Lecture 12
Reproducible research

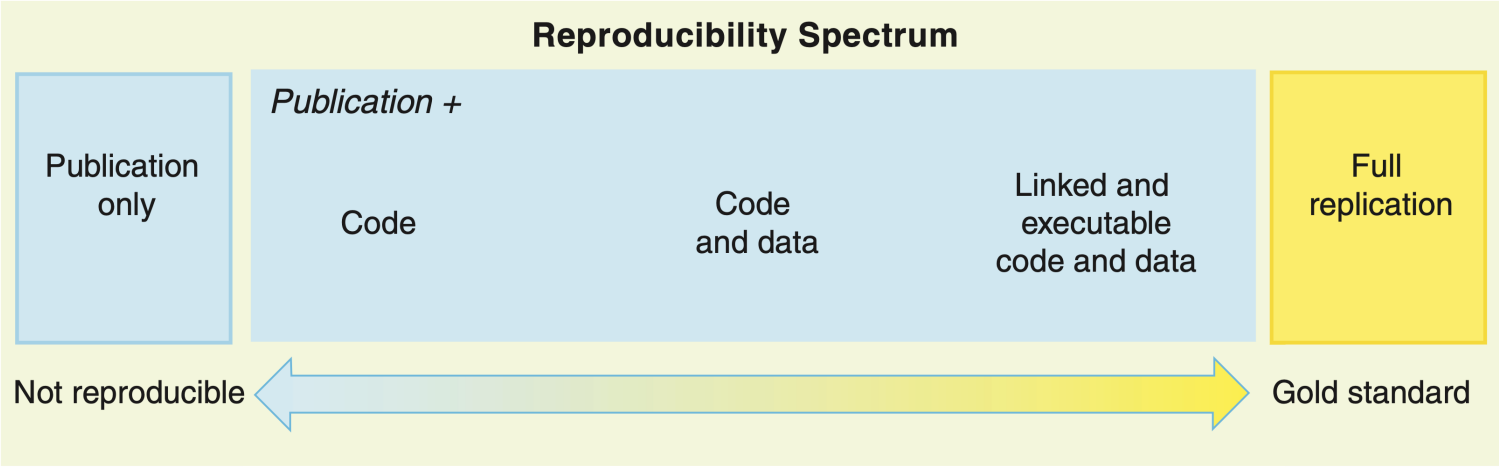
Chao Song

College of Ecology
Lanzhou University

November 24, 2022

What is reproducible research?

- **Reproducibility**: results obtained by a study can be achieved again with a high degree of reliability when the study is replicated.
- Reproducibility is the cornerstone of science. It is why science is **credible** and **useful**.



(Peng 2011, Science)

What is reproducible research?

- Reproducibility contains many aspects:
  - Methods reproducibility: provide enough detail so the procedures could be exactly repeated.
  - Results reproducibility: obtain similar results from an independent study with same procedures as original experiment.
  - Inferential reproducibility: draw the same conclusions from either an independent replication or a reanalysis of the original experiment.

- Reproducibility is often used in the narrow sense of "**computational reproducibility**": obtaining the same results given original data, code, and documentation.

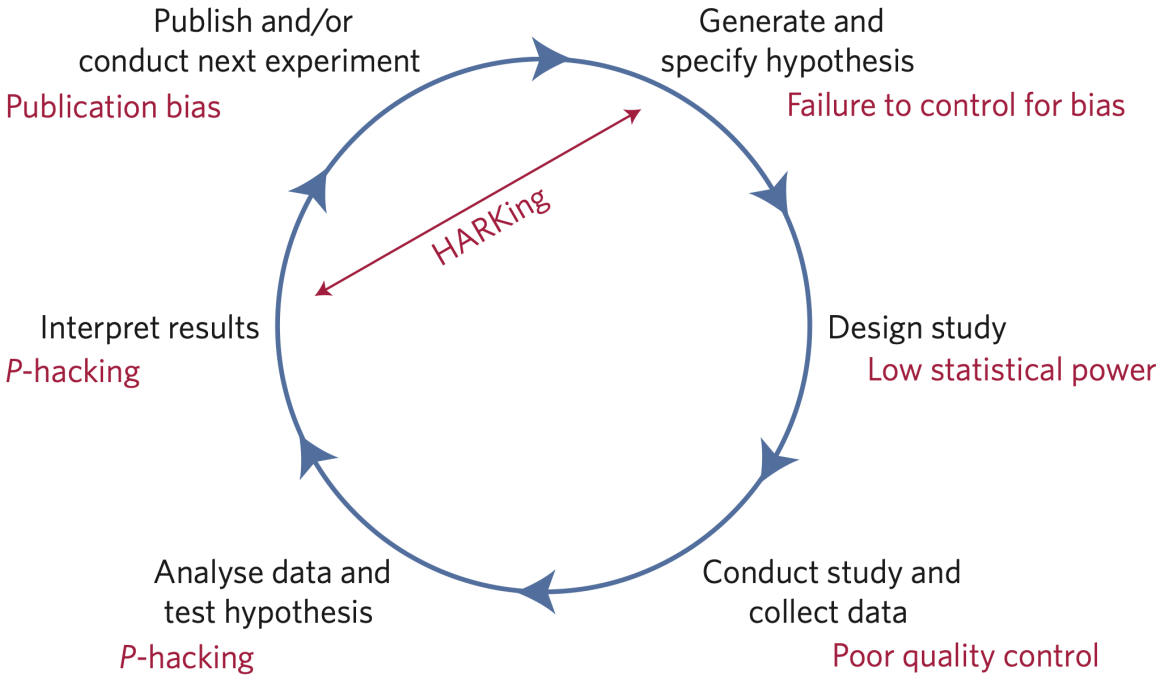
Benefits of reproducible research

- Reproducible research benefits you:
  - helps you remember how and why you performed specific analyses
  - enables you to quickly and simply modify analyses and figures
  - enables quick reconfiguration of previously conducted research tasks for new research
  - is a strong indicator to fellow researchers of rigor, trustworthiness, and transparency

- Reproducible research benefits the research community:
  - Allows others to learn from your work
  - Help others understand your work
  - Allows others to protect from your mistakes

Reproducibility crisis

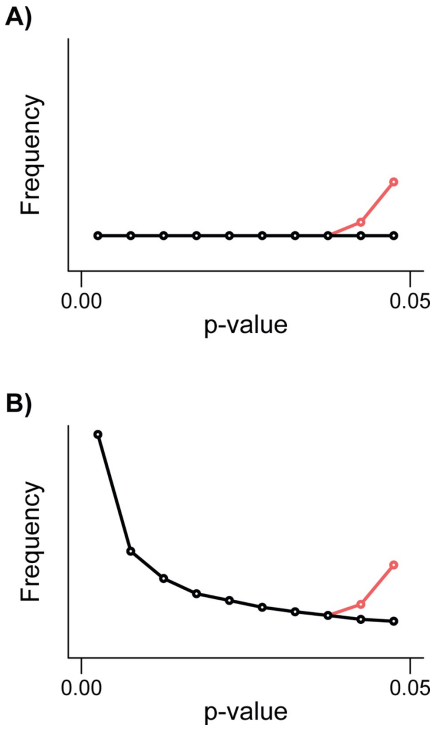
- Reproducibility is threatened by many questionable practices in the scientific research process.

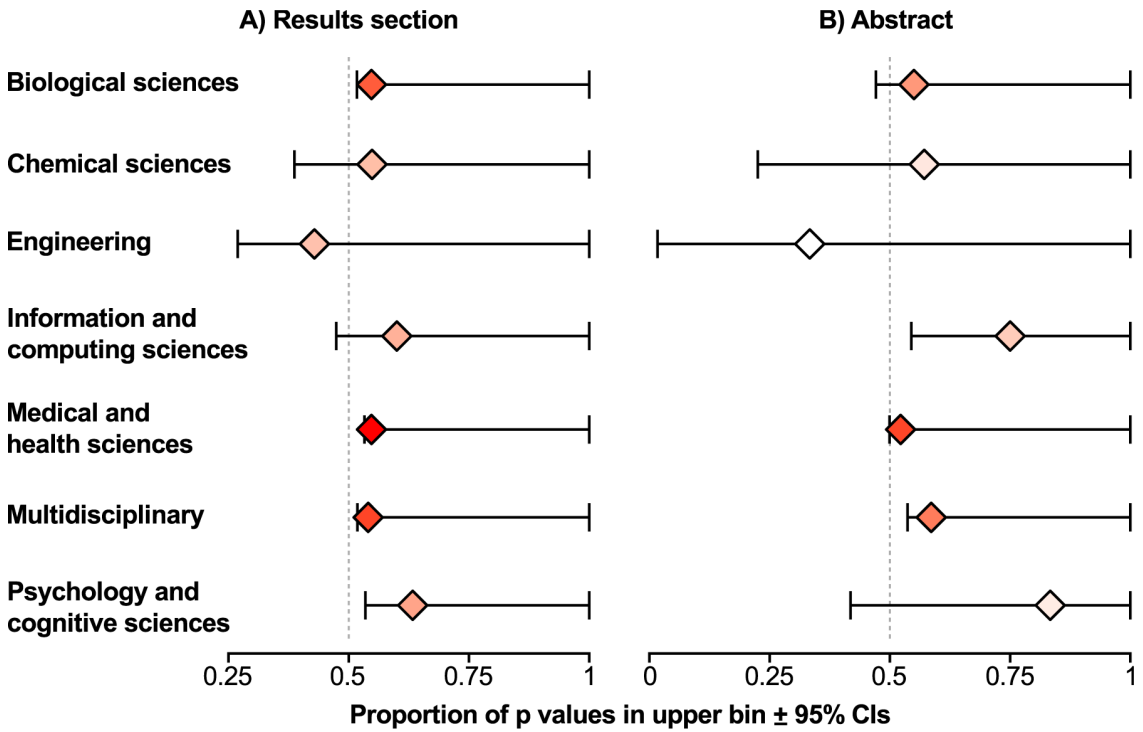


(Munafò et al 2017, Nature Human Behavior)

“P-hacking”

- **“P-hacking”** occurs when researchers try out several statistical analyses and/or data eligibility specifications and then selectively report those that produce significant results

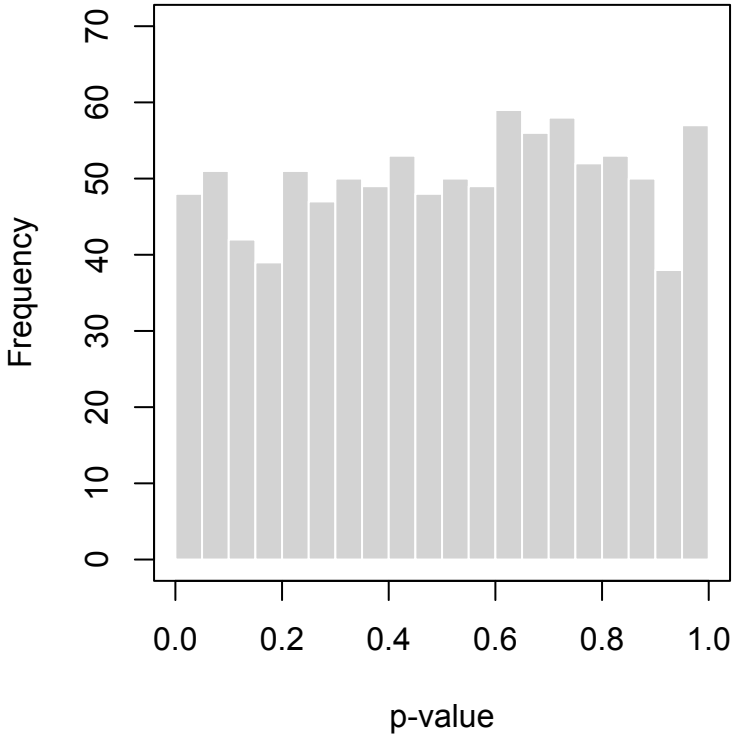




(Head et al 2015, PLOS Biology)

“Fishing expedition”

- **“Fishing expedition”** occurs when researchers indiscriminately examine associations between different combinations of variables not with the intention of testing a priori hypotheses but with the hope of finding something statistically significant.



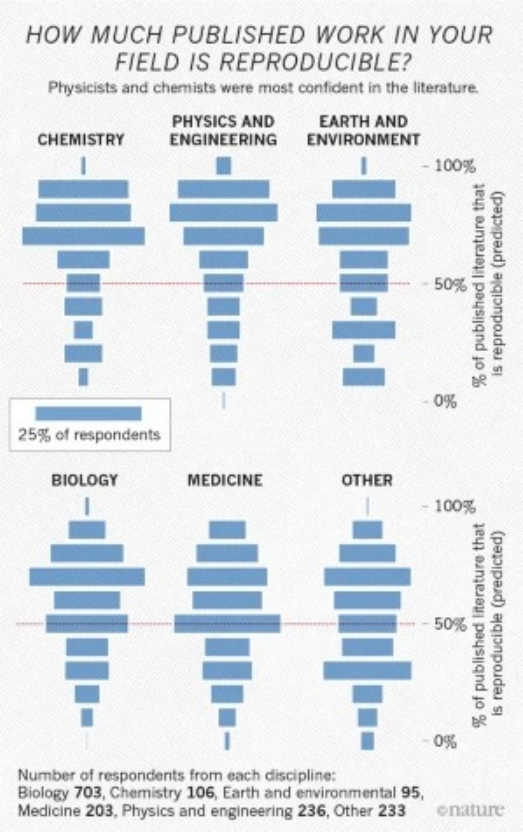
Relationship between two unrelated variables

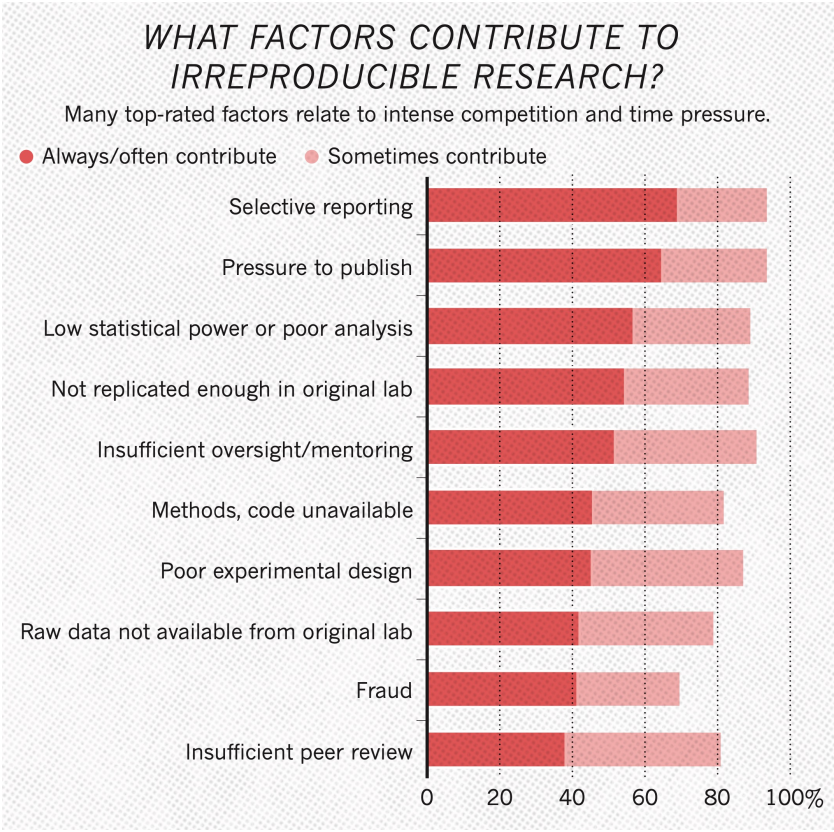
```
#Response sampled from standard normal distribution#
response <- rnorm(20,0,1)
#Vector to store p-values#
p <- numeric(length=1000)

for(i in 1:1000){
    #Predictor sampled from standard normal distribution#
    predictor <- rnorm(20,0,1)
    #Linear regression between response and preidictor#
    mod <- lm(response~predictor)
    #Extract p-value from regression testing slope=0#
    p[[i]] <- summary(mod)$coefficients[4]
}
```

Reproducibility crisis

- Perceived reproducibility varies among fields.
- Many factors contribute to irreproducible research.

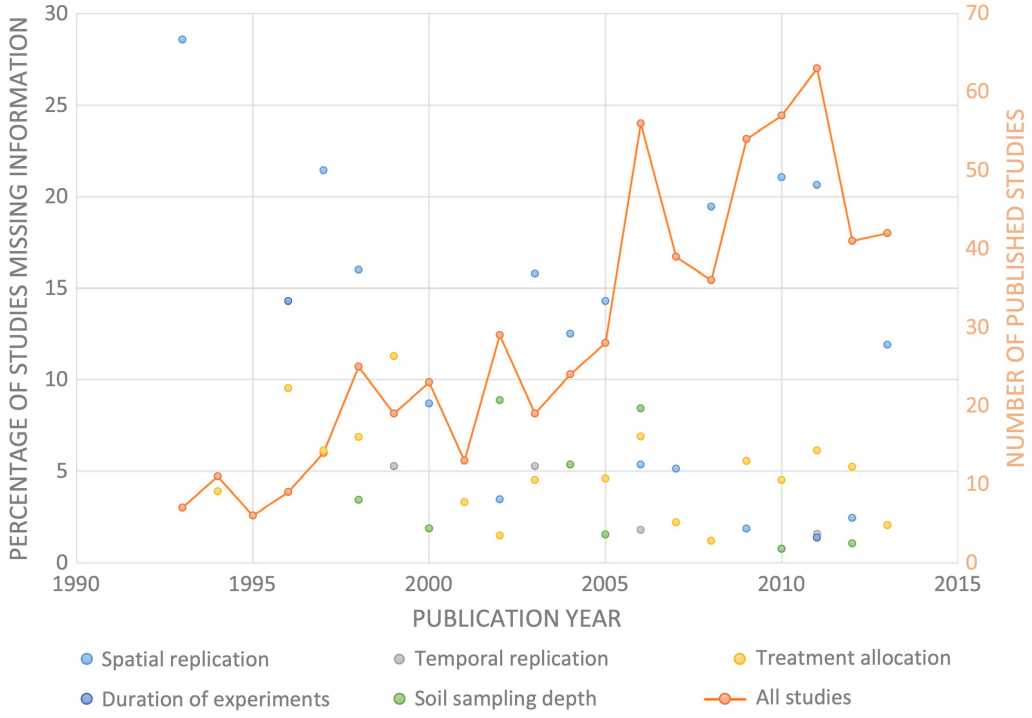




(Baker 2016, Nature)

Reproducibility crisis

- Many publications missing critical information in the methods.
- Example: in a systematic review of the impacts of agricultural management on soil organic carbon, 13% of studies per year did not report sample size.



(Haddaway and Verhoeven 2015, Ecology and Evolution)

Recommendations on methods reporting

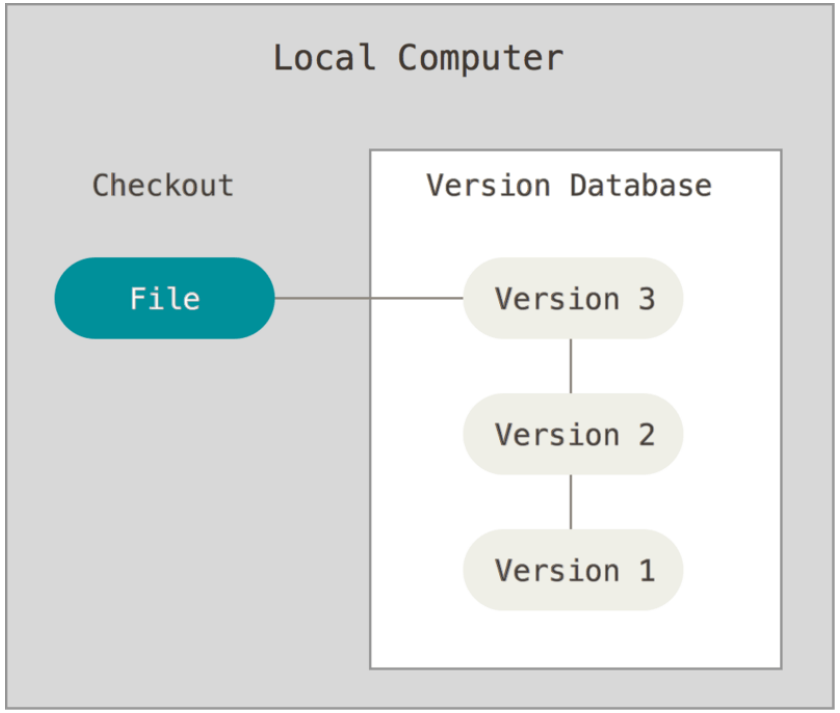
- Experimental setting
- Study dates and duration
- Sample selection and treatment allocation
- Level of true replication
- Level of subsampling
- Sampling precision
- Study spatial scale
- Study design (before–after, blocking, etc)
- Outcome measurements method and equipment
- Description of any data manipulation, modeling and statistical analysis

Improve computational reproducibility

- The key to improving computational reproducibility is to be open and transparent about your data and analysis;
- Lots of efforts in the research community were spent on facilitating data and code availability;
- We should strive to make data and code available and well documented so that it is accessible to the broad scientific community.

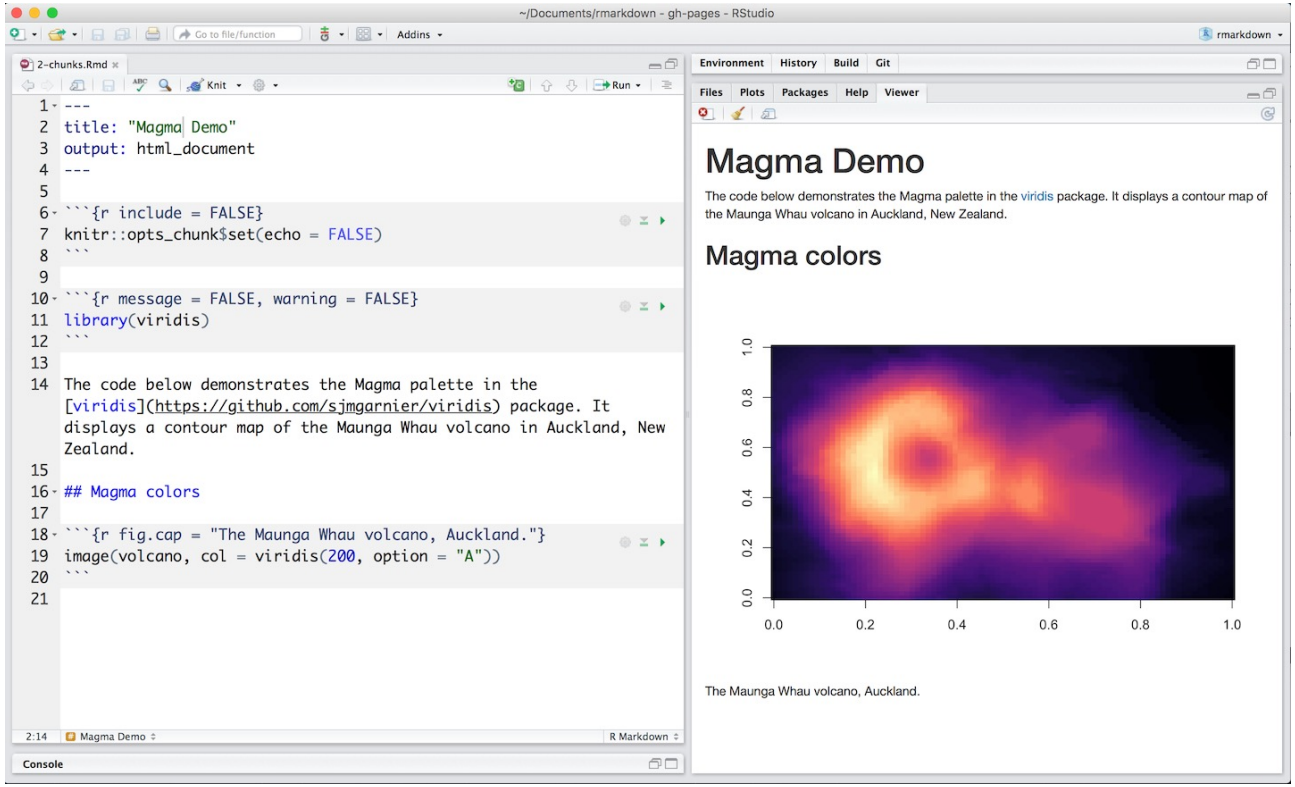
Tools for computational reproducibility

- Version control using git: this allows you to go back and forth between versions, and allows for each collaboration.
- Version control can be integrated with online services like GitHub or Gitee.



Tools for computational reproducibility

- Writing dynamic documents using R Markdown, Sweave, Jupyter Notebook or similar tools.
- They allow you to combine text and programing code in a single document.



Recommended practice

- Make data and code available
  - Submit data as supplementary information of a paper
  - Use data repository: Dryad, figshare, Zenodo, Open Science Framework
- Share research
  - Preprint server: ArXiv, bioRxiv, EcoEvoRxiv
- Document data and code well
  - Follow good coding style (R coding style)
  - Always provide metadata
- Make data and code accessible
  - Use non-proprietary file format
  - Ensure consistent appearance (embed font, use PDF)

A manifesto for reproducible science

Table 1 | A manifesto for reproducible science.

Theme	Proposal	Examples of initiatives/potential solutions (extent of current adoption)	Stakeholder(s)
Methods	Protecting against cognitive biases	All of the initiatives listed below (* to ****) Blinding (**)	J, F
	Improving methodological training	Rigorous training in statistics and research methods for future researchers (*) Rigorous continuing education in statistics and methods for researchers (*)	I, F
	Independent methodological support	Involvement of methodologists in research (**) Independent oversight (*)	F
	Collaboration and team science	Multi-site studies/distributed data collection (*) Team-science consortia (*)	I, F
Reporting and dissemination	Promoting study pre-registration	Registered Reports (*) Open Science Framework (*)	J, F
	Improving the quality of reporting	Use of reporting checklists (**) Protocol checklists (*)	J
	Protecting against conflicts of interest	Disclosure of conflicts of interest (***) Exclusion/containment of financial and non-financial conflicts of interest (*)	J
Reproducibility	Encouraging transparency and open science	Open data, materials, software and so on (* to **) Pre-registration (**** for clinical trials, * for other studies)	J, F, R
Evaluation	Diversifying peer review	Preprints (* in biomedical/behavioural sciences, **** in physical sciences) Pre- and post-publication peer review, for example, Publons, PubMed Commons (*)	J
Incentives	Rewarding open and reproducible practices	Badges (*) Registered Reports (*) Transparency and Openness Promotion guidelines (*) Funding replication studies (*) Open science practices in hiring and promotion (*)	J, I, F

Estimated extent of current adoption: *, <5%; **, 5–30%; ***, 30–60%; ****, >60%. Abbreviations for key stakeholders: J, journals/publishers; F, funders; I, institutions; R, regulators.

(Munafò et al 2017, Nature Human Behavior)