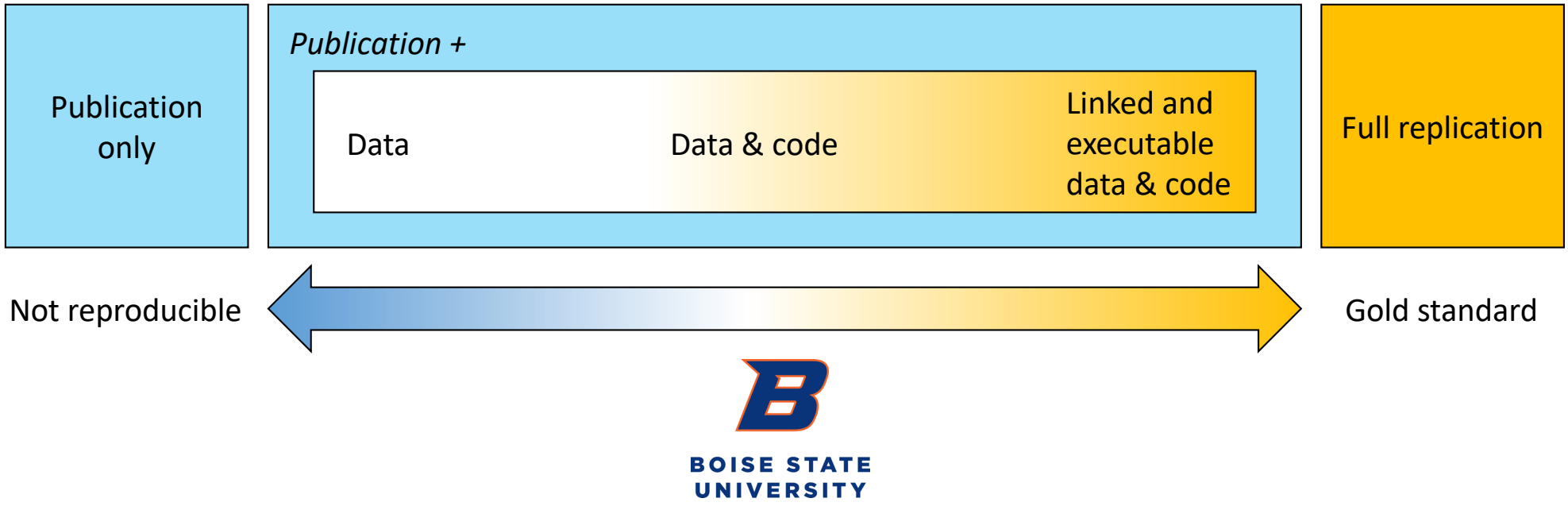
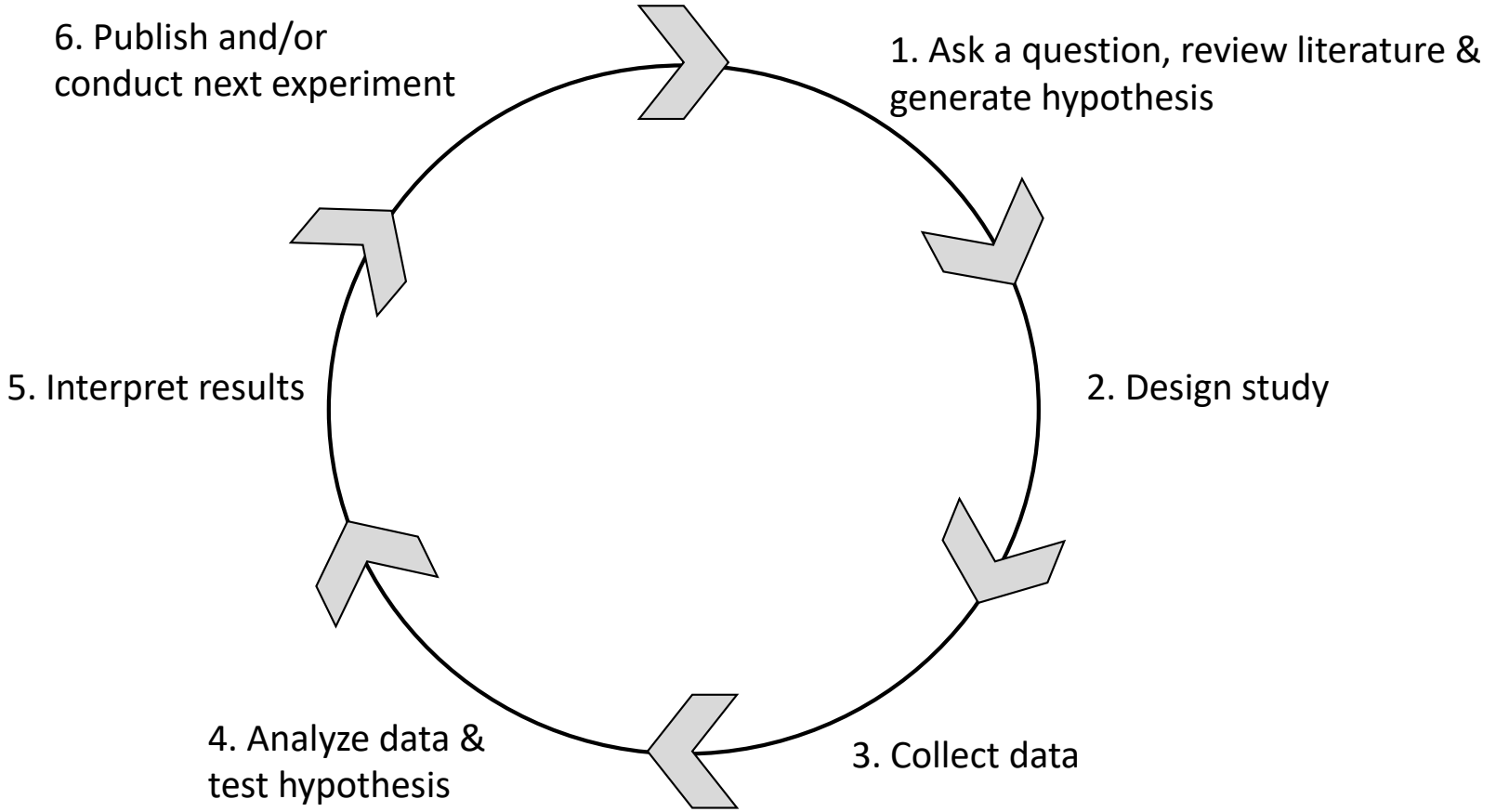
EEB 603 – A road map to implement reproducible science in Ecology & Evolution



BOISE STATE UNIVERSITY

THE SCIENTIFIC PROCESS



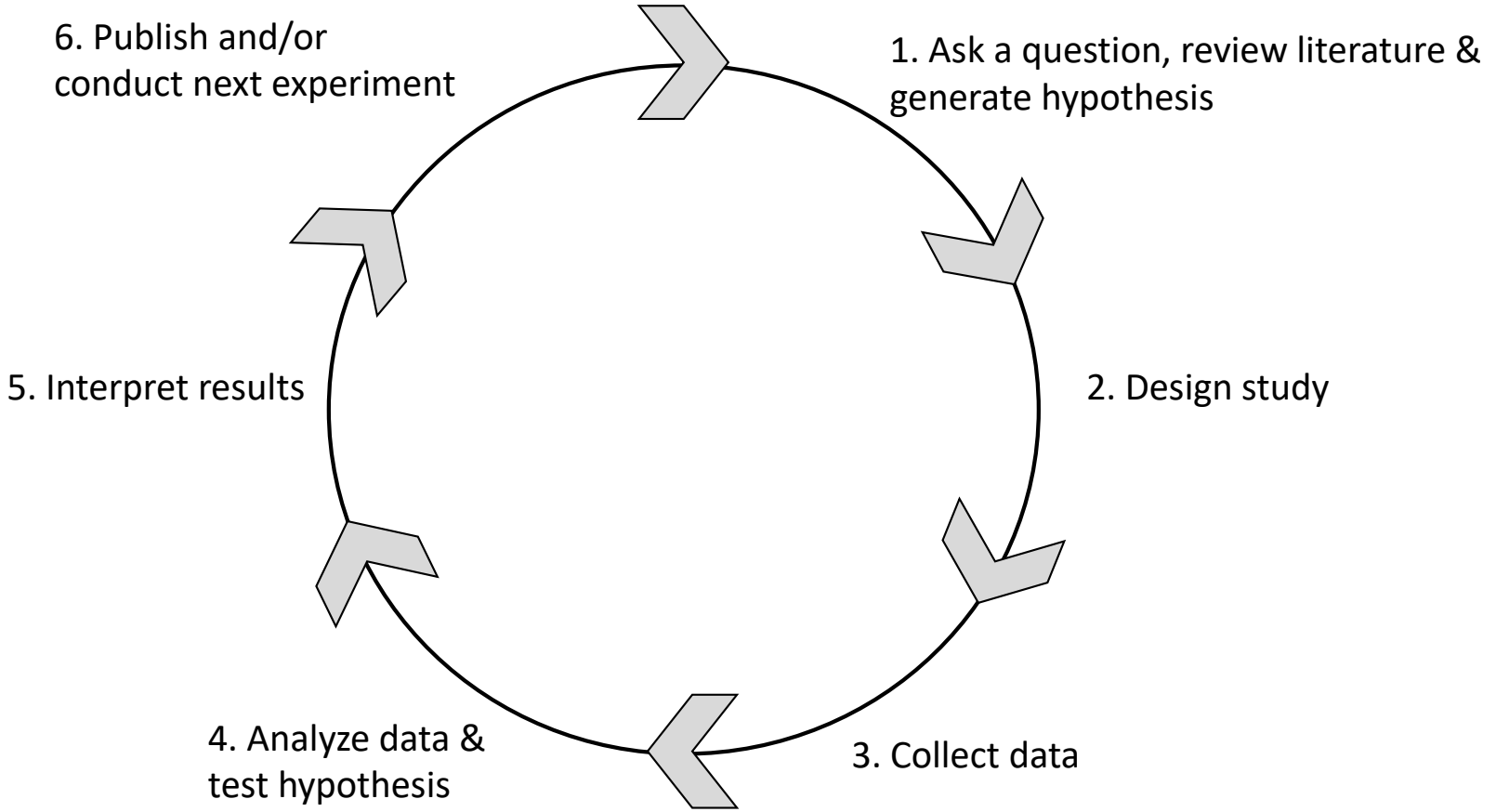
WHAT IS A HYPOTHESIS?

- A **hypothesis** is a tentative, **testable answer to a scientific question**.
- Use question to perform a literature review to establish baseline information on the topic.
- Use evidence from literature review to articulate a hypothesis, which tentatively answers your scientific question.
- The hypothesis must be testable since the next step will be to conduct an experiment to determine the validity of the hypothesis.

WHAT IS A HYPOTHESIS?

- A hypothesis leads to one or more predictions that can be tested by experimenting.
- Predictions often take the shape of "If … then … " statements, but do not have to.
- Predictions should include both an independent variable (the factor you change in an experiment) and a dependent variable (the factor you observe or measure in an experiment).
- A single hypothesis can lead to multiple predictions.

THE SCIENTIFIC PROCESS

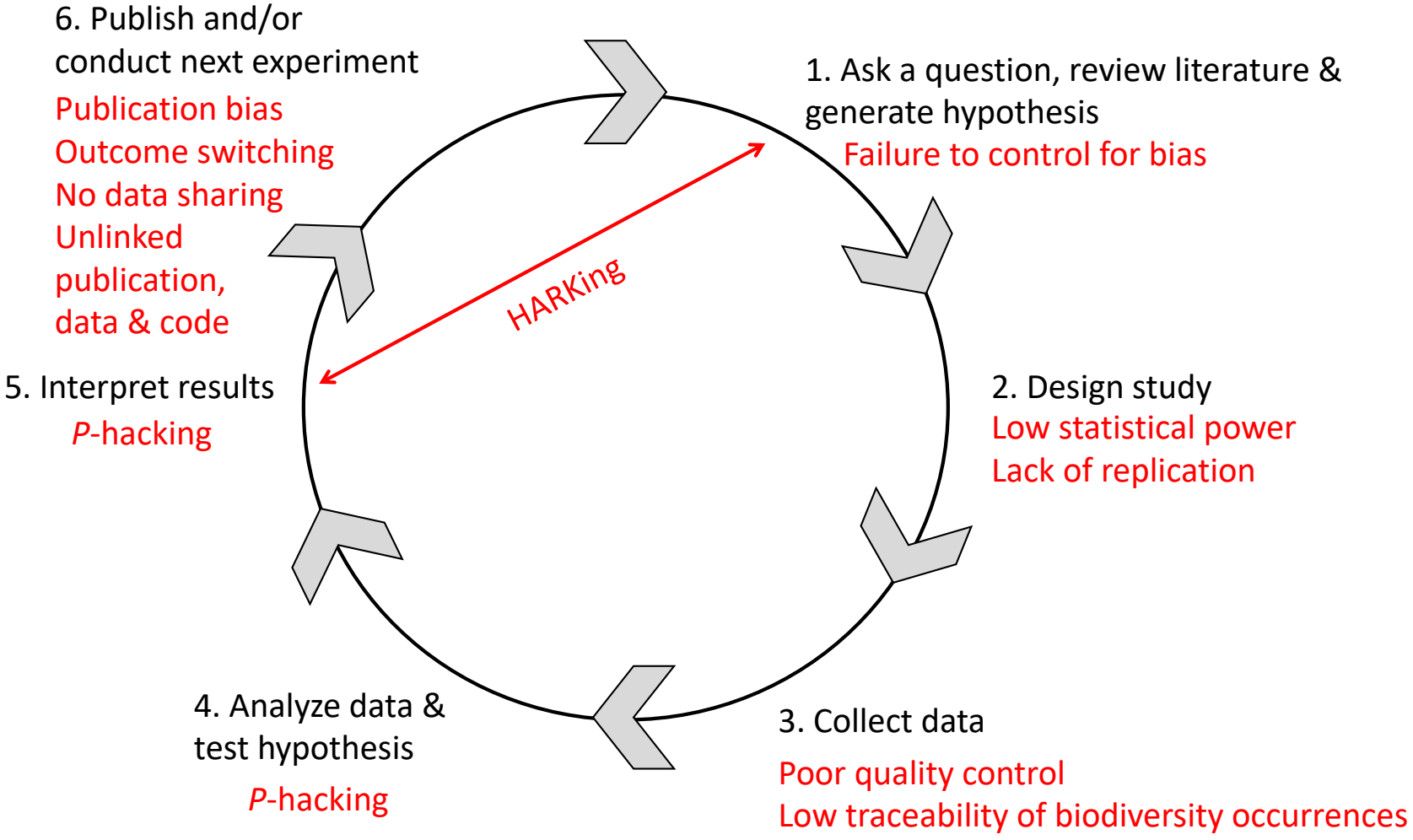


THREATS TO THE SCIENTIFIC PROCESS

"The first principle is that you must not fool yourself – and you are the easiest person to fool." Richard Feynman

Richard Feynman (1918-1988) was one of the great scientists and physicists of our time. He won a Nobel Prize for his work in developing an understanding of quantum mechanics.

THREATS TO THE SCIENTIFIC PROCESS



DEFINITIONS OF THE THREATS

- **HARKing:** HARKing (**h**ypothesizing **a**fter the **r**esults are **k**nown) is defined as presenting a *post hoc* hypothesis (i.e., one based on or informed by one's results) in one's research report as if it were, in fact, an *a priori* hypothesis.

DEFINITIONS OF THE THREATS

- ***P*-hacking:** also known as "Data dredging" is the misuse of data analysis to find patterns in data that can be presented as statistically significant when in fact there is no real underlying effect.
- ***P*-hacking** is done by **performing many statistical tests on the data and only paying attention to those that come back with significant results**, instead of stating a single hypothesis about an underlying effect before the analysis and then conducting a single test for it.

DEFINITIONS OF THE THREATS

- **Publication bias:** also known as the file drawer problem, refers to the fact that many more studies are conducted than published. **Studies that obtain positive and novel results are more likely to be published than studies that obtain negative results or report replications of prior results.**

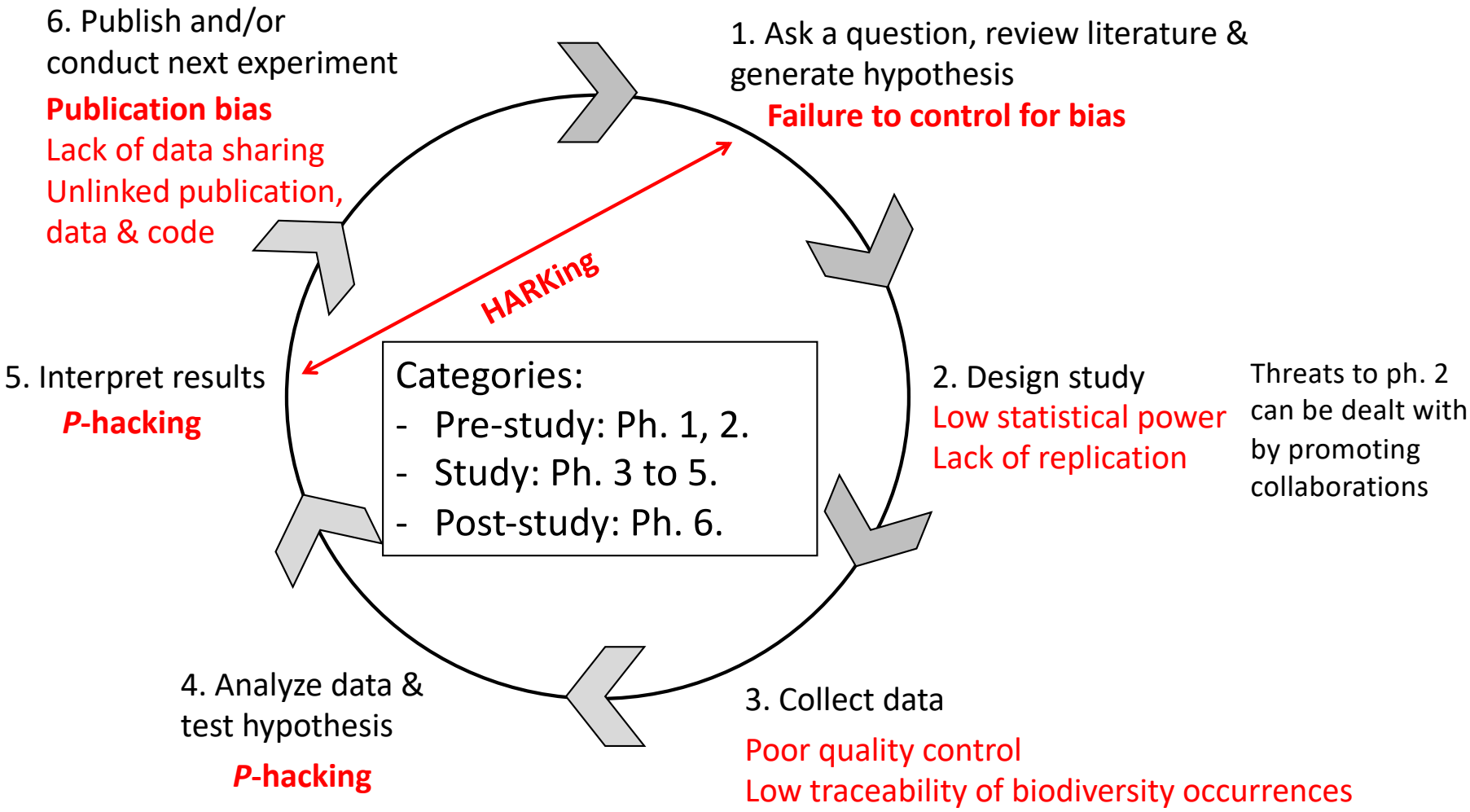
- The consequence that the published literature indicates stronger evidence for findings than exists in reality.

DEFINITIONS OF THE THREATS

- **Outcome switching:** refers to the possibility of **changing the outcomes of interest in the study depending on the observed results**.
- For instance, a researcher may include ten variables that could be considered outcomes of the research, and — once the results are known — intentionally or unintentionally **select the subset of outcomes that show statistically significant results as the outcomes of interest.**
- The consequence of this bias is an increase in the likelihood that reported results are spurious by leveraging chance, while negative evidence gets ignored.

How can we fix these threats?

By splitting the scientific process into 3 categories and writing a study pre-registration (or a research proposal as requested by the EEB program)


6. Publish and/or
conduct next experiment
Publication bias
Lack of data sharing
Unlinked publication,
data & code
1. Ask a question, review literature &
generate hypothesis
Failure to control for bias
HARKing
5. Interpret results
P-hacking
Categories:
- Pre-study: Ph. 1, 2.
- Study: Ph. 3 to 5.
- Post-study: Ph. 6.
2. Design study
Low statistical power
Lack of replication
Threats to ph. 2
can be dealt with
by promoting
collaborations
4. Analyze data &
test hypothesis
P-hacking
3. Collect data
Poor quality control
Low traceability of biodiversity occurrences

PROMOTING STUDY PRE-REGISTRATION

- **Progress in science relies in part on generating hypotheses with existing observations and testing hypotheses with new observations.** This distinction between postdiction (explanation after the facts) and prediction is appreciated conceptually, but it is not respected in practice.
- **An effective solution is to define the research questions and analysis plan before observing the research outcomes—a process called pre-registration.**

PROMOTING STUDY PRE-REGISTRATION

- In its simplest form study pre-registration may simply comprise the registration of the basic study design, but it can also include a detailed pre-specification of the study procedures, outcomes and statistical analysis plan.
- Center for Open Science

What is Preregistration?

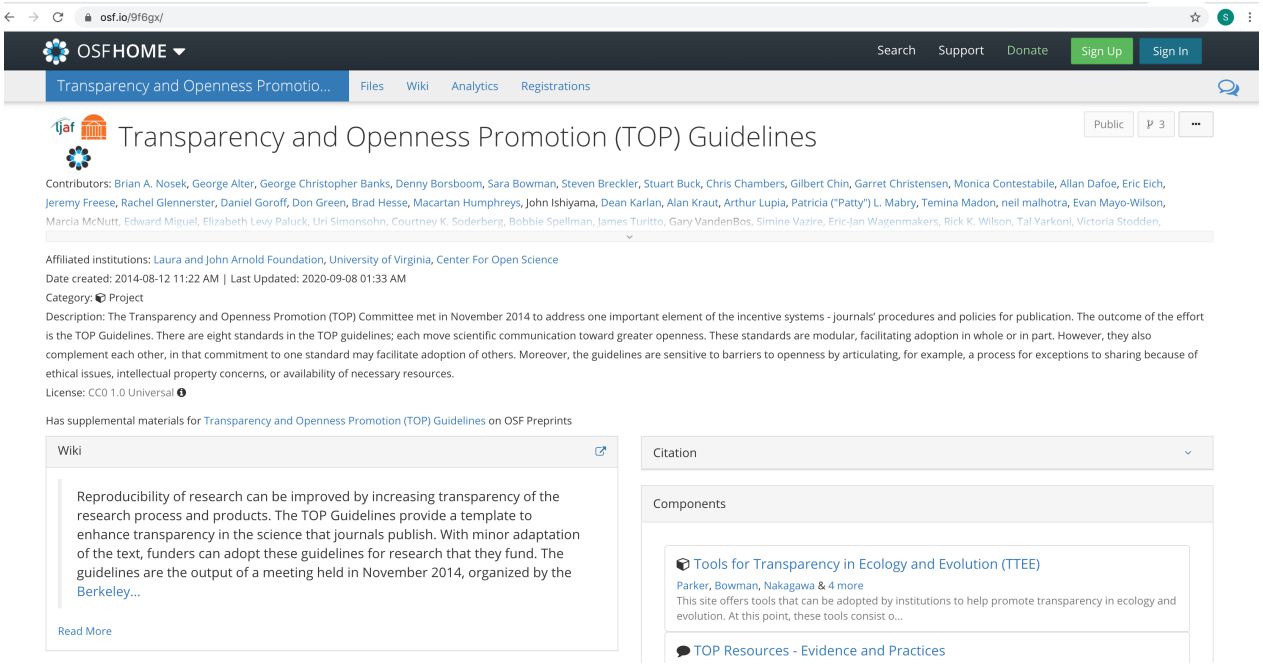
When you preregister your research, you're simply specifying to your plan in advance, before you gather data. Preregistration separates *hypothesis-generating* (exploratory) from *hypothesis-testing* (confirmatory) research. Both are important. But the same data cannot be used to generate and test a hypothesis, which can happen unintentionally and reduce the credibility of your results. Addressing this problem through planning improves the quality and transparency of your research, helping others who may wish to build on it.

For additional insight and context, you can read The Preregistration Revolution.

Pre-registration will improve discoverability of research, but discoverability does not guarantee usability (and transparency)

PROMOTING USABILITY WITH THE TOP GUIDELINES

- **TOP guidelines offer standards as a basis for journals and funders to incentivize or require greater transparency in planning and reporting of research.**



PROMOTING USABILITY WITH THE TOP GUIDELINES

- **TOP guidelines include 8 modular standards, each with three levels of increasing stringency:**
  1. Citation standards (citation of data sets etc.)
  2. Data transparency (data archiving)
  3. Analytic methods (code) transparency (code archiving)
  4. Research materials transparency (materials archiving)
  5. Design and analysis transparency (reporting of details of methods and results)
  6. Pre-registration of studies (registering study prior to initiation)
  7. Pre-registration of analysis plans (registering analysis plan prior to study initiation)
  8. Replication (a study designed to replicate a previously published study)

TOP: Transparency and Openness Promotion

TOP Guidelines summary table.

	Not Implemented	Level I	Level II	Level III
Citation Standards	Journal encourages citation of data, code, and materials, or says nothing.	Journal describes citation of data in guidelines to authors with clear rules and examples.	Article provides appropriate citation for data and materials used consistent with journal's author guidelines.	Article is not published until providing appropriate citation for data and materials following journal's author guidelines.
Data Transparency	Journal encourages data sharing, or says nothing.	Article states whether data are available, and, if so, where to access them.	Data must be posted to a trusted repository. Exceptions must be identified at article submission.	Data must be posted to a trusted repository, and reported analyses will be reproduced independently prior to publication.
Analytic Methods (Code) Transparency	Journal encourages code sharing, or says nothing.	Article states whether code is available, and, if so, where to access it.	Code must be posted to a trusted repository. Exceptions must be identified at article submission.	Code must be posted to a trusted repository, and reported analyses will be reproduced independently prior to publication.
Research Materials Transparency	Journal encourages materials sharing, or says nothing.	Article states whether materials are available, and, if so, where to access them.	Materials must be posted to a trusted repository. Exceptions must be identified at article submission.	Materials must be posted to a trusted repository, and reported analyses will be reproduced independently prior to publication.
Design and Analysis Transparency	Journal encourages design and analysis transparency, or says nothing.	Journal articulates design transparency standards.	Journal requires adherence to design transparency standards for review and publication.	Journal requires and enforces adherence to design transparency standards for review and publication.
Study Preregistration	Journal says nothing.	Article states whether preregistration of study exists, and, if so, where to access it.	Article states whether preregistration of study exists, and, if so, allows journal access during peer review for verification.	Journal requires preregistration of studies and provides link and badge in article to meeting requirements.
Analysis Plan Preregistration	Journal says nothing.	Article states whether preregistration of study exists, and, if so, where to access it.	Article states whether preregistration with analysis plan exists, and, if so, allows journal access during peer review for verification.	Journal requires preregistration of studies with analysis plans and provides link and badge in article to meeting requirements.
Replication	Journal discourages submission of replication studies, or says nothing.	Journal encourages submission of replication studies.	Journal encourages submission of replication studies and conducts results blind review.	Journal uses Registered Reports as a submission option for replication studies with peer review prior to observing the study outcomes.

Adopting journals (>1k) select among the levels based on readiness to adopt milder to stronger transparency standards for authors and researchers.

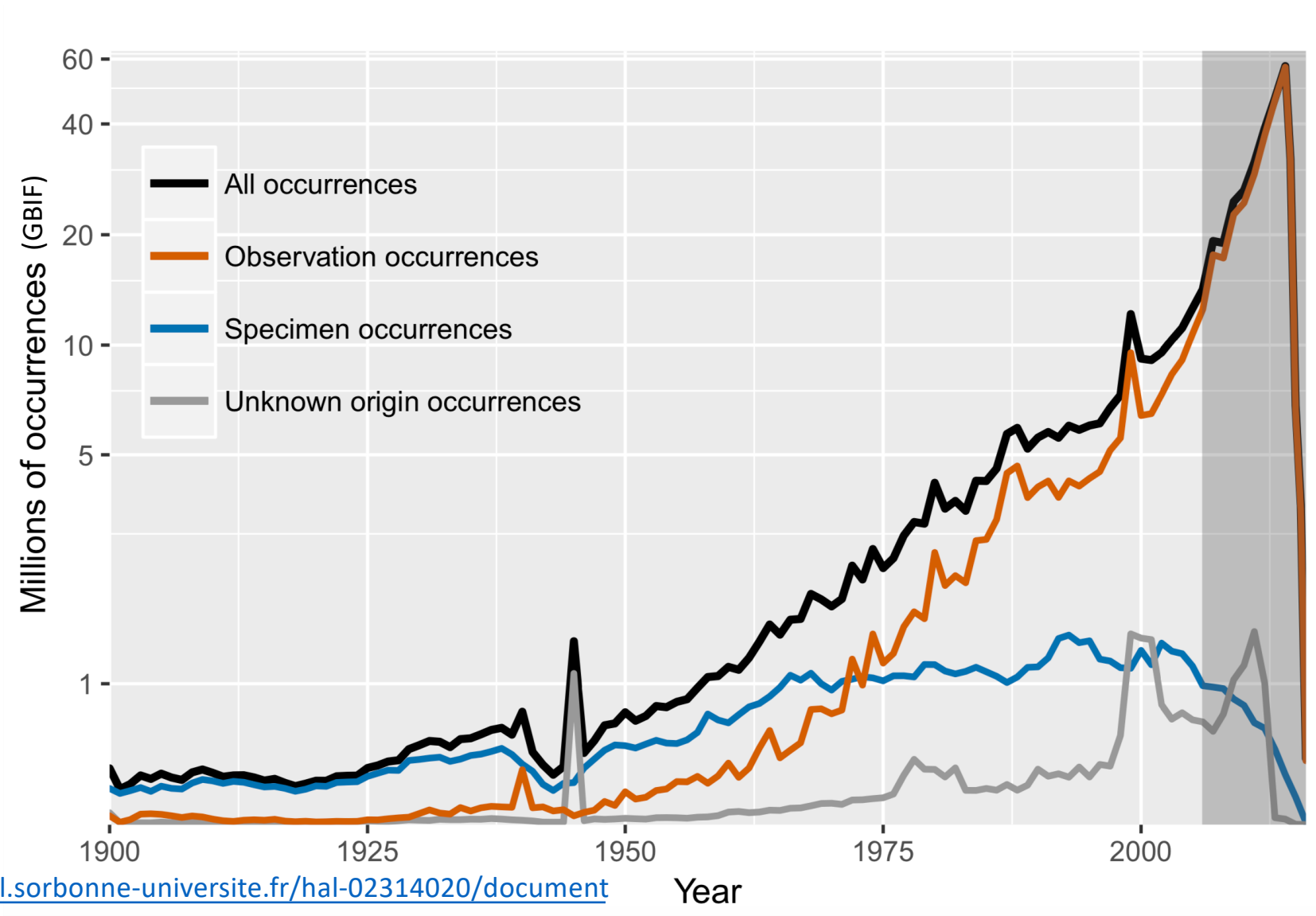
PROMOTING EVIDENCE SUPPORTING BIODIVERSITY DATA

- **Primary biodiversity occurrence data are at the core of our research.** They are, however, no longer gathered as they used to be and the mass-production of observation-based (OB) occurrences is overthrowing the collection of specimen-based (SB) occurrences.

https://hal.sorbonne-universite.fr/hal-02314020/document

PROMOTING EVIDENCE SUPPORTING BIODIVERSITY DATA

- Analyses conducted on 536 million occurrences from GBIF concluded that from 1970 to 2016 the proportion of occurrences marked as traceable to tangible material (SB occurrences) fell from 68% to 18%.
- This alarming trend (i.e. the low traceability of occurrences and therefore the low confidence of species identifications) threatens the reproducibility of biodiversity research.



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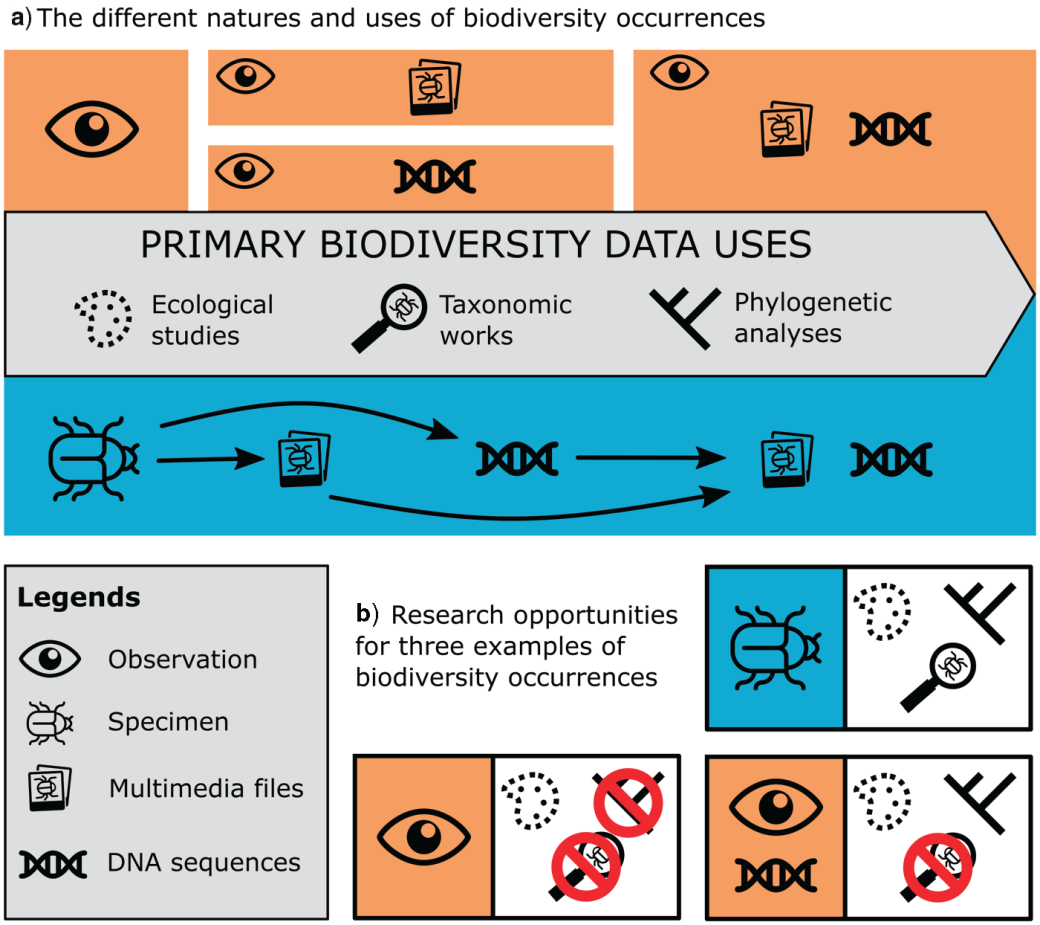
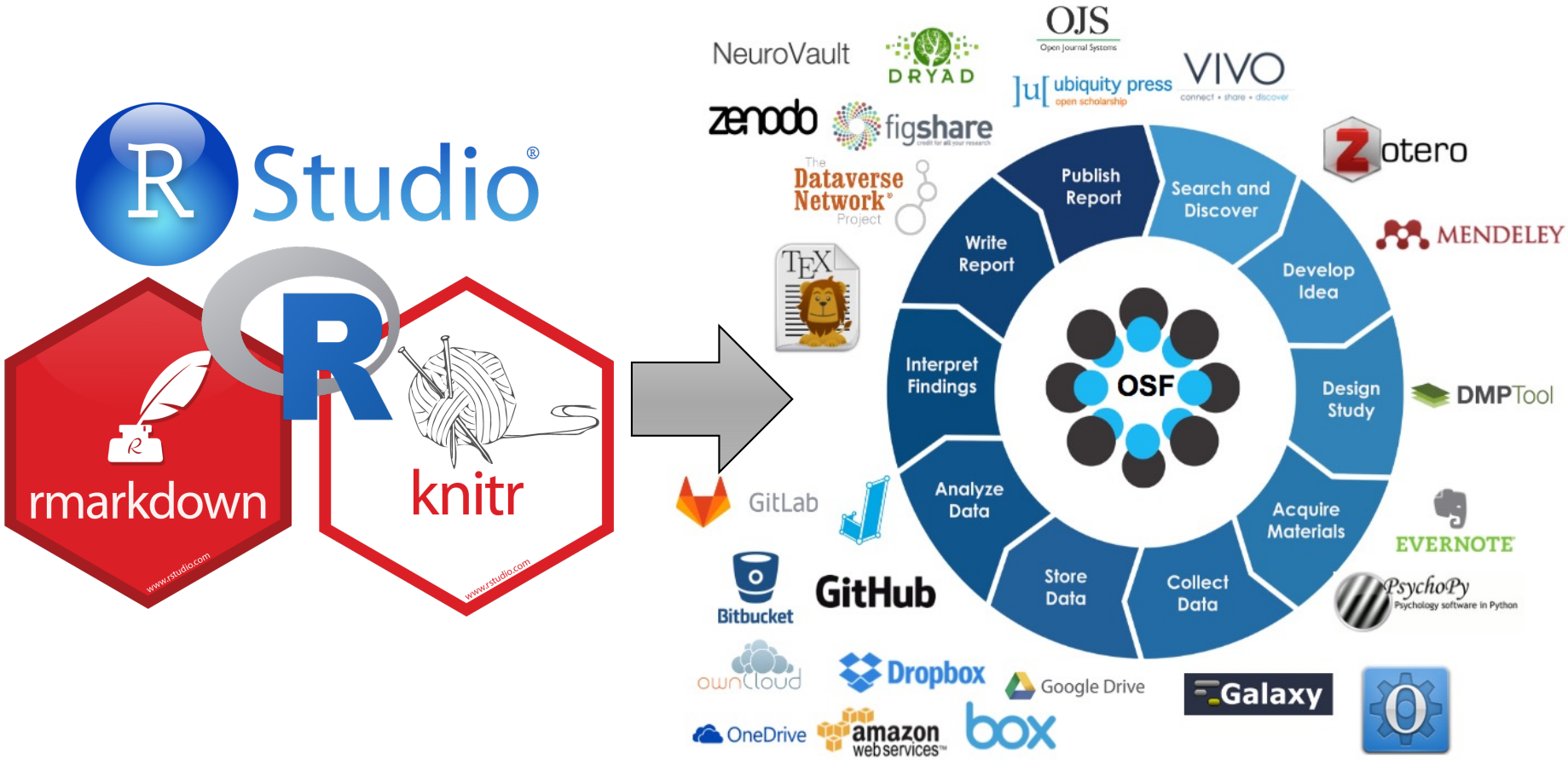
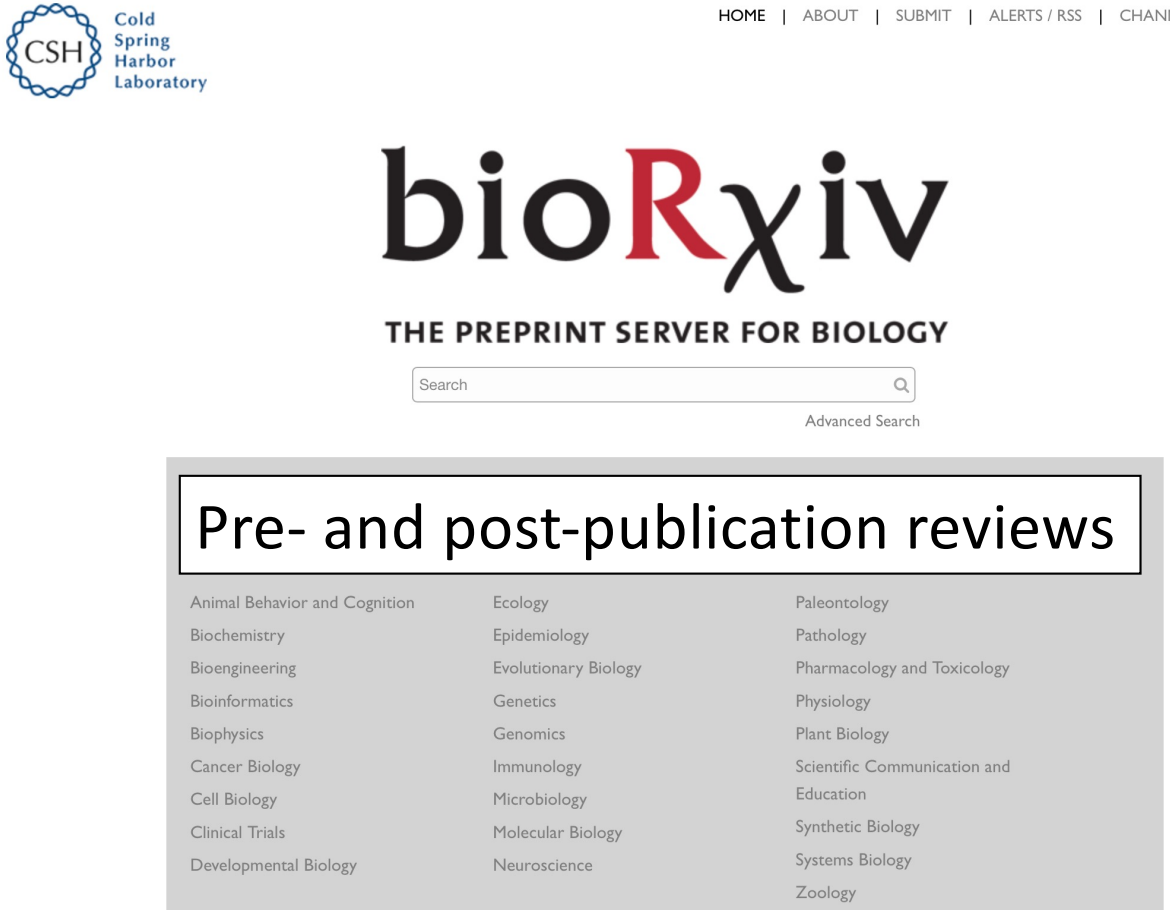
PROMOTING EVIDENCE SUPPORTING BIODIVERSITY DATA



LINKING PUBLICATION, DATA, CODE & ANALYSES



IMPROVING RESEARCH DISSEMINATION & EVALUATION



+ get feedback on your research before submitting paper and after publication

→ This speeds review process and expands it to larger scientific community

PROMOTE TRANSPARENCY & OPEN SCIENCE

frontiers

Funders need to support open science

European funders commit to science without paywalls by 2020

In a bold commitment to Open Access, 11 national research funding organizations, supported by the European Commission and the European Research Council (ERC), have announced their plan to make full and immediate Open Access to research publications a reality.

This coalition of European funders is implementing fundamental principals to mandate that from 1 January 2020, any scientist they fund publishes their research Open Access.