



## ***Promoting Reusable and Open Methods and Protocols (PRO-MaP): Draft recommendations to improve methodological clarity in life sciences publications***

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## Abstract

Detailed, accessible methods are essential for reproducibility, trust in science and scientific advancement; yet, many studies suggest that the reporting of methodological details in life sciences research publications is often incomplete. This may be due to a lack of incentives or reporting standards, or other cultural or educational factors. **Promoting Reusable and Open Methods and Protocols (PRO-MaP)** aims to increase and improve the reporting of detailed, reusable and open methods and reusable step-by-step protocols in the life sciences. This initiative began with a workshop convened by the EU Reference Laboratory for alternatives to animal testing (EURL ECVAM) at the European Commission's Joint Research Centre, which included representatives from various stakeholder groups. Our draft recommendations outline actions that four stakeholder groups, researchers, research institutions and departments, publishers and editors, and funders, can take to achieve these goals. While some recommendations address study design and reporting guidelines, the primary focus is on capturing clear, accurate, methodological detail, e.g. with re-usable step-by-step protocols. We welcome feedback on these draft recommendations from members of each stakeholder group, including experts in improving methodological reporting. The final recommendations will be released after incorporating feedback received during consultation sessions. Once the recommendations are finalized, we hope that organizations and individuals from each stakeholder group will join us in collaboratively working to improve the reporting of detailed methods and reusable step-by-step protocols in the life sciences.

## Keywords

Open methods, reusable step-by-step protocols, reproducibility, scientific rigor, reporting, reporting standards

## Introduction

Well described methods and reusable, step-by-step protocols are a cornerstone of trust for scientific outputs. In industrial and regulatory settings, protocols are often translated into Standard Operating Procedures (SOPs). In life sciences research, however, the format for sharing methods is variable and often incomplete. Inadequate reporting of methods has been documented in many types of studies, including cancer research, fMRI research [1] and clinical trials [2]. The methods section of a research article alone is often insufficient to reproduce results or reuse methods [3,4], and private sharing remains the most common approach to sharing details of methods [4]. 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 [5]. No paper contained sufficient methodological details to allow researchers to design and conduct a replication study [3]. Contact with authors was always required to design and conduct replication studies, and many authors were not helpful or did not respond.

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. The lack of openly accessible detailed methods undermines trust in published data and severely limits the uptake of new methods, as well as 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 of 2022 (S1 Text), by the EU Reference Laboratory for alternatives to animal testing (EURL ECVAM [6]) at the European Commission’s Joint Research Centre (EC-JRC). 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.

The PRO-MaP recommendations build on prior European Commission reports [7,8], which point to transparency and sharing of research details such as protocols as avenues for building reproducibility and trust. Furthermore, 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 [9].

This document briefly outlines key principles underlying the recommendations for various stakeholder groups, defines the scope of the recommendations; then presents 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 to determine whether these methods used are appropriate to answer the research question and to evaluate the scientific rigor of the experiment. Due to historical space limitations, methods often provide limited detail and refer 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 to 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 to 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 (GLP), protocols are normally called Standard Operating Procedures (SOPs) [10]. Even where such protocols exist, they are currently rarely incorporated into, linked to or cited in primary research articles.

**Study design protocols:** Study design protocols describe the design of a specific study, and may also contain 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 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 also include reusable protocols that describe how specific measurements will be performed.
- Pre-registered protocols describe the design of a specific study. These protocols are documented and time stamped 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.
- GLP study plans define the objectives and experimental design for the conduct of the study, and includes any amendments.

**Protocol repository:** An online repository where scientists can deposit detailed protocols and make these protocols publicly accessible with a DOI. Protocols posted on repositories are typically not peer reviewed, although some repositories partner with journals to offer peer review and publication options. Repositories also offer other features to 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 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, allowing the protocol creators to see how others are adapting their protocol.

**RRIDs (Research Resource Identifiers):** Unique, persistent identifiers that specify what was used [11]. 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 (<https://scicrunch.org/resources>).

**Structured methods:** A structured methods section is divided into informative subsections that allow readers to clearly identify the methods 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:** When writing the methods section of the paper, the authors cite another resource instead of providing a detailed description of the method [12]. This resource may, or may not, fully describe the relevant method.

**Preprints:** Manuscripts of research papers that are posted on public servers before formal publication and typically before peer review. Preprints may be designated as “refereed preprints” if authenticated reviewer reports have been added.

For more terms, please check box S1 in the supplementary materials section.

We welcome feedback on these draft recommendations from members of each stakeholder group, including experts in improving methodological reporting. We will hold a series of consultation sessions to solicit feedback, which will be used to improve the recommendations. Once the recommendations are finalized, we will welcome contributions and collaborations with stakeholders working to implement these recommendations. Implementation will require a community effort, where activities are coordinated and harmonized across stakeholder groups. Actions should focus on:

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 to share, publish and discover protocols
4. **Offering rewards and incentives:** Reward and incentivize reporting of detailed, open methods and reusable step-by-step protocols

## Principles

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

**Principle 1:** We need a cultural shift to reward and incentivize methods development and sharing of reusable, open methods and protocols. Life sciences publications are heavily focused on findings and conclusions, with limited space dedicated to methodology. Research findings are important, but are not useful if the methods used to generate the data are not accessible or not sufficiently detailed to allow reproducibility, understanding and trust. Furthermore, we can't reuse data to generate meaningful and trustworthy results if we don't know how the data were produced. We need to reward open protocols, open data and open code alongside traditional publications – until we do this, researchers who share protocols and other materials are doing

more work for the same unit of credit. The involvement of research institutions, departments and funders is essential to facilitate this cultural shift.

**Principle 2:** 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, especially methods papers, should include links to reusable step-by-step protocols that describe how the method was implemented (see Principles 3 and 4). All stakeholder groups should work to create a culture that encourages and rewards protocol sharing.

**Principle 3:** Protocols need to have the following key characteristics to facilitate scientific progress: protocols need to be detailed, clear, transparent, complete, transferable (across research groups), reusable, reliable, reproducible and accessible.

**Principle 4:** Protocols should be cited and shared on dynamic platforms (Table S1), so that they can be versioned or forked (Box 1) as the protocol evolves or is adapted by 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 about protocols is not whether they will change, but when and how they will evolve or be adapted by others. We need to embrace dynamic protocol sharing platforms that reflect this reality.

**Principle 5:** We need to encourage researchers to use methodological shortcut citations responsibly [12]. Researchers use a methodological shortcut citation when they replace a section of their methods with a citation. Shortcut citations can be very effective if, for example, the authors cite a recent methods paper or protocol that describes exactly what they did [12]. In contrast, shortcut citations adversely affect reproducibility if the cited resource is inaccessible, doesn't mention or fully describe the cited method, or cites another resource instead of fully describing the method [12]. 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 the paper [12]. Shortcut citations are different from citations used for other reasons, as readers will need to consult the cited resource if they want to implement the method described. We therefore recommend that authors follow the guidelines below when using shortcut citations, to ensure that readers have access to information needed to critically evaluate and implement the method described.

- **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 details needed to allow others to reproduce the method; 3) Be open access [12].
- **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 on an open access protocol repository that allows versioning and forking and has a long-term preservation strategy [12].
- **Describe all modifications** made to the cited method.
- **Provide details needed to locate the method in the cited resource.** 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 ebook 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 shortcut citations.** 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)”) [12].
- **Share missing information.** 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, on an open access repository. When depositing a protocol, credit the original source.

## 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, e.g. with re-usable step-by-step protocols. This includes standalone protocols for reusable methods, as well 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, pre-registrations, or GLP study plans) are not the main focus of PRO-MaP. Study design protocols include many details that are essential to understand and critically evaluate the study, but are less likely to be reused (e.g. because the study population, inclusion and exclusion criteria are unique to the study).

## Recommendations

The following sections recommend actions that each of the four stakeholder groups can take to improve reporting of methods and reusable step-by-step protocols in scientific preprints and publications. We do not expect any individual, research group or organization to have the time or resources to immediately implement all recommendations, 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 more challenging recommendations.



# 1. Researchers

Researchers are critical to 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 reporting of methods and protocols within their own research groups (recommendations 1-7), while supporting institutions and other stakeholder organizations in creating a culture and rewards and incentivized sharing of detailed, open methods and protocols (recommendations 8-9).

Table 1: Recommendations for researchers

Recommendation	Specific actions
<p><b>1. Document, share and follow protocols within your research group</b></p>	<p>1.1 <b>Write down protocols</b> to capture undocumented knowledge and ensure that procedures are consistent across all research team members. <b>Box 3</b> provides additional information about essential elements of a reusable, step-by-step protocol.</p> <p>1.2 <b>Search protocol repositories (e.g. Table S1) and journals for existing protocols</b> when implementing new research procedures within your team. Cite protocols that your team uses and report any modifications when sharing your work.</p> <p>1.3 <b>Ensure that team members follow protocols</b> when running experiments</p> <p>1.4 <b>Ensure that team members update protocols</b> in a timely manner as materials and procedures evolve.</p> <p>1.5 <b>Increase accountability and participation by regularly discussing protocols and protocol modifications.</b></p> <p>1.6 <b>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</b> (Table S1). 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, whereas the DOI ensures that your protocol has a unique persistent identifier that can be cited. <b>A long-term preservation strategy ensures that protocols remain accessible if the repository ceases to exist.</b></p> <p>1.7 <b>Cite protocols</b> in methods papers, original research papers, datasets and pre-registrations to give readers detailed information about your methods (see recommendation 4). Cite the version</p>



	<p>of the protocol that was used for the specific experiment or study.</p>
<p><b>2. Follow relevant study design and reporting guidelines when designing and conducting your study and writing your methods</b></p>	<p><b>2.1 Identify and use study design and reporting guidelines relevant to your field or study type when designing and reporting your study.</b> Look for guidelines that were established by the scientific community. Use study design guidelines when designing a study; examples include PREPARE [13] (preclinical animal studies) and SPIRIT [14,15] (clinical trials). Reporting guidelines specify details that should be reported when publishing your study. When possible, consult reporting guidelines at the design phase to ensure that you are collecting all necessary information. Examples of reporting guidelines include MDAR [16], CONSORT [17–19], ARRIVE [20,21], PRISMA [22], SciRAP [23] and GD211 [24]. Some guidelines, e.g. GIVIMP [25] and GCCP [26], address both study design and reporting.</p> <p><b>2.2 Complete the checklist for the reporting guideline that you used when writing your paper</b> to ensure that you have addressed all required elements.</p> <p><b>2.3 Include completed guideline checklists</b> in the supplemental files of your paper.</p>
<p><b>3. Describe methods in enough detail to allow others to reproduce the experiment. Details may be presented in the methods section, or through responsible use of shortcut citations</b> (see Box 2 and Recommendation 5 in this table).</p>	<p><b>3.1 Describe exactly what you did</b>, even if there is overlap with previously published methods. If a shortcut citation is used to replace a detailed description, follow criteria for responsible use of shortcut citations (see Box 2).</p> <p><b>3.2 Specify what materials were used:</b> Include details of the materials, model organisms and equipment used (MDAR [16]). Information provided should allow readers to identify the specific material/reagent unambiguously (see recommendation 3.3), and provide information that is known to contribute to variability (e.g. lot numbers, software versions, etc.).</p> <p><b>3.3 Report research resource identifiers (RRIDs) to unambiguously identify cell lines, antibodies, model organisms, plasmids and software and tools.</b> These unique persistent identifiers allow others to determine exactly what was used, even if the catalog number changes, the product is discontinued, or the product is transferred to</p>

	<p>another supplier. Researchers can look up or create new RRIDs using the RRID portal (<a href="https://scicrunch.org/resources">https://scicrunch.org/resources</a>).</p>
<p><b>4. Strengthen static methods sections by linking out to protocols posted on dynamic platforms that allow versioning and forking</b></p>	<p><b>4.1 Post protocols in an open access protocol repository that allows versioning and forking, provides DOIs for publicly available protocols, and has a long-term preservation strategy</b> (see Table S1 in the supplementary material).</p> <p><b>4.2 Avoid posting the same protocol in different repositories.</b> This wastes time and creates confusion about whether the protocols are different, and which protocol to use, cite, version or fork.</p> <p><b>4.3 Avoid publishing detailed methods information in supplemental files [27] or on lab or project websites.</b> Deposit methods in an open access repository that provides DOIs, offers versioning and forking and has a robust long-term preservation strategy.</p>
<p><b>5. Use methodological shortcut citations responsibly</b></p>	<p><b>5.1 Follow the criteria outlined in Box 2</b></p>
<p><b>6. Include methods and materials availability statements in papers and publications</b></p>	<p><b>6.1 Include a methods availability statement:</b> These statements should specify whether detailed protocols are openly available and include links to and citations of protocols published in repositories</p> <p><b>6.2 Do not state that “methods are available upon reasonable request”.</b> Make methods and materials available to other researchers before submitting your paper (many journals already require this). If you are unable to make your methods available, explain why your methods cannot be shared.</p> <p><b>6.3 Include a materials availability statement,</b> as mandated by the MDAR guidelines [16]. This statement should specify the availability of newly created materials, as well as procedures required to access those materials if they are not openly accessible through a materials repository.</p>
<p><b>7. Ensure that methods sections are clearly formatted and user friendly, and make it easy to connect data to specific methods used to generate the data</b></p>	<p><b>7.1 Write well-structured, clearly formulated methods sections</b> that are easy for readers from different research backgrounds to understand.</p> <p><b>7.2 When sharing, presenting or describing data (e.g. figures, tables, supplemental data,</b></p>

	<p><b>datasets deposited on repositories), clearly state the name of the method used to generate the data.</b> This will help readers to quickly find methods that were used to generate specific data. Data repositories should cite protocols or other published methods used to generate the data.</p>
<p><b>8. Advocate for, or offer, training in open and reproducible methods and protocols</b></p>	<p><b>8. Partner with instructors and organizations to offer training in different settings</b> (e.g. research group, department, institution, scientific society, journal, funding agency). See training resources in the supplement. Topics should include:</p> <ol style="list-style-type: none"> <li>1. Using study design and reporting guidelines</li> <li>2. Writing and depositing reusable step-by-step protocols in public repositories</li> <li>3. Using research resource identifiers (RRIDs) for cell lines, antibodies, plasmids, model organisms and software and tools, to specify exactly what was used [11]</li> <li>4. Using shortcut citations responsibly</li> <li>5. Writing reproducible methods sections</li> </ol>
<p><b>9. Support a culture that rewards and incentivizes methods development and protocol sharing</b> (check section 2. Recommendations for research institutions and departments)</p>	<p><b>9.1 Cite protocols deposited by others when using or adapting their methods. Consider sharing a forked version of the protocol to show how you adapted the method.</b> Citing gives the protocol creators credit for their protocol development work. Forking allows the protocol creators and the scientific community to track the evolution of protocols across research groups.</p> <p><b>9.2 Add a “Methods and protocols” section to your CV.</b> List methods papers, protocol papers and protocols deposited in public repositories. Encourage members of your research group to do the same.</p> <p><b>9.3 Encourage your institution and/or funder(s) to require researchers to list methods and protocols as academic outputs on CVs and progress reports</b></p> <p><b>9.4 Encourage your organization to adopt “open and reproducible methods” requirements for theses.</b> This might include requiring, or strongly recommending, that students deposit protocols for their dissertation in a public repository and cite these protocols in their dissertation.</p> <p><b>9.5 Integrate open and reproducible methods into hiring and performance evaluation criteria</b></p>

## **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 RRIDs to identify cell lines, antibodies, plasmids, model organisms, software and tools and core facilities
- Specify vendor information when relevant, as well as other key identifiers (e.g. software version numbers, lot numbers for polyclonal antibodies, CAS numbers for (control) chemicals)
- Provide details of solutions (recipe, ingredients, concentrations)
- Provide details on biological material - species origin; concentration/density/dilution, stability of material (e.g. acceptable numbers 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**

- Single step instructions (one instruction per line)
- Use active voice
- Provide detailed instructions to allow 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
- For timed protocols, specify the time needed for each step
- 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 things that do not work.

### **Expertise**

- Describe the expertise or training needed to implement the protocol

### **Safety information**

- Include safety warnings

### **Protocol Limitations and Assumptions**

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

### References

- If relevant, cite references (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 to 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, which contains a list of 17 items that are essential to execute a protocol [28].

## Context for key recommendations

**Recommendations 1-7:** These recommendations highlight actions that researchers can take to improve methodological reporting and normalize sharing of detailed methods and step-by-step protocols within their own research groups. While implementing these recommendations takes time and resources, these actions may help researchers to 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 hasn't 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 show researchers 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 especially 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.

Protocols do not need to be novel to be deposited in a protocol repository. One can share a particular research team's version of a common method, a modification, adaptation or advancement of a previously described method, or a new method.

The supplementary materials section of this article lists training resources that may support researchers in implementing these recommendations.

**Recommendations 8-9:** 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. Recommendations 8-9 outline actions that researchers can take to support their institutions and other organizations in creating a culture that rewards and incentivizes reporting of detailed methods and sharing of reusable step-by-

step protocols. We ask 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 others to adopt recommendations 8-9.

## 2. Research institutions and departments

Participation of research institutions and departments is essential to create a culture that rewards and incentivizes 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 programs. Institutional and departmental leadership have the responsibility to reward and incentivize 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, vs. 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 programs should also work to implement the recommendations for funders (see section 4) that apply to their programs.

**Table 2: Recommendations for research institutions and departments**

Recommendation	Specific actions
<p><b>1. Create a culture that recognizes the value of sharing open and reproducible methods</b></p>	<p><b>1.1 Implement, disseminate and incentivize the recommendations for researchers (Table 1)</b> among researchers in your institution</p> <p><b>1.2 Encourage all research team members to share detailed methods and protocols.</b> This includes researchers, laboratory technicians and students. 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.</p> <p><b>1.3 Support and facilitate the use of tools to record and share methods and protocols,</b> within and beyond the same research group or institution. Examples might include protocol repositories or electronic lab notebooks.</p> <p><b>1.4 Encourage a culture change</b> towards the deposition of protocols in open protocol repositories.</p> <p><b>1.5 Encourage researchers to cite protocols</b> describing their methods in publications.</p>

	<p>1.6 <b>Consider protocol and methods sharing for hiring, promotion and tenure evaluations.</b> This may include adding a “Methods and protocols” section to scientists’ CVs or other reporting forms.</p>
<p>2. <b>Require and offer training on writing and openly sharing detailed methods and reusable step-by-step protocols</b></p>	<p>2.1 <b>Include modules on good protocol writing and reporting in education programs.</b> Tailor content to different career stages or professional roles (e.g. researcher vs. technician). Examples might include providing first year graduate students with a lecture or hands-on workshop on "how to write a reproducible protocol", 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. The supplementary materials section of this article lists some available training resources.</p> <p>2.2 <b>Disseminate training and guidelines</b> for good method/protocol reporting within your institution</p> <p>2.3 <b>Promote hands-on training</b>, where participants write or update and deposit protocols used in their own research</p> <p>2.4 <b>Where possible, dedicate a budget line item to training and/or access to tools or platforms</b> that facilitate sharing of open reusable, step-by-step protocols</p>
<p>3. <b>Integrate detailed methods and reusable step-by-step protocols into thesis requirements</b></p>	<p>3.1 <b>Graduate degree programs should highlight the importance of open and reusable methods and protocols</b>, alongside open data, by offering training (see Recommendation 2).</p> <p>3.2 <b>Require or incentivize graduate students to use and deposit protocols when conducting thesis research</b></p> <p>3.3 <b>Recognize methods and protocol publications as chapters that can be included in theses</b></p> <p>3.4 <b>Encourage local or national funders to require, incentivize and reward methods papers, protocol papers and depositing of protocols on open access repositories</b> (see Table S1 in the supplementary materials section) <b>in training grants</b></p>
<p>4. <b>Offer prizes or awards for protocol sharing</b></p>	<p>4.1 <b>Offer prizes or awards</b> for research groups or individuals that share reusable step-by-step protocols</p> <p>4.2 <b>Identify the best reward system to motivate everyone in the institution to deposit and publish protocols.</b> Monitor and publicly share the effects of</p>



these programs to allow others to learn from your experience.

### 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 the openness and reproducibility of methods in scientific publications. Following the table, we briefly provide 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	Specific actions
<p><b>1. Ensure that methods are described in enough detail to reproduce the experiment. Details may be presented in the methods section, or through responsible use of shortcut citations</b> (see Recommendation 3).</p>	<p><b>1.1 Eliminate word limits for methods sections</b></p> <p><b>1.2 Encourage authors to describe exactly what they did</b>, 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 [12] (Recommendation 3, <b>Box 2</b>).</p> <p><b>1.3 Allow authors to re-use text describing detailed methods. Raise awareness about policies permitting this among authors.</b> Clearly specify that it is acceptable to copy or quote exact methods from previous work, with attribution. Plagiarism screening should only be performed on methods sections to ensure that duplications are attributed to the source paper, or to identify plagiarism of methods written by a separate team of authors. Plagiarism screening software should be improved to allow users to evaluate screening results from methods sections separately.</p> <p><b>1.4 Adopt structured methods reporting to ensure that key elements of methods are addressed:</b> Structured methods should follow a standard format that is transferable across journals, and has been developed through consultation with the scientific community.</p>

	<p>1.5 <b>Require authors to specify materials:</b> Authors should include details of the materials, model organisms and equipment used. Information provided should allow readers to identify the material, and provide information that is known to contribute to variability (e.g. lot numbers, software versions). Require authors to report unique persistent identifiers, such as RRIDs (<a href="https://scicrunch.org/resources">https://scicrunch.org/resources</a>), when they are available.</p>
<p><b>2. Encourage authors to strengthen static methods sections by linking out to reusable step-by-step protocols posted on dynamic platforms.</b> Linking out to protocols provides valuable methodological details for all original research articles, especially methods papers.</p>	<p>2.1 <b>Encourage authors to post protocols on open access protocol repositories that allow versioning and forking, provide DOIs, and have a long-term preservation strategy</b> (Table S1). Repositories that don't currently allow versioning and forking should be encouraged to add these capabilities. Specifically state that it's okay for authors to deposit protocols, even if they partially duplicate information contained in the methods section of the original research article.</p> <p>2.2 <b>Do not ask authors to post the same protocol in different repositories</b> (e.g. don't ask authors to repost a protocol in a repository run by the publisher if it has already been shared in an open access repository).</p> <p>2.3 <b>Ask authors to avoid publishing detailed methods information in supplemental files or on lab or project websites.</b> Ask authors to deposit methods in an open access repository that has a robust long-term preservation strategy.</p>
<p><b>3. Promote responsible use of methodological shortcut citations</b></p>	<p>3.1 <b>Ask authors to use shortcut citations responsibly,</b> by adhering to the practices outlined in Box 2.</p> <p>3.2 <b>Ensure that publication pipelines and bibliography formats allow authors to provide the additional information needed to locate the cited method</b> within the cited resource. This might include page numbers in books or other location identifiers for ebooks, or the name and location of details about the method in the specified publications.</p> <p>3.3 <b>Raise awareness about responsible use of shortcut citations among editors and authors.</b> This may include organizing webinars</p>

	and workshops. The supplementary materials section of this report lists training resources.
<b>4. Move methods sections in front of the paywall</b>	<b>4.1 Ensure that all readers can access the methods section, free of charge and without a subscription.</b> Use a CC-BY license for methods sections.
<b>5. Require methods and materials availability statements</b>	<p><b>5.1 Require machine-readable Methods Availability Statements, in front of any paywall:</b> These statements should specify where detailed protocols are openly available and include links to and citations of protocols published in repositories.</p> <p><b>5.2 Do not allow statements that “methods are available upon reasonable request”</b></p> <p><b>5.3 Require a materials availability statement,</b> as mandated by the MDAR guidelines [16]. This statement should specify the availability of newly created materials, as well as procedures required to access those materials if they are not openly accessible through a materials repository.</p>
<b>6. Ensure that methods sections are clearly formatted, user friendly, and make it easy to connect data to specific methods used to generate the data</b>	<p><b>6.1 Encourage authors to write well-structured, clearly formulated methods sections</b> that are easy for readers from different research backgrounds to understand.</p> <p><b>6.2 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.</b> This will help readers to quickly find methods that were used to generate specific data. Data repositories should cite protocols or other published methods used to generate the data.</p>
<b>7. Issue corrections to fix mistakes in methods or protocols</b>	<p><b>7.1 Publish correction notices to correct mistakes in the methods section of a paper, using standard procedures</b></p> <p><b>7.2 Expand the normal corrections process to address mistakes in protocols that are linked in a paper.</b> Authors may correct the protocol and notify the journal. The journal</p>

	<p>would then publish a corrected version of the paper, which links to the corrected protocol.</p>
<p><b>8. Enforce policies on the availability of materials</b></p>	<p><b>8.1 Support readers who have difficulty accessing materials from prior publications at a reasonable cost:</b> 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.</p> <p><b>8.2 Enforce policies on the availability of materials:</b> When necessary, follow up with authors.</p>
<p><b>9. Develop implementation plans to facilitate uptake of new practices</b></p>	<p><b>9.1 Integrate new policies into the manuscript submission and assessment process.</b> This may include implementing checks for crucial details. Some journals implement checks for new practices partway through the editorial process (e.g., when requesting a revision) to increase author motivation and avoid unnecessary burdens during the initial submission phase.</p> <p><b>9.2 Raise awareness of new policies, along with relevant training materials and tools, among editors, reviewers and authors.</b> Existing research shows that journal policy changes and editorials have little or no impact on reporting quality, especially if there is no editorial oversight (e.g., [29–33]). Publishers need to engage with journal communities to emphasize the benefits to authors of implementing new practices and make implementation easy.</p> <p><b>9.3 Monitor for intended and unintended consequences, share experiences and adapt as needed.</b> This is essential to determine whether policy changes and interventions are having the desired effect. Examples of unintended consequences might include an increase in the number of authors copying methods sections from prior 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.</p>

<p><b>10. Update guides for authors to promote high quality reporting of methods</b></p>	<p><b>10.1 Update the guide to authors to address the changes described above.</b> Many authors do not review guidelines in detail; therefore, publishers may want to consider sharing information in more engaging formats (e.g., video tutorials).</p> <p><b>10.2 Recommend that authors take the following four actions to improve the quality of methodological reporting:</b></p> <ol style="list-style-type: none"> <li>1. Follow relevant reporting guidelines established by the scientific community. Examples include MDAR [16], CONSORT [17–19], ARRIVE [20,21], PRISMA [22], GCCP [26], GIVIMP [25], SciRAP [23] and GD211 [24].</li> <li>2. Use research resource identifiers (RRIDs) for cell lines, antibodies, plasmids, model organisms and software and tools, to specify what was used</li> <li>3. Use shortcut citations responsibly</li> <li>4. Share protocols in open access repositories that allow versioning and forking. Cite these protocols in the methods section.</li> </ol>
<p><b>11. Update guides for reviewers to address methods reporting</b></p>	<p><b>11.1 Update guides for reviewers</b> to address the changes described above.</p>

## Context for key recommendations

**Recommendation 1:** 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 transfer optimized descriptions of methods from one paper to the next. 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.

**Recommendation 2:** Methods sections of papers and reusable step-by-step protocols fulfill different functions. The methods section of a paper provides a general overview of the methods used, which helps readers to determine whether they are appropriate to answer the research question and to evaluate the scientific rigor 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 (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) their 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 out to protocols deposited in repositories, which can be versioned and forked as the protocol evolves.

**Recommendation 3:** When used responsibly, shortcut citations are a powerful tool [12]. Authors can share detailed protocols with readers who want this information, without making the methods section long and unreadable to readers who only want a general overview. Unfortunately, shortcut citations can also cause problems [12]. 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 [12]. In some cases, the cited resource also uses a shortcut citation instead of describing the method [12]. 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 (Box 2) [12], and raise awareness of these criteria among authors.

**Recommendation 4:** For journals that are not fully open access, moving 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 move methods sections in front of the paywall for methods papers, protocol papers and papers published for approximately 5 years before the open access transition, as these papers may be cited as shortcuts.

**Recommendation 5:** Many journals require data availability statements, and we recommend extending this practice to include a methods availability statement. Statements that “Methods are available upon reasonable request” should not be permitted, as many studies on data availability statements have shown that authors who use “Data available upon request” statements rarely provide data when contacted (e.g., [34]).

**Recommendation 9:** 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 behavior. Updating journal policies to require RRIDs, for example, increases the number of papers reporting RRIDs

by 1% [29]. A study of animal studies published in Nature journals revealed that the percentage of papers reporting the Landis 4 criteria (blinding, randomization, sample size calculation, exclusions) increased from 0% to 16.4% after new guidelines were released [30]. In contrast, a randomized controlled trial showed that requiring authors to complete the ARRIVE checklist when submitting an animal study to PLOS One did not improve reporting [31]. Some improvements in reporting of inclusion and exclusion criteria, sample size justification, and confidence intervals were observed after Psychological Science introduced new policies [32], 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 [33]. Editors and authors often underestimate journal policies and may not understand when policies are addressed during the submission and review process [35]. 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 with clear and consistent language, align policy requirements with standards and best practices, and collaborating with repository experts for policy implementation and support [35].

## 4. Funders

Reproducibility is a priority for research funding organizations, who are uniquely placed to incentivize researchers to adopt good protocol reporting practices. Research that cannot be reproduced represents a waste, not only of time, materials, and (in *in vivo* studies) animal lives, but also of 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 don't know what was done.

Table 4 outlines specific recommendations 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 organization.

**Table 4: Recommendations for funders**

Recommendation	Specific Actions
<p><b>1. Embed open protocol reporting in research funding to support protocol review and reuse</b></p>	<p>1.1 Require that researchers publish (or make available by other means) <b>open access, reusable step-by-step protocols associated with any scientific publication supported by awarded funding</b>. Ask researchers to specify procedures for making protocols available in data management plans. Ideally, protocols should be deposited on open access repositories that allow versioning and forking, and have a long-term preservation plan (see Table S1 in supplementary material).</p>



	<p>1.2 Require <b>scientific review committees</b> 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.</p> <p>1.3 Mandate that a <b>reproducibility assessment</b> 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 reproducibility of protocols.</p> <p>1.4 <b>Recognize applicants with a demonstrable record of transparent reporting</b> of methods and reusable step-by-step protocols. Developing automated screening tools to check publications may facilitate implementation (see action 4.1, below).</p>
<p><b>2. Reward and incentivize sharing of detailed methods and reusable, step-by-step protocols</b></p>	<p>2.1 Reward publishing reusable, step-by-step protocols, for example <b>through awards and prizes</b>.</p> <p>2.2 <b>Recognize methods and protocols as a scientific output</b>, valued on par with publications, by creating a specific section for them on CVs.</p> <p>2.3 <b>Fund rewards and incentives for sharing of detailed methods and reusable, step-by-step protocols</b>.</p> <p>2.4 <b>Fund training on how to write reusable step-by-step protocols</b></p>
<p><b>3. Integrate sharing of detailed methods and reusable step by step protocols into training and assessment criteria for graduate students</b></p>	<p>3.1 <b>When funding PhD or masters' students:</b></p> <ul style="list-style-type: none"> <li>● <b>Require training</b> on reproducibility, including open and reproducible methods and protocols, when funding PhDs / doctoral programs</li> <li>● <b>Require reproducibility and transparency actions in Masters and PhD degree expectations</b>. This may include depositing reusable step-by-step protocols for thesis research in public repositories.</li> </ul>
<p><b>4. Use evaluation indicators to track progress in reporting detailed methods and reusable step-by-step protocols</b></p>	<p>4.1 <b>Support the development of automated tools to track methods reporting practices</b>, such as deposition of protocols, citation of methods papers, or the use of methodological shortcut citations (Box 2), in preprints and papers</p>

	<p><b>4.2 Require the creation of public dashboards illustrating methods and protocol sharing practices.</b> 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.</p> <p><b>4.3 Ensure that research assessment criteria focus on good research practice, including the quality of the experimental design and methods,</b> and not only on research results.</p> <p><b>4.4 Evaluate the outcomes and impact of newly implemented approaches</b> designed to reward and incentivize reporting of detailed methods and sharing of reusable step-by-step protocols. Openly share the results of these evaluations.</p> <p><b>4.5 Create a research transparency metric which includes sharing of reusable step-by-step protocols.</b></p>
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## Context for key recommendations

**Recommendations 1-2:** Two recent European Commission reports [7,8] addressed the reproducibility of EU-funded projects. The first of these, on “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 rigor, data-sharing) and provide professional incentives for formally reproducing the work of others and demonstrating reproducibility related practices” [8].

Despite this, the report acknowledges that the number of funding organizations investing directly in increasing reproducibility remains relatively low. One exception is Aligning Science Across Parkinson’s [27]. Requirement 3 of their open access policy mandates that “all research outputs (data, protocols, code) must be deposited in publicly accessible repositories and cited in the publication [27]. 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.

**Recommendation 3:** Investing in education offers a career development opportunity for early career researchers, as well as 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 [36], 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 incentivizing and rewarding scientists for sharing detailed methods and reusable step-by-step protocols (**Recommendation 2**).

**Recommendation 4:** Specific actions outlined in this section will help funding agencies to evaluate current practices and monitor the impact of policy changes and new strategies to improve reporting of methods and protocols.

## Call to action

We welcome feedback on these draft recommendations from members of each stakeholder group, including experts in improving methodological reporting. Consultation sessions will be held with members of each stakeholder group to solicit feedback. Feedback provided during these sessions will be used to improve the recommendations. Interested parties who are unable to attend a consultation session can send feedback directly to the corresponding author.

## 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 with the European Food Safety Authority (EFSA) in the Unit PREV that provides scientific and administrative support to the Panel on Plant Protection Products and their Residues in the area Assess Dept. However, the present article is published under the sole responsibility of the author/s and may not be considered as an EFSA scientific output. The positions and opinions presented in this article are those of the author/s alone and represent the views/any official position or scientific works of EFSA. To know about the views or scientific outputs of EFSA, please consult its website under <http://www.efsa.europa.eu>.

Matthew Brooke is an employee of the NC3Rs, this role includes promotion of the ARRIVE guidelines and coordination of the RIVER recommendations working group.

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## Supplementary Materials

### Process for developing the draft PRO-MaP recommendations

**Rationale for the workshop:** The Directorate-General Joint Research Central (DG-JRC) at the European Commission believed that more could be done to set 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 EURL ECVAM [6], at the European Commission Joint Research Centre (EC-JRC). EURL ECVAM has been working 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 to facilitate transferability and uptake of methods across laboratories, as well as detailed understanding by evaluators. 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 would represent, 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, followed by three discussions:

- What is the current situation regarding methods and protocols in peer-reviewed publications: 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 organizations 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.

## Training Resources

- **Protocols.io:** Contact [info@protocols.io](mailto:info@protocols.io) to request training, or see recorded webinars here: <https://www.protocols.io/webinars>
- **Bio-protocol:** Contact [editorial@ed.bio-protocol.org](mailto:editorial@ed.bio-protocol.org) to request training
- **ReproducibiliTeach:** The “Make your methods section more transparent” playlist 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](https://www.youtube.com/watch?v=0xNb1KD5ZaU&list=PLWb8IFSveQ61MDUdJ3UaXI_FtQMvTDnSd)

### Box S1: 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” [37].

**Standard Operating Procedure (SOP):** According to the OECD Principles of Good Laboratory Practice (GLP) [10], Standard Operating Procedures (SOPs) are defined as documented procedures which describe how to perform testing methods or activities normally not specified in detail in study plans or Test Guidelines (TGs). Formal SOPs facilitate consistency in the quality and integrity of a product or end-result, and are required by GLP. SOPs may include testing methods, instructions, worksheets, and laboratory operating procedures. SOPs are essential in a quality management system and must be formally authorized 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 minimize the risk for misinterpretation.

An *in vitro* method will be supported and documented with a number of different SOPs, forms, templates and worksheets. Besides the description of the main test procedure, SOPs for supporting procedures (e.g., the handling of cell cultures, waste handling, cleaning procedures, operating and calibration instructions for the equipment, record keeping, reporting, archival, quality assurance procedures, etc.) need also to be available and used. 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 [25].

**Table S1: Examples of protocol repositories**

Repository	Open Access	Versioning	Forking	DOI Citable	Long-term Preservation Strategy
protocols.io [38]	✓	✓	✓	✓	✓
Protocol Exchange	✓	✓	X	✓	✓
Bio-protocol Preprint repository*	✓	✓	✓	✓	✓

This table compares selected protocols according to the criteria below. Note that 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.

\* The Bio-protocol preprint repository is in development and is anticipated to be released in June 2023.