

The Case of the Finicky Reactions: A Case Study of Trust, Accountability, and Misconduct

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Abstract: Scientific knowledge-building requires careful engagement with the phenomena being studied and with other researchers. In instances where attempts to replicate research findings fail, it can be challenging to determine whether the source of the problem is an experimental factor or a scientist who is not trustworthy. This paper presents a case study to illuminate the ethical challenges of responding to a failure to reproduce an experiment in a training environment. Ethical analysis of the case takes account of features of the situation connected to knowledge-building and to competition between scientists for credit, and includes consideration of how obligations to trainees and to the broader scientific community can shift depending on the facts in evidence.

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1. Introduction

Chemistry is a field where knowledge-building involves working with a team, making sure the results you find are reproducible, and trying to find the source of the problem when results turn out not to be reproducible. It is also a field whose practitioners use published scientific results and techniques described in the literature as the starting point for their own knowledge-building projects.

Knowledge is not fixed for all time when it is published in a scientific journal. We assume that additional research may reveal new effects, better interpretations of old data, the limitations of particular experimental methods, even mistakes. However, published reports of research cannot play even this role, of tentative knowledge, if they are fabricated or falsified.

Fabrication is making up data or results rather than actually collecting them from observation or experimentation. Falsification involves ‘adjusting’ real data – changing the values, adding some data points, omitting other data

points. Both fabrication and falsification amount to lying about the empirical data, which means that these practices undermine the project of building a body of reliable knowledge about the world. Plagiarism is misrepresenting the words or ideas (or, for that matter, data or computer code, for example) of others as your own. Plagiarism is a sort of dishonesty that robs someone else of their credit in the knowledge-building project. There are other behaviors that can do damage to knowledge-building efforts within the community of science, such as sabotaging someone's equipment or refusing to share important research materials like reagents or cell lines. However, fabrication, falsification, and plagiarism are recognized as 'high crimes' against the scientific endeavor (Zigmond & Fischer 2002) and as such are explicitly included in official definitions of scientific misconduct.

Scientific misconduct provides a special challenge for both knowledge-building and ethical decision-making in science. It is hard enough to understand a phenomenon or to work out how to control an experiment when you and the other scientists with whom you are working are honest about the data observed and the procedures used to obtain the data. If one or more of those scientists is lying about procedures or observations, what conclusions can you draw?

Part of the challenge is that experimental results themselves are not enough to distinguish hard-to-reproduce results from made-up results. If you cannot replicate an experiment, it might mean that you failed to follow all the necessary procedures, that your experimental skill was not sufficient, that your equipment was not precise enough, that your reagents were not pure enough. It might mean that the description of the experiment you are trying to reproduce failed to identify a parameter that matters a lot to producing the desired outcome. But it could also mean that the scientist who described that experiment and reported those results is not trustworthy.

The fact that scientists compete with each other (to be the first to a discovery, or to secure scarce research funding or jobs) complicates things. Researchers are engaged in building a shared body of reliable knowledge about the world, which requires that they cooperate with each other and evaluate each other's results. At the same time, they have individual incentives that pull against cooperation so they can stake their priority claims or win their grants. These dynamics can make it harder to identify misconduct, because an ethical scientist trying to control the flow of information before her findings are published can be hard to distinguish from a scientist who is being secretive because her 'data' are made up. Fierce competition for scarce resources can also make it hard to know whether practices falling short of misconduct might still be ethically problematic, either because they undermine knowledge-building or because they are unfair to other knowledge-builders.

Because doing chemistry means engaging with chemical phenomena and with other people, chemistry students should understand the harm scientific misconduct does to the knowledge-building endeavor. They should also recognize the challenges of identifying and addressing misconduct, and how these challenges can fall heavily on scientific trainees.

In real life, unless you yourself are consciously committing an act of misconduct, it can be hard to tell whether the situation in which you find yourself involves misconduct or something else. But scientists are always placed in the position of drawing the best conclusions they can on the basis of incomplete information. Sometimes these are judgments about the chemical systems they are studying, and sometimes they are judgments about how much they can trust their fellow scientists.

2. The Case of the Finicky Reactions

The case presented here is fictional, although it bears some resemblance to a number of real cases. I have opted for a fictionalized case in part because the central players in real misconduct cases are usually not forthcoming about the details of what they did and why they did it. They often dispute the facts asserted in official findings or by other parties, and they frequently see little benefit in being candid about their motivations.

The case itself is presented in three parts, meant to reflect one way the situation described here could unfold. Remember that an inescapable feature of our ethical decision-making is that we cannot know in advance exactly what consequences will come from our decisions. We make the best decisions we can on the basis of the evidence we have, and we never have the luxury of delaying action until we have complete information.

When thinking through each part of this case, it is worth asking: What do the characters here know? About which of their questions are they uncertain? What is the ethical weight of what they know and what they do not know? It is also worth considering how differing roles (Ph.D. student or professor) bring with them different interests, obligations, and likely consequences for one's actions. Especially important in understanding likely consequences are the power differentials, especially between students and research directors.

Part 1

At the end of her first year of her Ph.D. studies in chemistry, Anna Bijou joins the research group of Dr. Martin Green. The first project Dr. Green

assigns her involves extending a set of organometallic reactions that were the centerpiece of the doctoral thesis of Paul Fanning, a recently graduated Ph.D. from the Green group. Fanning's journal articles on these reactions were part of what attracted Bijou to the Green group, so she is excited to carry this research forward.

Bijou's excitement does not last. Her initial attempts to reproduce Fanning's reactions, guided by the 'Materials and Methods' sections of his journal articles, fail to produce the desired products. Reasoning that the reactions might not be working because they are sensitive to experimental conditions that are not fully described in Fanning's journal article, she sets about trying to find Fanning's lab notebooks.

"Paul left eleven notebooks from his six years in the lab," says Tony Pham, a third-year doctoral student in the group. "They're on the bookshelf in Room 203. But there aren't many helpful details in them."

"What do you mean?" asks Anna Bijou.

"If Dr. Green has you trying to reproduce Paul's reactions, the scratchings in those notebooks will probably be of as little use to you as they were to me. But maybe the notebooks I kept will give you something," Pham says, handing them over to her. "You could also look at Carole Lee's notebooks. She actually got a couple of those reactions to work once or twice, back when Paul was still in the lab."

"I don't think I've met Carole yet," Bijou replies. "I should, so I can ask her – and you – what I'm doing wrong."

Shaking his head sadly, Tony Pham answers, "I'll tell you what I can on my way out, and I'll give you my email in case you want to ask more, but Carole's gone and this is my last day. When we couldn't get Paul's reactions to work, the boss decided to cut us loose. I'm not sure how much help I can be. And, if you want to stay on good terms with Dr. Green, you should probably keep your distance from me."

Anna Bijou is startled at this revelation. She thanks Pham for his help, then sits down with a stack of lab notebooks from Paul Fanning, Tony Pham, and Carole Lee, trying to figure out her next approach to her experiments.

By the end of the afternoon, she has discovered that Paul Fanning's notebooks are nearly incomprehensible. In contrast, Tony Pham's and Carole Lee's notebooks contain clear, detailed descriptions of multiple attempts, over many months, to reproduce Fanning's reactions. Lee's notebooks include especially exhaustive details of experimental runs and trouble-shooting as Lee tried to repeat her own limited success and to determine which piece of the experimental set-up had changed beyond the absence of Paul Fanning.

Anna Bijou plans her next experimental attempt, but she fears that Fanning's reactions may not be reproducible. She feels like she ought to communicate her concerns to Dr. Green, but she is scared by his apparent

dismissal of Tony Pham and Carole Lee for their inability to get these reactions to work. What if Dr. Green responds by dismissing her, too? As she gathers her things, she takes a deep breath and hopes against hope that her next experimental run will be more successful.

Questions

1. Should Anna Bijou bring her concerns to Dr. Green? If so, how should she present them? If not, what else should she do instead?
2. Anna Bijou's decision is difficult because she is uncertain how Dr. Green will react if she shares her concerns. What is the best reaction she might hope for? What is the worst reaction she might fear? How could these reactions translate into consequences for Anna Bijou, in both the short-term and the long-term?
3. Because Dr. Green has enormous power over her scientific future, Anna Bijou might feel safest just trying to keep him happy and keeping her concerns to herself. If she chooses this course of action, who will benefit? Who will be hurt?
4. Anna Bijou may feel that Dr. Green's response to the two students he dismissed is unethical. However, telling her supervisor she thinks he is being unethical is risky. As a student, who else could she turn to for help? Who else might have the power to assist her? Who else might have the responsibility to assist her?

Part 2

Dr. Martin Green is a recently tenured Associate Professor of Chemistry at a major research university, running a research group with eight graduate students and two postdocs. Almost two years ago, one of his first graduate students, Paul Fanning, earned his Ph.D. Fanning discovered a series of new organometallic reactions, and the journal articles that Fanning and Green coauthored on these reactions lent significant weight to Green's tenure case.

Since Fanning graduated and left the Green group to pursue a postdoc at another university, things have not been going so smoothly.

Martin Green finds himself frustrated that none of his current personnel seem to have the experimental skills or the patience to get Fanning's reactions to work. Indeed, two of the graduate students he assigned to projects that were to build off of Fanning's reactions wasted more than a year each without success. Rather than recognizing their own experimental shortcomings (or working to remedy them), they tried to excuse their failures by suggesting that Paul Fanning might not have gotten exactly the results reported in the journal articles. One of these students even suggested to Green that the results might have been fabricated (although she did not use the word).

Finally, Dr. Green ran out of patience and dismissed these students, Carole Lee and Tony Pham, from his research group. He had enough to do without having to micromanage students' experimental attempts, and their negativity was hurting morale in the lab.

Green is hopeful about the new doctoral student, Anna Bijou, who has recently joined the research group. Assigned to pick up where Fanning's projects left off, she has been working diligently at the bench, and carefully studying both the journal articles describing Fanning's reactions and the lab notebooks kept by lab members (including Fanning, Lee, and Pham) who have been working on these reactions. Bijou's experimental skills are not yet where Fanning's were, but Green is sure they will improve rapidly, given her work ethic and her determination.

Dr. Green's hope starts to fade when, at their weekly one-on-one meeting, Anna Bijou describes all of the things she has tried in her efforts to reproduce Fanning's reactions. "I have ruled out every possible problem I could think of," she tells him. "Maybe they're very finicky reactions, because I'm setting them up exactly as described and I'm not finding any trace of the products Fanning says he got."

Green expects to feel the same impatience that led him to dismiss Carole Lee and Tony Pham. Instead, he realizes that what he feels is fear. *Maybe something is wrong with the results he and Fanning published.*

Sitting across the desk from him, Anna Bijou asks Dr. Martin Green, "What would you like me to do next?" Green realizes that he is not sure what he should do next.

Questions

1. What, if anything, should Dr. Martin Green do given his worry that something might be wrong with Fanning's published results?
2. What responsibilities does Dr. Green have to Anna Bijou? Does the news she is sharing about the finicky reactions change any of his responsibilities to her?
3. What responsibilities does Dr. Green have to the other personnel in his research group? To Paul Fanning? To the students he dismissed from the group? To his department? To his scientific community?
4. Dr. Green secured tenure partly on the strength of his scientific research and publications. What negative consequences might he face if the results he published with Paul Fanning turn out to be wrong?
5. Are there any positive consequences that could come to Dr. Green from identifying and addressing a problem with his publications on the finicky reactions?

Part 3

After many discussions with his graduate student Anna Bijou, some of them in the lab as she was conducting her experiments, Dr. Martin Green is almost certain that something is wrong with the organometallic reactions Paul Fanning said he discovered, reactions that Fanning and Green reported as coauthors. Bijou's experimental skills are very good, her lab records are exhaustive, and her logical reasoning in trying to track down the experimental problem has been impressive.

All the evidence suggests that the reactions described in those journal articles just do not work. The only question that remains for Dr. Green is whether this comes down to an honest mistake on Fanning's part or an intentional deception.

Either way, Dr. Green decides that he will have to retract those articles to correct the scientific record. And, because Paul Fanning is the first author on the articles, Green will probably have to contact Fanning about the planned retractions.

While he contemplates these unpleasant tasks, Dr. Green checks his email and finds a message from the coordinator of the department's NMR facility. When Anna Bijou had been running through possible explanations for the discrepancies between her experimental results and Paul Fanning's experimental results, she decided it was worth checking whether there had been any issues with the NMR facilities (either for her runs or during Fanning's time in the lab) that might have led to misidentification of the products. The NMR facility coordinator's email notes that the equipment was operating without problems for all of Anna Bijou's runs. It also notes that the facility has no record of an NMR account for Paul Fanning.

NMR spectra featured prominently in the journal articles by Fanning and Green on the troublesome reactions, so this news disturbs Dr. Green. He sets it aside to have a quick conversation with his lab manager about why the lab's spending lately seems to have accelerated. "Elemental analyses," she tells him. "Your grad students have been ordering elemental analyses of their products, and those aren't cheap."

"I don't remember them being so expensive a few years ago, when Paul Fanning was running all those reactions and characterizing all of his products," Dr. Green says wistfully.

"Paul Fanning never placed an order for an elemental analysis in the six years he was in the lab," the lab manager replies.

Martin Green adds this to the other pieces of bad news and wonders whether he can get through a phone call with Paul Fanning without screaming. As he imagines what he could say to Fanning, Anna Bijou knocks timidly at his door. "I found something in one of Paul's notebooks," she says. "I

think it's pretty bad." She clutches an NMR spectra print-out which, when held up to the light, shows clear signs of being altered with correction fluid.

Questions

1. Should Dr. Martin Green contact Paul Fanning directly about his plans to retract their papers? If so, should he mention these other issues? If not, what should he do instead?
2. Have Dr. Green's responsibilities to Paul Fanning changed in light of what he has learned?
3. What are the potential consequences of trying to handle the situation with Paul Fanning quietly? Who benefits if Dr. Green chooses this course of action? Who will be harmed, and how?
4. What responsibility does Dr. Green have for conditions and practices in his research group that led to what now looks like fraudulent publications? Which particular practices seem to have enabled sloppy work or wrongdoing? What should Dr. Green do to prevent such problems going forward?
5. What does Dr. Green owe Tony Pham and Carole Lee? What does the department owe them?

3. Ethical Analysis of the Case

Here, I draw on the strategy for ethical decision-making described by Muriel J. Bebeau (1995). The strategy involves identifying who has an interest in the situation where an ethical decision must be made, considering the consequences (positive or negative, short term or long term) that might come to those interested parties depending on what action is taken, and the obligations (responsibilities, duties) of the person trying to make an ethical decision towards each of those interested parties (including to themselves). Once this information is on the table, the task is to choose an ethical course of action. This may be the course of action that maximizes the good consequences and minimizes the bad consequences for all the interested parties in the aggregate (a consequentialist approach). Or it may be the course of action that allows the protagonist in the case to fulfill their duties to all the interested parties insofar as this is possible, recognizing that some duties are stronger than others and that obligations can conflict with each other (a Kantian approach). Or it may be the course of action that a properly functioning scientist would take in the situation, where 'proper functioning' amounts to being able to play their proper role as a knowledge-builder and a

trainer of new scientists (a virtue ethics approach). If possible, it is desirable to choose a course of action that is ethical from each of these perspectives.

In this case, we are presented with two protagonists who are trying to make good ethical decisions, Anna Bijou, a graduate student working toward her Ph.D., and Dr. Martin Green, a professor who is supervising Anna Bijou's research and training. These two players have different interests, different obligations, different information about the situation that is unfolding, and vastly different amounts of power.

Anna Bijou has an interest in getting good scientific training in her Ph.D. program. As a chemist in training, she has an interest in building reliable knowledge and cultivating the skills to be a successful knowledge-builder in her scientific field. She also has an interest in cultivating the relationships that will help her further her scientific career. This includes having a good working relationship with Dr. Martin Green, her advisor. As well, Anna Bijou has interests connected to her own sense of herself, including an interest in maintaining her own integrity and in having a clear conscience.

Dr. Martin Green has many similar interests here. As a scientist, he has an interest in building reliable knowledge and in maintaining good relations with other members of the scientific community. He also has an interest in avoiding harm to his reputation and career (including his tenure), and in protecting his own integrity and conscience. But his career stage and professional role bring some additional interests. Because he heads a research group, Dr. Green has an interest in having group members who accept his guidance and respect his expertise. He also has an interest in having group members who do honest work and who communicate important information to him. He has an interest in bringing in grant money to support the work of his research group, in securing credit for his scientific findings, and in providing good training to new members of the scientific community.

Other parties besides Anna Bijou and Dr. Martin Green have relevant interests in this case. Paul Fanning is certainly an interested party. He has an interest in protecting his own reputation and career, as well as his priority claim on his scientific discoveries. He also has an interest in being treated fairly by others in his scientific community. Tony Pham and Carole Lee are also interested parties who, among other things, have an interest in some recognition of their efforts to build reliable scientific knowledge and to develop good experimental skills. The other members of Dr. Green's research group have an interest in a research environment where they can trust each other's work and they can share their concerns without fear of retaliation. Other faculty, students, and staff in Dr. Green's department and university have an interest in maintaining the integrity and the reputation of the organization. Members of the scientific community have an interest in being able to trust that what is reported in the scientific literature reflects honest efforts to

build objective knowledge – and an interest in being able to trust other members of the scientific community more generally. Members of the general public also have an interest here; since public money is allocated to support scientific research, the public has an interest in that money going to good use to build reliable knowledge and to train researchers who are skilled and ethical.

In contemplating what to do, the person confronted with an ethical decision ought to consider potential consequences for the course of action they are contemplating. It is not enough to choose a path likely to result in the best outcomes for oneself. Rather, an ethical decision ought to give consideration to producing good outcomes and avoiding bad outcomes for the other interested parties as well.

In Part 1 of the case, Anna Bijou is weighing the consequences of telling Dr. Green that the reactions he has asked her to reproduce are not reproducible against the consequences of doing something else instead. The fact that she is a relatively new member of Dr. Green's research group means that she may not have much information from which to predict how Dr. Green will respond to her. Given what she has learned about his dismissal of Carole Lee and Tony Pham, though, Bijou may suspect that telling Dr. Green that she cannot get the reactions to work could lead to her own dismissal from the research group. If that happens, depending on the policies in their department and university, Bijou may need to find another faculty member with the funding and space in their research group to accept her as a student; otherwise, being dismissed from Dr. Green's research group is *de facto* being dismissed from the graduate program. Even if Bijou finds another research group willing to have her, this may require her to shift her area of research. The time and effort she has already invested in her research for Dr. Green would be lost.

Beyond the consequences for Anna Bijou in terms of her progress to her Ph.D., telling Dr. Green that she cannot reproduce Paul Fanning's experiments could have an impact on her relationship with Dr. Green. He might judge her to be a poor experimentalist, or a quitter. Given the importance of Dr. Green's assessment of her for her future as a chemist in his subfield, if he develops a negative opinion of her it could have lasting repercussions for her career.

But there are also potential consequences for Anna Bijou if she decides to keep her concerns to herself. She may engage in more futile attempts to get the reactions to work, and after that additional time and effort Dr. Green may still judge her a poor experimentalist. Perhaps she will figure out a way to make the reactions work after all. Or, faced with mounting pressure from Dr. Green to get the reactions to work, she may feel pressured to fake experimental success. This response would probably impact Bijou's conscience

and, in the case that her fakery is discovered, it could well mean the end of her scientific reputation and career.

Anna Bijou's choice here will have consequences for the other interested parties as well. If she keeps her concerns to herself, Paul Fanning maintains his reputation and his career trajectory. The Green group maintains its stellar publication record. But, if there is actually something wrong with the results reported in Fanning's journal articles – if those reactions really are irreproducible – keeping her concerns to herself means that other scientists might be trying to base their own research projects on these erroneous results. That might mean that they are wasting time and effort on a dead-end – and that scarce research funding is being wasted, too.

On the other hand, if Anna Bijou shares her concerns with Dr. Green, he potentially faces a number of consequences. His relationship with Paul Fanning may suffer. His confidence in the research output of his lab, and in the decisions he has made in managing his lab personnel (including dismissing Carole Lee and Tony Pham) may also be undermined. Because of the important role his research collaboration with Fanning and the publications that resulted from it played in his tenure case, Dr. Green may worry about whether he ought to have been tenured – and whether, if Fanning's results are not reproducible, his employment status at the university might be at risk. On the other hand, if Fanning's reactions really do not work, it might be better for Green's scientific reputation if this news comes from his own research group rather than from a scientific competitor.

What are Anna Bijou's obligations as she decides what to do about her concerns? She has obligations to Dr. Green, as her mentor and boss, to perform the tasks assigned to her, to respect his knowledge, experience, and judgment, but also to share relevant information with him. She has an obligation to her department and university to uphold their standards and not to sully their reputation. She has an obligation to other members of the scientific community to play her part in building a shared body of reliable knowledge, including identifying problems that ought to be corrected with the scientific record. To the other members of the scientific community she also has an obligation to cultivate a good reputation with the public. This includes an obligation not to make baseless accusations against other scientists. Anna Bijou also owes it to the scientific community to cultivate the kind of honest communication between scientists without which the knowledge-building project is impossible. Finally, Anna Bijou has obligations to herself: to look out for her own reputation and career, not to derail her educational progress, not to undermine her integrity or to make a decision that will make it hard for her to live with herself.

Note that the focus on Anna Bijou's obligations here, in the context of her efforts to choose an ethical course of action, does not erase Dr. Martin

Green's obligations! Given the details of the case, there is ample reason to believe Green has fallen down on a number of his obligations, especially on those to his trainees. However, the power imbalance means the consequences for Anna Bijou of telling Dr. Green his conduct has been unethical could be extreme. While she has an obligation to be honest, her obligations to herself and her own well-being in the short-term and long-term mean that she must be strategic.

Question

Part 2 of the case shows us Anna Bijou communicating her concerns to Dr. Martin Green. Is there anything else she could have done here that would have been ethical?

Part 2 of the case shifts to the point of view of Dr. Martin Green. Green is trying to decide what, if anything, he should do about the possibility that there is something wrong with the results he published with Paul Fanning.

The interested parties are the same as those Anna Bijou might have been considering in deciding whether to communicate her concerns to Dr. Green. As she did when choosing her ethical course of action, Dr. Martin Green must now consider the potential consequences, for himself and for the other interested parties, of what he does next.

An option that may be tempting is to set Fanning's reactions aside and to shift the group's focus to devising other organometallic reactions. This would let Anna Bijou and other members of the group spend their time more productively, rather than to keep them stuck on what seems to be a dead-end. However, making this shift internal to the group without sharing his concerns with the larger scientific community could result in scientists in other research groups wasting their time on this dead-end. Without Green's intervention, his articles with Fanning may stay in the scientific record asserting that these reactions are possible when maybe they are not.

No matter what Green decides to do here, his opinion of Fanning is likely impacted. As things stand, Green may not know whether Fanning just missed an elusive factor necessary to make a finicky reaction run reliably, or whether he missed a more obvious factor due to carelessness, or whether he was dishonest about the research he conducted. If Green contacts Fanning to discuss his concerns with the reactions, Fanning might help him figure out what the problem is – or, Fanning might tell Green something aimed at protecting his own reputation rather than at getting to the bottom of the problems with the reactions.

If Green decides to investigate what is wrong with the reactions without involving Fanning, it might hurt Fanning's reputation within the research group, which could in turn impact Fanning's reputation in the wider scien-

tific community. Keeping Fanning out of the loop could also mean that Anna Bijou and other members of Dr. Green's research group do not have crucial pieces of information about how to get the experiments to work that they might otherwise be able to get from Fanning. Then again, asking Fanning for help here will only be useful if Fanning was honest about being able to run the reactions in the first place. If the problem here is less a finicky set of reactions than a dishonest chemist, involving Fanning gives him the opportunity to interfere. (In Part 1, Tony Pham told Anna Bijou that Carole Lee was only able to get Paul Fanning's reactions to work herself when Fanning was still in the lab. If Bijou has shared this information with Dr. Green, he needs to consider what kind of conditions for a replication would convince him that the reactions – and Fanning – are reliable.)

If Dr. Green decides to dig deeper into what is going on with these reactions, and with Fanning, there could be significant consequences for Green, members of his research group, his department and university, and his scientific community, depending on what he finds. Green might get a reputation as someone whose group produces sloppy results (or worse), or he might get a reputation as an honest researcher interested in maintaining the quality of the scientific record. He might be looked upon as a scientist committed primarily to the truth, even if it means correcting findings that have come from his own research group, or he might get a reputation as someone who played favorites, to the extent that he would dismiss graduate students making reasonable attempts to correct the record if it meant protecting himself and his favorite former student. The department and university could lose some prestige for their connection to published results that do not hold up (and to Fanning, who produced them). The fact that Lee and Pham were dismissed might also discourage future graduate students from choosing this department or Green's research group. If there is a scandal around Fanning's findings, the public's opinion of these scientists – and of scientists in general – might be harmed. Potentially, this could have an impact on public funding for scientific research in the future.

As a professor, Dr. Martin Green's obligations are somewhat different from Anna Bijou's obligations. He has an obligation to Anna Bijou, and to all the graduate students in his research group, to provide good scientific training, to provide good mentoring, and to set a good scientific example. Arguably, Dr. Green has an obligation to treat his trainees as future colleagues, not simply as cheap labor to generate scientific results. Part of this is a duty to take seriously what they tell him about their experiments and the work conditions and interpersonal interactions in the lab group.

Green has also obligations to his former students. He has an obligation to Paul Fanning to respect him as a member of their scientific community. This includes not assuming wrongdoing on Fanning's part without evidence, as

well as looking out for Fanning's reputation and career. Even though Fanning has received his Ph.D. and moved on from the Green group, Green arguably has a duty to continue mentoring Fanning and to set a good example of how to be a responsible scientist for him.

As well, Green has obligations to Carole Lee and Tony Pham, the graduate students he dismissed from his research group. If he dismissed them primarily because they were unable to reproduce Fanning's reactions, Green arguably has an obligation to address the harm this dismissal may have done to their education and their careers.

Dr. Green has obligations to his department and university to do research, to train students, to bring in funding, to uphold standards, and to contribute positively to their reputation. He has obligations to his research group to provide funding, safe lab conditions, guidance, and oversight, and to ensure that the group is functioning well.

Green has obligations to the journal that published his papers with Fanning. These include the obligation to make corrections or retractions if the situation warrants it. He also has obligations to the scientific community to contribute to honest knowledge-building, to train future members of the community to be responsible scientists, to help correct known errors in the scientific record, and to identify wrongdoers in the community lest they deceive other scientists.

Finally, Dr. Martin Green has obligations to himself. Among these are the obligation to protect his own reputation and career, his own integrity and conscience. Green has a duty to be the kind of scientist he knows he ought to be. This includes admitting past mistakes and addressing them.

Whatever particular course of action Dr. Martin Green elects to pursue at the end of Part 2 of the case, it is reasonable to assume he has an obligation to do what he can to get to the truth of what is happening with these chemical reactions – and with Paul Fanning.

In Part 3 of the case, Dr. Green becomes aware of new information that may shift his obligations, especially in terms of the prospects for being able to fulfill them all or having to recognize some conflicts between them. From working closely with Anna Bijou and observing her experimental efforts, he has good empirical evidence that the reactions as described in Fanning's journal articles just do not work. From his lab manager, he has evidence that Fanning did not order elemental analyses of the products of his reactions. From the coordinator of the NMR facility, he has evidence that Fanning did not have an NMR account. Finally, he has the altered NMR spectra Anna Bijou found in Fanning's lab notebook. Taken together, these facts seem to support the hypothesis that the problem is not just that the desired reactions are finicky, but that Paul Fanning may have fabricated or falsified the results he reported.

It is also worth noting that Dr. Martin Green now knows that there are other people who have reason to believe there is a problem here (Anna Bijou, the lab manager, and the NMR facility coordinator). Arguably, whether or not other people know there is a problem should not wholly determine Green's response, since *he* knows there is a problem. However, the fact that other people are aware that all is not well might well lead to consequences that are relevant. For example, students and staff members who know that something is wrong but who see the cognizant faculty member doing nothing to address the problem may become cynical and start to believe that the 'rules' of honest science can be sacrificed to get publications or to protect one's reputation. This is a potential consequence that could be corrosive to the cooperation and trust scientific communities need to build reliable knowledge.

How have Dr. Martin Green's obligations shifted by Part 3 of the case? Given the facts in evidence, the likelihood that there has been a significant problem, and that the problem is the result of misconduct, is too high to ignore. Given his relationships (with Paul Fanning and Anna Bijou, among others) and his interests (to be an honest scientist, to protect his reputation), Dr. Green needs to recognize that he may not be the right person to untangle what really happened. Green has an obligation to recognize his own biases here. On account of these biases, Green should pass on the evidence he has to someone who can be more objective, like the university Research Integrity Officer, so that they can investigate whether Fanning has committed scientific misconduct.

It's worth noting that bringing in the Research Integrity Officer is a best practice. Someone involved in the research (especially someone who has earned tenure on the basis of it) will have biases on the basis of their relationships with the other personnel and their attachments to their own scientific hypotheses and intuitions. The Research Integrity Officer is more likely to have enough distance from the matter to make a more objective determination of the facts, and has the institutional authority to report findings to the appropriate parties, including funding agencies and journals.

In light of what he knows at this point, Dr. Green has an obligation to other scientists who may consult those journal articles he coauthored with Fanning to signal that there is a problem with them. When the exact nature of the problem is known (perhaps through the Research Integrity Officer's investigation), he has a duty to be transparent about it, contacting the journal editors to communicate corrections or retractions as needed.

It may be tempting for Dr. Martin Green to blame all the problems in this case on Paul Fanning, identifying him as a bad apple in an otherwise ethical research group. However, as head of the lab, Green has an obligation to think hard about whether the way he has been running the lab may have contribut-

ed to this situation. Has he been providing enough guidance for his graduate student researchers? Has he provided too little oversight, either of experiments and data or of interactions with the NMR facility or requests for elemental analyses? Especially in large research groups, it can be tempting for the lab head to delegate oversight to a lab manager and transmission of best practices (e.g., standards for keeping notebooks and other research records) to advanced graduate students. A case like this illustrates the risks inherent in that approach.

Has Dr. Green conveyed to his lab members, explicitly or implicitly, that experimental failures are unacceptable? Did he come into this research with such a strong expectation that these reactions should work that he failed to exercise sufficient skepticism about positive results, or that he was overly skeptical of negative results? Has he engaged in favoritism? Green has a duty to address any issues in his lab management style that incentivize cheating, that create barriers to honest communication, or that otherwise undercut his ability to train responsible scientists while building reliable knowledge.

How do Dr. Green's duties to Paul Fanning shift by Part 3? While Green still has obligations to Fanning, an obligation to cover up Fanning's misdeeds is not among them. Concealing misconduct would run counter to his duties to the larger scientific community. Handing the investigation over to a more objective party like the Research Integrity Officer would mean that Green understands that his duty to uphold standards of scientific integrity outweighs his duty to protect Fanning's reputation. But Green still has duties to Fanning as a scientific colleague – indeed, as a colleague he mentored and trained as a scientist. One of these may be an obligation to share his assessment of Fanning's potential to contribute to the scientific community, and to share how the lab environment and his own management style may have contributed to Fanning's bad choices, with those investigating Fanning's conduct.

In his role as a mentor to Fanning, Green arguably has a duty to hear Fanning's side of things. As well, he has an obligation to communicate to Fanning just how damaging fabrication and falsification are to knowledge-building within their scientific field – and how personally hurtful Green finds it to have been lied to and to have his reputation on the line with Fanning's. However, it is not clear that Green has an obligation to engage in this direct communication with Fanning *before* a neutral third party has had a chance to investigate the situation. Communicating with Fanning before an investigator can secure the relevant evidence might give him a chance to tamper with it or destroy it.

Finally, Dr. Martin Green needs to consider his obligations to Carole Lee and Tony Pham, the graduate students he dismissed from his lab group when they failed to reproduce Paul Fanning's experiments. Given the facts in evi-

dence by Part 3 of the case, it is reasonable to conclude that these failures had more to do with problems with the purported reactions than with Lee's and Pham's experimental skills or scientific potential. Indeed, it now seems that they were doing exactly what individual scientists must do for science to be 'self-correcting'. They attempted to reproduce a finding, and when they could not, they shared that information with other scientists. Here, they shared the information with their lab head, Dr. Green, rather than taking it to a higher authority in the department or the university. Had they gone to a higher authority with their concerns, as 'whistleblowers' they might have been given some legal protection from retaliation, but they still might have lost their places in the Green lab. At this point, with compelling evidence that Lee and Pham were not wrong to be concerned about these chemical reactions (or about Paul Fanning), Green has an obligation to do what he can to make things right for them to the extent possible. This might mean making room for them in his lab group again, or using his professional network to help find them reasonable educational or employment situations elsewhere. It might also involve publicly acknowledging their role in identifying the problems with reactions he and Fanning reported in the literature. To fulfill his obligation to make things right for Lee and Pham, Green should probably start by *asking* them what kind of help they need from him.

It is important to note here that any ethical path forward in this case will involve some negative consequences for Dr. Martin Green. There are some options that might spare Green some negative consequences in the short term, but these are likely to bring him negative consequences in the longer term. Plus, these options have a good chance of bringing more bad consequences for most of the other interested parties. Even Paul Fanning may be better off in the long run if Martin Green intervenes now and argues for the possibility of rehabilitation. If Fanning continues on and racks up a record of more frauds before being caught, the prospects of mercy for him are slim.

4. Some Comparable Cases

Some key details of this case are inspired by the case of Bengü Sezen and Dalibor Sames in the Chemistry Department at Columbia University. The press coverage of the case began, in 2006, with a set of retracted papers and a dispute between Sames, the senior author, and Sezen, his former graduate student, about whether the papers ought to have been retracted, as well as about whether the experiments reported in those papers were reproducible (Chang 2006a/b). By the time the findings of the United States Department of Health and Human Services on the matter were published in the Federal

Register in 2010, Sezen had been found guilty of falsification, fabrication, and plagiarism of research data in three published papers and in her doctoral dissertation. As well, the investigation conducted at Columbia University found that Sames asked two graduate students who had devoted significant time and effort to attempts to replicate and extend Sezen's work to leave his group (Schulz 2011).

There are other cases involving disputes about whether a finding is reproducible in which misconduct is suggested but not proven. An interesting example of this sort is the case of Duke University biochemist Homme W. Hellinga and his graduate student, Mary Dwyer, who coauthored, and then retracted, a pair of papers on enzymes designed using computational methods. According to news coverage around the retractions, Dwyer was concerned that her experimental results were too variable to be ready for publication, while Hellinga thought that the amount of variability they were seeing was normal for this type of system. (The published papers, however, failed to note this experimental variability.) When other researchers tried repeating these experiments and found no enzymatic activity from the designed enzymes, Hellinga at first assured them that the experiments worked, and that he knew this because the Hellinga lab had run a number of negative controls. Later, according to Dwyer, Hellinga confronted her and said "I find it really hard to believe that you didn't make this up" (Hayden 2008, p. 277). Hellinga retracted the papers, but other researchers remained skeptical that the results reported in them could have been produced using the assays the papers described (Arnaud 2008, p. 41). An inquiry at Duke University cleared Dwyer of the allegations of falsification and fabrication of results. The Hellinga case raises a question that is also central to *The Case of the Finicky Reactions*, namely, how much responsibility does the senior researcher have for scientific work co-authored with his graduate student?

The differentials in experience and power between graduate students and principal investigators can complicate the kind of communication that is essential for knowledge-building. It is hard enough to share the news that one's experimental efforts have been unsuccessful. It is even harder to confront one's supervisor with concerns about misconduct. A number of real-world cases of scientific misconduct have come to light because graduate students or postdocs decided to be whistleblowers, reporting problems in their research groups so they could be addressed. Among these is the case of Diederik Stapel, a social psychologist forced to retract more than 50 publications because he fabricated the results that they reported. Some of his graduate students, concerned about what seemed to be anomalies in experimental results, asked Stapel if they could examine the raw data. When told he no longer had the raw data, they became suspicious but feared that reporting their suspicions would be damaging to their careers. Eventually, Stapel's stu-

dents were able to persuade his department chair that something was amiss, which ultimately led to Stapel's dismissal (Bhattacharjee 2013).

Another case illustrates the high costs for students of blowing the whistle on an advisor's misconduct. Students of Elizabeth Goodwin in the genetics department at the University of Wisconsin-Madison brought their concerns about experimental data and manipulated figures in Goodwin's grant proposals to their department chair. This resulted in a university inquiry that found Goodwin had falsified data in proposals, after which Goodwin resigned her post. Of the six students who brought forward these concerns, three left the Ph.D. program without their degrees, and two others were starting over in new graduate programs, essentially losing the years that they had invested as students in Goodwin's lab (Couzin 2006, p. 1222).

5. Conclusion

Determining whether research results are reproducible is a crucial piece of scientific knowledge-building, one that requires experimental skill, good record keeping, and a thoughtful approach to problem solving. Questions of reproducibility also involve the competence, and the honesty, of other researchers in generating and sharing their results. Scientific knowledge-building takes place in the context of competition between scientists for credit and for resources like funding and jobs. The stakes of the competition make it harder for scientists to be critical of their own positive research findings – especially once they have been published – which, in turn, makes it harder to correct the scientific record when errors creep in.

Especially in research environments that are also training environments, researchers with less power may fear significant negative consequences when they share negative findings or research difficulties with researchers with more power. Their results may be dismissed, or they themselves may be labeled as incompetents or troublemakers. Yet part of learning how to be a responsible scientist is working out how to share information, good or bad, that is relevant to the research with one's supervisor and research team.

This case explores how power disparities complicate the task of sharing information within a research team. From the perspective of graduate student Anna Bijou, we see the challenge of addressing irreproducible results with a lab head who seems to have reacted quite negatively to other students in the same situation. From the perspective of lab head Dr. Martin Green, we see a web of competing interests and obligations, a series of past decisions that have gone badly and the question of how to make things right going forward. Good knowledge-building requires awareness of where you might be mistak-

en, whether about results or people. Practices that make it less dangerous to recognize and address mistakes are vital.

Further Reading

On the Sezen/Sames case see particularly Chang 2006a/b and Schulz 2011. The Hellinga case is covered by Arnaud 2008 and Hayden 2008; the Stapel case by Bhattacharjee 2013; and the Goodwin case by Couzin 2006. On whistleblowing see Gunsalus 1998; on the responsibilities of mentors, see Weil 2001. More details on misconduct and rehabilitation can be found in Stemwedel 2014 and Djerassi 1991.

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