Reproducibility: Promoting scientific rigor and transparency

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What does reproducibility mean?

- Reproducibility is the ability to generate similar results each time an experiment is duplicated.
- Data reproducibility enables us to validate experimental results.
- Reproducibility is a key part of the scientific process; however, many scientific findings are not replicable.

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The Reproducibility Crisis

- ~2010 as part of a growing awareness that many scientific studies are not replicable, the phrase “Reproducibility Crisis” was coined.

- An initiative of the Center for Open Science conducted replications of 100 psychology experiments published in prominent journals. (Science, 349 (6251), 28 Aug 2015)
  - Out of 100 replication attempts, only 39 were successful.

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The Reproducibility Crisis

- According to a poll of over 1,500 scientists, 70% had failed to reproduce at least one other scientist's experiment or their own. (Nature 533 (437), 26 May 2016)

- Irreproducible research is a major concern because in valid claims:
  - slow scientific progress
  - waste time and resources
  - contribute to the public’s mistrust of science

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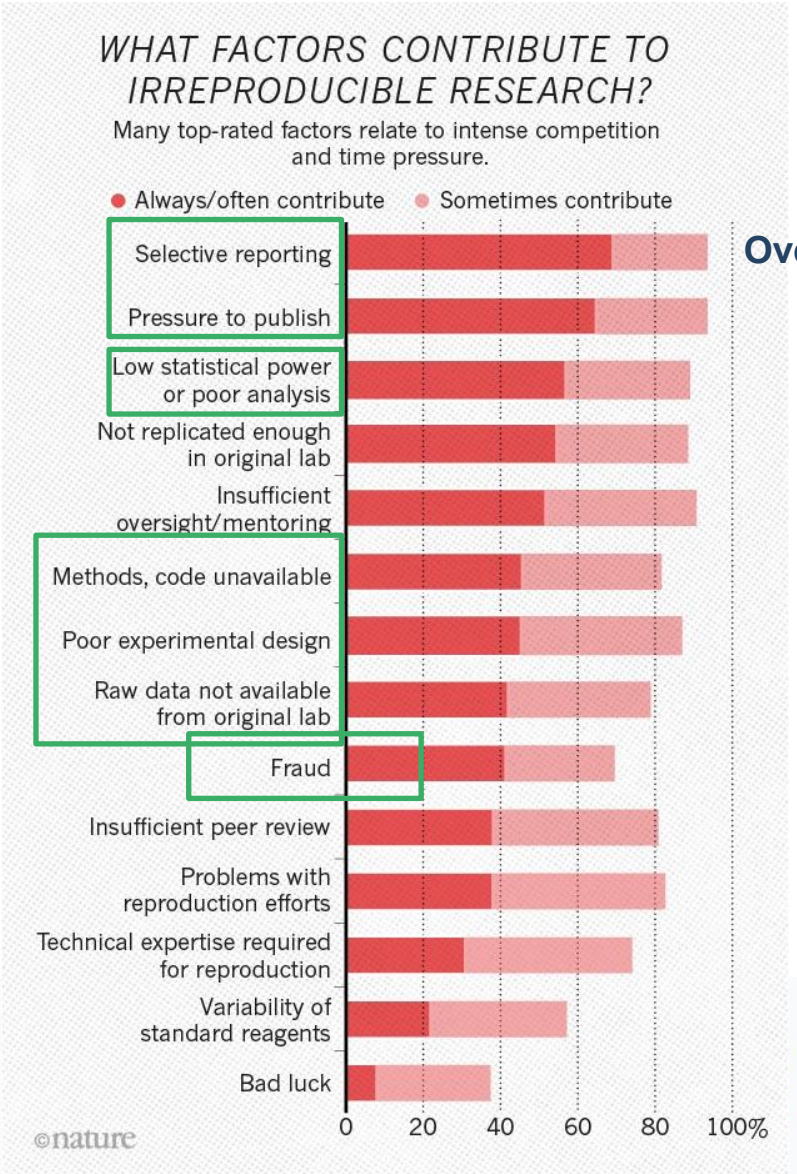
Factors contributing to irreproducibility



Over 80% of respondents

Nature | News Feature 25 May 2016

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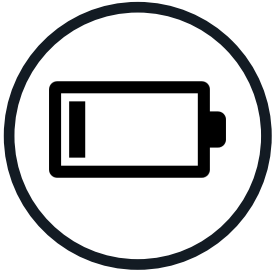
Factors contributing to irreproducibility

Underspecified methods

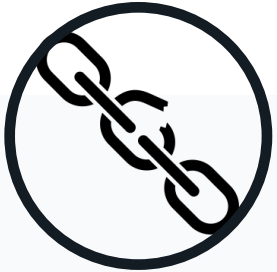
Data dredging/ p-hacking

Low statistical power

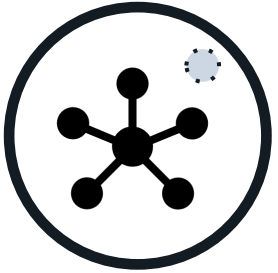


Technical errors

Weak experimental design



Bias - omitting null results



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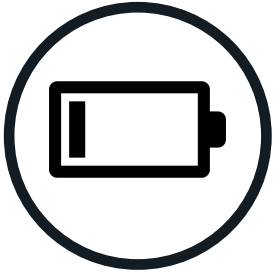

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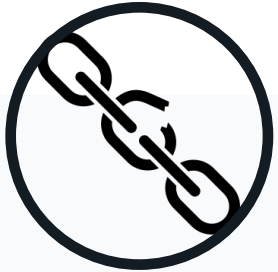

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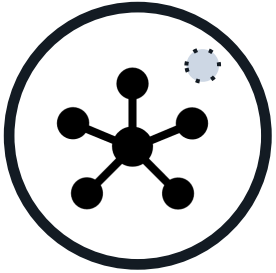

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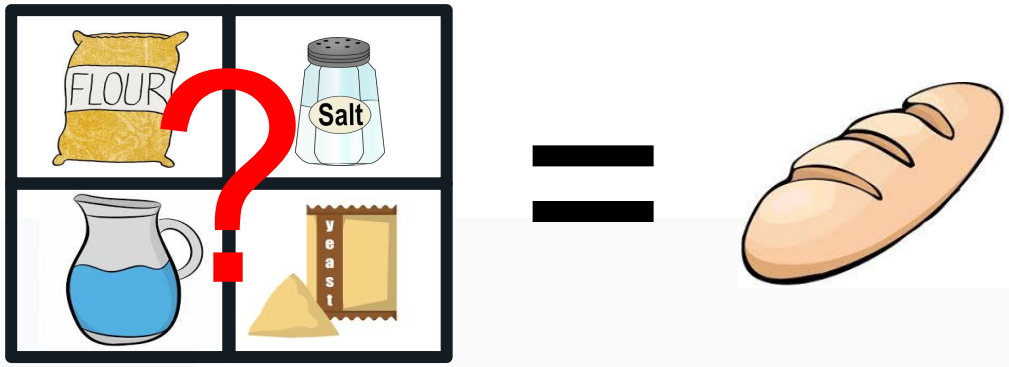
Underspecified methods

- When experimental details are omitted, the procedure needed to reproduce a study isn't clear.

- Underspecified methods are like providing only part of a recipe.



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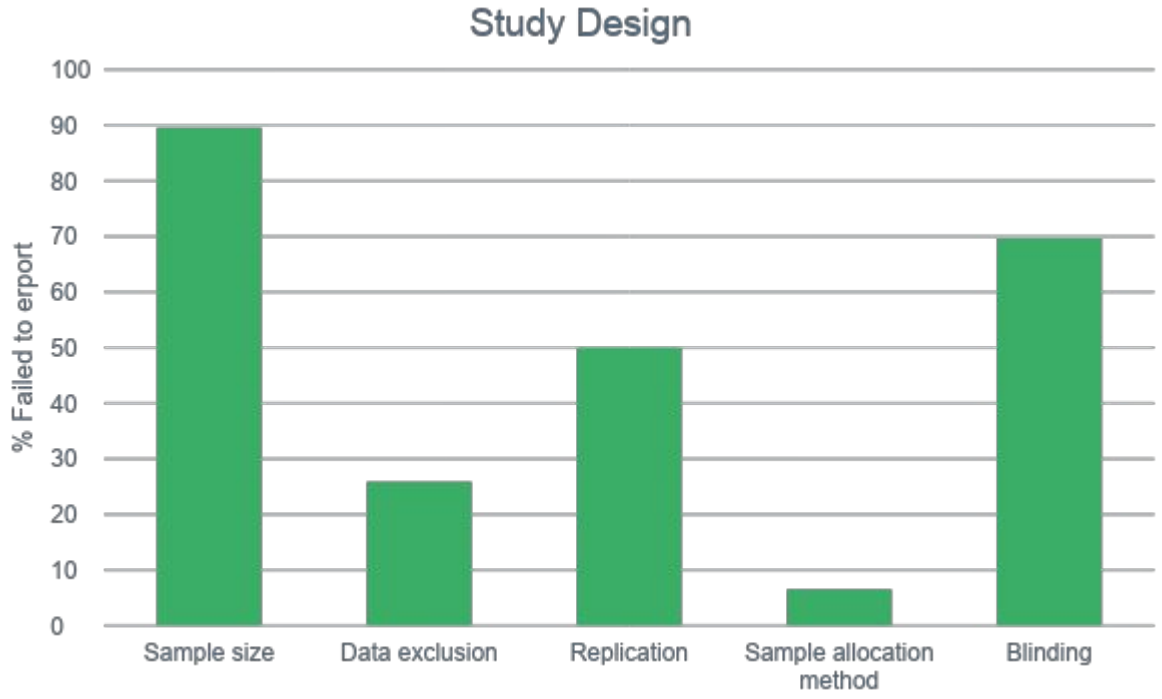

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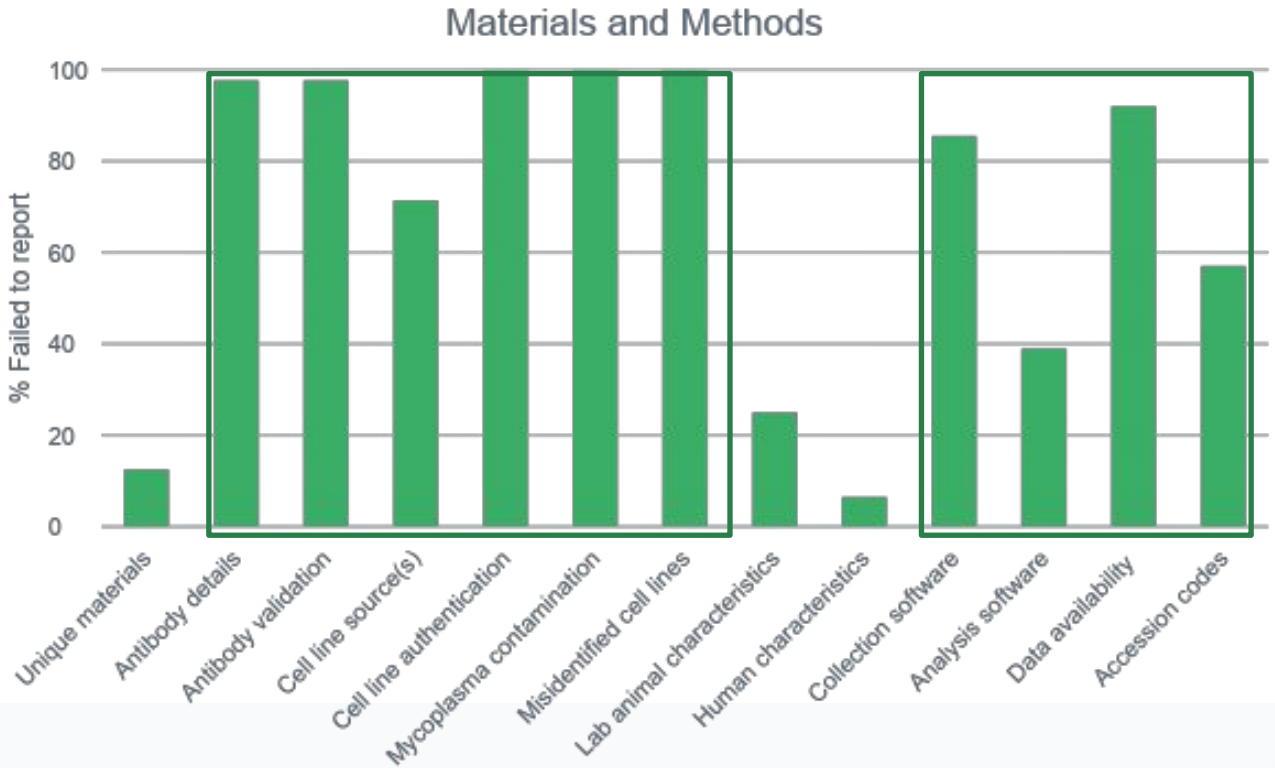

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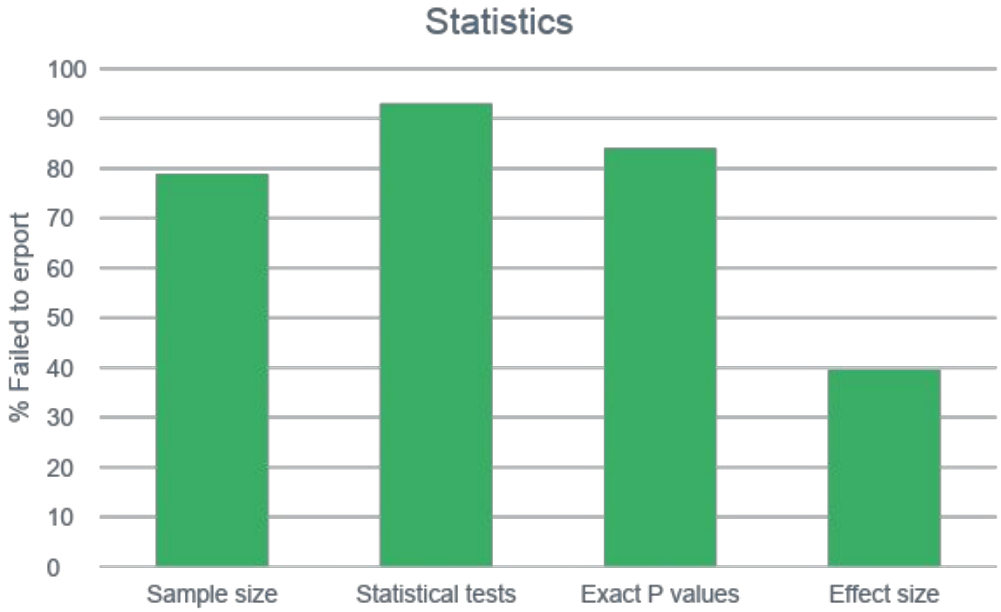

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Underspecified methods

- Like baking a loaf of bread, a “scientific recipe” should include all the details needed to reproduce the study.
  - materials
  - organisms
  - instruments
  - procedures

- Without these details, we don’t know if an irreproducible finding was due to procedural differences or if the result was incorrect.

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Underspecified methods

- Issues related to underspecified methods can be alleviated by:

  - decreasing journal constraints on the methods
  - publishing study protocols

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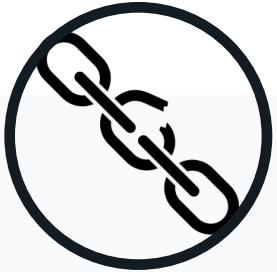

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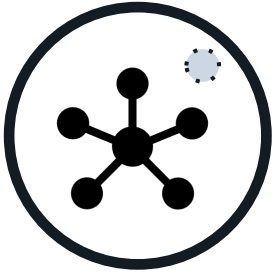

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Low statistical power

- Statistical power refers to the ability of an analysis to detect a true effect.

- Pressure to publish can lead to cutting corners – using a smaller sample size than needed to detect an effect.

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Low statistical power

- Underpowered studies are less likely to detect a true effect and are at a greater risk of being biased. (*Ioannidis, JPA; PLoS Medicine. 2005;2:e124*)

  - produce more false negatives
  - true effects are often exaggerated

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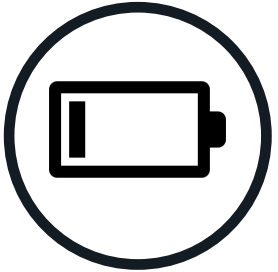

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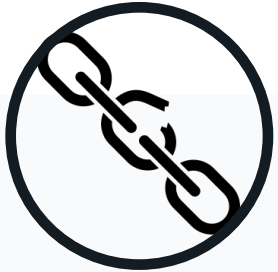

Bias - omitting null results

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Bias – omitting null results

- Novel, statistically significant results are more likely to published.

- Pressure to publish can lead to cherry-picking positive results and ignoring negative results.

- Consequences
  - no one learns from the null findings
  - time, money, resources are wasted

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Bias – omitting null results

- Publication of null findings contributes to scientific progress by:

  - providing information that we can learn from
  - preventing others from duplicating similar experiments

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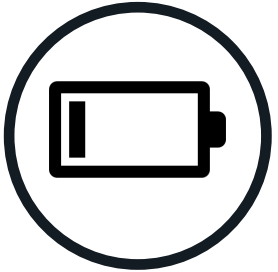

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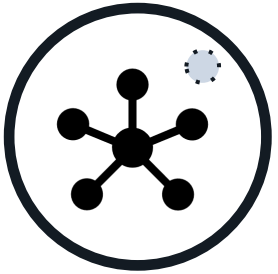

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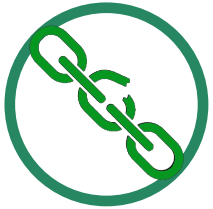

- The pressure to produce results quickly and publish them can lead to rushed experiments and cutting corners:

  - use smaller than adequate sample sizes
  - omit important control experiments
  - start an experiment before sufficient technical expertise has been acquired

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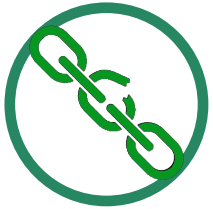
Weak experimental design



“By failing to prepare, you are preparing to fail.”
— Benjamin Franklin

Take time to carefully plan out your experiments to ensure a rigorous and thorough research plan.

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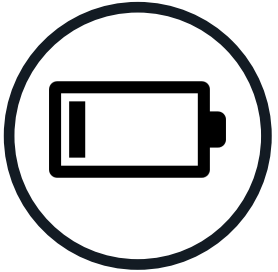

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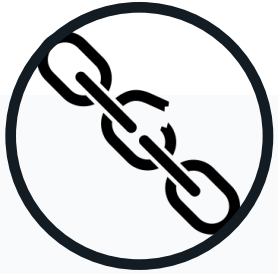

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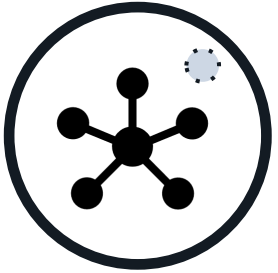

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Technical errors

- Ways to minimize technical errors

- automating your workflow - journal reporting guidelines and checklists
- be critical of positive results (not just the negative ones)

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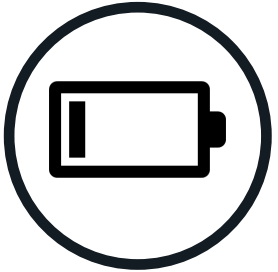

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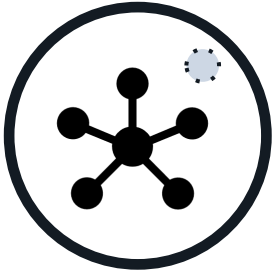

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Data dredging /p-hacking

- Data dredging and p-hacking refer to the practice of repeatedly analyzing a dataset until a significant effect is found.

- selectively reporting only significant results
- deciding to collect more data only after a significant effect was found
- excluding data after checking impact on p value (defining outliers post-hoc)

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Data dredging /p-hacking

- Data dredging /p-hacking practices should be avoided because:

  - not hypothesis driven
  - not statistically sound
  - severely bias results

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Conclusions

- Irreproducible findings are prevalent and are a major problem for science.
- Many common scientific practices contribute to the Reproducibility Crisis.
- By promoting more rigorous scientific practices, we can overcome this challenge.

Thank you!

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