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How to Conduct Responsible Research: A Guide for Graduate Students

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Abstract

Researchers must conduct research responsibly for it to have an impact and to safeguard trust in science. Essential responsibilities of researchers include using rigorous, reproducible research methods, reporting findings in a trustworthy manner, and giving the researchers who contributed appropriate authorship credit. This "how-to" guide covers strategies and practices for doing reproducible research and being a responsible author. The article also covers how to utilize decision-making strategies when uncertain about the best way to proceed in a challenging situation. The advice focuses especially on graduate students but is appropriate for undergraduates and experienced researchers. The article begins with an overview of the responsible conduct of research, research misconduct, and ethical behavior in the scientific workplace. The takeaway message is that responsible conduct of research requires a thoughtful approach to doing research to ensure trustworthy results and conclusions and that researchers receive fair credit.

Keywords

Responsible conduct of research; research integrity; research ethics; scientific integrity; graduate students; reproducibility; rigor; authorship; publication

INTRODUCTION

Doing research is stimulating and fulfilling work. Scientists make discoveries to build knowledge and solve problems, and they work with other dedicated researchers. Research is a highly complex activity, so it takes years for beginning researchers to learn everything they need to know to do science well. Part of this large body of knowledge is learning how to do research responsibly. Our purpose in this article is to provide graduate students a guide for how to perform responsible research. Our advice is also relevant to undergraduate researchers and for principal investigators (PIs), postdocs, or other researchers who mentor beginning researchers and wish to share our advice.

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We begin by introducing some fundamentals about the responsible conduct of research (RCR), research misconduct, and ethical behavior. We focus on how to do reproducible science and be a responsible author. We provide practical advice for these topics and present scenarios to practice thinking through challenges in research. Our article concludes with decision-making strategies for addressing complex problems.

What is the responsible conduct of research?

To be committed to RCR means upholding the highest standards of honesty, accuracy, efficiency, and objectivity (Steneck, 2007). Each day, RCR requires engaging in research in a conscientious, intentional fashion that yields the best science possible ("Research Integrity is Much More Than Misconduct," 2019). We adopt a practical, "how-to" approach, discussing the behaviors and habits that yield responsible research. However, some background knowledge about RCR is helpful to frame our discussion.

The scientific community uses many terms to refer to ethical and responsible behavior in research: responsible conduct of research, research integrity, scientific integrity, and research ethics (National Academies of Science, 2009; National Academies of Sciences Engineering and Medicine, 2017; Steneck, 2007). A helpful way to think about these concepts is "doing good science in a good manner" (DuBois & Antes, 2018). This means that the way researchers do their work, from experimental procedures to data analysis and interpretation, research reporting, and so on, leads to trustworthy research findings and conclusions. It also includes respectful interactions among researchers both within research teams (e.g., between peers, mentors and trainees, and collaborators) and with researchers external to the team (e.g., peer reviewers). We expand on trainee-mentor relationships and interpersonal dynamics with labmates in a companion article (Antes & Maggi, 2021). When research involves human or animal research subjects, RCR includes protecting the well-being of research subjects.

We do not cover all potential RCR topics but focus on what we consider fundamentals for graduate students. Common topics covered in texts and courses on RCR include the following: authorship and publication; collaboration; conflicts of interest; data management, sharing, and ownership; intellectual property; mentor and trainee responsibilities; peer review; protecting human subjects; protecting animal subjects; research misconduct; the role of researchers in society; and laboratory safety. A number of topics prominently discussed among the scientific community in recent years are also relevant to RCR. These include the reproducibility of research (Baker, 2016; Barba, 2016; Winchester, 2018), diversity and inclusion in science (Asplund & Welle, 2018; Hofstra et al., 2020; Meyers, Brown, Moneta-Koehler, & Chalkley, 2018; National Academies of Sciences Engineering and Medicine, 2018a; Roper, 2019), harassment and bullying (Else, 2018; National Academies of Sciences Engineering and Medicine, 2018b; "No Place for Bullies in Science," 2018), healthy research work environments (Norris, Dirnagl, Zigmond, Thompson-Peer, & Chow, 2018; "Research Institutions Must Put the Health of Labs First," 2018), and the mental health of graduate students (Evans, Bira, Gastelum, Weiss, & Vanderford, 2018).

The National Institutes of Health (NIH) (National Institutes of Health, 2009) and the National Science Foundation (National Science Foundation, 2017) have formal policies indicating research trainees must receive education in RCR. Researchers are accountable to these funding agencies and the public which supports research through billions in tax dollars annually. The public stands to benefit from, or be harmed by, research. For example, the public may be harmed if medical treatments or social policies are based on untrustworthy research findings. Funding for research, participation in research, and utilization of the fruits of research all rely on public trust (Resnik, 2011). Trustworthy findings are also essential for good stewardship of scarce resources (Emanuel, Wendler, & Grady, 2000). Researchers are further accountable to their peers, colleagues, and scientists more broadly. Trust in the work of other researchers is essential for science to advance. Finally, researchers are accountable for complying with the rules and policies of their universities or research institutions, such as rules about laboratory safety, bullying and harassment, and the treatment of animal research subjects.

What is research misconduct?

When researchers intentionally misrepresent or manipulate their results, these cases of scientific fraud often make the news headlines (Chappell, 2019; O'Connor, 2018; Park, 2012), and they can seriously undermine public trust in research. These cases also harm trust within the scientific community.

The U.S. defines research misconduct as fabrication, falsification, and plagiarism (FFP) (Department of Health and Human Services, 2005). FFP violate the fundamental ethical principle of honesty. Fabrication is making up data, and falsification is manipulating or changing data or results so they are no longer truthful. Plagiarism is a form of dishonesty because it includes using someone's words or ideas and portraying them as your own. When brought to light, misconduct involves lengthy investigations and serious consequences, such as ineligibility to receive federal research funding, loss of employment, paper retractions, and, for students, withdrawal of graduate degrees.

One aspect of responsible behavior includes addressing misconduct if you observe it. We suggest a guide titled "Responding to Research Wrongdoing: A User-Friendly Guide" that provides advice for thinking about your options if you think you have observed misconduct (Keith-Spiegel, Sieber, & Koocher, 2010). Your university will have written policies and procedures for investigating allegations of misconduct. Making an allegation is very serious. As Keith-Spiegel et al.'s guide indicates, it is important to know the evidence that supports your claim, and what to expect in the process. We encourage, if possible, talking to the persons involved first. For example, one of us knew of a graduate student who reported to a journal editor their suspicion of falsified data in a manuscript. It turned out that the student was incorrect. Going above the PI directly to the editor ultimately led to the PI leaving the university, and the student had a difficult time finding a new lab to complete their degree. If the student had first spoken to the PI and lab members, they could have learned that their assumptions about the data in the paper were wrong. In turn, they could have avoided accusing the PI of a serious form of scientific misconduct—making up data—and harming everyone's scientific career.

What shapes ethical behavior in the scientific workplace?

Responsible conduct of research and research misconduct are two sides of a continuum of behavior—RCR upholds the ideals of research and research misconduct violates them. Problematic practices that fall in the middle but are not defined formally as research misconduct have been labeled as detrimental research practices (National Academies of Sciences Engineering and Medicine, 2017). Researchers conducting misleading statistical analyses or PIs providing inadequate supervision are examples of the latter. Research suggests that characteristics of **individual researchers** and **research environments** explain (un)ethical behavior in the scientific workplace (Antes et al., 2007; Antes, English, Baldwin, & DuBois, 2018; Davis, Riske-Morris, & Diaz, 2007; DuBois et al., 2013).

These two influences on ethical behavior are helpful to keep in mind when thinking about your behavior. When people think about their ethical behavior, they think about their personal values and integrity and tend to overlook the influence of their environment. While "being a good person" and having the right intentions are essential to ethical behavior, the environment also has an influence. In addition, knowledge of standards for ethical research is important for ethical behavior, and graduate students new to research do not yet know everything they need to. They also have not fully refined their ethical decision-making skills for solving professional problems. We discuss strategies for ethical decision-making in the final section of this article (McIntosh, Antes, & DuBois, 2020).

The research environment influences ethical behavior in a number of ways. For example, if a research group explicitly discusses high standards for research, people will be more likely to prioritize these ideals in their behavior (Plemmons et al., 2020). A mentor who sets a good example is another important factor (Anderson et al., 2007). Research labs must also provide individuals with adequate training, supervision and feedback, opportunities to discuss data, and the psychological safety to feel comfortable communicating about problems, including mistakes (Antes, Kuykendall, & DuBois, 2019a, 2019b). On the other hand, unfair research environments, inadequate supervision, poor communication, and severe stress and anxiety may undermine ethical decision-making and behavior; particularly when many of these factors exist together. Thus, (un)ethical behavior is a complex interplay of individual factors (e.g., personality, stress, decision-making skills) and the environment.

For graduate students, it is important to attend to what you are learning and how the environment around you might influence your behavior. You do not know what you do not know, and you necessarily rely on others to teach you responsible practices. So, it is important to be aware. Ultimately, you are accountable for your behavior. You cannot just say "I didn't know." Rather, just like you are curious about your scientific questions, maintain a curiosity about responsible behavior as a researcher. If you feel uncomfortable with something, pay attention to that feeling, speak to someone you trust, and seek out information about how to handle the situation. In what follows, we cover key tips for responsible behavior in the areas of reproducibility and authorship that we hope will help you as you begin.

HOW TO DO REPRODUCIBLE SCIENCE

The foremost responsibility of scientists is to ensure they conduct research in such a manner that the findings are trustworthy. Reproducibility is the ability to duplicate results (Goodman, Fanelli, & Ioannidis, 2016). The scientific community has called for greater openness, transparency, and rigor as key remedies for lack of reproducibility (Munafò et al., 2017). As a graduate student, essential to fostering reproducibility is the rigor of your approach to doing experiments and handling data. We discuss how to utilize research protocols, document experiments in a lab notebook, and handle data responsibly.

Utilize research protocols

1. Learn and utilize the lab's protocols—Research protocols describe the step-by-step procedures for doing an experiment. They are critical for the quality and reproducibility of experiments. Lab members must learn and follow the lab's protocols with the understanding that they may need to make adjustments based on the requirements of a specific experiment.

Also, it is important to distinguish between the experiment you are performing and analyzing the data from that experiment. For example, the experiment you want to perform might be to determine if loss of a gene blocks cell growth. Several protocols, each with pros and cons, will allow you to examine "cell growth." Using the wrong experimental protocol can produce data that leads to muddled conclusions. In this example, the gene does block cell growth, but the experiment used to produce the data that you analyze to understand cell growth is wrong, thus giving a result that is a false negative.

When first joining a lab, it is essential to commit to learning the protocols necessary for your assigned research project. Researchers must ensure they are proficient in executing a protocol and can perform their experiments reliably. If you do not feel confident with a protocol, you should do practice runs if possible. Repetition is the best way to work through difficulties with protocols. Often it takes several attempts to work through the steps of a protocol before you will be comfortable performing it. Asking to watch another lab member perform the protocol is also helpful. Be sure to watch closely how steps are performed, as often there are minor steps taken that are not written down. Also, experienced lab members may do things as second nature and not think to explicitly mention them when working through the protocol. Ask questions of other lab members so that you can improve your knowledge and gain confidence with a protocol. It is better to ask a question than potentially ruin a valuable or hard-to-get sample.

Be cautious of differences in the standing protocols in the lab and how you actually perform the experiment. Even the most minor deviations can seriously impact the results and reproducibility of an experiment. As mentioned above, often there are minor things that are done that might not be listed in the protocol. Paying attention and asking questions are the best ways to learn, in addition to adding notes to the protocol if you find minor details are missing.

2. Develop your own protocols—Often you will find that a project requires a protocol that has not been performed in the lab. If performing a new experiment in the lab and no protocol exists, find a protocol and try it. Protocols can be obtained from many different sources. A great source is other labs on campus, as you can speak directly to the person who performs the experiment. There are many journal sources as well, such as *Current Protocols, Nature Protocols, Nature Methods,* and *Cell STAR Methods*. These methods journals provide the most detailed protocols for experiments often with troubleshooting tips. Scientific papers are the most common source of protocols. However, keep in mind that due to the common brevity of methods sections, they often omit crucial details or reference other papers that may not contain a complete description of the protocol.

3. Handle mistakes or problems promptly—At some point, everyone encounters problems with a protocol, or realizes they made a mistake. You should be prepared to handle this situation by being able to detail exactly how you performed the experiment. Did you skip a step? Shorten or lengthen a time point? Did you have to make a new buffer or borrow a labmate's buffer? There are too many ways an experiment can go wrong to list here but being able to recount all the steps you performed in detail will help you work through the problem. Keep in mind that often the best way to understand how to perform an experiment is learning from when something goes wrong. This situation requires you to critically think through what was done and understand the steps taken. When everything works perfectly, it is easy to pay less attention to the details, which can lead to problems down the line.

It is up to you to be attentive and meticulous in the lab. Paying attention to the details may feel like a pain at first, or even seem overwhelming. Practice and repetition will help this focus on details become a natural part of your lab work. Ultimately, this skill will be essential to being a responsible scientist.

Document experiments in a lab notebook

1. Recognize the importance of a lab notebook—Maintaining detailed documentation in a lab notebook allows researchers to keep track of their experiments and generation of data. This detailed documentation helps you communicate about your research with others in the lab, and serves as a basis for preparing publications. It also provides a lasting record for the lab that exists beyond your time in the lab. After graduate students leave the lab, sometimes it is necessary to go back to the results of older experiments. A complete and detailed notebook is essential, or all of the time, effort, and resources are lost.

2. Learn the note-keeping practices in your lab—When you enter a new lab, it is important to understand how the lab keeps notebooks and the expectations for documentation. Being conscientious about documentation will make you a better scientist. In some labs, the PI might routinely examine your notebook, while in other labs you may be expected to maintain a notebook, but it may not be regularly viewed by others. It is tempting to become relaxed in documentation if you think your notebook may not be reviewed. Avoid this temptation; documentation of your ideas and process will improve your ability to think critically about research. Further, even if the PI or lab members do not physically view your

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notebook, you will need to communicate with them about your experiments. This documentation is necessary to communicate effectively about your work.

3. Organize your lab notebook—Different labs use different formats; some use electronic notebooks while others handwritten notebooks. The contents of a good notebook include the purpose of the experiment, the details of the experimental procedure, the data, and thoughts about the results. To effectively document your experiment, there are 5 critical questions that the information you record should be able to answer.

1. Why I am doing this experiment? (purpose)
2. What did I do to perform the experiment? (protocol)
3. What are the results of what I did? (data, graphs)
4. What do I think about the results?
5. What do I think are the next steps?

We also recommend a table of contents. It will make the information more useful to you and the lab in the future. The table of contents should list the title of the experiment, the date(s) it was performed, and the page numbers on which it is recorded. Also, make sure that you write clearly and provide a legend or explanation of any shorthand or non-standard abbreviation you use. Often labs will have a combination of written lab notebooks and electronic data. It is important to reference where electronic data are located that go with each experiment. The idea is to make it as easy as possible to understand what you did and where to find all the data (electronic and hard copy) that accompanies your experiment.

Keeping a lab notebook becomes easier with practice. It can be thought of almost like journaling about your experiment. Sometimes people think of it as just a place to paste their protocol and a graph or data. We strongly encourage you to include your thoughts about why you made the decisions you made when conducting the experiment and to document your thoughts about next steps.

4. Commit to doing it the right way—A common reason to become lax in documentation is feeling rushed for time. Although documentation takes time, it saves time in the long-run and fosters good science. Without good notes, you will waste time trying to recall precisely what you did, reproduce your findings, and remember what you thought would be important next steps. The lab notebook helps you think about your research critically and keep your thoughts together. It can also save you time later when writing up results for publication. Further, well-documented data will help you draft a cogent and rigorous dissertation.

Handle data responsibly

1. Keep all data—Data are the product of research. Data include raw data, processed data, analyzed data, figures, and tables. Many data today are electronic, but not all. Generating data requires a lot of time and resources and researchers must treat data with care. The first essential tip is to keep **all** data. Do not discard data just because the experiment did not turn out as expected. A lot of experiments do not turn out to yield publishable data, but the results are still important for informing next steps.

Always keep the original, raw data. That is, as you process and analyze data, always maintain an unprocessed version of the original data.

Universities and funding agencies have data retention policies. These policies specify the number of years beyond a grant that data must be kept. Some policies also indicate researchers need to retain original data that served as the basis for a publication for a certain number of years. Therefore, your data will be important well beyond your time in graduate school. Most labs require you to keep samples for reanalysis until a paper is published, then the analyzed data are enough. If you leave a lab before a paper is accepted for publication, you are responsible for ensuring your data and original samples are well documented for others to find and use.

2. Document all data—In addition to keeping all data, data must be well-organized and documented. This means that no matter the way you keep your data (e.g., electronic or in written lab notebooks), there is a clear guide—in your lab notebook, a binder, or on a lab hard drive—to finding the data for a particular experiment. For example, it must be clear which data produced a particular graph. Version control of data is also critical. Your documentation should include “metadata” (data about your data) that tracks versions of the data. For example, as you edit data for a table, you should save separate versions of the tables, name the files sequentially, and note the changes that were made to each version.

3. Backup your data—You should backup electronic data regularly. Ideally, your lab has a shared server or cloud storage to backup data. If you are supposed to put your data there, make sure you do it! When you leave the lab, it must be possible to find your data.

4. Perform data analysis honestly and competently—Inappropriate use of statistics is a major concern in the scientific community, as the results and conclusions will be misleading if done incorrectly (DeMets, 1999). Some practices are clearly an abuse of statistics, while other inappropriate practices stem from lack of knowledge. For example, a practice called “p-hacking” describes when researchers “collect or select data or statistical analyses until nonsignificant results become significant” (Head, Holman, Lanfear, Kahn, & Jennions, 2015). In addition to avoiding such misbehavior, it is essential to be proficient with statistics to ensure you do statistical procedures appropriately. Learning statistical procedures and analyzing data takes many years of practice, and your statistics courses may only cover the basics. You will need to know when to consult others for help. In addition to consulting members in your lab or your PI, your university may have statistical experts who can provide consultations.

5. Master pressure to obtain favored results—When you conduct an experiment, the results are the results. As a beginning researcher, it is important to be prepared to manage the frustration of experiments not turning out as expected. It is also important to manage the real or perceived pressure to produce favored results. Investigators can become wedded to a hypothesis, and they can have a difficult time accepting the results. Sometimes you may feel this pressure coming from yourself; for example, if you want to please your PI, or if you want to get results for a certain publication. It is important to always follow the data no matter where it leads.

If you do feel pressure, this situation can be uncomfortable and stressful. If you have been meticulous and followed the above recommendations, this can be one great safeguard. You will be better able to confidently communicate your results to the PI because of your detailed documentation, and you will be more confident in your procedures if the possibility of error is suggested. Typically, with enough evidence that the unexpected results are real, the PI will concede. We recommend seeking the support of friends or colleagues to vent and cope with stress. In the rare case that the PI does not relent, you could turn to an advisor outside the lab if you need advice about how to proceed. They can help you look at the data objectively and also help you think about the interpersonal aspects of navigating this situation.

6. Communicate about your data in the lab—A critical element of reproducible research is communication in the lab. Ideally, there are weekly or bi-weekly meetings to discuss data. You need to develop your communication skills for writing and speaking about data. Often you and your labmates will discuss experimental issues and results informally during the course of daily work. This is an excellent way to hone critical thinking and communication skills about data.

Scenario 1 – The Protocol is Not Working: At the beginning of a rotation during their first year, a graduate student is handed a lab notebook and a pen and is told to keep track of their work. There does not appear to be a specific format to follow. There are standard lab protocols that everyone follows, but minor tweaks to the protocols do not seem to be tracked from experiment to experiment in the standard lab protocol nor in other lab notebooks. After two weeks of trying to follow one of the standard lab protocols, the student still cannot get the experiment to work. The student has included the appropriate positive and negative controls which are failing, making the experiment uninterpretable. After asking others in the lab for help, the graduate student learns that no one currently in the lab has performed this particular experiment. The former lab member who had performed the experiment only lists the standard protocol in their lab notebook.

How should the graduate student start to solve the problem?

Speaking to the PI would be the next logical step. As a first-year student in a lab rotation, the PI should expect this type of situation and provide additional troubleshooting guidance. It is possible that the PI may want to see how the new graduate student thinks critically and handles adversity in the lab. Rather than giving an answer, the PI might ask the student to work through the problem. The PI should give guidance, but it may not be an immediate fix for the problem. If the PI’s suggestions fail to correct the problem, asking a labmate or the PI for the contact information of the former lab member who most recently performed the experiment would be a reasonable next step. The graduate student’s conversations with the PI and labmates in this situation will help them learn a lot about how the people in the lab interact.

Most of the answers for these types of problems will require you as a graduate student to take the initiative to answer. They will require your effort and ingenuity to talk to other lab members, other labs at the university, and even scour the literature for alternatives. While labs have standard protocols, there are multiple ways to do many experiments, and working out an alternative will teach you more than when everything works. Having to troubleshoot problems will result in better standard protocols in the lab and better science.

HOW TO BE A RESPONSIBLE AUTHOR

Researchers communicate their findings via peer-reviewed publications, and publications are important for advancing in a research career. Many graduate students will first author or co-author publications in graduate school. For good advice on how to write a research manuscript, consult the *Current Protocols* article "How to write a research manuscript" (Frank, 2018). We focus on the issues of assigning authors and reporting your findings responsibly. First, we describe some important basics: journal impact factors, predatory journals, and peer review.

What are journal impact factors?

It is helpful to understand journal impact factors. There is criticism about an overemphasis on impact factors for evaluating the quality or importance of researchers' work (DePellegrin & Johnston, 2015), but they remain common for this purpose. Journal impact factors reflect the average number of times articles in a journal were cited in the last two years. Higher impact factors place journals at a higher rank. Approximately 2% of journals have an impact factor of 10 or higher. For example, *Cell, Science, and Nature* have impact factors of approximately 39, 42, and 43, respectively. Journals can be great journals but have lower impact factors; often this is because they focus on a smaller specialty field. For example, *Journal of Immunology* and *Oncogene* are respected journals, but their impact factors are about 4 and 7, respectively.

Research trainees often want to publish in journals with the highest possible impact factor because they expect this to be viewed favorably when applying to future positions. We encourage you to bear in mind that many different journals publish excellent science and focus on publishing where your work will reach the desired audience. Also, keep in mind that while a high impact factor can direct you to respectable, high-impact science, it does not guarantee that the science in the paper is good or even correct. You must critically evaluate all papers you read no matter the impact factor.

What are predatory journals?

Predatory journals have flourished over the past few years as publishing science has moved online. An international panel defined predatory journals as follows (Grudniewicz et al., 2019):

> Predatory journals and publishers are entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices. (p. 211)

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Often young researchers receive emails soliciting them to submit their work to a journal. There are typically small fees (around $99 US) requested but these fees will be much lower than open access fees of reputable journals (often around $2000 US). A warning sign of a predatory journal is outlandish promises, such as 24-hour peer review or immediate publication. You can find a list of predatory journals created by a postdoc in Europe at BeallsList.net ("Beall's List of Potential Predatory Journals and Publishers," 2020).

What is peer review?

Peer reviewers are other scientists who have the expertise to evaluate a manuscript. Typically 2 or 3 reviewers evaluate a manuscript. First, an editor performs an initial screen of the manuscript to ensure its appropriateness for the journal and that it meets basic quality standards. At this stage, an editor can decide to reject the manuscript and not send it to review. Not sending a paper for peer review is common in the highest impact journals that receive more submissions per year than can be reviewed and published. For average-impact journals and specialty journals, typically your paper will be sent for peer review.

In general, peer review focuses on three aspects of a manuscript: research design and methods, validity of the data and conclusions, and significance. Peer reviewers assess the merit and rigor of the research design and methodology, and they evaluate the overall validity of the results, interpretations, and conclusions. Essentially, reviewers want to ensure that the data support the claims. Additionally, reviewers evaluate the overall significance, or contribution, of the findings, which involves the novelty of the research and the likelihood that the findings will advance the field. Significance standards vary between journals. Some journals are open to publishing findings that are incremental advancements in a field, while others want to publish only what they deem as major advancements. This feature can distinguish the highest impact journals which seek the most significant advancements and other journals that tend to consider a broader range of work as long as it is scientifically sound. It is important to keep in mind that determining at the stage of review and publication whether a paper is "high impact" is quite subjective. In reality, this can only really be determined in retrospect.

The key ethical issues in peer review are fairness, objectivity, and confidentiality (Shamoo & Resnik, 2015). Peer reviewers are to evaluate the manuscript on its merits and not based on biases related to the authors or the science itself. If reviewers have a conflict of interest, this should be disclosed to the editor. Confidentiality of peer review means that the reviewers should keep private the information; they should not share the information with others or use it to their benefit. Reviewers can ultimately recommend that the manuscript is rejected, revised, and resubmitted (major or minor revisions), or accepted. The editor evaluates the reviewers' feedback and makes a judgment about rejecting, accepting, or requesting a revision. Sometimes PIs will ask experienced graduate students to assist with peer reviewing a manuscript. This is a good learning opportunity. The PI should disclose to the editor that they included a trainee in preparing the review.

Assign authorship fairly

Authorship gives credit to the people who contributed to the research. This includes thinking of the ideas, designing and performing experiments, interpreting the results, and writing the paper. Two key questions regarding authorship include: 1 - Who will be an author? 2 - What will be the order in which authors are listed? These seem simple on the surface but can get quite complex.

1. Know authorship guidelines—Authorship guidelines published by journals, professional societies, and universities communicate key principles of authorship and standards for earning authorship. The core ethical principle of assigning authorship is fairness in who receives credit for the work. The people who contributed to the work should get credit for it. This seems simply enough, but determining authorship can (and often does) create conflict.

Many universities have authorship guidelines, and you should know the policies at your university. The International Committee of Medical Journal Editors (ICMJE) provides four criteria for determining who should be an author (International Committee of Medical Journal Editors, 2020). These criteria indicate that an author should do all of the following: 1) make "substantial contributions" to the development of the idea or research design, <u>or</u> to acquiring, analyzing, or interpreting the data, 2) write the manuscript or revise it a substantive way, 3) give approval of the final manuscript (i.e., before it is submitted for review, and after it is revised, if necessary), and 4) agree to be responsible for any questions about the accuracy or integrity of the research.

Several types of authorship violate these guidelines and should be avoided. Guest authorship is when respected researchers are added out of appreciation, or to have the manuscript be perceived more favorably to get it published or increase its impact. Gift authorship is giving authorship to reward an individual, or as a favor. Ghost authorship is when someone made significant contributions to the paper but is not listed as an author. To increase transparency, some journals require authors to indicate how each individual contributed to the research and manuscript.

2. Apply the guidelines—Conflicts often arise from disagreements about how much people contributed to the research and whether those contributions merit authorship. The best approach is an open, honest, and ongoing discussion about authorship, which we discuss in #3 below. To have effective, informed conversations about authorship, you must understand how to apply the guidelines to your specific situation. The following is a simple rule of thumb that indicates there are three components of authorship. We do not list giving final approval of the manuscript and agreeing to be accountable, but we do consider these essentials of authorship.

1. *Thinking* – this means contributing to the ideas leading to the hypothesis of the work, designing experiments to address the hypothesis, and/or analyzing the results in the larger context of the literature in the field.
2. *Doing* – this means performing and analyzing the experiments.

3. *Writing* – this means editing a draft, or writing the entire paper. The first author often writes the entire first draft.

In our experience, a first author would typically do all three. They also usually coordinate the writing and editing process. Co-authors are typically very involved in at least two of the three, and are somewhat involved in the other. The PI, who oversees and contributes to all three, is often the last, or "senior author." The "senior author" is typically the "corresponding author"—the person listed as the individual to contact about the paper. The other co-authors are listed between the first and senior author either alphabetically, or more commonly, in order from the largest to smallest contribution.

Problems in assigning authorship typically arise due to people's interpretations of #1 (thinking) and #2 (doing)—what and how much each individual contributed to a project's design, execution, and analysis. Different fields or PIs may have their own slight variations on these guidelines. The potential conflicts associated with assigning authorship lead to the most common recommendation for responsibly assigning authorship: discuss authorship expectations early and revisit them during the project.

3. Discuss authorship with your collaborators—Publications are important for career advancement, so you can see why people might be worried about fairness in assigning authorship. If the problem arises from a lack of a shared understanding about contributions to the research, the only way to clarify this is an open discussion. This discussion should ideally take place very early at the beginning of a project, and should be ongoing. Hopefully you work in a laboratory that makes these discussions a natural part of the research process; this makes it much easier to understand the expectations upfront.

We encourage you to speak up about your interest in making a contribution that would merit authorship, especially if you want to earn first authorship. Sometimes norms about authoring papers in a lab make it clear you are expected to first and co-author publications, but it is best to communicate your interest in earning authorship. If the project is not yours, but you wish to collaborate, you can inquire what you may be able to contribute that would merit authorship.

If it is not a norm in your lab to discuss authorship throughout the life of projects, then as a graduate student you may feel reluctant to speak up. You could initiate a conversation with a more senior graduate student, a postdoc, or your PI, depending on the dynamics in the group. You could ask generally about how the lab approaches assignment of authorship, but discussing a specific project and paper may be best. It may feel awkward to ask, but asking early is less uncomfortable than waiting until the end of the project. If the group is already drafting a manuscript and you are told that your contribution is insufficient for authorship, this situation is much more discouraging than if you had asked earlier about what is expected to earn authorship.

How to report findings responsibly

The most significant responsibility of authors is to present their research accurately and honestly. Deliberately presenting misleading information is clearly unethical, but there are significant judgment calls about how to present your research findings. For example, an author can mislead by overstating the conclusions given what the data support.

1. Commit to presenting your findings honestly—Any good scientific manuscript writer will tell you that you need to "tell a good story." This means that your paper is organized and framed to draw the reader into the research and convince them of the importance of the findings. But, this story must be sound and justified by the data. Other authors are presenting their findings in the best, most "publishable" light, so it is a balancing act to be persuasive but also responsible in presenting your findings in a trustworthy manner. To present your findings honestly, you must be conscious of how you interpret your data and present your conclusions so that they are accurate and not overstated.

One misbehavior known as "HARKing," Hypothesis After the Results are Known, occurs when hypotheses are created after seeing the results of an experiment, but they are presented as if they were defined prior to collecting the data (Munafò et al., 2017). This practice should be avoided. HARKing may be driven, in part, by a concern in scientific publishing known as publication bias. This bias is a preference that reviewers, editors, and researchers have for papers describing positive findings instead of negative findings (Carroll, Toumpakari, Johnson, & Betts, 2017). This preference can lead to manipulating one's practices, such as by HARKing, so that positive findings can be reported.

It is important to note that in addition to avoiding misbehaviors such as HARKing, all researchers are susceptible to a number of more subtle traps in judgment. Even the most well-intentioned researcher may jump to conclusions, discount alternative explanations, or accept results that seem correct without further scrutiny (Nuzzo, 2015). Therefore, researchers must not only commit to presenting their findings honestly but consider how they can counteract such traps by slowing down and increasing their skepticism towards their findings.

2. Provide an appropriate amount of detail—Providing enough detail in a manuscript can be a challenge with the word limits imposed by most journals. Therefore, you will need to determine what details to include and which to exclude, or potentially include in the supplemental materials. Methods sections can be long and are often the first to be shortened, but complete methods are important for others to evaluate the research and to repeat the methods in other studies. Even more significant is making decisions about what experimental data to include and potentially exclude from the manuscript. Researchers must determine what data is required to create a complete scientific story that supports the central hypothesis of the paper. On the other hand, it is not necessary or helpful to include so much data in the manuscript, or in supplemental material, that the central point of the paper is difficult to discern. It is a tricky balance.

3. Follow proper citation practices—Of course, responsible authorship requires avoiding plagiarism. Many researchers think that plagiarism is not a concern for them because they assume it is always done intentionally by "copying and pasting" someone else's words and claiming them as your own. Sometimes poor writing practices, such as taking notes from references without distinguishing between direct quotes and paraphrased material, can lead to including material that is not quoted properly. More broadly, proper citation practices include accurately and completely referencing prior studies to provide appropriate context for your manuscript.

4. Attend to the other important details—The journal will require several pieces of additional information, such as disclosure of sources of funding and potential conflicts of interest. Typically, graduate students do not have relationships that constitute conflicts of interest, but a PI who is a co-author may. In submitting a manuscript, also make sure to acknowledge individuals not listed as authors but who contributed to the work.

5. Share data and promote transparency—Data sharing is a key facet of promoting transparency in science (Nosek et al., 2015). It will be important to know the expectations of the journals in which you wish to publish. Many top journals now require data sharing; for example, sharing your data files in an online repository so others have access to the data for secondary use. Funding agencies like NIH also increasingly require data sharing. To further foster transparency and public trust in research, researchers must deposit their final peer-reviewed manuscripts that report on research funded by NIH to PubMed Central. PubMed makes biomedical and life science research publicly accessible in a free, online database.

Scenario 2 – Authors In Conflict: To prepare a manuscript for publication, a postdoc's data is added to a graduate student's thesis project. After working together to combine the data and write the paper, the postdoc requests co-first authorship on the paper. The graduate student balks at this request on the basis that it is their thesis project. In a weekly meeting with the lab's PI to discuss the status of the paper, the graduate student states that they should divide the data between the authors as a way to prove that the graduate student should be the sole first author. The PI agrees to this attempt to quantify how much data each person contributed to the manuscript. All parties agree the writing and thinking were equally shared between them. After this assessment, the graduate student sees that the postdoc actually contributed more than half of the data presented in the paper. The graduate student and a second graduate student contributed the remaining data; this means the graduate student contributed much less than half of the data in the paper. However, the graduate student is still adamant that they must be the sole first author of the paper because it is their thesis project.

Is the graduate student correct in insisting that it is their project, so they are entitled to be the sole first author?

Co-first authorship became popular about 10 years ago as a way to acknowledge shared contributions to a paper in which authors worked together and contributed equally. If the postdoc contributed half of the data and worked with the graduate student to combine their interpretations and write the first draft of the paper, then the postdoc did make a substantial contribution. If the graduate student wrote much of the first draft of the paper, contributed significantly to the second half of data, and played a major role in the thesis concept and design, this is also a major contribution. We summarized authorship requirements as contributing to thinking, doing, and writing, and we noted that a first author usually contributes to all of these. The graduate student has met all 3 elements to claim first authorship. However, it appears that the postdoc has also met these 3 requirements. Thus, it is at least reasonable for the postdoc to ask about co-first authorship.

The best way to move forward is to discuss their perspectives openly. Both the graduate student and postdoc want first authorship on papers to advance their careers. The postdoc feels they contributed more to the overall concept and design than the graduate student is recognizing, and the postdoc did contribute half of the data. This is likely frustrating and upsetting for the postdoc. On the other hand, perhaps the postdoc is forgetting how much a thesis becomes like “your baby,” so to speak. The work is the graduate student’s thesis, so it is easy to see why the graduate student would feel a sense of ownership of it. Given this fact, it may be hard for the graduate student to accept the idea that they would share first-author recognition for the work. Yet, the graduate student should consider that the manuscript would not be possible without the postdoc’s contribution. Further, if the postdoc was truly being unreasonable, then the postdoc could make the case for sole first authorship based on contributing the most data to the paper, in addition to contributing ideas and writing the paper. The graduate student should consider that the postdoc may be suggesting co-first authorship in good faith.

As with any interpersonal conflict, clear communication is key. While it might be temporarily uncomfortable to voice their views and address this disagreement, it is critical to avoiding permanent damage to their working relationship. The pair should consider each other’s perspectives and potential alternatives. For example, if the graduate student is first author and the postdoc second, at a minimum they could include an author note in the manuscript that describes the contribution of each author. This would make it clear the scope of the postdoc’s contribution, if they decided not to go with co-first authorship. Also, the graduate student should consider their assumptions about co-first authorship. Maybe they assume it makes it appear they contributed less, but instead, perhaps co-first authorship highlights their collaborative approach to science. Collaboration is a desirable quality many (although arguably not all) research organizations look for when they are hiring.

They will also need to speak with others for advice. The pair should definitely speak with the PI who could provide input about how these cases have been handled in the past. Ultimately, if they cannot reach an agreement, the PI, who is likely to be the last or “senior” author, may make the final decision. They should also speak to the other graduate student who is an author.

If either individual is upset with the situation, they will want to discuss it when they have had time to cool down. This might mean taking a day before discussing, or speaking with someone outside of the lab for support. Ideally, all authors on this paper would have initiated this conversation earlier, and the standards in the lab for first authorship would be discussed routinely. Clear communication may have avoided the conflict.

HOW TO USE DECISION-MAKING STRATEGIES TO NAVIGATE CHALLENGES

We have provided advice on some specific challenges you might encounter in research. This final section covers our overarching recommendation that you adopt a set of ethical decision-making strategies. These strategies help researchers address challenges by helping them think through a problem and possible alternatives (McIntosh et al., 2020). The strategies encourage you to gather information, examine possible outcomes, consider your assumptions, and address emotional reactions before acting. They are especially helpful when you are uncertain how to proceed, face a new problem, or when the consequences of a decision could negatively impact you or others. The strategies also help people be honest with themselves, such as when they are discounting important factors or have competing goals, by encouraging them to identify outside perspectives and test their motivations. You can remember the strategies using the acronym **SMART**.

1. Seek Help

Obtain input from others who can be objective and that you trust. They can assist you with assessing the situation, predicting possible outcomes, and identifying potential options. They can also provide you with support. Individuals to consult may be peers, other faculty, or people in your personal life. It is important that you trust the people you talk with, but it is also good when they challenge your perspective, or encourage you to think in a new way about a problem. Keep in mind that people such as program directors and university ombudsmen are often available for confidential, objective advice.

2. Manage Emotions

Consider your emotional reaction to the situation and how it might influence your assessment of the situation, and your potential decisions and actions. In particular, identify negative emotions, like frustration, anxiety, fear, and anger, as they particularly tend to diminish decision-making and the quality of interactions with others. Take time to address these emotions before acting, for example, by exercising, listening to music, or simply taking a day before responding.

3. Anticipate Consequences

Think about how the situation could turn out. This includes for you, for the research team, and anyone else involved. Consider the short, middle-term, and longer-term impacts of the problem and your potential approach to addressing the situation. Ideally, it is possible to identify win-win outcomes. Often, however, in tough professional situations, you may need to select the best option from among several that are not ideal.

4. Recognize Rules and Context

Determine if any ethical principles, professional policies, or rules apply that might help guide your choices. For instance, if the problem involves an authorship dispute, consider the authorship guidelines that apply. Recognizing the context means considering the situational factors that could impact your options and how you proceed. For example, factors such as the reality that ultimately the PI may have the final decision about authorship.

5. **Test Assumptions and Motives**

Examine your beliefs about the situation and whether any of your thoughts may not be justified. This includes critically examining the personal motivations and goals that are driving your interpretation of the problem and thoughts about how to resolve it.

These strategies do not have to be engaged in order, and they are interrelated. For example, seeking help can help you manage emotions, test assumptions, and anticipate consequences. Go back to the scenarios and our advice throughout this article, and you will see many of our suggestions align with these strategies. Practice applying SMART strategies when you encounter a problem and they will become more natural.

CONCLUSION

Learning practices for responsible research will be the foundation for your success in graduate school and your career. We encourage you to be reflective and intentional as you learn and hope that our advice helps you along the way.

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