**Definitions of Reproducibility, Replicability, and Rigor**

**Reproducibility:** According to the National Academies of Science (NASEM), “reproducibility is obtaining consistent results using the same input data; computational steps, methods, and code; and conditions of analysis. This definition is synonymous with ‘computational reproducibility’” (2019).

**Replicability:** Replicability is defined by the NASEM as “obtaining consistent results across studies aimed at answering the same scientific question, each of which has obtained its own data” (2019).

**Rigor:** According to the National Institutes of Health (NIH), “scientific rigor is the strict application of the scientific method to ensure robust and unbiased experimental design, methodology, analysis, interpretation and reporting of results. This includes full transparency in reporting experimental details so that others may reproduce and extend the findings” (2023).

**Note:** While the following checklists are a good place to start in ensuring that research is documented in a way that promotes transparency, reproducibility, replicability, and rigor, individual disciplines may already have community standards in place. For biological and medical research, a list of checklists by study type can be found through the [Equator Network.](https://www.equator-network.org/toolkits/)

**Reproducibility Checklist**

This checklist is adapted from *Reproducibility and Replicability in Science,* guidance from the

Association for the Advancement of Artificial Intelligence, the MDAR checklist, the CONSORT

Checklist, and the ARRIVE checklist (NASEM 2019; 2023; Chambers et.al, 2019; Mohler et. al,

2010; National Centre for the Replacement and Reduction of Animals in Research, 2020).

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| **Data Availability** | **Indicate where provided or indicate if not applicable**  |
| The input data used in the study in an extension (text file or a binary) or intension file (script to generate data).  |  |
| Intermediate results and output data for steps that are nondeterministic (and therefore cannot be reproduced).  |  |
| Novel datasets are made publicly available at publication  |  |
| Datasets used from existing studies are cited and are publicly available  |  |
| Datasets that are not publicly available should be described extensively with an explanation as to why the data are not publicly available and why publicly available alternatives were not used.  |  |
| **Computational Methodology and Analysis** | **Indicate where provided or indicate if not applicable** |
| Detailed description of study methodology – preferably provided in an executable form  |  |
| Computational steps along with parameters are clearly described. Values of parameters are provided when applicable.  |  |
| Source code detailing new methods have clear descriptions detailing implementation along with citations accompanying each step.  |  |
| For algorithms that depend on randomness, methodology for setting seeds is detailed.  |  |
| The number of times an algorithm was run to compute a reported result is stated.  |  |
| A detailed description of the computational environment where the study was originally executed including:  |  |
|  Operating system |  |
|  GPU/CPU models  |  |
|  Names and versions of software |  |
|  Hardware architecture (including amount of memory) |  |
|  Library dependencies (any software needed for another software to run). |  |
| Statistical tests are clearly detailed including software used and choice of tests is justified. For each analysis, the exact value of n should be reported for each experimental group.  |  |
| Methods used to assess how data met assumptions of the chosen statistical tests are detailed. Actions taken if assumptions were not met are also described.  |  |
| **Reporting Results** | **Indicate where provided or indicate if not applicable** |
| Summary or descriptive statistics along with a measure of variability should be presented for each experimental group. When applicable, the effect size and confidence interval should be presented.  |  |
| Baseline characteristics including age, sex and gender, and ethnicity of all human subjects participants should be reported when possible.  |  |
| Report any omitted data points from analysis and provide a detailed justification as to why data was omitted (was it due to attrition or intentional exclusion). |  |
| Researchers should describe recognized sources of uncertainty and bias.  |  |

**Replicability Checklist**

This checklist is adapted from *Reproducibility and Replicability in Science,* guidance from the

Association for the Advancement of Artificial Intelligence, the MDAR checklist, the CONSORT

checklist and the ARRIVE checklist (NASEM 2019; 2023; Chambers et.al, 2019; Mohler et. al,

2010; National Centre for the Replacement and Reduction of Animals in Research, 2020).

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| **Materials**  | **Indicate where provided or indicate if not applicable** |
| A detailed materials availability statement outlining the availability of novel materials, how materials can be accessed, and any restrictions to availability.  |  |
| The supplier name, catalog number and research resource identification number (RRID) is provided for antibodies.  |  |
| Short novel DNA and RNA sequences should be included or available in a public repository. This includes sequences for primers and probes.  |  |
| Species information and strain is detailed for cell lines. Accession number in repository or supplier name with catalog number and clone number, or RRID should be provided.  |  |
| Species, strain, sex, age, and genetic modification status should be provided for all model organisms/animals. Accession number in repository or supplier name with catalog number and clone number, or RRID is necessary.  |  |
| Species, age, and sex should be provided for animals observed/captured from the field.  |  |
| Strain, ecotype, cultivar, accession number, and source (including location) should be detailed for plant specimens.  |  |
| Species, strain, accession number, and source should be detailed for microbial specimens.  |  |
| **Design** | **Indicate where provided or indicate if not applicable** |
| Study protocol should be described in detail and available in the appendix or cited.  |  |
| When applicable, a diagram of the experimental design and/or model should be presented.  |  |
| Laboratory protocols should be described in detail and available in the appendix or cited.  |  |
| Detailed descriptions of the following should be provided:  |  |
|  Sample size determination |  |
|  Randomization. Describe the method used to generate  allocations including the mechanism of randomization. Describe the strategy used to minimize confounding and specify if restriction was used.  |  |
|  Blinding. Describe who was aware of group allocations at the different stages of the experiment.  |  |
|  Inclusion and exclusion criteria. Describe if criteria were determined prior to study initiation.  |  |
|  Outcome measures. Define all outcome measures. For experiments with hypothesis testing, describe the primary outcome measure.  |  |
| The number of replications of an experiment should be clearly stated and data should be clearly defined as technical or biological replicates.  |  |
| For studies involving humans, experimental animals, specimens, and field samples, provide details on the authority granting ethics approval or permits with relevant reference numbers. If no approval or permits were obtained, justify.  |  |
| **Data Availability** | **Indicate where provided or indicate if not applicable**  |
| The input data used in the study in an extension (text file or a binary) or intension file (script to generate data).  |  |
| Intermediate results and output data for steps that are nondeterministic (and therefore cannot be reproduced).  |  |
| Novel datasets are made publicly available at publication  |  |
| Datasets used from existing studies are cited and are publicly available  |  |
| Datasets that are not publicly available should be described extensively with an explanation as to why the data are not publicly available and why publicly available alternatives were not used.  |  |
| **Methodology and Analysis** | **Indicate where provided or indicate if not applicable** |
| Detailed description of study methodology – preferably provided in an executable form  |  |
| Computational steps along with parameters are clearly described. Values of parameters are provided when applicable.  |  |
| Source code detailing new methods have clear descriptions detailing implementation along with citations accompanying each step.  |  |
| For algorithms that depend on randomness, methodology for setting seeds is detailed.  |  |
| The number of times an algorithm was run to compute a reported result is stated.  |  |
| A detailed description of the computational environment where the study was originally executed including:  |  |
|  Operating system |  |
|  GPU/CPU models  |  |
|  Names and versions of software |  |
|  Hardware architecture (including amount of memory) |  |
|  Library dependencies (any software needed for another software to run). |  |
| Statistical tests are clearly detailed including software used and choice of tests is justified. For each analysis, the exact value of n should be reported for each experimental group.  |  |
| Methods used to assess how data met assumptions of the chosen statistical tests are detailed. Actions taken if assumptions were not met are also described.  |  |
| **Reporting Results** | **Indicate where provided or indicate if not applicable** |
| Summary or descriptive statistics along with a measure of variability should be presented for each experimental group. When applicable, the effect size and confidence interval should be presented.  |  |
| Baseline characteristics including age, sex and gender, and ethnicity of all human subjects participants should be reported when possible.  |  |
| Report any omitted data points from analysis and provide a detailed justification as to why data was omitted (was it due to attrition or intentional exclusion). |  |
| Researchers should describe recognized sources of uncertainty and bias.  |  |

**Checklist for Assessing the Rigor of a Study**

This checklist was adapted from *Getting Rigorous with Scientific Rigor* (Hosfeth, 2018).

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| **Rigor criteria** | **Indicate any strengths, weaknesses, or gaps in research. Indicate if not applicable.**  |
| The appropriate positive and negative controls were used in every experiment  |  |
| The appropriate number of replicates were conducted within experiments – usually at least in triplicate.  |  |
| Randomization occurred when possible  |  |
| Blinding occurred when possible |  |
| Measures to control bias were discussed  |  |
| Inter-operator variability was controlled for |  |
| Statistical methodology is robust and appropriate  |  |
| Models are clearly described, validated, and appropriate  |  |
| Age, sex, and other relevant biological, clinical, or demographic variables are considered  |  |

**References:**

Association for the Advancement of Artificial Intelligence. (2023, January 29). *Reproducibility Checklist – AAAI* https://aaai.org/conference/aaai/aaai-23/reproducibility-checklist/

Chambers, K., Collings, A., Graf, C., Kiermer, V., Mellor, D. T., Macleod, M. R., ... & Sweet, D. (2019).

Towards minimum reporting standards for life scientists.

Hofseth L. J. (2018). Getting rigorous with scientific rigor. *Carcinogenesis*, *39*(1), 21–25.

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Moher, D., Hopewell, S., Schulz, K. F., Montori, V., Gotzsche, P. C., Deveraux, P. J., ... & Altman, D.

G. (2010). Research methods & reporting CONSORT 2010 Explanation and Elaboration: updated guidelines for reporting parallel group randomised trials. *BMJ*, *340*, c869.

National Academies of Sciences, Engineering, and Medicine. (2019). *Reproducibility and*

*replicability in science*. National Academies Press.

National Institutes of Health (2023, January 26). *Guidance: Rigor and Reproducibility in Grant Applications | grants.nih.gov*. https://grants.nih.gov/policy/reproducibility/guidance.htm