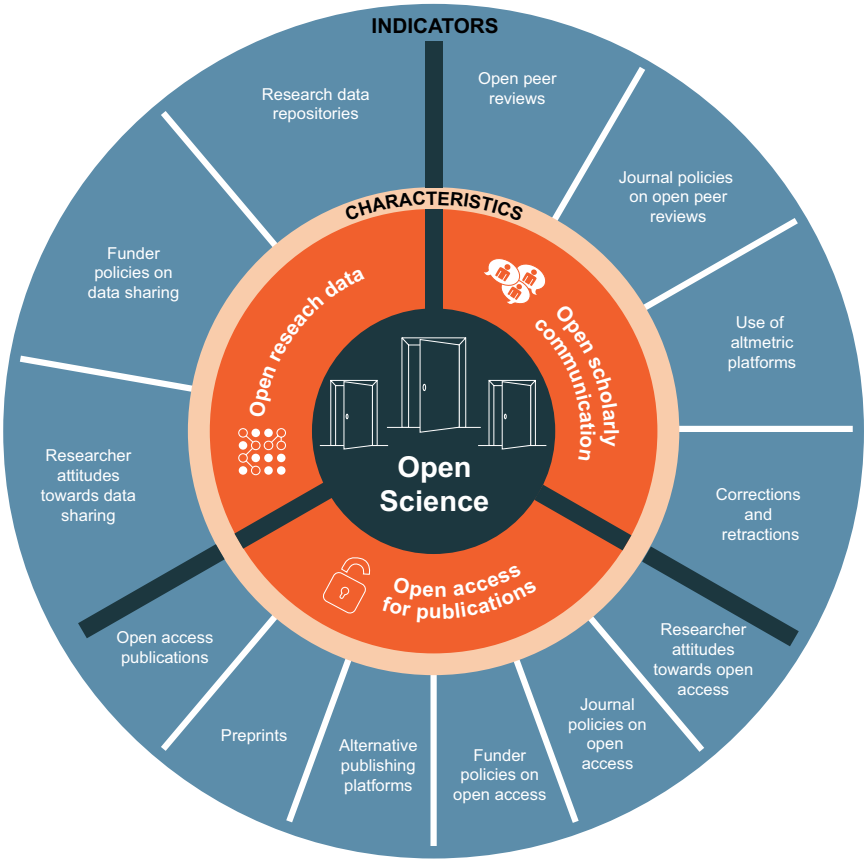
Scottish Science Advisory Council

scottish science advisory council

Open Research

How data sharing can advance scientific impact in Scotland

Summary of the issue



Scientists pursue knowledge about the Universe, building upon previous discoveries; or as Isaac Newton put it, we make progress by "standing on the shoulders of giants". To make the most of this principle of building progressively on existing knowledge, the open science movement advocates making all aspects of scientific research freely available, an advance made possible by the digital revolution. This includes making scientific publications free to read via open access publication, and sharing research datasets, software code, models and scientific methods. These principles of openness are designed to make scientific research more transparent, encourage speed verification or falsification of new hypotheses, and facilitate the translation of scientific progress into innovation to benefit society[1]. Substantial progress has been made on national and international levels in making research publications open access including Plan S, a new mandate for science funded by many major European funders to publish in fully open access journals[2]. Attention is now turning to making other research outputs freely available. This briefing note focuses on open data, its potential to enhance the impact of research, and how Scotland can contribute to and benefit from data sharing.

Providing researchers with the skills and competencies they need to practice Open Science. Open Science Skills Working Group Report (2017) https://ec.europa.eu/research/openscience/pdf/os_skills_wgreport_final.pdf

Open research increases transparency of the scientific process and enhances the potential for innovation arising from research by:

Moving science away from erroneous or inexact conclusions in the current thinking as quickly as possible (by sharing negative data and failures to replicate dominant hypotheses).

Accelerating the scientific process (by seeing in detail what has worked and not worked for other scientists).

Providing the means to identify rapidly, and therefore inhibit, scientific fraud.

Allowing re-use and reanalysis of data, potentially to answer different questions with one dataset and increase the reproducibility of scientific discoveries.

Providing the basis for social and commercial innovations that analyse, integrate and visualise the data.

Consideration of issues

What is Data Sharing?

Data sharing refers to making primary research data available to others. Scientists collaborate widely, with all members of their team sharing in the work and resulting data. However, making data available to anyone worldwide for free is a relatively new concept, facilitated by the digital revolution and the resulting ability to upload large amounts of data to the internet for anyone to access. Exactly what is meant by 'data' remains contentious and field-specific. Some scientists advocate sharing only fully analysed datasets (such as spreadsheets of analysed results) and others encourage the sharing of all 'raw' (but appropriately curated), unanalysed data, such as images from microscopes and telescopes, other raw readouts from equipment used in experiments, and all analysis methods. While sharing all raw data, analysed data, and analysis tools is the most open method and allows most re-use of the data, this also has the highest cost in terms of time and resources to host and to access and extract information from these data sets. In addition to the different types and extent of data shared, schemes are emerging for the level and quality of data sharing[3].

Reducing Scientific Fraud

Sharing raw data associated with publications facilitates detailed scrutiny by peers, reducing the risk of scientific fraud. Deliberate fraud among scientists is rare, but when it does occur, it can be very damaging. Take for example the paper linking autism to the MMR vaccine[4]. Upon investigation, it was found that every single one of the 12 cases reported in the original 1998 Lancet paper linking MMR to autism was misrepresented and none could be reconciled with the medical data. When the original paper was published, critics quickly pointed out serious experimental and conceptual flaws with the study as well as the failure of the peer review process. If anonymised medical data for each of these children had been made available to other scientists, these could have been discovered much earlier. This type of rare episode damages the reputation of scientists and the relationship between academia and the general public. In this case, it also led to outbreaks of preventable disease in children. In addition to rare, deliberate fraud, there is a growing recognition that conscious or unconscious biases and pressures can skew how researchers consider their findings. This may lead to a lack of reproducibility that erodes the integrity of the scholarly record[5 6]. If data sharing were mandatory alongside every publication, it would be less likely that both fraud and the occurrence of inadequately considered or biased results would occur.

Re-using Data

Sharing raw data allows other scientists to re-analyse data sets with different methods and with different questions in mind, without the expense of re-running the experiments. It is important to note that there is variability in the degree of quality assurance, which can be very important in deciding whether it is reliable for re-use or as a basis for policy development. Developments such as innovation centres or data portals are an opportunity both to share the raw data and to make this quality information available. Research funders and governments have created managed data repositories, which are excellent resources for providing access to curated data, this raises issues about who maintains data and provides support services for it, especially into the longer term when projects have ended. For example, the UK Data archive[7] formed by ESRC is the largest collection of digital research data in the social sciences in the UK. Similarly, the Open Data Institute, a UK non-profit company, interacts with government, commercial, and non-commercial organisations to promote data sharing. The European Bioinformatics Institute (EMBL-EBI) is the European partner for the majority of large-scale, international biomolecular databases (for example curating data on genes and molecular structures). EMBL-EBI archives experimental results, makes data and models available in standardised, easily usable formats, and adds value to the scientific community through services such as training[8].

Standardising Data

Data science and the standardisation of data outputs for large fields such as particle physics and genomics have led to the generation of repositories of structured data that have been instrumental in leading to new discoveries (for more details please see SSAC report: Big Data and Data Science in Scotland[9]: An SSAC Discussion Document from 2014). As well as these Big Data initiatives, less standardised data, which results from much of cutting-edge discovery science, can be shared. Often scientific experiments use new technologies or test entirely new paradigms, which do not have a standard data output format. Many institutions have online repositories for sharing this type of unstructured data, and several companies and coalitions have emerged that facilitate unstructured data sharing, such

Consideration of issues continued

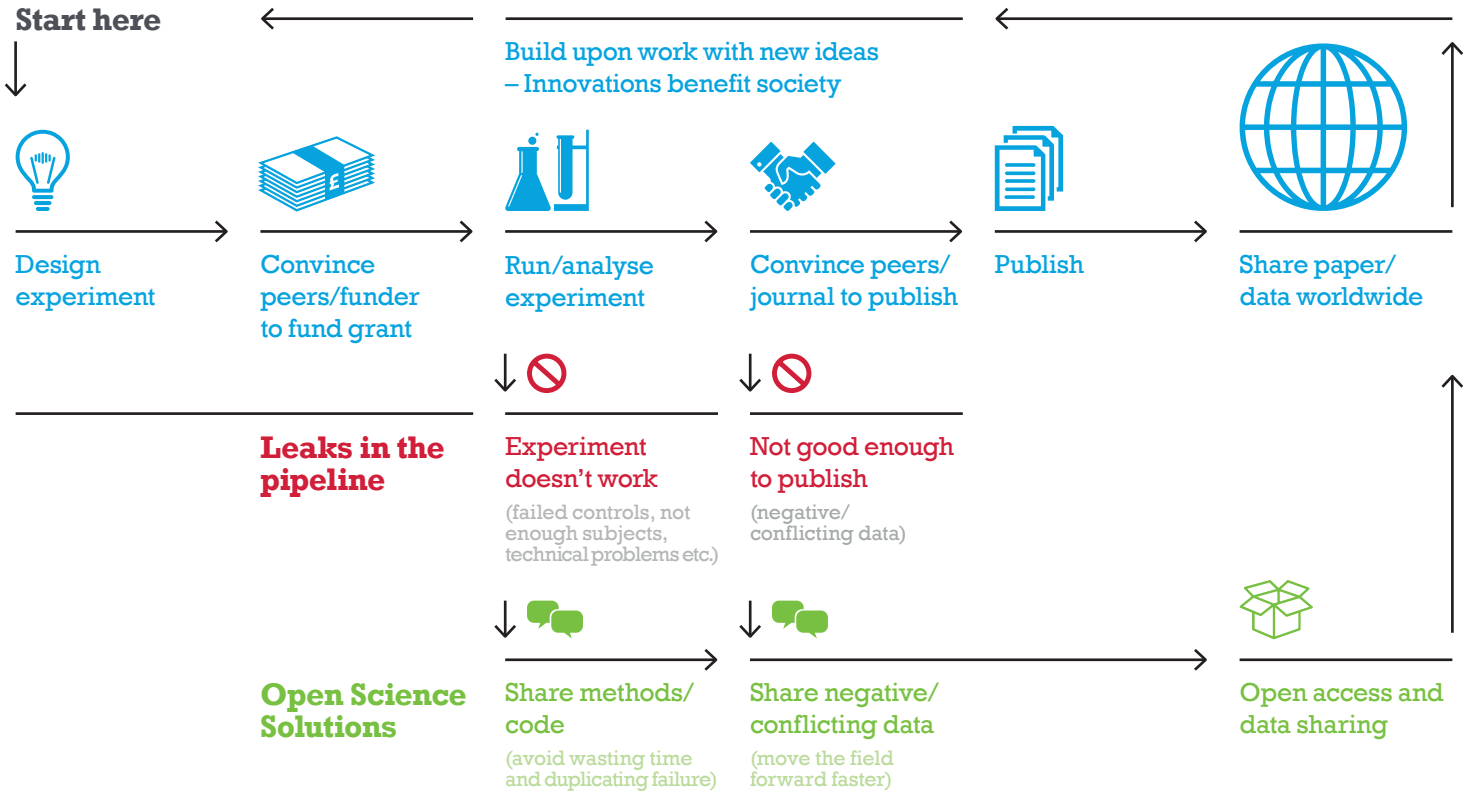
as FigShare, Dryad and Zenodo, or provide structure to 'long tail' data, such as FAIRDOM[10]. Acquiring the details of each experiment (metadata), which can be essential to understand the data, is especially challenging for 'long tail' data. Electronic Lab Notebook software can capture the metadata more easily than from a paper notebook. Adoption of the electronic systems has been slow.

Sharing Data in Real-Time

Digging furthest beneath the sharing of published works and finalised datasets, **sharing all methods and unpublished results** through open lab notebooks is another facet of open science. This is not practiced or appropriate for many labs, rather it is an intentionally extreme but logically consistent form of the transparency and openness that underlie the Open Science movement. The processes of experimental design, data collection, and analysis are complex and time consuming, and there is a huge amount of reinventing the wheel, with separate labs working on similar problems due to the abbreviated way methods are typically reported in scientific publications. The majority of experiments reported in the literature are not accompanied by enough detail (metadata) to reproduce the work. Open Notebook Science advocates argue that sharing experimental details in real time instead of waiting for a complete dataset or publication gets information out to peers more quickly, provides all the details needed to repeat the experiments, and importantly shows the parts of science that don't work or don't get published. These unpublished 'dark data' often contain negative results, which are difficult to publish but important to the field both to know which hypotheses do not hold up to scrutiny and to avoid running the same study again. Dark data also hide failed attempts at replicating published studies. Results that contradict previous studies can be difficult to publish but are important steps to overturn established, erroneous findings. The publication of data and results in preprints (public, online but before peer review) is an intermediate stage of openness. For example, Wellcome Trust will require its awardees to release their results in preprint form during public health emergencies, recognising the potential of preprints to accelerate discovery[11].

To help illustrate these benefits, the graphic below outlines the workflow of scientific research and points where open science can help.

Ideal Science 'Pipeline'



Drivers of open science

Most of the funding for scientific research comes from taxpayers through government grants, and through charities that fundraise for specific causes. Further, work to produce publications and peer review are all done by scientists who are mainly paid for from the public purse. This creates the need for accountability of researchers to the public who fund them and the drive for maximising the use of the resulting data to get the most possible benefit. The sense that the public is a major stakeholder in science is one of the drivers of the open access movement. The case for open access (OA) publishing has been made and accepted by governments and funders. In May 2016, the EU agreed that all scientific papers should be freely available by 2020. The EU, ERC and national funders including UKRI reinforced this commitment by supporting "Plan S" (2018; see box below). Multiple stakeholders have commented upon the implementation of Plan S[12] which will affect all research organisations in Scotland. Research Councils UK mandated OA publication from 2013, providing block grants to support some open access charges. For a paper to be considered for the next Research Excellence Framework (REF2021) assessment, it must satisfy minimum open access requirements, providing strong motivation for universities to make all published work open access. Institutions also push for OA publication because it can enhance the image and reputation of an organisation, by making the results of its research freely available to all.

A further boost to the open access movement is seen in the University of California system's decision in March 2019 to end their contract with the Elsevier publishing group, on grounds including that the publishing company was not willing to secure universal open access to their published research.[13]

The Ten Principles of Plan S

01 Authors retain copyright of their publication with no restrictions. All publications must be published under an open license, preferably the Creative Commons Attribution Licence CC BY. In all cases, the license applied should fulfil the requirements defined by the Berlin Declaration;

02 The Funders will ensure jointly the establishment of robust criteria and requirements for the services that compliant high quality Open Access journals and Open Access platforms must provide;

03 In case such high quality Open Access journals or platforms do not yet exist, the Funders will, in a coordinated way, provide incentives to establish and support them when appropriate; support will also be provided for Open Access infrastructures where necessary;

04 Where applicable, Open Access publication fees are covered by the Funders or universities, not by individual researchers; it is acknowledged that all scientists should be able to publish their work Open Access even if their institutions have limited means;

05 When Open Access publication fees are applied, their funding is standardised and capped (across Europe);

06 The Funders will ask universities, research organisations, and libraries to align their policies and strategies, notably to ensure transparency;

07 The above principles shall apply to all types of scholarly publications, but it is understood that the timeline to achieve Open Access for monographs and books may be longer than 1 January 2020;

08 The importance of open archives and repositories for hosting research outputs is acknowledged because of their long-term archiving function and their potential for editorial innovation;

09 The 'hybrid' model of publishing is not compliant with the above principles;

10 The Funders will monitor compliance and sanction non-compliance.

Drivers of open science continued

The push for open data is now growing, as full OA is closer to reality, with indications at the EU, UK, and Scottish levels that data sharing is the way forward. Though funders have highlighted the importance of Open Data for nearly as long as OA, data sharing policies are currently fragmented, incompletely implemented and patchily enforced, creating a complex situation for researchers, thus providing an opportunity for Scottish leadership. Research Councils UK developed common principles and guidance on data policy, which consider good data management and Open Data[14]. The principles were formalised in a 2016 Concordat that was signed by multiple funders[15]. However, each UK research council retains separate, detailed guidance. ESRC requires sharing of data generated from their grants, for example, for which they provide dedicated infrastructure through the UK Data Archive. In 2019, a UK Government task force report sought to rekindle interest in the Concordat principles[16].

At the European level, Open Research Data is nominally the default option in Horizon 2020[17] but in practice is implemented through an optional "pilot" scheme. Policies are also being put in place to encourage Open Science and change the culture of science as part of the 'Innovation Union'. The European Commission has already initiated several science policy actions, with two large open science pilot initiatives[18] [19]. The 2016 European Open Science Cloud initiative (EOSC) has growing, ministerial-level momentum to conceive, specify and fund the infrastructure for all aspects of Open Research[20] [21]. European Commissioners Moedas and Oettinger had already written a joint blog post in 2015 stating that *'Open Science describes the on-going transitions in the way research is performed, researchers collaborate, knowledge is shared, and science is organised. It represents a systemic change in the modus operandi of science and research. It affects the whole research cycle and its stakeholders, enhances science by facilitating more transparency, openness, networking, collaboration, and refocuses science from a 'publish or perish' perspective to a knowledge-sharing perspective.'* After preparatory projects, EOSC was launched in 2018[22]. Scotland is well represented through internationally-leading organisations such as the UK Digital Curation Centre and Software Sustainability Institute and through infrastructure providers such as EPCC, the centre for advanced computation at the University of Edinburgh.

Many other stakeholders are also pushing for open science. There are grassroots movements of scientists advocating open science including the global Research Data Alliance and The Committee on Data of the International Council for Science. The Force11 group advocates for Open Research and was instrumental in developing the FAIR guiding principles[23], which state that shared data should be Findable, Accessible, Interoperable and Reusable. The H2020 Open Research Data Pilot quickly adopted the FAIR principles. The League of European Research Universities[24] is a strong advocate for open research, publishing a comprehensive position in 2018[25]. In the publishing industry, some open access publishers, spearheaded by Public Library of Science (PLoS) are also now formally requiring open data associated with all of their published articles[26].

Hurdles to open science

With all of the benefits of open science, one might wonder why this is not the norm in the scientific community. There are serious ethical considerations that prevent sharing some types of data, for example knowledge related to making nuclear weapons or personal data on human subjects (a topic covered very well by the Royal Society and the RSE Young Academy of Scotland[27]). There are also some intellectual property considerations, particularly for applied science, which are resolved by the FAIR principles: FAIR data need not be Open, but Open data that is not FAIR might be hard to re-use. Where these caveats do not apply, in general, academia is moving towards open science, but several hurdles remain. The biggest impediments to realising the dream of completely open science are time, money, and culture.

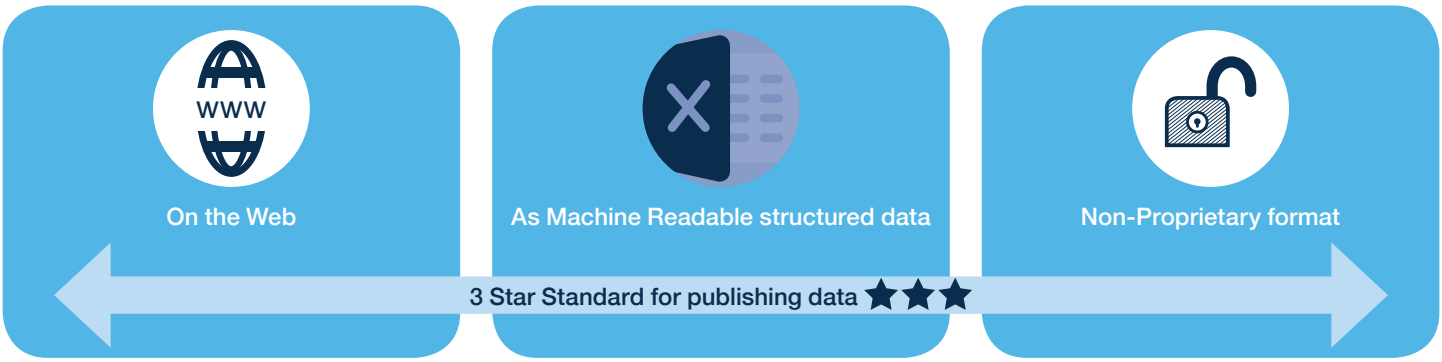
Scientists work in what some call a 'publish or perish' environment. There are few incentives or rewards to spend time curating data for sharing, few software systems to make data management a natural part of daily research, and little funding to support and sustain the infrastructure necessary for data sharing. Modern science generates very large datasets that are expensive to host indefinitely: the EOSC initiative might resolve this at a supranational level and the role of research institutions in EOSC is currently unclear.

In addition, sharing raw data without the accompanying metadata and analysis methods does not allow colleagues to see how conclusions were reached. The creation of the analysis code is time consuming and a skill that not everyone has whilst development of common standards to enable analysis also takes considerable time. Some researchers are reluctant to share code despite the benefits to the wider field, either because the code may have taken weeks or months to perfect, or because they won't share 'sub-standard' work but aspire to professional standards that are higher than their time allows. Scientists and organisations are also concerned about competitors using data without attribution (which amounts to intellectual theft), whereas closed data offers a competitive advantage to support further publications. OA papers on average receive more citations, and datasets can now be cited[28]. These benefits mainly accrue to group leaders over several years. They currently do not outweigh the costs in time and money for mainly junior researchers on short contracts to share their data as part of their daily research workflow. Discipline-specific software systems that both increase productivity and facilitate sharing can change this balance. The cost of developing and providing such infrastructure should be set against the greater cost of human data curation, which is otherwise required to acquire partial metadata *post-hoc*.

Processes to account for ethical concerns (protecting personal data in medical research) and monetary and impact concerns (protecting intellectual property) are now being implemented in the processes of data sharing. It is also worth noting that a top-down 'one size fits all' solution is unlikely to succeed when the balance between the cost of sharing compared to the cost of recreating a data set varies enormously, from laboratory studies that are routine, to long-term ecological observations that are unique. There are some potential cost savings to collaboration on OA, but when it comes to data, each sector already has its own data centres, innovation centres, etc. There may, however, be advantages in sharing best practice and developments in data science and management. Institutions do collaborate to create their data repository systems and there may be a role for the Scottish Government in promoting this in Scotland.

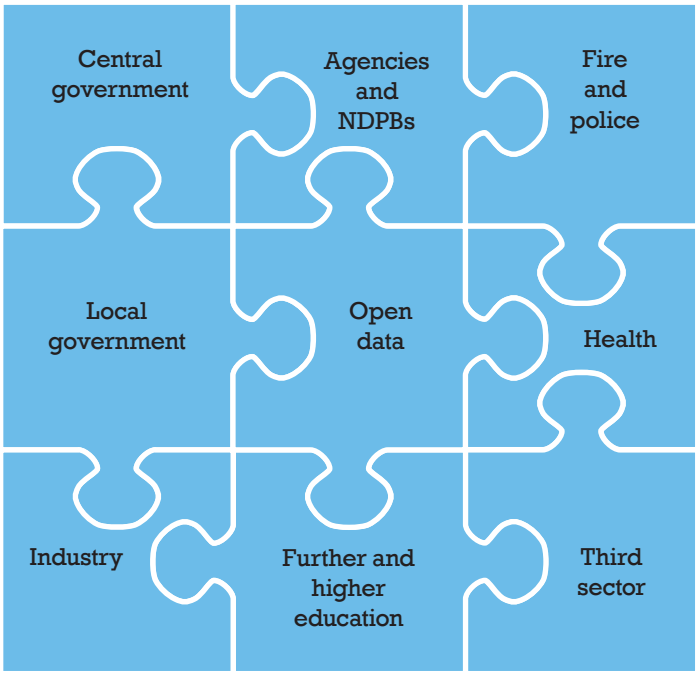
Scottish context and impact

Open science is in line with key Scottish Government priorities of innovation and openness and the idea that 'openness supports innovation.' Mandates for data sharing are already in place for the public sector. The Scottish Government's Open Data strategy published in 2015 sets out the ambition to make government data open and available. The strategy supports Open Data by default for Scottish public sector bodies, and encourages all Scottish public bodies to publish their data to three-star standard shown in the diagram below. The public value in open dissemination is balanced against public value in the completion of ongoing research, and this principle is legally recognised. Freedom of Information law protects the results from ongoing programmes of research, and hence the interests of researchers[29]. The Open movement will need to acknowledge the differences in funding, motivation and constraints, in order to gain best advantage from combining data from discovery research with the national capabilities of public bodies.



Capitalising on existing strengths through Open Science

Scottish research has led parts of the Open Research agenda. Even before Open Access was required by REF in 2014, Scottish publications had the most Open Access in the world[30]. Scotland has been very successful in creating and having the ability to link large-scale administrative datasets, particularly in the demographic and health fields, following ethical approval and scrutiny by a public privacy and benefits panel. Part of this comes from the way the Scottish Government departments are less siloed than many governments' hence it may be easier to share data in a trustworthy way. Similarly, there are prominent academics and researchers in government working together to lead curation of datasets. The comparatively smaller network of people involved in Scotland also facilitates open data. Ensuring ongoing public engagement in the holding of personal data and their use for societal benefits is vital, as evidenced by the work of the Farr Institute of Health Informatics research, Informatics and Development of a Proportionate Governance Framework, which has been led by Scotland.



Scottish Government Open Data Resource Pack
https://www.gov.scot/Resource/0050/00504861.pdf

Capitalising on existing strengths through Open Science continued

Key Scottish data and open-data related institutes are:

- Health data research UK[31] – a UK-wide research collaboration co-funded by the Chief Scientist Office (Scotland), aims to "deliver high-quality, cutting-edge research using 'big data' to advance the health and care of patients and the public."
- Digital Health and Care Institute[32] – a Scottish Funding Council Innovation Centre Programme aiming to bring together people and organisations to "develop new ideas for digital technology that will improve the delivery of health and care services for the people of Scotland".
- DataLab[33] – facilitates collaborations between industry, public sector, and universities to exploit data science.
- Stratified Medicine Scotland[34] – a Scottish Funding Council Innovation Centre based at Queen Elizabeth University Hospital (QEUH) in Glasgow which aims to link disease genotype and phenotype data to predict patient response to individual therapies.
- Scotland's Environment Web[35].
- City of Edinburgh Council provides data for apps to make city life easier[36].
- National Marine Plan interactive (NMPi) is a collection of data to assist in the development of national and regional marine planning[37].

UK national bodies that are partly located in Scottish institutions:

- Digital Curation Centre (DCC)
- Software Sustainability Institute (SSI)

UK national providers located in Scottish institutions:

- EPCC, which hosts and runs the UK national supercomputer ARCHER[38] and the EPSRC/NERC Research Data Facility.

Moving forward, Scotland can harness the benefits of open science in many areas. Just three examples are:

- Health – In addition to the health-related initiatives outlined above, Scotland has a Health and Biomedical informatics research strategy to use routinely collected patient data for research[39] as well as multiple research cohort studies that generate data relevant to improving health (Generation Scotland, Lothian/ Aberdeen Birth Cohorts, European Prevention of Alzheimer's Disease, etc). This gives Scotland the potential to be a world leader in stratified medicine and translational biomedical research.
- Education – tapping into the open data institutes and initiatives provides a wealth of opportunities for learners to participate in research and data analysis.
- Environment – the Scotland's Soils website[40] offers data and maps from multiple Scottish sources especially the James Hutton Institute and shows the potential uptake (>6k page views per month). Using these data, a Scottish Government policy team clarified an EU regulation that avoided thousands of farmers across Scotland facing penalties in 2018[41]. Many other types of environmental and agricultural data could deliver similar benefits. For example, a 2018 review of biodiversity information offers the opportunity to design a new system for this area[42].

Conclusions and questions for Scottish Government's consideration

If scientists, government, other funders, publishers, and other stakeholders work together, we can change the culture to ensure that the output of scientific studies does not end with publication, but ends with FAIR and Open Data models and research methods. The impact of this culture shift would be significant, society at large would benefit from getting more from the money spent on research and progressing faster to innovations that benefit the public. Additionally, it would make the scientist's role in peer review a more complete process informed by the raw underlying data. Publishers too would benefit, with papers submitted from studies that are truly repeatable so less likely to be retracted. To foster this culture of openness, government can build on the progress that has been made in Open Access publication, largely through funder mandates and providing funds to pay open access charges. The same approach can now be applied to share data, models and methods.

Possible routes for Scotland to encourage Open Science are:

- **Require data sharing from all Scottish Government funded research.** For example, the Chief Scientist Office (CSO) funds health research grants and already encourages open access publication for their projects. Funds are provided by the CSO, within certain parameters, for OA access publication and separately to facilitate data sharing, including preparation of datasets for archiving. A similar model could support data sharing that is required in future Scottish Government funded research. Joining the international initiatives such as EOSC as a signatory would signal this trajectory. Implementing the 2016 UK Concordat on Open Research Data[43] would provide the type of specific mandate that REF2021 used successfully to change Open Access culture. Open Data is more laborious and discipline-specific than Open Access, so Scottish Government might usefully broker the sharing of best practice among institutions. Some SG-funded institutions are required to follow UK-level practice, such as the DEFRA Joint Code of Practice for Research[44] for its research institutes, so broader negotiation might be required in these cases. Staging of the mandate's introduction should recognise the time needed for investment and training, but also the advantage in being prepared before an international mandate is introduced, for example from EOSC.
- **Fund the people and infrastructure to facilitate data sharing.** For example, the platform created for statistics.gov.scot could be expanded to include some scientific data. Scottish institutions support significant research data repositories, including UK national resources, providing a pool of expertise as well as infrastructure to support the process. A government mandate might contribute to shape the European Open Science Cloud in directions that include these stakeholders. The scale of investment required is significant: EOSC estimates that 5% of total research spending should be dedicated to managing and 'stewarding' data[45] and this is consistent with the experience of Scottish researchers.
- **Foster a change in culture towards being more open and less competitive.** For example, create uniform incentives for data sharing, by setting the expectation that such recognition will be part of institutional processes.
- **Establish norms that allow institutions to take action against the re-use of research results without attribution:** Concerns over such 'intellectual theft' form a barrier to Open sharing, which no individual researcher can resolve.
- **Scottish Government and SSAC should engage Scottish researchers and their institutions in a process to implement Open Science in practice.** It will be important to discuss the mechanisms, infrastructure and incentives required to achieve open science; to agree mandates that kick-start the process in a cost-effective manner; and to anticipate how the outputs of open science can serve to build trust with and benefit society, indirectly through new products and services and directly empowering people to participate in civic society and citizen science programmes.

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scottishscience@gov.scot