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Promoting Reusable and Open Methods and Protocols (PRO-MaP)

Recommendations to improve methodological clarity in life sciences publications

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Promoting Reusable and Open Methods and Protocols (PRO-MaP)

Recommendations to improve methodological clarity in life sciences publications

PRO-MaP
PROMOTING REUSABLE
OPEN METHODS & PROTOCOLS

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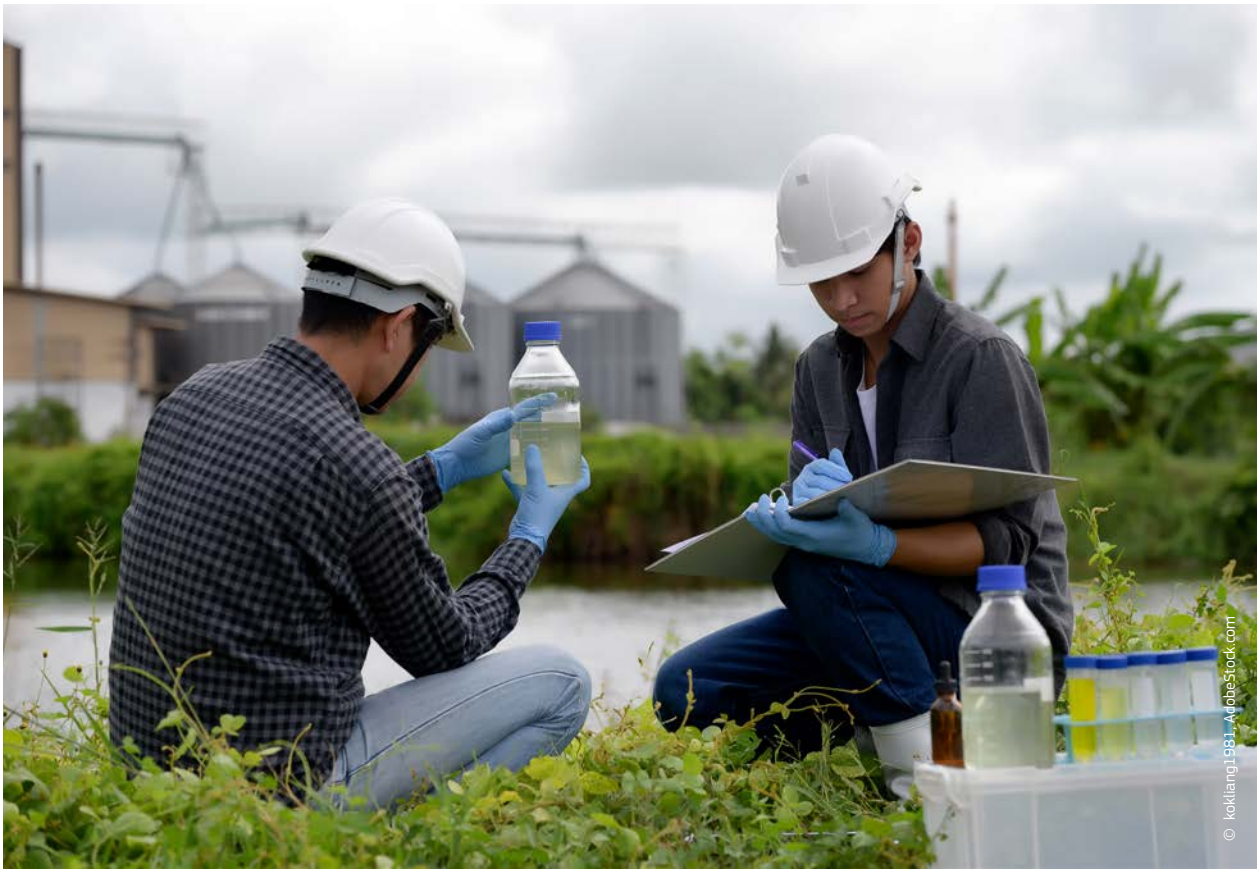
Abstract

Academic research papers from life sciences fields, such as biomedicine and biology, are often missing essential details about study methods. This can undermine trust, limit the use of new methods and hinder reproducibility and data reuse. Promoting Reusable and Open Methods and Protocols (PRO-MaP) aims to increase and improve the reporting of detailed, structured and open methods and reusable step-by-step protocols in the life sciences, supporting the EU's open science and valorisation policies. These recommendations outline actions that four stakeholder groups – researchers, research institutions and departments, publishers and editors, and funders – can take to achieve these goals. The recommendations are designed to improve the quality of method reporting, to reward and incentivise method sharing, to encourage sharing of step-by-step protocols in dynamic repositories that enable protocols to be updated as they evolve, and to promote responsible use of methodological shortcut citations. While some recommendations address study design and reporting guidelines, the primary focus is on capturing clear, accurate methodological detail. Policy changes, accompanied by implementation and monitoring plans, will be particularly important when implementing the recommendations for research institutions and departments, publishers and editors, and funders. These organisations must act to create an environment that incentivises scientists to implement the recommendations for researchers and rewards them for doing so.



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Executive summary

Policy context: Academic life sciences publications are routinely missing essential methodological details. The lack of openly accessible detailed methods undermines trust in published data and severely limits the uptake of new methods. Inadequate methodological detail also limits data reuse, as researchers and regulatory bodies cannot reuse data responsibly without knowing how those data were generated. European Commission reports highlight the importance of sharing research outputs, including protocols, to improve reproducibility and build trust.

Promoting Reusable and Open Methods and Protocols (PRO-MaP) aims to increase and improve the reporting of detailed, reusable and open methods and step-by-step protocols in the life sciences. The recommendations outline actions that four stakeholder groups – researchers, research institutions and departments, publishers and editors, and funders – can take to achieve these goals. These recommendations were developed through a workshop convened by the EU Reference Laboratory for alternatives to animal testing ([1]) of the European Commission Joint Research Centre and subsequently revised based on stakeholder feedback.

PRO-MaP supports the EU's open science policy ([2]) by outlining strategies to improve its key aims of reproducibility, rewards and the future of scholarly communication. As providing detailed methods is essential for responsible data reuse, PRO-MaP also supports the Open Data (FAIR) objective. Finally, PRO-MaP is also very relevant to the EU valorisation policy ([3]), since good reporting and publishing practices are critical for technology transfer and commercialisation, making research results more valuable for regulatory use.

Key conclusions: There are many actions that researchers, research institutions and departments, publishers and editors, and funders can take to increase and improve the reporting of detailed methods and reusable step-by-step protocols in the life sciences. Policy changes, accompanied by implementation and monitoring plans, will be particularly important for research institutions and departments, publishers and editors, and funders when implementing the recommendations. Actions by these organisations are crucial to create an environment that incentivises scientists to implement the practices outlined in the recommendations for researchers and rewards them for doing so. The table below highlights key policy-relevant recommendations for organisational stakeholder groups.

Stakeholder group	Key recommendations
Research institutions and departments	▸ Reward and incentivise sharing of detailed methods and step-by-step protocols ▸ Require and offer training on writing and openly sharing detailed methods and reusable step-by-step protocols ▸ Integrate sharing of detailed methods and reusable step-by-step protocols into thesis requirements
Publishers and editors	▸ Ensure that methods are described in enough detail to reproduce the experiment ▸ Encourage authors to strengthen static methods sections by linking to reusable step-by-step protocols uploaded to dynamic platforms ▸ Promote responsible use of methodological shortcut citations ▸ Put methods sections in front of the paywall ▸ Require methods and materials availability statements
Funders	▸ Embed open protocol reporting in research funding to support protocol review and reuse ▸ Reward and incentivize sharing of detailed methods and reusable step-by-step protocols ▸ Integrate sharing of detailed methods and reusable step-by-step protocols into training and assessment criteria for graduate students ▸ Use evaluation indicators to track progress

1 https://joint-research-centre.ec.europa.eu/eu-reference-laboratory-alternatives-animal-testing-eurl-ecvam_en

2 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en#Future%20of%20Open%20Science%20Under%20Horizon%20Europe

3 https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/eu-valorisation-policy_en

Main findings:

Principles. Four principles guided this work.

1. **Cultural change.** We need a cultural shift to reward and incentivize methods development and sharing of reusable open methods and protocols. All stakeholder groups must act.
2. **Share reusable step-by-step protocols, and cite them in publications.** Research papers should include links to reusable step-by-step protocols describing how methods were implemented.
3. **Protocols should be citable and shared on dynamic platforms**. This allows versioning or forking as the protocol is adapted by its creators, or others.
4. **Use methodological shortcut citations responsibly**. Researchers use a shortcut citation when they cite a resource that used the method instead of fully describing the method themselves. Researchers should ensure that cited resources are accessible and contain a detailed description of the methods that the citing authors used.

Scope. While these recommendations are intended for the life sciences, some recommendations may apply to other fields. The recommendations focus on capturing clear, accurate methodological detail, for example by sharing and citing reusable step-by-step protocols. This includes stand-alone protocols describing how to implement a specific procedure and protocols for reusable methods that are embedded in study design protocols. A few recommendations address study design; however, clinical study protocols, preregistrations and other study design protocols are not the main focus. PRO-MaP does not address method validation or computational protocols.

Recommendations. The preceding section lists recommendations that have policy implications for stakeholder organisations. The recommendations for researchers are below.

Stakeholder group	Key recommendations
Researchers	▸ Document, share and follow protocols within your research group ▸ Follow study design and reporting guidelines when designing and conducting your studies and reporting results ▸ Describe methods in enough detail to allow others to reproduce the experiments ▸ Ensure availability of methods and materials reported in papers and publications ▸ Support a culture that rewards and incentivises method development and protocol sharing

Related and future JRC work. The authors welcome collaborations with organisations that are working to implement these recommendations. This will provide valuable insight into how to implement the more challenging actions and provide roadmaps for others. In addition, we may explore opportunities to adapt this work to other fields.

Quick guide. Research papers from fields such as biomedicine and biology are often missing essential details about study methods. This can undermine trust, limit the use of new methods and hinder data reuse. The PRO-MaP recommendations seek to address this problem by outlining actions that four stakeholder groups – researchers, research institutions and departments, publishers and editors, and funders – can take to improve the reporting of detailed, reusable methods and step-by-step protocols. Such protocols describe how a specific procedure is performed rather than describing the design of a single research study. PRO-MaP supports the European Commission's open science and valorisation policies. These recommendations were developed through a workshop and revised after consultation with stakeholders.

1. Introduction

Well-described methods and reusable step-by-step protocols are the foundation of trust in scientific outputs. In industrial and regulatory settings, protocols are often translated into standard operating procedures (SOPs); however, in academic life sciences research, the format for documenting and sharing methods is variable and often incomplete. Inadequate reporting of methods has been documented in many types of studies, including cancer research (Errington et al., 2021), functional magnetic resonance imaging research (Carp, 2012) and clinical trials (Dechartres et al., 2017). The details in the methods section of a research article alone are often insufficient to reproduce results or reuse methods (Errington et al., 2021; LaFlamme et al., 2024), and private sharing remains the most common approach to sharing details of methods (LaFlamme et al., 2024). Inadequate reporting of methods also contributes to what is sometimes referred to as the reproducibility crisis. The 'Reproducibility project: cancer biology', for example, sought to replicate findings from 193 high-profile experiments in cancer research (Morrison, 2014). No paper contained sufficient methodological details to allow researchers to design and conduct a replication study (Errington et al., 2021). Information from the original authors was always required to design and conduct replication studies, and discussions with these authors did not always resolve unanswered questions.

Progress on open methods has lagged behind other developments in open science, including open access (publications), open data and open code. This is particularly problematic, as methods and protocols are some of the most reusable outputs that researchers create. Furthermore, we can only fully interpret and reuse data to generate trustworthy and useful results if we understand how the data were generated, including the data collection methods and limitations of the experimental design (Weissgerber et al., 2024). The lack of openly accessible detailed methods undermines trust in published data and severely limits the uptake of new methods and the use of data produced by these methods by researchers, regulatory bodies and others.

Promoting Reusable and Open Methods and Protocols (PRO-MaP) was established to increase and improve the reporting of detailed, reusable and open methods and protocols in the life sciences. We have drafted recommendations outlining actions that four stakeholder groups – researchers, research institutions and departments, publishers and editors, and funders – can take to achieve these goals. These recommendations were developed through a workshop convened in June 2022 (see **Annex 1**), by the EU Reference Laboratory for Alternatives to Animal Testing ([4]) at the European Commission's Joint Research Centre. Workshop participants included members of each stakeholder group who are working to increase the clarity and accessibility of methods reporting in life science preprints and publications. Draft recommendations (Leite et al., 2023) were refined through consultation with additional members of each stakeholder group.

PRO-MaP supports the European Commission's open science policy ([5]) by offering strategies to address its reproducibility aim. As detailed methods are essential for responsible data reuse (Weissgerber et al., 2024),

4 https://joint-research-centre.ec.europa.eu/eu-reference-laboratory-alternatives-animal-testing-eurl-ecvam_en

5 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en#Future%20of%20Open%20Science%20Under%20Horizon%20Europe

implementing PRO-MaP is also crucial for addressing the Open Data (FAIR) aim. PRO-MaP is also relevant to the future of scholarly communication aim, which focuses on sharing different types of research outputs. Furthermore, PRO-MaP supports the rewards aim by highlighting opportunities for different stakeholders to reward sharing of open detailed methods and reusable step-by-step protocols. Finally, PRO-MaP supports the EU valorisation policy ([6]), as good reporting and publishing practices are critical for technology transfer and commercialisation, making research results more valuable for regulatory use.

The PRO-MaP recommendations build on previous European Commission reports (European Commission, Directorate General for Research and Innovation, 2020, 2022), which underline the importance of transparency and sharing of research details, such as using protocols as avenues for building reproducibility and trust. In addition, the UNESCO open science recommendations clearly state that scientific outputs, including workflows and protocols related to publications and/or data, should be deposited in an open repository and available for reuse and redistribution (UNESCO, 2021).

This document briefly outlines key principles underlying the recommendations for various stakeholder groups, defines the scope of the recommendations and presents the recommendations for each group. Throughout this document, we will use the term 'protocols' to refer to reusable step-by-step instructions describing how to implement a method (**Box 1**). We are not referring to study design protocols (e.g. clinical study protocols, pre-registrations or Good Laboratory Practice (GLP) study plans).

Box 1. Important terms

Method. A description of the experimental or computational approaches, models, techniques and assays used in a scientific study. Methods are normally reported in a dedicated section in life sciences publications. The methods section provides a general overview of the methods used, which helps readers determine whether the methods used are appropriate for answering the research question and evaluate the scientific rigour of the experiment. Due to historical space limitations, methods sections often provide limited detail and refer readers to either other primary research papers or supplementary documents for further information. The information provided is usually insufficient to implement the approach in another laboratory or reproduce the study.

(Reusable step-by-step) Protocol. A sequence of operations that have to be executed to complete a scientific procedure. A well-written protocol is very detailed, with step-by-step instructions that allow others to reproduce or implement the method. Protocols often include references to equipment and equipment settings, software, reagents, chemicals and critical steps. Within good laboratory practices (GLPs), protocols are normally called standard operating procedures (SOPs) (OECD, n.d.). Even where such protocols exist, they are currently rarely incorporated into, linked to or cited in primary research articles.

Study design protocols. A description of the design of a specific study, which may include reusable step-by-step protocols for performing certain procedures. While study design and reporting guidelines are mentioned in some recommendations, study design protocols are not the main focus of Promoting Reusable and Open Methods and Protocols (PRO-MaP). However, many PRO-MaP recommendations would apply to reusable step-by-step protocols included within study design protocols. Study design protocols can be written for many types of studies. Examples include the following:

- clinical study protocols describe the design of clinical studies (e.g. study population, recruitment strategies, inclusion and exclusion criteria, patient selection procedures) and may include reusable protocols that describe how specific measurements will be performed;
- preregistered protocols describe the design of a specific study. These protocols are documented and timestamped before the study begins, allowing readers to determine whether and how the study design changed once data collection began;
- systematic review protocols describe procedures for conducting a systematic review or meta-analysis of the scientific literature;

6 https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/eu-valorisation-policy_en

- GLP study plans define the objectives and experimental design for the conduct of the study, including any amendments.

Protocol repository. An online repository where scientists can deposit detailed protocols and make these protocols publicly accessible using a DOI. Protocols uploaded to repositories are typically not peer reviewed, although some repositories partner with journals to offer peer review and publication options. Repositories offer other features to help users determine whether the protocol is being used by others (e.g. information about the number of forks and downloads, links to papers citing the protocol or a 'works for me' button). Furthermore, some protocols deposited on repositories may have been used and cited in peer-reviewed published studies and may or may not have been examined by reviewers during the publication process.

Versioning. Posting an updated version of a research team's own previously posted or published protocol. Versions are linked to the original protocol so that readers can see how the protocol has evolved over time.

Forking. Posting a modification of a protocol originally developed by another research team. Forks should link back to the original protocol to allow the protocol creators to see how others are adapting their protocol.

Core facilities. Laboratories that provide common equipment, facilities and/or services to researchers within an institution to facilitate the design and conduct of research studies. Core facilities often have extensive, well-documented protocols, and personnel may play a major role in designing and conducting experiments. However, the contributions and expertise of core laboratory personnel are sometimes overlooked when preparing research papers.

Research resource identifiers (RRIDs). Unique, persistent identifiers that specify what was used (Bandrowski and Martone, 2016). RRIDs are currently available for cell lines, antibodies, plasmids, model organisms, software and tools, and research core facilities. Scientists can look up or create new RRIDs using the RRID Portal (7).

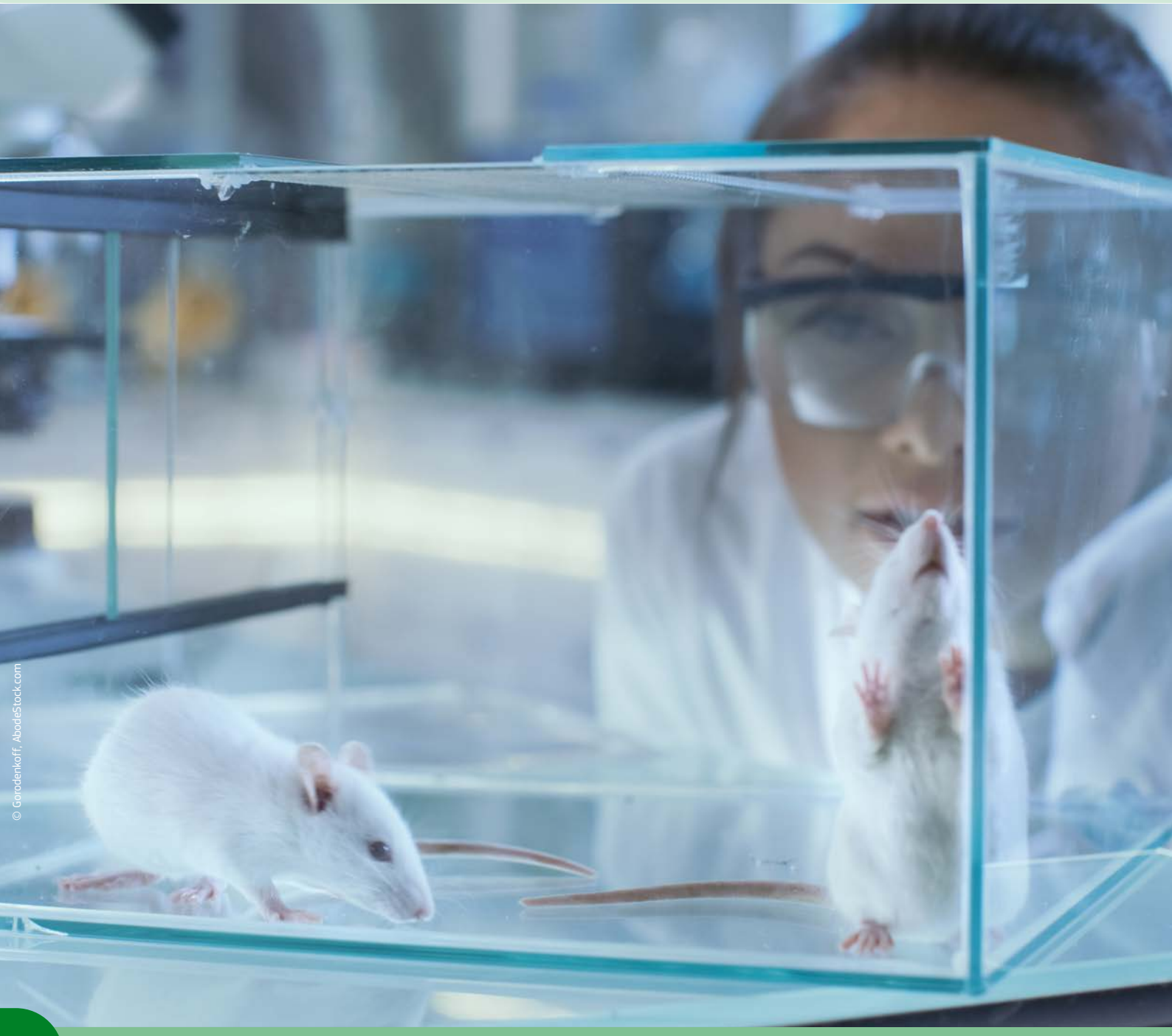
Structured methods. A methods section that is divided into informative subsections, allowing readers to clearly identify the methods used for a particular experiment. Ideally, subsections allow readers to locate the methods used to generate data presented in specific tables or figures in a preprint or published article.

Methodological shortcut citations. Citations used by authors to refer readers to another resource that is intended to explain how a method was performed. The cited resource may or may not fully describe the relevant method (Standvoss et al., 2024). Authors use shortcut citations instead of providing a detailed description of the method in the methods section of the paper.

Preprints. Manuscripts of research papers that are uploaded to public servers before formal publication and typically before peer review. Preprints may be designated 'refereed preprints' if authenticated reviewer reports have been added.

For more terms, please refer to **Annex 2**.

7 https://scicrunch.org/resources



2. Principles

Four important principles emerged from the workshop that guided the development of the recommendations for each stakeholder group.

Principle 1: cultural change. We need a cultural shift to reward and incentivise methods development and sharing of reusable open methods and protocols. Life sciences publications focus heavily on findings and conclusions, with limited space dedicated to methodology. Research findings are important, but they are not useful if the methods used to generate the data are not accessible or not sufficiently detailed to ensure reproducibility, understanding and trust. Furthermore, we cannot reuse data to generate meaningful and trustworthy results if we do not know how the data were produced. In addition to rewarding traditional publications, we need to reward open protocols, open data and open code as separate and valuable research outputs – until we do this, researchers who share protocols and other materials are doing more work for the same amount of credit. The involvement of research institutions, departments and funders is essential to facilitate this cultural shift.

Principle 2: share reusable step-by-step protocols, and cite them in publications. Reusable step-by-step protocols are much more valuable for implementing a method than free text descriptions that provide a general overview of the method, such as those typically found in the methods section of scientific papers. Research papers should include links to reusable step-by-step protocols that describe how the method was implemented (see principle 3). Reusable protocols need to have certain key characteristics. They need to be clear, transparent, written in the active voice, detailed, complete, transferable (across research groups), reliable, reproducible and permanently accessible. Protocols do not need to be novel to be shared in a protocol repository. For example, a researcher can share a description of a commonly used method, as it was performed by their team for a particular research study.

Principle 3: protocols should be citable and shared on dynamic platforms (see **Annex 3**), so that they can be versioned or forked (see **Box 1**) as the protocol evolves or is adapted by its creators or other research groups. Static methods and protocol papers reflect what one research group has done at a single point in time and, in many fields, quickly become outdated. The question is not whether protocols will change, but when and how they will evolve or be adapted by others. Using dynamic protocol-sharing platforms is the best way to address this reality. Each protocol object (with a DOI) represents the static version of a protocol used for a specific experiment; versioning and forking allow researchers to create new citable objects that more accurately reflect the methods used in their current experiments.

Principle 4: methodological shortcut citations should be used responsibly (Standvoss et al., 2024). Researchers use a methodological shortcut citation when they cite a resource that used the method instead of fully describing the method in the methods section of their paper. Shortcut citations can be very effective if, for example, the authors cite a recent methods paper or protocol that describes exactly what they did (Standvoss et al., 2024). In contrast, shortcut citations hinder reproducibility if the cited resource is inaccessible, does not mention or fully describe the cited method, or cites another resource instead of fully describing the method (Standvoss et al., 2024). **Box 2** outlines criteria for responsible use of shortcut citations.

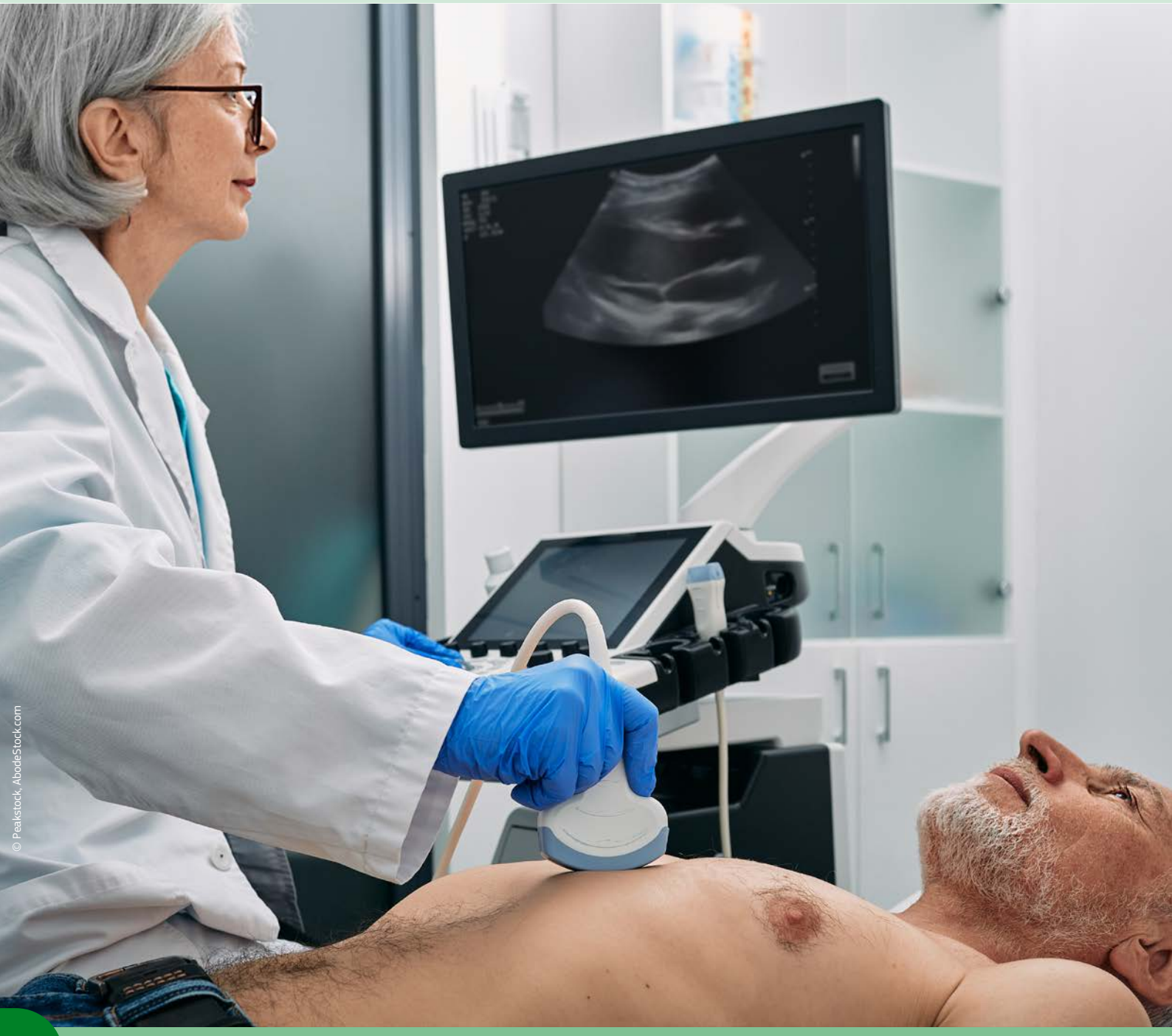
Box 2. Guidelines for responsible use of methodological shortcut citations

Authors use a shortcut citation when they cite another resource instead of fully describing the method in the methods section of their paper (Standvoss et al., 2024). Shortcut citations are different from citations used to support a claim, as they contain essential methodological details needed to critically evaluate and implement the method described. Readers need to consult the cited resource if they want to implement the method. We therefore recommend that authors follow the guidelines below when using shortcut citations.

- **Resources cited as shortcuts should meet three criteria.** They should (1) describe a method very similar or identical to the method used by the authors; (2) provide the details needed to allow others to reproduce or reuse the method; and (3) be open access (Standvoss et al., 2024).
- **Resources that do not meet the criteria listed above can be cited to give credit but not as shortcuts**. If no appropriate shortcut citation is available, authors should fully describe the method or create their own shortcut citation by depositing a reusable step-by-step protocol in an open access protocol repository that allows versioning and forking and has a long-term preservation strategy (Standvoss et al., 2024).
- **All modifications made to the cited method should be described.**
- **The details needed to locate the method in the cited resource should be provided**. Authors should reference specific subsections of the paper and specify which method or parts of the method described in the shortcut were used. When a book or manual is cited as a shortcut, the citation should include page numbers or other e-book location identifiers. When a website is linked or cited, authors should use an internet archive to ensure that the site is preserved. In some cases, it may be clearer to quote text directly from the cited source, with attribution.
- **Outdated methodological citations can be cited to give credit but not as shortcuts.** Older citations that do not reflect the methods used by the authors should not be used as shortcuts but can be cited to give credit. The age at which a citation is too old to describe current methods will depend on the method and field. One can cite a newer paper describing current methods as a shortcut citation, as well as an older citation to give credit to those who developed the methods. The sentence should clearly distinguish between the 'shortcut' citation and the 'credit' citation (e.g. 'Method X was implemented using a modified version [shortcut citation] of a method originally developed by Smith et al. [credit citation]') (Standvoss et al., 2024).
- **Missing information should be shared.** When using methods published by others, scientists often gain additional information through conversations with methods' creators or through lessons learned during implementation. Share these details when citing the original resource as a shortcut. Provide the missing details in the methods section of the paper after the shortcut citation, or deposit a reusable step-by-step protocol, with the additional details, in an open access repository. When depositing a protocol, credit the original source.

3. Scope

While our recommendations are intended for methods and protocols in the life sciences, some recommendations may also apply to other fields. Our recommendations' primary focus is on capturing clear, accurate methodological detail, for example with reusable step-by-step protocols. This includes stand-alone protocols for reusable methods and protocols for reusable methods that may be embedded in study design protocols. While a few recommendations address reporting guidelines and study design, study design protocols (e.g. clinical study protocols, preregistrations or GLP study plans) are not the main focus of PRO-MaP. Study design protocols include many details that are essential to understanding and critically evaluating the study but are less likely to be reused (e.g. because the study population and inclusion and exclusion criteria are unique to the study). PRO-MaP also does not address method validation or computational protocols. While some PRO-MaP recommendations may apply to computational protocols, these protocols have some unique features that are not discussed here. Furthermore, computational protocols are often shared on different types of repositories (e.g. GitHub).



4. Recommendations

The following sections recommend actions that each of the four stakeholder groups can take to improve the reporting of methods and reusable step-by-step protocols in scientific preprints and publications. We do not expect any individual, research group or organisation to have the time or resources to immediately implement every recommendation, and not all recommendations will be applicable to every stakeholder. We hope that stakeholders might start by implementing a few important and feasible recommendations while developing medium- and long-term plans to implement the more challenging recommendations.

4.1. Researchers

Researchers have a critical role to play in efforts to improve reporting of methods and protocols, as they create methods and protocols, use methods and protocols to generate data, and share their research with others. The recommendations in **Table 1** highlight actions that researchers can take to improve the reporting of methods and protocols within their own research groups while supporting institutions and other stakeholder organisations in creating a culture and rewards that incentivise sharing of detailed open methods and protocols. Actions by research institutions and departments, publishers and editors, and funders are particularly important when it comes to changing research culture so that researchers are incentivised to implement good research practices and are funded to and rewarded for doing so.

Table 1. Recommendations for researchers

Recommendation	Actions
R1. Document, share and follow protocols within your research group	R1.1. **Write down or obtain the detailed protocol(s) that captures the experimental procedure as it is performed** by all research team members in the laboratory or core facility.
	R1.2. **Write well-structured, clearly formulated methods sections** that are easy for readers from different research backgrounds to understand. Use subheadings to make it easy for readers to find details related to specific studies or methods. **Box 3** provides additional information on the essential elements of a reusable step-by-step protocol.
	R1.3. **Search protocol repositories** (see **Annex 3**) **and journals for existing protocols** when implementing new research procedures within your team. Cite protocols that your team uses and report any modifications when sharing your work.
	R1.4. **Ensure that team members follow protocols, update them** before or after running experiments and **document changes between versions**. Regular discussion of protocols and modifications to procedures will increase accountability and participation.
R2. Follow relevant study design and reporting guidelines when designing and conducting your studies and reporting your results.	R2.1. **Identify and use study design and reporting guidelines relevant to your field or study type when designing and reporting your study** (see **Annex 4**). Use study design guidelines when designing a study, and reporting guidelines to determine what should be reported in publications. When possible, consult reporting guidelines in the design phase to ensure that you are collecting all necessary information. Some guidelines address both study design and reporting.
	R2.2. **Complete the checklist for the reporting guideline that you used when writing your study report or publication** to ensure that you have addressed all required elements.

Recommendation	Actions
R3. Describe methods in enough detail when publishing or sharing for other purposes to allow others to reproduce the experiments. Details may be presented in the methods section or through responsible use of shortcut citations (see **Box 2**).	R3.1. **Describe exactly what you or the collaborating core facility did**, even if there is overlap with previously published methods. If a shortcut citation is used to replace a detailed description, follow the criteria for responsible use of shortcut citations (see **Box 2**).
	R3.2. **Share protocols in a format that can be cited and updated. Use an open access repository that allows protocol versioning and forking, provides DOIs for citation purposes and has a long-term preservation strategy that ensures that protocols remain accessible if the repository ceases to exist** (**Annex 3**). Open access ensures that your protocols are available to everyone. Versioning and forking allow your research group and the scientific community to track the evolution of protocols within and across research groups, while a DOI ensures that your protocol has a unique persistent identifier that can be cited.
	R3.3. **Avoid uploading the same protocol to different repositories.** This wastes time and creates confusion about whether the protocols are different and which protocol to use or cite.
	R3.4. **When sharing, presenting or describing data (e.g. figures, tables, supplemental data, datasets deposited on repositories), clearly state the name of the method and the version used to generate the data.** This will help readers quickly find the methods that were used to generate specific data.
	R3.5. **Specify what materials were used.** Include details of the materials, model organisms and equipment used following the Materials Design Analysis Reporting (MDAR) framework for transparent reporting in the life sciences (Macleod et al., 2021). The information provided should allow readers to identify the specific material/reagent unambiguously (see **recommendation R3.6**). Provide information that is known to contribute to variability (e.g. lot numbers, software versions).
	R3.6. **Report research resource identifiers (RRIDs) to unambiguously identify cell lines, antibodies, model organisms, plasmids and software and tools.** These unique persistent identifiers allow others to determine exactly what was used, even if the catalogue number changes, the product is discontinued or the product is transferred to another supplier. Researchers can look up or create new RRIDs using the RRID Portal (https://scicrunch.org/resources).
	R3.7. **Include completed checklists from reporting guidelines** (see **recommendation R2.2**) in the supplemental files of your publication.
	R3.8. **Provide the raw data in a public repository.** Data repositories should cite protocols or other published methods used to generate the data.

Recommendation	Actions
R4. Ensure the availability of methods and materials reported in papers and publications	R4.1. **Include a methods availability statement:** this statement should specify whether detailed protocols are openly available and include links to and citations of protocols published in repositories. It is not acceptable to state that 'methods are available upon request'. If you are unable to make your methods available, explain why your methods cannot be shared.
	R4.2. **Include a materials availability statement**, as mandated by the MDAR guidelines (Macleod et al., 2021). This statement should provide details on the availability of newly created materials and the procedures to follow to access those materials if they are not openly available in a materials repository.
R5. Support a culture that rewards and incentivises methods development and protocol sharing (refer to **Section 4.2.** for recommendations for research institutions and departments)	R5.1. **Promote the use of online public repositories and help fellow researchers use them.**
	R5.2. **Use online public repositories to publish detailed protocols and cite them appropriately in your theses / dissertation and papers.**
	R5.3. **Add a "Methods and protocols" section to your CV.** List methods papers, protocol papers and protocols deposited in public repositories. Encourage members of your research group to do the same.

Box 3. Good protocol reporting

Reusable step-by-step protocols should include the following information.

Abstract

- Clearly specify what the protocol produces

List of required items

- Clearly specify the materials needed to perform the method
- Subdivide the list into sections according to item type (e.g. reagents, solutions, materials, equipment, biological samples or organisms, etc.)
- Use research resource identifiers to identify cell lines, antibodies, plasmids, model organisms, software and tools, and core facilities
- Specify vendor information and other key identifiers (e.g. software version numbers, lot numbers for polyclonal antibodies, CAS numbers (when available) for chemicals) when relevant
- Provide details of solutions (recipe, ingredients, concentrations)
- Provide details on biological materials (e.g., species origin, concentration/density/dilution, stability of material, such as acceptable number of passages for cells)
- Provide details on the type of equipment needed and its requirements (e.g., plate reader with specific filters)

Chronological step-by-step instructions

- Provide single-step instructions (one instruction per line)
- Use the active voice

- Provide detailed instructions to enable someone else to implement the protocol (e.g. include times, volumes, temperatures, centrifugation speeds in 'g' instead of 'rpm'); when specifying a range of values, state what factors influence which values one should select
- Identify critical steps and expected outcomes for these steps
- Specify the time needed to carry out each step of the protocol
- Replace general information (e.g., "Procedure performed according to kit instructions") with specific detailed steps
- Give instructions on which raw data to record and how to process and interpret the data

Troubleshooting

- Provide troubleshooting tips
- Specify common errors to avoid or practices that do not work

Expertise

- Describe the expertise or training needed to implement the protocol

Safety information

- Include safety warnings (e.g., laboratory biosafety level requirements)

Protocol limitations and assumptions

- Describe limitations of or assumptions underlying the protocol (e.g. protocol does not work for a particular sample type)

References

- Cite references if relevant (e.g. references describing materials, compounds or organisms, studies that used the protocol)

Elements that improve readability

- Explain abbreviations and definitions
- Include photos or videos that illustrate complex steps
- Consider offering a graphical overview

This list was compiled by the authors based on their expertise. We also encourage researchers to consult the SMART protocols ontology ([8]) (Giraldo et al., 2018), which contains a list of 17 items that are essential to execute a protocol.

8 https://smartprotocols.github.io/checklist1.0/

4.1.1. Context for key recommendations

The following sections provide a brief context for the recommendations in **Table 1**.

4.1.1.1. Recommendations R1 to R4

These recommendations highlight actions that researchers can take to improve methodological reporting and normalise sharing of detailed methods and step-by-step protocols within their own research groups. Although implementing these recommendations takes time and resources, these actions may help researchers improve their science by capturing undocumented methodological knowledge and ensuring that all team members are following the same best practices and procedures.

There are several advantages to sharing well-documented protocols. Good protocols may increase efficiency when training new team members. Protocols that are shared on protocol repositories remain accessible even if the research team has not used the method recently, the person responsible for the protocol has left the research group or you move to another research group or institution. Furthermore, examining forks and citations allows researchers to see how others are building upon their work and can be useful in establishing collaborations. Finally, depositing protocols makes it easier for others to find a research team's work. This is particularly valuable for those who would be interested in a team's methods but would not normally read the team's papers because they work in a different field or on a different research topic.

Annex 5 lists training resources that may support researchers in implementing these recommendations.

4.1.1.2. Recommendation R5

In addition to implementing best practices in their own work, researchers play a vital role in establishing and maintaining research culture within their institutions, fields and scientific societies. Recommendation R5 outlines actions that researchers can take to support their colleagues in creating a culture that rewards and incentivises reporting of detailed methods and sharing of reusable step-by-step protocols. We also encourage researchers to leverage their many roles (e.g. as instructors and mentors; members of thesis evaluation, hiring and tenure committees; peer reviewers; and members of scientific societies) to encourage research institutions and departments to implement recommendations that may lead to systemic change, as described in **Section 4.2**.

4.2. Research institutions and departments

Participation of research institutions and departments is essential to create a culture that rewards and incentivises sharing of detailed open methods and protocols. Institutions and, in some countries, departments, set criteria for hiring, assessing and promoting researchers at every career stage. They also establish degree requirements and provide training and career development programmes. Institutional and departmental leadership are responsible for rewarding and incentivising trustworthy science that is useful to scientists and society, as their actions influence the priorities and culture of their research community. **Table 2** recommends actions that research institutions and departments may take to create or further develop a culture that values clear, reusable and open methods and protocols. Actions that are most appropriate for institutions and for departments may vary depending on the country, field and institutional structure. Actions taken by institutions and departments can have greater impact when combined with actions by other stakeholders. Many institutions also provide research funding; hence, those involved in institutional funding programmes should also work to implement the recommendations for funders (see **Section 4**) that apply to their programmes. Some actions listed in **Table 2** can be implemented using top-down or bottom-up approaches, whereas others need to be implemented by institutional, departmental or programme leadership. Actions that require support from leadership are marked in **Table 2** by an asterisk.

Table 2. Recommendations for research institutions and departments

Recommendation	Actions
ID1. Create an environment that recognizes the value of sharing open and reproducible methods	ID1.1. **Implement and disseminate the recommendations for researchers** (see **Table 1**) among researchers in your institution and **incentivise** them to use the recommendations (*).
	ID1.2. **Encourage all research team members to share detailed methods and protocols**. This includes researchers, laboratory technicians, students and personnel working in core facilities. Sharing of methods within the research team, from the beginning of methods development, facilitates sharing of expertise**.** Public sharing may also foster collaborations with experts outside the research team.
	ID1.3. **Encourage researchers to deposit protocols** in open protocol repositories **and cite protocols** describing their methods in publications.
ID2. Reward and incentivize sharing of detailed methods and reusable step-by-step protocols	ID2.1. **Consider protocol and methods sharing in hiring, promotion and tenure evaluations** (*)**.** This may include adding a 'Methods and protocols' section to scientists CVs or other reporting forms.
	ID2.2. **Offer prizes or awards** for research groups, core facilities or individuals that share reusable step-by-step protocols (*).
	ID2.3. **Identify the best reward system to motivate institutional researchers to deposit and publish protocols** (*)**.** Monitor and publicly share the effects of these programmes to allow others to learn from your experience.
ID3. Require and offer training on writing and openly sharing detailed methods and reusable step-by-step protocols	ID3.1. **Include modules on good protocol writing and reporting in undergraduate, graduate and continuing education programmes.** Tailor content to different career stages or professional roles (e.g. researcher or technician). Examples include presenting a lecture or holding a hands-on workshop on how to write a reproducible protocol for first-year graduate students or providing senior graduate students with opportunities to enhance protocol development skills and gain feedback via protocol peer review exercises. Invest in training students and trainers. **Annex 5** lists some available training resources.
	ID3.2. **Promote hands-on training,** where participants write or update and deposit protocols used in their own research.
	ID3.3. **Where possible, dedicate a budget line item to training and/or access to tools or platforms** that facilitate sharing of open and reusable step-by-step protocols (*).

Recommendation	Actions
ID4. Integrate sharing of detailed methods and reusable step-by-step protocols into thesis requirements	ID4.1. **Require or incentivize graduate students to use and deposit protocols when conducting thesis research** (*).
	ID4.2. **Recognize methods and protocol publications as chapters that can be included in theses** (*)**.**
	ID4.3. **Encourage local or national funders to require, incentivize and reward** methods papers, protocol papers and depositing of protocols on open access repositories (see **Annex 3**) in **training grants.**
ID5. Monitor practices and obtain feedback on programmes	ID5.1. **Select and prioritize a few recommendations for researchers** that institutional leadership would like researchers to implement (*). Involve research groups and core facilities in this process.
	ID5.2. **Reward researchers for implementing these practices** (see **recommendation ID2**, (*)).
	ID5.3. **Offer education and training related to these priorities** (see **recommendation ID3**).
	ID5.4. **Monitor the uptake of practices related to these selected recommendations** (e.g., protocol sharing). Use dashboards to share this data with researchers and institutional personnel.
	ID5.5. **Obtain feedback on barriers to implementation and the effectiveness of programs and educational activities.** Use this feedback to remove barriers and refine programmes.

(*) Actions that may require support from institutional, departmental or educational programme leadership.

4.3. Publishers and editors

Scientific journals should strive to publish papers that are fully reproducible and this requires a sufficiently detailed description of methods, protocols and materials. **Table 3** recommends actions that publishers and editors can take to improve access to and the reusability and reproducibility of methods in scientific publications. Following the table, we provide a brief context for a few crucial recommendations. Encouraging scientists to share detailed methods and reusable step-by-step protocols in papers and on repositories will require a shift in culture and practice, and publishers and editors should play a fundamental role in facilitating this shift.

Table 3. Recommendations for publishers and editors

Recommendation	Actions
P1. Ensure that methods are described **in enough detail to enable others to reproduce the experiment.** Details may be presented in the methods section or through responsible use of shortcut citations (see **recommendation P3**).	P1.1. **Eliminate word limits for methods sections**
	P1.2. **Encourage authors to describe exactly what they did**, even if there is overlap with previously published methods. If a shortcut citation is used to replace a detailed description, the authors should follow criteria for responsible use of shortcut citations (Standvoss et al., 2024) (see **recommendation P3** and **Box 2**).
	P1.3. **Allow authors to re-use text describing detailed methods, with attribution. Raise awareness about policies permitting this among authors.** Clearly specify that it is acceptable to copy or quote exact methods from a previous work, with attribution. Plagiarism screening may still be performed on methods sections to ensure that duplications are attributed to the source paper or identify plagiarism of methods written by a separate team of authors. Plagiarism screening software should allow users to evaluate screening results from methods sections separately.
	P1.4. **Develop and adopt structured methods reporting to ensure that key elements of methods are addressed**. Structured methods should follow a standard format that is transferable across journals, and should be developed through consultation with the scientific community.
	P1.5. **Require authors to specify materials.** Authors should include details of the materials, model organisms and equipment used. The information provided should allow readers to identify the material and include details that are known to contribute to variability (e.g. lot numbers, software versions). Require authors to report unique persistent identifiers, such as research resource identifiers (RRIDs) (https://scicrunch.org/resources), when they are available.
P2. Encourage authors to strengthen static methods sections by linking to reusable step-by-step protocols uploaded to dynamic platforms	P2.1. **Encourage authors to upload protocols to open access protocol repositories that allow versioning and forking, provide DOIs, and have a long-term preservation strategy** (**Annex 3**). Repositories that do not currently allow versioning and forking should be encouraged to add these capabilities. Specifically state that authors are permitted to deposit protocols, even if they partially duplicate information contained in the methods section of the original research article.
	P2.2. **Do not ask authors to upload the same protocol to different repositories** (e.g. if authors have already shared their protocol on a repository of their choice, do not ask them to upload it to a repository affiliated with the publisher).
	P2.3. **Ask authors to avoid publishing detailed methods information in supplemental files or on lab or project websites.** Encourage authors to deposit methods in an open access repository that has a robust long-term preservation strategy instead.

Recommendation	Actions
P3. Promote responsible use of methodological shortcut citations	P3.1. **Ask authors to use shortcut citations responsibly**, by adhering to the practices outlined in **Box 2**.
	P3.2. **Ensure that publication pipelines and bibliography formats allow authors to provide the information needed to locate the cited method** within the cited resource. This may include page numbers in books, other location identifiers for e-books or the name and location of details about the method in the specified publications.
	P3.3. **Raise awareness about responsible use of shortcut citations among editors and authors.** This may include organizing webinars and workshops. **Annex 5** lists training resources.
P4. Move methods sections in front of the paywall	P4.1. **Ensure that all readers can access the methods section, free of charge and without a subscription.**
P5. Require methods and materials availability statements	P5.1. **Require machine-readable methods availability statements in front of any paywall.** These statements should specify where detailed protocols are openly available and include links to and citations of protocols published in repositories.
	P5.2. **Do not allow the statement 'Methods are available upon reasonable request'.**
	P5.3. **Require a materials availability statement** as mandated by the MDAR guidelines (Macleod et al., 2021). This statement should provide details on the availability of newly created materials and the procedure to follow to access those materials if they are not openly available in a materials repository.
P6. Ensure that methods sections are clearly formatted, user friendly, and make it easy to connect data to specific methods used to generate the data	P6.1. **Encourage authors to write well-structured, clearly formulated methods sections** that are easy for readers from different research backgrounds to understand.
	P6.2. **When data are shared, presented or described (e.g. figures, tables, supplemental data, datasets deposited on repositories), ask authors to clearly state the name of the method used to generate the data.** This will help readers quickly identify the methods that were used to generate specific data. Data repositories should cite protocols or other published methods used to generate the data.
P7. Issue corrections to fix mistakes in methods or protocols	P7.1. **Publish correction notices to correct mistakes in the methods section of papers, using standard procedures**
	P7.2. **Expand the normal corrections process to address mistakes in protocols that are linked in a paper.** Authors may correct the protocol and notify the journal.

Recommendation	Actions
P8. Enforce policies on the availability of materials	P8.1. **Support readers who have difficulty accessing materials from prior publications at a reasonable cost.** Clearly state that readers can contact the publisher for help if they are having difficulty obtaining materials that should be accessible. Outline the procedure for requesting support if readers believe that publisher policies are being violated. When necessary, follow up with authors.
P9. Develop implementation plans to facilitate uptake of new practices	P9.1. **Integrate new policies into the manuscript submission and assessment process.** This may include implementing checks for crucial details. Some journals implement checks for new practices when requesting a revision to increase author motivation and avoid unnecessary burdens during the initial submission phase. P9.2. **Raise awareness of new policies, along with relevant training materials and tools, among editors, reviewers and authors.** Existing research shows that journal policy changes and editorials have little or no impact on reporting quality, particularly if there is no editorial oversight (e.g. Bandrowski et al., 2015; Diong et al., 2018; Giofrè et al., 2017; Hair et al., 2019; The NPQIP Collaborative group, 2019). Publishers need to engage with journal communities to emphasise the benefits to authors of implementing new practices and make implementation easy. P9.3. **Monitor for intended and unintended consequences, share experiences and adapt as needed.** This is essential to determine whether policy changes and interventions are having the desired effect. Examples of unintended consequences may include an increase in the number of authors copying methods sections from previous papers without describing modifications, or uncertainty about whether peer reviewers are examining protocols that are cited and linked in papers. Sharing experiences and solutions among publishers will accelerate progress.
P10. Update guides for authors to promote high quality reporting of methods	P10.1. **Update the guide for authors to address the changes described above.** Many authors do not review guidelines in detail; therefore, publishers may want to consider sharing information in more engaging formats (e.g. video tutorials). P10.2. **Recommend that authors take the following four actions to improve the quality of methodological reporting:** 1. Follow relevant reporting guidelines established by the scientific community (see **Annex 4** for examples). 2. Use RRIDs for cell lines, antibodies, plasmids, model organisms and software and tools, to specify what was used. 3. Use shortcut citations responsibly. 4. Share protocols in open access repositories that allow versioning and forking. Cite these protocols in the methods section.
P11. Update guides for reviewers to address methods reporting	P11.1. **Update guides for reviewers** to address the changes described above.

4.3.1. Context for key recommendations

The following sections provide a brief context for some of the recommendations in **Table 3**.

4.3.1.1. Recommendation P1

The proposed actions would allow authors to fully describe methods instead of reducing the number of words in the methods section to leave more words available for the results and discussion sections. Furthermore, authors could reuse optimised descriptions of methods in future papers, as long as the method has not changed. Without these actions, scientists may cite another paper that used the methods without fully describing them, eliminate details or modify the description in other ways to avoid plagiarism detection at the expense of clarity. Allowing authors to repeat descriptions of methods in previous papers may be very valuable if these descriptions provide details needed for implementation. Such policies may have unintended consequences, however, if authors repeat insufficiently detailed descriptions of methods or copy methods without reporting modifications.

4.3.1.2. Recommendation P2

Methods sections of papers and reusable step-by-step protocols fulfil different functions. The methods section of a paper provides a general overview of the methods used, which helps readers determine whether they are appropriate for answering the research question and evaluate the scientific rigour of the experiment. Step-by-step protocols are more useful to a reader who wants to implement the method described.

While current approaches to publishing methods and protocols are generally static, methods and protocols are dynamic. The question is not whether a given protocol will change but when and how it will change or be adapted by others. While a publication may link to a static protocol describing what was done for a specific experiment, readers often want to know how that protocol has evolved since the paper was published or share their own adaptations of that protocol.

Depositing methods in open access protocol repositories allows authors to provide the details needed to implement the method while sharing living protocols that can be versioned and forked (see **Box 1**). Versioning and forking allow scientists to track protocol reuse while examining the evolution of protocols within and across research groups. Even if a research group never updates (versions) its protocol, sharing the protocol in a repository makes it easy for others to share forks that link back to the original protocol. Depositing methods in open dynamic repositories, rather than hiding them in static supplemental files, also makes it easier for others to find and reuse methods.

While protocol journals also publish protocols, these publications are static documents that reflect what a single research group is doing at one point in time. In many fields, static protocols quickly become outdated. Protocol journals and methods journals can support the scientific community's need for living protocols by linking to protocols deposited in repositories, which can be versioned and forked as the protocol evolves.

4.3.1.3. Recommendation P3

When used responsibly, shortcut citations are a powerful tool (Standvoss et al., 2024). Authors can share detailed protocols with readers who want this information without making the methods section long and hard to read for readers who only want a general overview. Unfortunately, shortcut citations can also cause problems (Standvoss et al., 2024). Readers may be unable to identify or access the cited resource; the cited resource may not include the method mentioned by the citing authors; or the description of the method may be inadequate (Standvoss et al., 2024). In some cases, the cited resource also uses a shortcut citation instead of describing the method (Standvoss et al., 2024). This frustrates readers, wastes time and increases the likelihood of the problems mentioned above. We encourage publishers and editors to adopt criteria for responsible use of methodological shortcut citations (see **Box 2**) (Standvoss et al., 2024), and raise awareness of these criteria among authors.

4.3.1.4. Recommendation P4

For journals that are not fully open access, putting methods sections for all papers in front of any paywall, as is currently done for references, would allow everyone to view methods of papers that are cited as shortcuts. Journals that are transitioning to open access should still put methods sections in front of the paywall for methods papers, protocol papers and papers published during a period of approximately 5 years before the open access transition, as these papers may be cited as shortcuts.

4.3.1.5. Recommendation P5

Many journals require data availability statements, and we recommend extending this practice to include a methods availability statement. The statement 'Methods are available upon reasonable request' should not be permitted, as many studies on data availability statements have shown that authors who use the statement 'Data available upon request' rarely provide data when contacted (e.g. Gabelica et al., 2022).

4.3.1.6. Recommendation P9

Many publishers already have policies related to some of the recommendations above, and other publishers may update their policies in accordance with these recommendations. Policy changes should be accompanied by implementation plans, as research suggests that changing journal policy has limited effects on author behaviour. Updating journal policy to require RRIDs, for example, increases the number of papers reporting RRIDs by 1 % (Bandrowski et al., 2015). A study of animal studies published in Nature journals, however, revealed that the percentage of papers reporting the Landis 4 criteria (blinding, randomisation, sample size calculation, exclusions) increased from 0 % to 16.4 % after new guidelines were released (The NPQIP Collaborative group, 2019). It is important to note that this intervention used a four-item checklist, editorial checks were performed and authors were provided with editor feedback (The NPQIP Collaborative group, 2019). In contrast, a randomised controlled trial showed that requiring authors to complete the 20-item ARRIVE checklist when submitting an animal study to PLOS ONE did not improve reporting (Hair et al., 2019). The completed checklist was not assessed by editors (Hair et al., 2019). Some improvements in reporting of inclusion and exclusion criteria, sample size justification and confidence intervals were observed after Psychological Science introduced new policies (Giofrè et al., 2017), although widespread changes in the field may have been a contributing factor. An editorial series published in the British Journal of Pharmacology and the Journal of Physiology did not improve data presentation or statistical reporting (Diong et al., 2018). Editors and authors may be unaware of journal policies or underestimate what the policies require (Christian et al., 2020). Recommendations for developing data availability policies, which may also be useful for implementing the policies recommended above, include engaging the stakeholder community in policy development and implementation, expressing policy requirements using clear and consistent language, aligning policy requirements with standards and best practices, and collaborating with repository experts on policy implementation and support (Christian et al., 2020).

4.4. Funders

Reproducibility is a priority for research funding organisations, which are uniquely placed to incentivise researchers to adopt good protocol reporting practices. Research that cannot be reproduced represents a waste of not only time, materials and (in in vivo studies) animal lives but also the financial investment that research funders have made. Reproducibility starts with methods and protocols – scientists cannot evaluate, reproduce or build upon the work of others if they do not know what was done.

Table 4 outlines recommendations specifically for funders. These recommendations are not designed to be prescriptive; they are examples of how research funders can support more open and transparent reporting of protocols. There are many different types of funding agencies and no recommendation will be feasible or appropriate for all funders. We encourage funders to implement the recommendations that are most appropriate for their organisation.

Table 4. Recommendations for funders

Recommendation	Actions
F1. Embed open protocol reporting in research funding to support protocol review and reuse	F1.1. Require that researchers publish (or make available by other means) **open access, reusable step-by-step protocols associated with any scientific publication supported by awarded funding**. Ask researchers to specify procedures for making protocols available in data management plans. Ideally, protocols should be deposited in open access repositories that allow versioning and forking, and have a long-term preservation plan (see **Annex 3**).
	F1.2. Clearly indicate that **researchers are expected to include funds to support method and protocol sharing and necessary method development work in their budgets when applying for grants.**
	F1.3. Require **scientific review committees** to evaluate the provisions for reproducibility of proposed projects, in the same way that ethics committees evaluate ethical aspects. Assess protocol reporting practices as a point of evaluation, either during grant funding or when funding is completed.
	F1.4. Mandate that a **reproducibility assessment** is included in reporting requirements for funded projects. This assessment should address methods reporting and protocol sharing. Funders that review work at the end of the application should ask reviewers to evaluate the reusability of protocols.
	F1.5. **Recognise applicants with a demonstrable record of transparent reporting** of methods and reusable step-by-step protocols. Developing automated screening tools to check publications may facilitate implementation (see action **F4.1**, below).
F2. Reward and incentivize sharing of detailed methods and reusable, step-by-step protocols	F2.1. **Fund rewards and incentives for sharing detailed methods and reusable, step-by-step protocols.** Offer awards and prizes.
	F2.2. **Recognise methods and protocols as a scientific output**, valued on par with publications, by creating a specific section for them on CVs.
	F2.3. **Fund training on how to write reusable step-by-step protocols**
F3. Integrate sharing of detailed methods and reusable step-by-step protocols into training and assessment criteria for graduate students	F3.1. **When funding graduate students or programs:** • **require training** on reproducibility, including open and reproducible methods and protocols. • **require reproducibility and transparency actions in Masters and PhD degree expectations**; this may include depositing reusable step-by-step protocols for thesis research in public repositories.

Recommendation	Actions
F4. Use evaluation indicators to track progress in reporting detailed methods and reusable step-by-step protocols	F4.1. **Fund the creation of search engines to find methods and protocols, or support activities to add this feature to existing search engines.** Researchers cannot reuse methods and protocols if they can't find them.
	F4.2. **Support the development of automated tools to track methods reporting practices**, such as depositing protocols, citing methods papers and using methodological shortcut citations (**Box 2**), in preprints and papers
	F4.3. **Require the creation of public dashboards illustrating methods and protocol sharing practices**. For example, a dashboard might illustrate changes over time in the proportion of papers funded by the funder that cite a protocol deposited in a public repository, and show the number of citations of protocols resulting from funded research. Funders could also support other stakeholders in monitoring progress by funding the creation of similar dashboards assessing protocol deposition or other methodological reporting practices for papers written by authors at a particular institution, or published in specific journals.
	F4.4. **Adopt research assessment criteria that focus on good research practice, including the quality of the experimental design and methods**, and not only on research results.
	F4.5. **Evaluate the outcomes and impact of newly implemented approaches** designed to reward and incentivize reporting of detailed methods and sharing of reusable step-by-step protocols. Openly share the results of these evaluations.
	F4.6. **Create a research transparency metric that includes sharing of reusable step-by-step protocols.**

4.4.1. Context for key recommendations

The following sections provide a brief context for some of the recommendations in **Table 4**.

4.4.1.1. Recommendations F1 and F2

Two recent European Commission reports (European Commission, Directorate General for Research and Innovation, 2020, 2022) addressed the reproducibility of EU-funded projects. The second of these, Assessing the reproducibility of research results in EU framework programmes for research, recommends that research funders:

Continue the establishment of reward and recognition structures that incentivise good reproducibility behaviours that focus less on outputs (e.g. publications), are more focused on processes (e.g. methodological rigour, data-sharing) and provide professional incentives for formally reproducing the work of others and demonstrating reproducibility related practices (European Commission, Directorate General for Research and Innovation, 2022).

Despite this, the report acknowledges that the number of funding organisations investing directly in increasing reproducibility remains relatively low. One exception is Aligning Science Across Parkinson's (Lloyd, n.d.). Requirement 3 of its open access policy states that

'all research outputs (data, protocols, code) must be deposited in publicly accessible repositories and cited in the publication' (Lloyd, n.d.). Another example is NC3Rs, which offers an open access publication platform where grant holders can publish research outputs, including methods and step-by-step protocols (https://f1000research.com/nc3rs).

By mandating good protocol reporting practices and supporting tools that facilitate these practices, funders can ensure that their investments in research result in science that can be reproduced, relied upon and used to inform future research, policy and patient care. This improves return on investment by increasing the reliability and impact of science.

4.4.1.2. Recommendation F3

Investing in education offers a career development opportunity for early-career researchers and others. Early-career researchers are both creators and users of methods and protocols, as they typically play a prominent role in collecting research data. While early-career researchers are future leaders and change-makers in scientific research (Kent et al., 2022), many will require the support of supervisors and more senior collaborators to implement detailed reporting of methods and protocols. Funding agencies can facilitate a cultural change by incentivising and rewarding scientists for sharing detailed methods and reusable step-by-step protocols (**recommendation F2**).

4.4.1.3. Recommendation F4

Actions outlined in recommendation F4 will help funding agencies evaluate current practices and monitor the impact of policy changes and new strategies to improve reporting of methods and protocols.

5. Conclusions

PRO-MaP outlines specific actions that researchers, research institutions and departments, publishers and editors, and funders can take to increase and improve the reporting of detailed methods and reusable step-by-step protocols in the life sciences. Policy changes, accompanied by implementation and monitoring plans, will be particularly important when implementing the recommendations for research institutions and departments, publishers and editors, and funders. Actions by these organisations are crucial to create an environment that incentivises scientists to implement the practices outlined in the recommendations for researchers and rewards them for doing so.

PRO-MaP supports the European Commission's open science policy ([9]) and is particularly relevant to the reproducibility, Open Data (FAIR), rewards and future of scholarly communication aims. PRO-MaP is also relevant to the EU valorisation policy ([10]), as good reporting and publishing practices are critical for technology transfer, commercialisation and enhancing the value of research results for regulatory use.

5.1. Call to action

The PRO-MaP authors welcome contributions from and collaborations with stakeholders working to implement these recommendations. Implementation will require a community effort, where activities are coordinated and harmonised across stakeholder groups. Actions should focus on the following.

1. **Explaining why.** Raise awareness of the importance of openly sharing detailed methods and reusable step-by-step protocols.
2. **Explaining how.** Raise awareness of how to prepare and openly share detailed methods and reusable step-by-step protocols.
3. **Developing infrastructure.** Develop better tools for sharing, publishing and discovering protocols.
4. **Offering rewards and incentives.** Reward and incentivise reporting of detailed open methods and reusable step-by-step protocols.

9 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en#Future%20of%20Open%20Science%20Under%20Horizon%20Europe.

10 https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/eu-valorisation-policy_en

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List of abbreviations and definitions

Abbreviations	Definitions
CV	curriculum vitae
DOI	digital object identifier
GLP	good laboratory practice
MDAR	materials design analysis reporting
PRO-MaP	promoting reusable and open methods and protocols
RRID	research resource identifier
SOP	standard operating procedures

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Annexes

Annex 1. Process for developing the PRO-MaP recommendations

Rationale for the workshop. The Directorate-General Joint Research Central at the European Commission believed that more could be done to establish policies and standards for describing methods and protocols in the life sciences. While the number of scientific publications has been increasing exponentially over the years, sharing of methods and protocols has lagged behind other scholarly communication reforms, such as open access, open data and open code. The workshop aimed to identify solutions to address this problem.

Goals. The workshop focused on strategies to increase and improve the reporting of detailed, reusable and open methods and protocols in the life sciences.

Organizers. The workshop was initiated by the EU Reference Laboratory for alternatives to animal testing ([11]) at the European Commission Joint Research Centre. The EU reference laboratory works on the promotion and use of (non-animal) methods for regulatory and biomedical research purposes. When working with methods, especially in regulatory assessment, such as chemical and drug risk safety, detailed standard operating procedures (SOPs) are essential. This helps facilitate transferability and uptake of methods across laboratories and aids evaluators' understanding. Detailed, open and reproducible methods build trust in the methods and the resulting data.

Participants. Participants were selected by invitation based on their affiliation, the stakeholder group they represented and their involvement in activities to increase the clarity and accessibility of methods reporting. Most participants continued working on these recommendations after the workshop and are listed as authors. .

Workshop structure and process. The meeting began with a session that built a shared understanding of the issue of reproducibility of methods and protocols among the 20 participants. Discussions then took place on the following topics.

- What is the current situation regarding methods and protocols reporting in peer-reviewed publications: what are their strengths and weaknesses?
- Who are the relevant stakeholders who shape or influence how methods and protocols are currently shared and could steer improvement?
- How can we motivate each of these stakeholders to make a difference? (This discussion included both abstract ideas and concrete actions.)

After the workshop, participants continued working to recommend actions that individuals and organisations in each of the four stakeholder groups could take to increase and improve the reporting of detailed, reusable and open methods and protocols in the life sciences.

Draft recommendations. Draft recommendations were shared as a preprint (Leite et al., 2023).

Feedback sessions. Feedback sessions were held with members of each stakeholder group to invite comments and suggestions to improve the draft recommendations (Leite et al., 2023). Participants were invited to comment anonymously via Mentimeter, as well as engage in discussion during the feedback sessions. Participants who could not attend a feedback session were encouraged to share feedback via email. Feedback obtained across all sessions was used to revise the recommendations.

11 https://joint-research-centre.ec.europa.eu/eu-reference-laboratory-alternatives-animal-testing-eurl-ecvam_en

Annex 2. Additional terms

Test Method. A process or procedure used to obtain information on the characteristics of a substance or agent. Toxicological test methods generate information regarding the ability of a substance or agent to produce a specified biological effect under specified conditions. This term is used interchangeably with 'test' and 'assay' (OECD, 2005).

Standard Operating Procedure (SOP). According to the OECD principles of good laboratory practice (GLP) (OECD, n.d.), SOPs are documented procedures that describe how to perform testing methods or activities not usually specified in detail in study plans or test guidelines. Formal SOPs facilitate consistency in the quality and integrity of a product or end result, and are a requirement of GLP. SOPs may include testing methods, instructions, worksheets and laboratory operating procedures. SOPs are essential in a quality management system and must be formally authorised by management in a GLP test facility.

The aim of SOPs is to ensure that procedures are carried out in a consistent and reproducible way by qualified personnel. Therefore, SOPs need to describe, in sufficient detail, clear work instructions for a trained user to minimise the risk of misinterpretation.

In vitro methods are supported by and documented using a number of different SOPs, forms, templates and worksheets. SOPs need to be available and used for supporting procedures (e.g. the handling of cell cultures, waste handling, cleaning procedures, operating and calibration instructions for the equipment, record keeping, reporting, archiving, quality assurance procedures) as well as for describing the main test procedure. To avoid lengthy documents, the instructions are preferably divided into a series of SOPs. The SOPs must be readily available to personnel in each working area (OECD, 2018).

Annex 3. Examples of protocol repositories

Table 5. Examples of protocol repositories

Repository	Open access	Versioning	Forking	DOI citable	Long-term preservation strategy
protocols.io (Teytelman et al., 2016)	✓	✓	✓	✓	✓
Protocol Exchange*	✓	✓	X	✓	✓
Bio-protocol Preprint repository	✓	✓	✓	✓	✓

* Protocol Exchange is no longer accepting new protocols. Content from Protocol Exchange has been moved to protocols.io.

This table compares protocol repositories using the criteria below. Note that this list includes repositories for reusable step-by-step protocols that the authorship team is aware of. This is not intended to be an exhaustive list of all protocol repositories.

- **Open access.** This ensures that all readers can access deposited protocols.
- **Versioning and forking.** The ability to create versions and forks of existing protocols is essential to track the evolution of protocols within and across research groups.
- **DOI citable.** This ensures that deposited protocols have a persistent identifier that can be cited to give the protocol depositors credit for their work.
- **Long-term preservation strategy.** Repositories should have a long-term preservation strategy to ensure that deposited protocols are not lost if the repository ceases to exist.

Generalist repositories that allow researchers to share many types of output, including methods and protocols, are popular in some fields. Examples include the Open Science Framework, Zenodo and FigShare. We have chosen to highlight repositories that are designed specifically for sharing reusable step-by-step protocols. As these repositories share only protocols, they have dedicated fields that prompt authors to enter information that is particularly relevant for protocols. Furthermore, researchers can easily search these repositories to find protocols related to a particular method. Generalist repositories lack these features. Furthermore, many generalist repositories also lack metadata that would allow researchers to determine what type of information is stored in a particular repository entry (e.g. protocol, data, code, open educational resource). The lack of metadata makes it very difficult to search for relevant protocols.

Researchers who deposit code or work in computationally intensive fields often use GitHub to share code. It is important to note that GitHub does not have a long-term preservation strategy.

Annex 4. Resources for researchers

Table 6. Resources for researchers

Resource	Description
RRID Portal	Portal for registering and looking up research resource identifiers, which are unique persistent identifiers for antibodies, cell lines, model organisms, plasmids, software and tools, and core facilities (https://scicrunch.org/resources)
PREPARE (Smith et al., 2018)	Study design guideline for preclinical animal studies
SPIRIT (Chan et al., 2013a,b)	Study design guideline for clinical studies
MDAR (Macleod et al., 2021)	General study reporting guideline for many types of biomedical studies. MDAR stands for materials, data, analysis and reporting.
CONSORT (Butcher et al., 2022; Moher et al., 2010; Schultz et al., 2010)	Study reporting guideline for clinical trials
ARRIVE (Percie du Sert et al., 2020; Percie Du Sert et al., 2020)	Study reporting guideline for preclinical animal studies

Resource	Description
PRISMA (Page et al., 2021)	Study reporting guideline for systematic reviews and meta-analyses
RIVER (The River working group, 2023)	Draft study reporting guideline for *in vitro* experiments – currently undergoing user testing
SciRAP (Roth et al., 2021)	Study reporting guideline for evaluating the reliability and relevance of *in vitro* studies
GD211 (Government of Canada, 2011)	Study reporting guideline for 'Guidance on the content of quality management system audit reports'
GIVIMP (OECD, 2018)	OECD guidance on good in vitro method practices – this document provides guidance for all in vitro method elements, including quality considerations, experimental design, SOP development, assessment of method performance, reporting of results and retention of data and records
GCCP (Pamies, 2021)	Study design and reporting guideline for good cell culture practice
EQUATOR Network	The EQUATOR Network provides an extensive list of study design and reporting guidelines for different types of clinical studies (https://www.equator-network.org)

Annex 5. Training materials

Protocols.io. Contact info@protocols.io or watch recorded webinars on the company website (https://www.protocols.io/webinars).

Bio-protocol. Contact editorial@ed.bio-protocol.org to request training

ReproducibiliTeach. The "Make your methods section more transparent" playlist on the ReproducibiliTeach YouTube channel (http://youtube.com/@reproducibiliteach) includes videos on writing step-by-step protocols that others can easily reuse, using research resource identifiers to specify exactly what you used, depositing protocols, responsible use of shortcut citations and other topics (https://www.youtube.com/watch?v=0xNb1KD5ZaU&list=PLWb8IFSVeQ61MDUdJ3UaXI_FtQMvTDnSd).

Annex 6. Disclosures and conflict of interest

As is noted in the author affiliations, some of the experts who contributed to these guidelines are employed by protocol repositories, protocol journals or publishers that publish protocol papers, methods papers, protocol journals or methods journals.

Sofia Batista Leite is employed by the European Food Safety Authority (EFSA) in the unit PREV, which provides scientific and administrative support to the Panel on Plant Protection Products and their Residues in the area assessment department. However, the present article is published under the sole responsibility of the authors and may not be considered an EFSA scientific output. The positions and opinions presented in this article are those of the authors alone and do not represent the views/any official position or scientific works of EFSA. To find out about the views and scientific outputs of EFSA, please consult its website (http://www.efsa.europa.eu).

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