Seven steps to enhance open science practices in animal science

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Opinion paper

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Abstract
The Open Science movement aims at ensuring accessibility, reproducibility and transparency of research. The adoption of Open Science practices in animal science, however, is still at an early stage. To move ahead as a field, we here provide seven practical steps to embrace Open Science in animal science. We hope that this paper contributes to the shift in research practices of animal scientists towards open, transparent and reproducible science, enabling the field to gain additional public trust and deal with future challenges to guarantee reliable research.

Keywords: open access, open data, open peer-review, open science, preregistration

Introduction

The knowledge produced by science is a public good and, as such, both the outcome of research and the evidence that supports the scientific claims (*e.g.*, protocols, data, models and program code) should be transparent and publicly accessible. Open Science (OS) is an umbrella of practices referring to the process of making scientific knowledge transparent, reproducible and accessible to everyone (Munafò et al., 2017). Transparency and accessibility help improve the quality and production of scientific knowledge (Crüwell et al., 2019). In addition to the general societal and academic benefits of OS (Tennant et al., 2016), Nawroth and Krause (2021) recently argued that, specifically in animal sciences, OS practices also strengthen adherence to the 3Rs (Replacement, Reduction and Refinement) principles for ethical research on animals through the possibility of reusing protocols and data, and *via* fast dissemination of protocols and findings. However, incorporating OS practices is still relatively limited in the animal science domain. By animal science, we refer primarily to research on domestic animals, including nutritional, behavioural and physiological aspects. Breaking the barriers to engaging with OS may require learning new skills and adopting new habits. One of the major obstacles in OS engagement is the lack of institutionalised incentives and training opportunities on OS practices. Inspired by guiding papers in the domains of psychological science (Crüwell et al., 2019; Houtkoop et al., 2018) and ecology (O'Dea et al., 2021), we here provide seven practical steps to encourage the adoption of OS in the animal science field. In addition, we propose answers to some common questions related to the adoption of OS practices (Box 1) and suggest engagement actions to enhance OS in our field (Box 2).

Step 1: Share your code and data

Some research communities, such as those working in genomics and proteomics, have a long history of data sharing in specific repositories. However, the animal science field is still subjected to barriers to data sharing (see Box 1). If we were (more) willing and able to provide open access (OA) to our data, codes, and models, these resources could more easily be part of meta-analyses (Sielemann et al., 2020) and help ensuring the reproducibility of experiments. The 'FAIR Guiding Principles for scientific data management and stewardship' (Wilkinson et al., 2016) describe general guidelines to improve the findability, accessibility, interoperability, and reuse (FAIR) of digital assets (see here for more information on FAIR). One of the barriers to sharing data and code is the need to guarantee that they are stored safely and are citable (assigned a Digital Object Identifier; DOI). Several open research data repositories (*e.g.,* Zenodo, Fighsare) are available. The site re3data is a directory of the main data repositories. More recently, some research institutes have launched their own solutions to facilitate data sharing and open data publications for their researchers and collaborators (*e.g.,* the Portail Data INRAE, Open Agrar). For data connected to publications, journals may impose specific repositories. In addition to data repositories, several platforms providing data services are available such as OpenAIRE and EOSC among others.

To follow the FAIR principles, it is important to add a description of your data set in the data repository. This set of information describing a data set is called metadata. It is important to use the same terms when referring to the same variables. Ontologies have been developed for livestock phenotypic traits (ATOL), for lab analyses data (JERM) and for bioinformatics analyses (Gene Ontology).

After depositing your data in to repositories, you can disseminate your data *via* a data paper, which is an article that describes research data in a structured and readable form. Some journals accepting data papers are CABI Agriculture and Bioscience, Animal Open Space and Data in Brief.

For source code, it is important to consider the purpose of sharing and to make your code easy for others to use. Storing your code as open-source makes it freely accessible, (re)usable, and improvable by anyone. You will need to provide instructions for running your code with a reproducible example and to list required software with their version details. You can provide your method as an installable library (*e.g.,* R or Python package), including appropriate documentation (Prlić and Procter, 2012). Software packaged as a library can also be installed directly from a repository in many programming languages. The Software Carpentry and Data Carpentry non-profit communities provide workshops and online lessons for adopting open science practices. Repositories such as GitHub and Sourceforge provide useful services for sharing scientific software.

Several funding agencies now encourage researchers to think about data sharing (which, when, with whom) from the start of research projects. A Data Management Plan (DMP) is now mandatory in projects funded by the European Commission, describing how data will be collected, processed, shared within the collaborators of the project, made openly accessible, and preserved. DMP templates and tools (*e.g.,* OPIDoR, ARGOS) can be found on websites of funding agencies.

Step 2: Preprint your findings

Peer review is fairly important but often takes months – so access to methods and test protocols is limited at best. To make new methods and developments accessible at an early stage, it is essential to make these protocols and results available for researchers and other stakeholders as soon as possible. Preprints offer a solution for this: they are published manuscripts which have not (yet) gone through formal peer-review. A DOI assignment guarantees that the authors can stake a claim on their findings (please note that some preprint servers/repositories such as arXiv and HAL do not provide a DOI but a permanent URL). The DOI and permanent URL allow the preprint to be cited and to be findable, *e.g.* in Google Scholar. As well as early accessibility, preprints also allow informal feedback from peers prior to formal peer review (see Step 5) and thus may help improve manuscripts before submission to a scientific journal. The major drawback of the preprint model is the lack of formal peer review that can help safeguard the scientific quality of the posted manuscripts. This drawback can be partly circumvented by the use of open peer-review platforms (Step 5).

Most journals in animal science allow preprinting (see Sherpa Romeo to check the journal policy). Preprints can be deposited in three types of platforms: (1) preprint servers like *e.g.,* bioRxiv, arXiv, OSF, (2) institutional repositories of which many universities and institutes have their own and (3) multidisciplinary archives like Zenodo and HAL. There are plenty of established preprint servers for life sciences, but only very few are specifically for animal science (*e.g.,* agriRxiv). OpenDOAR is a directory of OA repositories. Once a server is chosen, the actual preprinting is relatively simple: upload your final document and add meta-data – that's it. It is the best practice to upload the most recent version to the preprint server (the file will be updated, but previous versions are still accessible). However, it should be noted that some platforms, such as agriRxiv, do not accept versioning at the moment. Once published in a journal, you should include the full reference and

link to your journal article in the preprint version – both steps will facilitate access to the most recent content and ensure your work is cited properly. Services such as Google Scholar allow you to merge the preprint and the corresponding peer-reviewed journal papers, so they won't be duplicated in your publication list and will not bias the calculation of some metrics such as the h-index.

Step 3: Publish your articles under Open-Access licenses

Making scientific publications freely available is an essential part of OS. The Open Access (OA) publication in journals occurs in mainly two routes: the gold route and the green route (see Step 4). The gold route refers to the publication in journals where all the articles are published under an OA license. There are several OA journal business models including an Article Processing Charge (APC) model in which the author pays a publication fee to make their work OA. Although the APC model allows breaking the barrier imposed by journal paywalls, the high costs of APCs (up to 9500 €) imposes economic barriers that discriminate against researchers in low- and middle-income countries.

Many so-called predatory journals use the OA system to lure researchers offering special rates or fast processing times for their manuscripts (Grudniewicz et al., 2019). Be aware, you can check dedicated websites that help you identify predatory journals (see, *e.g.*, here and here).

A derivative of the gold OA is the publication in hybrid journals, which are traditional subscription journals (with paywalls) that offer the OA option *via* APC. The business model of the hybrid journal is controversial since both authors and readers are charged (APC and paywalled subscription fees).

An alternative solution to the obstacles of APC is given by diamond (sometimes called platinum labelled) OA journals, often managed by non-commercial and non-profit societies and organizations. In these journals, publications are made OA at no cost for authors and readers, with the cost being generally covered by a financial and in-kind donation from research institutions and universities. Diamond OA journals operate mainly at local and national levels. The Directory of Open Access Journals (DOAJ) indexes most of the journals using the OA model.

In 2018, the Plan S initiative for Open Access publishing was launched. This initiative is supported by an international consortium of organisations that fund and carry out research. Plan S requires that, from 2021, scientific publications resulting from research funded by public grants must be published in compliant OA journals or platforms. The journals aligned with Plan S can be found here.

Step 4: Upload your non-Open Acess papers into a repository

Often scholars and institutions do not have the funding to cover APCs to publish under an OA license. But even when published behind a paywall, these articles can be made OA *via* the green route by posting a postprint, *i.e.*, the final version of a manuscript following peer-review but without the journal layout, to a research repository like those mentioned in Step 2. Many institutions already have OA policies that require the uploading of postprints into an institutional repository. But authors should be aware that publishers have different embargo periods for publishing these postprints (check Sherpa Romeo for the journal of your choice). Keep in mind that some countries impose constraints on these embargo periods. For example, in France, researchers are authorized to do green OA archiving of publications from work that has received public funds no matter the

publisher's policy (embargos in France are thus set at 6 months for basic sciences and 12 months for human and social sciences). You should check the policies of your institution and country to know when and in which repository you should deposit postprints.

Publishing *via* the green route is not only an option to save resources when submitting a new manuscript due to saving APCs, it can also be of relevance for previously pay-walled published work. Years ago, authors might not have considered the additional value of making research accessible to everyone (or may not even have had this option) and do now, in hindsight, regret their choice of not publishing OA. With the green route, authors can also make all their previous research accessible – better late than never! Depositing postprints in repositories is also a way to preserve the scientific literature since journals can disappear from the internet (see here). Similar to preprinting, when uploading your postprint, you should provide a reference and link to the full paper on the title page of your manuscript – this will make the published paper easier to find and cite.

Step 5: Participate in open peer-review

The traditional journal evaluation process (*i.e.,* peer-review) is often a black box where peers not involved in the process have limited insight into the discussions and criteria leading to the acceptance of published articles. Open peer-review (OPR) refers to a set of features that makes the full process of evaluation of scientific articles open and transparent (Ross-Hellauer and Görögh, 2019). Here, we focus on the feature of making the review reports by peers public – a practice that strengthens the scientific debate, increases accountability and reproducibility, and contributes to the development of constructive peer-review. In addition to promoting transparent and constructive debate, OPR acknowledges the work carried out by editors and reviewers (if they decide to be named). Platforms like Publons give peer-review recognition (see here a comment about peer review recognition) and allow reviewers to make their reviews public if they wish.

For journals adopting OPR, the reviewers reports and the editorial decision are made public when the paper is published. The journal implementation of OPR is often made as an optional feature for the authors and reviewers. Some journals like PLOS ONE, eLife and Royal Society Open Science have implemented the OPR option. To our knowledge, disciplinary journals in animal science have not yet adopted OPR within their evaluation system, yet. The Open Science initiative Peer Community In (PCI) Animal Science and the Peer Community Journal, which belong to the parental project Peer Community In, provide a free process of OPR evaluation of preprints (see here an example of OPR by PCI Animal Science).

OPR can also take place after the publication of a manuscript by tools developed by journal publishers (*e.g.* Frontiers In) or *via* independent platforms. These platforms can be used for the evaluation of published articles and preprints. Some examples are PREreview, F1000Research, Review Commons, Hypothes.is and PubPeer.

We encourage you to adopt OPR in your research practices as both author and reviewer. As reviewer, you can go further and align with the Peer Reviewers' Openness Initiative (Morey et al., 2015) by providing comprehensive reviews of a manuscript only if it meets minimum open science requirements (*e.g.*, the data should be made publicly available). Keep in mind that making the identity of reviewers open is a controversial issue. For example, Early Career Researchers may not want to go public when reviewing work by more established scientists.

Step 6: Preregister your study

To ensure appropriate methods are used when collecting and analysing data, test protocols and analysis plans should be preregistered (Nosek et al., 2018). This consists of authors depositing their hypotheses and study designs on preregistration servers (*e.g.*, https://osf.io/) before data collection begins. There are also specific registries for animal experiments, such as the Animal Study Registry. Preregistration can be useful to prevent questionable research practices such as p-hacking (*i.e.*, changing statistical methods until a *p*-value below 0.05 appears) and HARKing (Hypothesising After Results are Known) (Kerr, 1998). Both of these are highly problematic as they can mislead researchers that a biological relevant effect exists where there isn't any. The early documentation of the test and analysis protocol has the potential to increase the credibility of results and thus public trust in science. It should be noted that preregistrations have the option to be made public only after a certain embargo period, so that the research idea will remain protected.

Step 7: Submit your preregistration as a Registered Report

Preregistrations of studies (see Step 6) can also be submitted to a journal and undergo formal peer-review – with the resulting article type being called 'Registered Report'(RR)**;** (Chambers and Tzavella, 2021). In general, RRs give rise to much lower effect sizes, proving that biases (such as negative results not being published) have caused inflation of effects in traditional, non-preregistered published articles (Schäfer and Schwarz, 2019; Scheel et al., 2021).

Academics can receive a provisional acceptance by a journal based on their submitted RR, thereby streamlining the submission and publication processes. RRs should not take more time than conventional publishing, because the time spent writing and reviewing the first half of a scientific paper is simply done before the experiment is conducted. It is therefore not more work but rather a reorganisation of the different steps involved in the process. Additional advantages for the authors of RRs is the possibility to get feedback at a point in the research project when the experimental design can actually be improved (with potential animal welfare improvements, Nawroth & Krause, 2021). It also ensures that negative (lack of significant) results from animal experiments become available to the public. Especially, Early Career Researchers will benefit as acceptance of a RR can be useful for job or funding applications, as it occurs early in the research process. In the animal science domain, few journals such as Animal Behavior & Cognition accept RRs (see this list with journals accepting RRs). The PCI Registered Reports is dedicated to RRs.

Box 1. Frequently Asked Questions about Open Science

Questions	Answers
Why should I share my data?	Sharing data enables building aggregated datasets in the long term which promotes methodological progress, validation of findings and reproducibility. Shared datasets can also increase the interest of others towards your work and lead to more citations and new collaborations.
The development of my model was a very time-consuming task, why should I share it?	Once your paper is published, submitting the code in an adapted repository ensures that your results are re-usable. Your code can also be cited. Sharing your code will increase visibility and citation of your work. Others may build upon your work and improve the method.
Do preprints provide a record of the originality of my research? If I publish a preprint, can my research be scooped?	Preprints establish priority of discovery (Vale and Hyman, 2016). Preprints prevent your research from getting scooped since they represent date-stamped priority claims (more information here). However, be aware that your preprint might attract the attention of the media, which can refer to your manuscript as if it was a peer-reviewed article. Also note that a preprint is a public disclosure and that intellectual protection depends on the license you choose when depositing the preprint (see here for information on licenses).
Will my preprint negatively affect the citations of my subsequent journal article?	Preprints increase the visibility of your work. Some studies show positive correlations between preprint posting (and downloads) and citation metrics of the subsequent journal paper (Fu and Hughey, 2019). Note that Google Scholar allows you to merge preprints and published articles.
I have preregistered my work. Is it still possible to change my test protocol?	Yes, it is possible to alter your test protocol. However, these changes have to have very pragmatic reasons and have to be transparently outlined in the preregistration/final article. If you have submitted a Registered Report, it is best to contact the editor of your submission and get approval from the journal side.
Where can I learn about open source software development, data sharing and other OS features?	Software Carpentry and Data Carpentry are good places to start for beginners. Getting involved in existing open source projects is also a good way to learn. The FOSTER open science project is a great resource of courses for OS training. Check your institution training offer in OS.

Box 2. How can you engage in the Open Science debate and break down barriers?

- Engage with your colleagues: share your experiences of OS, teach, and promote OS practices. Use this or similar articles (Nosek et al., 2015) for your next journal club. Promote OS workshops in your network (see an example here).
- Adopt OS practises in your team: discuss how the revenue scheme can be changed to reward OS and open-project collaborative research. Forward the questions and solutions to your group leader or head of institute.
- Engage with institutions and funders: promote the recognition of OS practices in the evaluation of job and project applications, and in our scientific societies. Discuss the positive and negative aspects of different metrics (*e.g.,* impact factors) in science evaluation within your network (*e.g.,* Muñoz-Tamayo, 2016). Invite your institutions to engage in OS actions (LERU, 2020) and adopt quality research assessment indicators as proposed by the San Francisco Declaration on Research Assessment (DORA), and the Leiden Manifesto (Hicks et al., 2015).
- Engage with journals: promote data and code sharing, question preprint policies, and suggest ways to improve reproducibility in particular when you are an editor. Suggest sharing of code and data in your peer-reviews even if it is not required by the journal.
- Promote bibliodiversity: explore innovative publication models that go beyond traditional journal formats. This includes data papers and submitting to alternative peer-review schemes such as Peer Community in Animal Science (see, *e.g.,* the Jussieu call for OS and biodiversity).

Conclusions

The OS umbrella covers several practices aiming at making scientific knowledge transparent, reproducible and accessible. We provide here an overview of seven steps to better embrace OS in animal science research. Most of the actions are relatively easy to put into practice (*e.g.,* depositing a manuscript in a preprint server takes less than 5 min. You can start today!). Other actions require certain expertise and effort (*e.g.,* building a data management plan). We encourage you to adopt the OS practices presented here in your research. Start progressively, choosing the steps that you feel more comfortable with as a start, keeping in mind that the time you spend on implementing OS practices will be rewarded. We expect that OS becomes *the new normal* in our field. This can only be possible by our engagement within our perimeter of action (Box 2).

Acknowledgements

We thank Denis Bourguet and Thomas Guillemaud, founders of the open science initiative Peer Community In, for their inspiring engagement in the open science movement. Rafael Muñoz-Tamayo thanks Eva Legras (AgroParisTech, France) for her outstanding work on training and raising awareness on open science practices in the AgroParisTech community. We thank Eva Legras and Denis Bourget for proofreading the manuscript and providing valuable feedback to improve the paper.

Authors contributions

Contributor roles according to CRediT.

Muñoz-Tamayo, Birte L. Nielsen, Christian Nawroth: conceptualization; writing – original draft; writing – review & editing.
Florence Gondret, E. Tobias Krause: writing – original draft; writing – review & editing.
Mohammed Gagaoua, Diego P. Morgavi, I. Anna S. Olsson, Matti Pastell, Masoomeh Taghipoor, Luis Tedeschi, Isabelle Veissier: writing - review & editing.

Declaration of interest

We established as conflict of interest the involvement of authors in journal boards or OS initiatives mentioned in the manuscript.
All authors but E. Tobias Krause are members of the open science initiative Peer Community In Animal Science. Anna Olsson is academic editor for PLOS ONE. Birte Nielsen is academic editor for Frontiers in Veterinary Science. Christian Nawroth is academic editor for Animal Behaviour & Cognition and Frontiers in Veterinary Science. Diego Morgavi is academic editor for Frontiers in Microbiology. Rafael Muñoz-Tamayo is member of the scientific board of Animal.

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