1 Preregistration and increased transparency will benefit science.

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8 Science advances by improving existing explanations and by creating new ones. The
9 process of refining our knowledge about how the universe works is one in which
10 models are proposed, tested, and refined. Confirming these explanations is distinct
11 from generating new ones¹. Conflating these two processes, confirmation and
12 exploration, is easy to do. It is also rewarded in scientific communication because it
13 makes an explanation appear to be more credible than it really is. This is so because
14 when we use data to help make an explanation (a hypothesis) and then use that
15 same data to confirm that hypothesis, we fall victim to circular reasoning that
16 invalidates the test. Preregistration specifies in advance how data will be analyzed
17 and thus separates the process of making an explanation from the process of
18 confirming that explanation.

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20 Another common problem is a lack of transparency in how science is conducted.
21 Sharing data, analysis code, or detailed methodologies is still the exception, not the
22 rule. While few casual readers value such details, they are essential for truly
23 understanding, replicating, or building upon any scientific finding.

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25 Finally, systematic evaluation of any scientific claim is difficult or impossible
26 because of the well known bias against publishing null results². This bias results in a
27 body of literature that does not accurately represent what we know³.

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29 The combination of these three problems, conflating exploration and confirmation,
30 incomplete methods reporting, and biased reporting of results, results in a body of
31 scientific evidence that is less reproducible than it should be⁴⁻⁸. Conducting direct
32 replications of published studies is difficult, because there is little reward in doing
33 so. Furthermore, replication studies that do not have similar findings to the original
34 article create tension between the original and replication results. However, direct
35 replications are the best way to evaluate the credibility of any scientific claim⁹.
36 Having a productive conversation about scientific claims cannot take place without
37 more openness into the process of science and removing bias from the publication
38 workflow.

Increasing the transparency of science requires change, which is a slow process. However, there are easy first steps that we can take, and the Transparency and Openness Promotion (TOP) Guidelines¹⁰ provide this map. The TOP Guidelines consist of eight policies that can be applied by journals, publishers, and funders. Each standard is modular and can be implemented independent of any other standard. The standards include language for data citation principles; data, materials, and code transparency; reporting guidelines; preregistration; and replication.

Crucially, each standard is tiered into three levels of increasing rigor. This simultaneously lowers barriers to adoption, while providing recommendations for future, more ideal actions. At the first level, journals can require disclosure of transparent research practices. In this level, a researcher simply must state whether or not data, for example, are available, and if so, provide a link to an appropriate data repository. Higher levels of TOP policies either mandate transparency (for example, require data sharing when ethically possible) or include independent verification (for example, verification of the dataset during peer review). The complete policy language for each standard is available and free to use at <https://cos.io/top>.

Preregistration is one standard that is not widely practiced outside of the clinical sciences. Fears about preregistration are that it is overly burdensome¹¹ or devalues exploratory research¹². Transparent reporting of preregistered research with clear delineation of any unexpected, unregistered analyses address the latter fear¹³. As for the former, building an easy to use workflow can help the researcher plan their study while simultaneously creating a persistent registration. Better planning puts some more work upfront, but pays dividends later on. This is what we created as part of our ongoing education campaign, the Preregistration Challenge¹⁴. The workflow, available on the Open Science Framework (OSF) at <https://osf.io/prereg>, walks researchers through the creation of a completely pre-specified study and analysis plan. Preregistrations can be made public immediately, or entered into an embargo of up to 4 years. Publicly available preregistrations are discoverable through the OSF Registry.

There is one solution that builds upon preregistrations and removes bias from the publication process. Registered Reports¹⁵ are a publishing format in which a preregistration is submitted for peer review and improvement before conducting the study^{16,17}. These preregistrations, which are essentially proposals with very detailed analysis plans, are initially evaluated on 1) the importance of the questions to the field, and 2) the ability of the proposed methods and analyses to address

those questions. Only if both of those conditions are met, a study is granted “in principle acceptance” (IPA) before results are known. The final publication decision relies on a second, shorter round of peer review where adherence to the accepted protocol and the successful completion of any outcome-independent quality checks (e.g. positive controls or manipulation checks) is evaluated. Those quality checks ensure that the study was conducted in a competent manner, in order to ensure that any null results are more likely to be “true negatives.” Final studies are published without regard to perceived impact or significance, which are not relevant to the scientific validity of any finding.

Finally, a common concern about implementing new policies is the burden placed on authors and journals for compliance with new mandates. Fortunately, there is an easy way to change behavior without the burden of regulatory oversight. Allowing researchers to signal to their peers adherence to ideal scientific practices is effective at spurring behavior change. Open Science Badges¹⁸ are effective at increasing transparency¹⁹ and are the only evidence-based incentive program beyond mandates that result in more data sharing²⁰. If complete transparency were to become part of normal scientific practice, badges may no longer be necessary. Until that utopian ideal is achieved, they are both effective and avoid the understandable hesitancy to impose a mandate.

Two goals of the open science movement are to increase clarity and decrease bias from the research workflow. Rewarding researchers for practicing behaviors that align with these values will allow science to occur as it should occur. The motto of the Royal Society, “Nullius in verba” (“Take nobody's word for it”)²¹, professes that evidence should be transparently evaluated. Up until recently, this was not possible. Given the ubiquity of effective tools for enabling ideal scientific practices, only our inertia is to blame for the status quo. Please take this article as a standing invitation to assist any stakeholder with implementing solutions that improve the openness, transparency, or reproducibility of science.

Conflicts of Interest: DTM is an employee of the Center for Open Science (COS) (<https://cos.io>), a non-profit company that builds the open source Open Science Framework (OSF) (<https://osf.io>) and advocates for policies and practices discussed in this article.

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