in isolated comments.
- Panels evaluating multidisciplinary proposals should include people who are themselves appropriately experienced in multidisciplinary research.
- Evaluation panels should not penalise people who have taken non-conventional career paths. Additional skills and professional experience from work experience outside the academic environment should be valued when assessing the merit of a researcher. Someone who has returned to academia after spending several years in industry or the public sector, for example, can bring valuable experience and attributes (even if their *m*-index (see Annex 2) may be lower).

Potential Questions for Assessing Multidisciplinary Research:

- Describe your collaborative efforts to date.
- Will this proposal involve collaboration?
- Is this research overlapping, combining, or bridging disciplines?
- Do you have a track record of working fruitfully with people from other disciplines?
- What are you bringing to the proposal that makes possible something that would not otherwise have been possible?
- How has your openness (e.g. sharing of data, knowledge, skills) resulted in your work being used by others?
- How effectively have you communicated your work to a broader audience?
- What is your most important paper in your opinion and why (not necessarily focusing on where it was published)?

Recommendations for Funders and Publishers

- Similar to funders, publishers should also guide the members of their evaluation panels on how to best assess multidisciplinary papers.

- In addition to the criteria used to assess the research question (that is, the hypothesis and methodologies), the merit of the collaboration, its multidisciplinary approach, the breadth of disciplines and expertise, and the collaborative leadership needed for the proposal should be part of the assessment criteria and should be highly valued. Furthermore, it cannot necessarily be expected that every constituent discipline will contribute cutting-edge research – the innovation is in the combined application of disciplines (applies for papers and proposals).

- For publishers, efforts should be made to increase the transparency of peer review in order to reach a decision on a submission. In general, much greater transparency about the procedures used in research evaluation would be beneficial, so that researchers at all stages understand how they will be evaluated, and to emphasise that a broad range of accomplishments and attributes will be taken into account.

- More data should be collected on current best practices in terms of criteria and guidance for assessing collaborative work for funding and publishing decisions.

Other Recommendations for All

- Applicants for a job, promotion, fellowship, grant or tenure should be required to submit a contribution list of all other outputs, together with their relevant publications, to the evaluators, employer and/or funding organisation. The contribution list should be considered as a mandatory document for the various evaluation procedures.

- An agreement and commitment from all actors is needed in order to develop and implement a new system to credit scientific contributions, especially for data, tools and software, and to set rules for recommendations for a new policy to make data and software available in a mandatory way. Some funding agencies have already moved towards collaborative, multi- and interdisciplinary research and many of their approaches to mandatory sharing and methods of crediting such science could be shared. Consistency and similar approaches would be beneficial for European research.

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Annex 1

Programme

1 and 2 December 2015 // Sofitel Europe, Brussels

Tuesday 1 December

09.30–10.00 Introduction to Science Europe
Amanda Crowfoot, Director of Science Europe

Introduction to Workshop Concept and Expected Results
Dr Bonnie Wolff-Boenisch, Head of Research Affairs at Science Europe

Stocktaking
Professor Dirk Inzé, Flemish Institute for Biotechnology, Department of Plant Systems Biology, Belgium

10.00–10.20 **What can we Learn from the Other Research Disciplines?**
Moderator **Professor Hojka Kraigher**, Slovenian Forestry Institute, Slovenia

The Solid-Earth Science Perspective
Professor Rinus Wortel, Utrecht University, Netherlands

The Climate Modelling Perspective
Professor Ina Tegen, Leibniz Institute for Tropospheric Research, University of Leipzig, Germany

The Oceanic and Atmospheric Sciences Perspective
Professor Peter Liss, School of Environmental Sciences, University of East Anglia, United Kingdom

10.20–13.30 **Collecting Ideas, Views and Practices**

A View of the Future of Multidisciplinary Research Teams in Life Sciences
Moderator **Professor Lucia Banci**, Centre of Magnetic Resonance, University of Florence, Italy

Crediting from the Biological Perspective
Professor Barend Mons, Leiden University Medical Centre, Netherlands Bioinformatics Center, and ELIXIR

The People behind Research Software – Crediting from the Informatics/ Technical Point of View
Professor Carole Goble, University of Manchester, United Kingdom, ELIXIR-UK Deputy Head of Node, ISBE FAIRDOM Director, and Software Sustainability Institute PI

Current Bottlenecks in Multidisciplinary Research Teams in Life Science
Moderator **Professor Janusz. M. Bujnicki**, International Institute of Molecular and Cell Biology, Poland

Irreconcilable Differences: the Need for Bio-informatics and Bio-informaticians in Academia
Assistant Professor Jeffrey Chang, University of Texas Health Science Center, Houston, United States

The Problem of Authorship and Recognition in Systems Biology – Maintaining the Dew Point
Dr Nicolas le Novère, Babraham Institute, United Kingdom

1 and 2 December 2015 // Sofitel Europe, Brussels

Practical Approaches

Moderator **Professor Janusz. M. Bujnicki**

Initiatives: the Project CRediT and Mozilla Badges
Dr Liz Allen, F1000, Project CRediT, United Kingdom

Best Practices at a University
Professor Bert Overlaet, LERU and KU Leuven, Belgium

13.30–15.00 **Influencers**

Moderator **Dr Bonnie Wolff-Boenisch**

Round Table discussion with publishers from journals that experiment with new formats for multidisciplinary data science and new ways of peer review, on a possible framework for a new authorship standard in the Life Sciences.
Dr Catriona MacCallum, PLOS, **Dr Thomas Lemberger**, EMBO Press, **Dr Kamila Markram**, Frontiers, **Dr Mark Patterson**, eLife, and **Dr Bahar Mehmani**, RELX Group

15.00–17.10 **Parallel Breakout Sessions**

After a short introduction, participants will break up into three separate breakout groups on the following suggested topics:

Collaborative Work – LEGS Recommendation 2: Capture the added value of collaborative research: various evaluation and promotion committees include the number of co-publications, co-patents, networking efforts and research collaborations as indicators of an individual scientist's capacity to cross the boundaries of a single discipline, and as demonstration of active engagementin multidisciplinary research.
Chair and rapporteur: **Professor Lucia Banci** and **Professor Kai Lindström**

Basis – LEGS Recommendation 3: Make data available to the scientific community at large through freely available data access models, repositories and web metrics. The output should be considered equal in importance to scientific publications.
Chair and rapporteur: **Professor Ina Tegen**

Tools – LEGS Recommendation 4: Recognise the development of enabling tools such as methods, algorithms and software as a significant contribution to knowledge creation and management. The success of such endeavors should be measured by the number of downloaded applications by users relying on such valuable research tools.
Chair and rapporteur: **Professor Peter Liss** and **Professor Rinus Wortel**

17.10 **Summary of Results from Breakout Sessions**

1 and 2 December 2015 // Sofitel Europe, Brussels

Wednesday 2 December

09.30–10.15 Evaluation of the Discussions in the Breakout Sessions
Chair and rapporteur: **Annalisa Montesanti PhD** and **Dr Babette Regierer**

10.15–11.45 **What Next?**
Moderators **Professor Dirk Inzé** and **Dr Iain Cameron**

Round Table Discussion with Stakeholders on 'What Next?' and LEGS Recommendation 1: *Applicants for a job, promotion, fellowship, grand and tenure are required to submit a contribution list, together with the relevant publications, to the evaluators, employers and funding organisations. The contribution list should be considered a mandatory document for the various evaluation procedures.*
Dr Mike Mugabushaka, Head of Sector of Support to Monitoring and Evaluation of ERC Activities; **Professor Bernard Rentier**, EUA; **Mr Paul Harris**, DG Education and Culture, Unit for Innovation in Education, EIT and MSCA; and **Dr Chonnettia Jones**, Wellcome Trust

11.45–12.00 **Wrap-up**

Next Steps
Professor Dirk Inzé, Professor Janusz M. Bujnicki and **Dr Bonnie Wolff-Boenisch**

12.00 **End of Workshop**

Annex 2

List of tools and standards mentioned at the workshop and in the report:

- **CASRAI CRediT project:** CASRAI is an international non-profit organisation dedicated to reducing the administrative burden and improving impact measurements for researchers. The CRediT project (Contributor Roles Taxonomy) brings together a diverse set of stakeholders with a common interest in better understanding and communicating the different kinds of contributor roles in research outputs. It proposes a taxonomy describing 14 roles to which members of a research team can be ascribed to make clear their contribution to the research as published.
  - http://dictionary.casrai.org/Contributor_Roles

- **Mozilla Badges:** The Mozilla Open Badges (Open Badge Infrastructure or OBI) project is a programme by Mozilla that issues digital badges to recognise skills and achievements (using the same taxonomy as the above CRediT project.) The badge structure allows one to display real-world achievements and skills with the goal to help with future career and education opportunities.
  - http://openbadges.org

- **ORCID and Vivo:** Researchers can sign up to the unique digital identifier ORCID or to Vivo, which are tools linking data regarding scholarship and other useful information. ORCID numbers are unique strings of digits that are permanently allocated to individual researchers and authors. It is an ideal tool for a researcher's CV, being open source, generally respected and well supported. Researchers simply give their number in a proposal instead of retyping all the information in various application formats.
  - http://orcid.org and http://www.vivoweb.org

  Post-workshop note: a group of eight journals and publishers signed an open letter on 1 January 2016, committing them to require ORCID identifiers for corresponding authors of published papers starting in 2016. These include the publishers PLOS, EMBO Press, the Royal Society, IEEE, Hindawi and the American Geophysical Union. The Science journals, published by the American Association for the Advancement of Science, and eLife, jointly supported by the Wellcome Trust, the Howard Hughes Medical Institute have also signed up.[10]

- **Loop:** A 'research network' intended to foster and support open science. A Loop profile is a showcase of publications and achievements, and Loop disseminates the work and ensures that it is disseminated. Their online impact metrics provide feedback on a researcher's reach and impact across institutions, geographies, disciplines and other key metrics. Loop automatically promotes a person's research without them having to do anything.
  - http://loop.frontiersin.org/

- **Hirsch index:** An existing and potentially useful way of moving away from evaluation by traditional methods of using a journal's impact factor and the publication list of an author, uses H- and M-indexes of scientific output, which provide a more objective measure of scientific impact, and can be weighted to take into account the stage of a scientist's career. The definition of the '*h*-index' is that a scholar with an index of *h* has published h papers each of which has been cited in other papers at least *h* times.[12] Thus, the *h*-index reflects both the number of publications and the number of citations per publication. The index is designed to improve upon simpler measures such as the total number of citations, or publications measured alone. Citation conventions differ widely across different fields and the *h*-index works properly only for comparing scientists working within the same field. M-indexes bring in the number of years in full-time research it took to have created so many publications. The *m*-index is defined as *h/n*, where *n* is the number of years since the first published paper of the scientist.[13] Caution: these newer bibliometric methods still weigh heavily upon publications as a sole measurable research output, therefore will not accurately describe 'real contribution'.

- **Digital Object Identifier.** A digital object identifier (DOI) is a series of characters used to uniquely identify an object such as an electronic document. Metadata about the object is stored in association with the DOI name and this metadata may include a location, such as a URL (Uniform Resource Identifier, or webpage address), where the object can be found.
  - https://www.doi.org/

- **FORCE11:** FORCE11 is a data and software citation working group of a community of scholars, librarians, archivists, publishers and research funders that arose (after a workshop in Germany in 2011) to help facilitate the change toward improved knowledge creation and sharing. Individually and collectively, they aim to bring about a change in modern scholarly communications through the effective use of information technology.
  - https://www.force11.org/

- **Ten Simple Rules:** An article was published in 2014 which details'Ten Simple Rules for the Care and Feeding of Scientific Data'. This article is an outcome of an exploratory seminar called 'What to Keep and How to Analyze It: Data Curation and Data Analysis with Multiple Phases',[14] organised at Harvard University, Cambridge, Massachusetts, United States.
  - DOI: 10.1371/journal.pcbi.1003542

- **Depsy:** Depsy is a free website launched in November 2015 that aims to "measure the value of software that powers science". Depsy searches through research papers to discover both citations and informal mentions of software. Depsy's creators hope that their platform will provide a transparent and meaningful way to track the impact of software built by academics. The technology behind it was developed by Impactstory, a non-profit firm based in Vancouver, Canada.
  - http://depsy.org/

- **FAIRDOM:** FAIRDOM's primary mission is to support researchers, students, trainers, funders and publishers by enabling systems biology projects to make their Data, Operating procedures and Models, Findable, Accessible, Interoperable and Reusable (FAIR).
  - http://fair-dom.org/

- **ResearchObject:** ResearchObject aims to map the landscape of initiatives and activity in the development of 'Research Objects', an emerging approach to the publication and exchange of scholarly information on the web. ResearchObject aims to improve reuse and reproducibility by: supporting the publication of more than just PDFs, making data, code, and other resources first class citizens of scholarship; recognising that there is often a need to publish collections of these resources together as one shareable, cite-able resource; and enriching these resources and collections with any and all additional information required to make research reusable, and reproducible.
  - www.researchobject.org

- **DORA (Declaration of Research Assessment):** Due to the pressing need to improve the ways in which the output of scientific research is evaluated by funding agencies, academic institutions, and other parties, the American Society for Cell Biology and activists involved with scholarly publications created the San Francisco Declaration on Research Assessment i.e. DORA, (which is largely in response to perceived misuse of the Journal Impact Factor (JIF)), asserts that while the JIF may provide a gauge by which to judge the quality of a journal's contents, it presents an incomplete and sometimes skewed account of specific research, namely, a particular article or author. The group developed a set of recommendations, which are listed on their website.
  - http://www.ascb.org/dora/

- **The European Open Science Cloud (EOSC):** The EOSC aims to create a trusted environment for hosting and processing research data to support EU science. The EOSC offers a cloud-based, virtual environments which is free to use, open for use by anyone and offers safe and seamless services for storage, management, analysis and re-use of data that are linked to research activities, across borders and scientific disciplines.
  - https://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud

- **ELIXIR:** ELIXIR is a pan-European infrastructure for biological information/data, supporting life science research and its translation to medicine, agriculture, bio-industries and society. It provides facilities for life science organisations and researchers to manage and safeguard the massive amounts of data being generated every day by publicly funded research.
  - https://www.elixir-europe.org/

Science Europe is a non-profit organisation based in Brussels representing major Research Funding and Research Performing Organisations across Europe.

More information on its mission and activities is provided at www.scienceeurope.org.

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