Béla Z. Schmidt

Career Advice for Young Scientists in Biomedical Research

How to Think like a Principal Investigator

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To my lovely wife, Sabrina Noel who helped me to get this far on this path, and to Judit Sándorné Gál and George Füst who put me on it.

Preface

How This Book Can Help You (. . .Become a Principal Investigator and a Successful Scientist)

When was the last time the head of the laboratory sat you down and said: you seem to be less focused on your project lately, let me tell you how I motivate myself. Or: this is how I think about building up a manuscript, or: when you will have your own lab, this is how you will know if a project is going well. . . or: this is how I choose new people for the lab. . .

Unless you are blessed with an exceptionally conscientious and dedicated mentor, your answer to these questions is no. Most principal investigators (PIs)[1] are way too busy with keeping grant money flowing in the lab and keeping the research activity going to give this kind of mentoring to their people.

If your supervisor is available enough and you are observant enough, you may pick some of these things up from her or him. But how many PIs will you work with closely before applying for that first tenure-track position? Three, four? In this book, you will find the summary of advice from over a hundred PIs about how they operate, pick projects, write grants, evaluate data, decide what to spend their and the lab's time on, craft manuscripts, etc.—details that many PIs themselves were not fully aware of until they began answering the interview questions for this book.

Nothing is a waste of time if you use the experience wisely. (August Rodin)

I have spent thirty years in academic laboratories, and, although I am not a head of a laboratory, I know well enough how labs operate to ask the right questions. I started this project to find out what I could have done better to become a PI, which was my original goal. What you are getting here is not my advice, but the collective wisdom of more than a hundred biomedical scientists leading their own laboratories, from 44 research institutions in 11 countries, including a Nobel Prize winner and many others with decades of experience as a principal investigator. At the time of the

[1] Principal investigator (head of a research laboratory)

interviews, the total experience of PIs added up to a whopping sum of 1896 years of leading a lab! I did the work for you: found PIs who were willing to give me an hour of their time, collected their answers, and summarized them for you.

If time machines existed and I could go back to tell my freshly graduated self all that is written in this book, I would tell him: “This is how PIs operate. Do it like them and you will likely succeed, too.” Since this is not possible, I am doing the next best thing, publishing what I have learned from talking with successful principal investigators so that early-career scientist can benefit from it.

This book will be useful to PhD students and postdocs planning to pursue an academic career, as well as medical students or MDs who are thinking about going into biomedical research in academia or getting a PhD. It can also help PhD students who do not aspire to an academic career in the long term but want to learn more about the mindset of their supervisors to complete their projects to graduate. Additionally, I hope that even young principal investigators may find this book a useful source of inspiration on how to achieve their goals.

This book is unique in the sense that the reader gets a summary of the common thinking patterns and values as well as the range of opinions of a large group of active principal investigators—without having to read more than a hundred autobiographies. But this is not a cookbook that gives you a sure-fire way to get tenured (sorry!). When I saw a common theme in the answers I did mention it, of course, but many times there was no consensus, only several alternative approaches to do the same thing.

The parts of the book reporting different opinions and approaches may give you the impression that you are reading “The Natural History of the PI” instead of a career advice book, but I think these parts make this book very valuable. I firmly believe that flexibility, both in their way of thinking and their behavior, is an important contributor to the success of PIs. It is easy to get in a rut and keep doing things the same way as you have always done them, even if the results are suboptimal—this is true not only for physical activities but also for thinking patterns. I hope that reading about the many ways PIs work and think will give you the will to try some ways that do not come to you naturally but may give better results. This book gives you a wide range of building blocks that you can try out to build your own success story.

Developing a career in biomedical research can be a daunting task, considering the increased competition and the uncertain career prospects in academia. I included the many difficulties, burdens, and stresses PIs mentioned during the interviews, as well, so that you can have a more complete picture of what this career entails and step on this path with your eyes wide open.

Leuven, Belgium Béla Z. Schmidt

Acknowledgments

The one hundred and six principal investigators who volunteered for an interview have my deepest gratitude. Despite how incredibly busy they are, each of them gave me over an hour of their uninterrupted attention to answer my questions to help to mentor the next generation. I hope they will consider it time well spent.

There would have been no book without Prof. Rick Morimoto whose encouragement and enthusiasm for this project early on sustained me during this work.

David Payne, Chief Careers Editor at Nature, gave me an opportunity to write about my interviewing project in the Careers Column, and Karen Kaplan, Careers Editor, helped with getting the piece published—the visibility they gave me was a great help in recruiting principal investigators for an interview, and the emails I received from readers in response to the piece gave me great motivation to see this book through.

I am grateful to Rasha Msallam, PhD (Duke-NUS Medical School, Singapore, Singapore), Miriam Latuske, PhD (Springer, Heidelberg, Germany), Domiziana Costamagna, PhD (KU Leuven, Leuven, Belgium), and professors Irene Miguel-Aliaga (Imperial College London, London, UK) and Richard Sifers (Baylor College of Medicine, Houston, Texas, USA) for the critical reading of the manuscript and their suggestions.

I heard the quotes from August Rodin (Preface) and Sir Arthur Conan Doyle (Chap. 5) in the “Writer’s Almanac” podcast by Garrison Keillor.

Contents

About the Author

Béla Z. Schmidt trained to be an immunologist when he was earning his PhD in Hungary, but he got interested in cell biology and protein quality control during his first postdoctoral position. He studied how cells handle various disease-associated misfolded proteins as he was going through a succession of postdoctoral positions in the USA, first at Washington University and then the University of Pittsburgh.

Béla returned to Europe and got a Marie Curie fellowship to study the aggregation of a tumor suppressor protein at KU Leuven in Belgium. He had to move on due to lack of funding and had a brief but pleasant engagement at a small biotechnology company in Hungary.

He returned to KU Leuven to be an innovation manager, but this position turned out to be a poor fit for him, after all. Béla is now a senior staff employee at the Flanders Institute for Biotechnology (VIB) and working as a science writer in the Switch Laboratory at the VIB-KU Leuven Center for Brain & Disease Research.

List of Abbreviation

PI Principal investigator (head of a research laboratory)

List of Figures

List of Tables

“Carving Your Own Path”: Shaping Your Scientific Identity

1

Abstract

A PI with over ten years of experience leading her lab called the process of establishing your scientific identity “carving your own path” during our conversation, which is a very colourful, visceral way to express what is usually talked about as “finding your niche”. But finding your niche sounds like finding a hole and sitting in it, whereas establishing your scientific identity is a much more active process. As we will talk about it in this chapter, carving your own path involves finding ideas you are really excited about, developing them into projects, and managing those projects well, including knowing when to continue projects and when to stop them.

Curiosity Drives All

Most funding channels in the biomedical sciences are interested in funding translational projects and expect a connection of your project to a societal problem. When talking about science in general, several PIs expressed concern that the agenda of the funding agencies are directing what research is done, to the detriment of curiosity-derived science. Despite this, it seems that most research projects are curiosity driven: the motivation mentioned by most PIs to start a project is curiosity! Most projects are started because the PI found a question intriguing, they saw something in it that got them excited about the project. For some, the possibility of a high-impact publication (*“this may end up in Nature or Science”*, as one PI said) is a factor, too, but *“curiosity drives all, not the end result”*—as one of them put it.

> *“Do meaningful work, not just quick projects to get a paper.” (professor, PI for over 20 years, over 100 publications, H-index over 30)*

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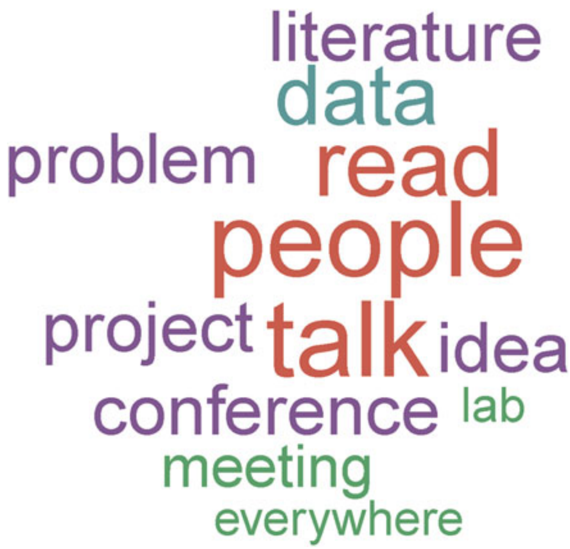
Although some PIs said that they start some projects out of practical reasons, e.g. they do industrial collaborations because it earns them some money that they can use to finance other high-risk projects or they want to help their students to find employment at the industrial partner after they graduate, or a collaborator needs special expertise the lab has or a student needs a project to graduate. But even these projects will not happen if the PI does not find an interesting element in them.

Getting Ideas for New Projects

PIs mentioned many sources of inspiration, but verbal communication (be it listening to a talk or an informal discussion) and reading the literature were the most commonly listed sources that spark ideas in the head of PIs.



Listening to Talks

"The most productive time to think about new directions is when I am sitting in talks at a scientific meeting", said one PI, and others also said that they found attending conferences inspiring. *"I always return full of ideas"*, said one PI and another also said that he gets his best ideas *"usually on the plane flying back from a scientific meeting"*.

Some PIs like large meetings because they can hear about all new directions in their field at once, for others, the change of scenery is the key factor. *"A meeting is a good environment for new ideas because you are not so caught up in the everyday* *tasks"*, said one PI with over twelve years of experience, and another PI also said that *"being in a different environment helps"* him to get new ideas. He added that sometimes he even has his group meetings in a different environment to increase the creativity of his group.

Besides going to meetings, many PIs mentioned attending talks on campus as a source of inspiration. *"When I hear any science, new ideas jump up about how to take it further or apply it to my research"*, said one PI, and several PIs recommended attending talks from other fields, especially if the presenter was excellent in their field. *"[Ideas come] sometimes from other disciplines! It is important to go to talks on very different topics"*, said one PI, adding that "*[you] may see similarities in the problems they are dealing with and may pick up useful ways of thinking about it"*. Another PI also recommended *"listening to colleagues in different departments, literature, invited lecturers coming to the university"*, and a third PI said, *"when I am going to a seminar, I listen with one ear, and think how this is relevant to my work"*. Sometimes you don't even need to leave your office: one PI mentioned that she realized that nobody was taking advantage of a *"super cool technology"* in her area after listening to a webinar.

Giving Talks

Perhaps a little more surprisingly, giving talks can also lead to getting new ideas. *"Sometimes I get interesting questions from other people at presentations"* that lead to new projects, said one PI. Another PI said a similar thing: it happened that he gave a talk and somebody came up to him at the end of the talk and asked something he could not answer—he started reading up on it and got a good idea. *"Being challenged on a point is an important source [of new projects]"*, confirmed a third PI.

Informal Discussions

Besides listening to or giving talks, conversations are also very likely to spark ideas. *"I want to be on the cutting edge, not see what others have already done"*, said a professor with over a dozen years of experience leading her own lab (and the impressive H-index of 64, I should add). For her, a moment of inspiration is *"more likely to happen during the conversation with peers after a presentation than during the presentation"*. Another PI also said that he stays to chat after scientific talks and these discussions often lead to new realizations, or it can also happen that someone else suggests a project: *"I love to meet personally people whom I consider smarter than myself"* said third PI, *"questions grow into projects"*.

"A lot of ideas come from talking with people", said another PI, *"especially ideas for EU grants that require consortia. I love it when there is a real synergy between labs with different expertise"*. Another PI said that discussions with his co-PI are an

important source of ideas and others mentioned that visiting other labs or discussing with clinicians can give ideas, as well (*“What is the clinical need?”*, asks one PI).

Other PIs also said that ideas come from *“everywhere, constantly”* as they are picking up information during talking with others, not necessarily fellow scientists. One PI said that *“sometimes I am discussing with industrial people telling me about some problem they have repeatedly and I decide to address it”*.

Literature

Reading the literature was another activity frequently mentioned by PIs when they talked about getting new ideas or refining the ideas that came up during the talks they have heard or their discussions with others. *“I think ‘this is interesting, perhaps we can solve this’, and then I look at the literature if someone has addressed the problem”*, said one of these PIs. Another said that during such *“directed reading”* he often finds a second or third idea. *“Very often it starts with discussions that give me an idea and then I start reading. I read about something that gets me thinking and formulating a hypothesis—then I get motivated to test it!”*, explained her process another PI.

For others, literature is their primary source of ideas. *“I think ‘no one is studying that’, I look for what is not being done”*, said one PI who gets her ideas from the literature. Another PI said that sometimes he reads something and says to himself: *“hey, this could be interesting for us!”*. A third PI who got an idea for a project from historical data said *“I am studying something first described in 1853, and still unexplained”*. Reading can also *“make you think in a different way about what you are doing now”*, as one PI said, and another said reading in the literature what he thinks is the wrong interpretation of the data gives him ideas.

Similarly to hearing talks outside of your field, several PIs said that *“it is important to read broadly, outside your field”* because *“sometimes new concepts emerging in other fields give ideas”*. “*When you know a topic well, you also know the open questions. You find new open questions by exploring new topics and thinking about them”*, said another PI. Another, highly successful PI (H-index of 94, over 15 years of experience) said that he gets his ideas *“from studying unrelated stuff”*. He said that online searches are not useful for this because they are limited to the keywords you use. Instead, he likes to scroll through journals. A third PI mentioned that she also follows publications like the “Scientist”, and the media highlighting recent results to get exposed to all kinds of topics.

Data

After verbal communication and reading the literature, the next most frequently mentioned source of ideas for new projects was the data produced in the lab or the PI’s clinical experience. *“New ideas are usually a continuum of the existing ones”*, said one PI. She said that anytime she reads the conclusions of a paper, new questions come up, *"and the same thing can happen with my own data"*. Another PI also said that often new projects *"are a spin-out of existing work, existing models from the lab, with a new angle to pursue"*.

Many PIs said that it is best to have some unexpected (but solid) data and then take a *"follow the data"* approach. *"I like to stick with what I do, but on a deeper level"*, said one PI, one of several who advocated building on your own data and letting new projects *"flow naturally from your expertise"*. As one of them said, new projects are *"determined by the profile of the lab, the skills of her co-workers"*, although she also added that her projects tend to branch out, as well. *"I am unlikely to come up with a project out of the blue. New projects are born from interesting pieces of data. I have an iterative approach"*, said another PI.

"For good publishing, it is good to follow the earlier projects (each new project is a consequence of the previous project). A lot of energy can be lost when going into a new area. If you are well supported, you have the luxury to go to a new direction", said another PI. *"Many postdocs make the mistake of following a totally new idea, going into a new field—it can cost a lot of time to get up to speed and acquire the expertise needed"*, he added.

Another PI, working on metabolic pathways also said that the results of ongoing projects are an important source of new project ideas for her because she often finds *"much more interesting effects in another pathway than what was in the original plan"*. Many PIs suggested following up on your own data when you get the feeling that *"there is something there…"*.

One PI said that unexpected results from her students can give her project ideas, and another said that *"sometimes 'failed' experiments"* give her ideas. *"Variability in the results, inconsistent data between seemingly identical experiments"* was also mentioned by several PIs as a source of new projects. We will talk about experimental failure in Chap. 6, but I would like to mention already here that it is important to train your students to tell you about results that don't meet their expectations because if you don't know about the variability in the data, you will not wonder about the reason for it!

New projects are often *"a combination of results you do not understand and the reading you do to understand them"*, said one PI. Another PI also said that when her data gives her an idea, she goes to the literature to see if anybody has done something like what she is thinking about—*"sometimes I find some stuff that leads me to refine my idea"*, she added. The juxtaposition of the literature and your primary data can also be inspiring: *"sometimes I see that the two do not fit"*, said another PI.

"Patients frequently give me ideas, if I see an unsolved problem", said a PI, one of several PIs with a medical background or working closely with clinicians who frequently get ideas for new projects from clinical observations. *"Part of my inspiration comes for the hospital: what are the unsolved problems?"*, said another one of them. A third PI said that she works on questions she would ask herself clinically but are not testable in people. Finally, clinical questions can come to a PI even without a medical background or working closely with clinicians: as one PI explained, one of her current major projects was inspired by a close friend of hers who was diagnosed with cancer. She decided to study improving blood cell recovery

in cancer patients after noticing that her friend's therapy was dependent on the blood cell counts. She could not save her friend, but her results may help other patients.

Thinking

A minority of PIs (14%) mentioned one of those time-tested sources of ideas: their own thoughts and imagination. One PI said that he sits down and thinks about *"what it is in the whole world that [he] is the most interested in right now"*.

None of them said that they sit down to "think" to get ideas, but several mentioned that they get ideas when they are in places where they are not bothered by others (including listening to talks, as mentioned already). One PI duo co-heading a lab arranges their schedule to have "clear" weeks when they don't have meetings to give themselves larger chunks of time when they can plan and perhaps have new ideas. Another PI mentioned that her knowledge of her field is an important source of inspiration, and she asks herself *"what kind of big questions need to be answered?"* to get ideas. *"You have to be familiar with the lay of the land to choose new directions"*, said third PI, *"[this why] it is easier to see future direction at the end of one's PhD thesis. I look for what is NOT being done"*.

"It can happen anytime", said another PI about getting new ideas, *"by free association, for example when watching the kids play soccer"*. Several other PIs explained that talking with others, listening to talks or reading etc. puts information next to each other in their brain and then they *"just have a thought as the result of some unconscious process"* later, e.g. when they are riding their bike somewhere or walk down the corridor. *"Ideas just 'appear', combining information from the mix of my own data, literature, and opportunities that come by"*, said one of them, and another said that it works *"like a puzzle"* for him. A third PI said that sometimes she wakes up with an idea.

Others

There were a few, less frequently mentioned sources of inspiration, for example, a new technology becoming available. *"It is good to be in a cutting-edge institute: it is easy to poach new techniques, easy to be an early adapter"*, said one PI about implementing brand new techniques in her own field. *"Sometimes technological advances trigger me: suddenly there is a way to solve some a problem I could not solve in the past"*, said another PI, and a third said the *"the idea can be of using a new approach to get over some stumbling block—this can come from reading a paper (from another field) or listening to conference talks."*

The possibility of a grant application can also be inspiring. *"Grant announcements ... make me start thinking how I could apply, how I could connect my field with the announced topics"*, as one PI said. Finally, another PI said that reviewing grant applications is his *"antenna for where the field is going"* and that gives him ideas of what the next step could be.

Top Publishers

Top Publisher PIs (see Methods for definition) mentioned utilizing more sources of ideas, and a larger proportion of these PIs mentioned informal discussions (70% versus 42%) as a source of inspiration.

Picking Projects

How do ideas grow into projects, how do PIs decide which idea they want to work on next?

Novelty (or the *"thrill of the new"*, as one PI put it) is the number one criterion defining whether an idea has a chance to become a project. *"Me, too, science"* is a non-starter for most PIs, even when they are only a collaborator supplying a part of the results in somebody else's project (or for some of them, even for industrial collaborations). PIs check the literature whether their idea is novel, then, as one PI said *"if during reading, I become convinced that this is interesting and not much has been done about it, I may go ahead to formulate a project"*.

Although most PIs are attracted to subject matters that they find convincing, we should not discount the importance of an emotional connection with the topic when PIs pick projects—40% of PIs mentioned that they want to be "touched" by a topic to find it interesting. These PIs said that being touched by a subject may tell them that the subject is important, even if they are not yet convinced about it. The PIs who want to be both touched and convinced by a topic to find it interesting said that being touched by a topic gives them the motivation to pursue it—being convinced alone may not be enough to make the project happen, the emotional connection is important for really pursuing a topic. *"I need to be touched by a topic to be interested in it for my research",* said one PI, and he added that although he can appreciate other research topics and can be convinced of their importance, he works only on topics that touch him. *"There is no real difference [between being touched and convinced]*", said another PI: *"if you are emotional enough about something, you convince yourself*". Other PIs also agreed that being excited about the question is an absolute must because *"there is no way to do science otherwise"*, as one PI said it. This excitement can manifest either as a *"gut feeling"* about the project or as an intellectual pleasure (*"the feeling derived from having a good idea contributes to my well-being"*, said one PI) or an irresistible urge to find out if their hypothesis is correct. *"The possibility that this crazy idea could be true"*—as one of them put it, is an important motivator.

Some PIs maintain an *"overall area of interest"* all their life. One of these PIs said that the long-term vision behind the project provides the motivation to start a project: he draws *"a red line going to his vision, and the project has to strengthen this red line"*. Having a set of tools that helped you to publish before and for which your lab gets to be known also helps to convince a funding body that you can accomplish the goals you set out. *"Continuous change is not a good idea, it is better to continue what you are known for*"—as another PI said. In the case of most PIs, the project has to trigger their curiosity personally, but there was one PI who is more democratic about the projects and lets the people he recruits decide on the projects—he only wants the projects to fit with his overall areas of interest. Other PIs said that the project has to fit with projects already going on in the lab. Running projects that fit with the rest of the projects in the lab helps to consolidate the expertise in the lab and establish your credibility, and it gives some redundancy in case things do not work out. Several PIs mentioned having some *"crazy projects"* going on in their lab, but they are doing these on the side as pilots. They develop these into full-fledged projects only if they get some initial data so that they can convincingly ask for funding for these projects if they happen to work out.

Although *"no project is ever in a vacuum"*, many PIs feel an aversion to *"incremental projects"* that hope to gain trivial or incremental insights. Most PIs get excited by great science: projects that have the potential to fill a great gap in our knowledge. The project gets even more appealing if PIs have a hypothesis that could explain some unexpected outcomes (or as one of them called it, have *"the fantasy of the answer"*). One PI explained that she initiates a project when *"pieces seem to click"*: when several pieces of what is known in the literature seem to click with pieces she knows from her own work. She and many others said that they want to discover new puzzle pieces, new connections that nobody else noticed before. They like intuiting new connections—then they set out to prove that the connections exist!

Having a hypothesis to prove or disprove is a requirement for many PIs, and the broader the capacity of the hypothesis is to explain unexpected results (the wider the gap of knowledge is that they think they can fill), the more exciting the project becomes. The best is if the project promises to solve a big problem, related to some known process—if you find a gap in the field, a problem that you (your lab) are the expert(s) to solve, it makes writing the eventual paper much easier (*"this way the intro and the discussion [of the paper] are already covered, you just have to work on the results section"*, said one PI).

PIs apply a set of filters to decide which ideas they should pursue. One obvious aspect to consider before initiating a project is resources. You will need money to pay the people working on the project, and for the reagents needed etc. For some PIs, the availability of funding or a student is the primary criterion to start a project, and some pick projects to fit into a grant application. Others, on the other hand, had a very different opinion. *"It is more about the vision than the funding"*, said a professor who has been leading her lab for over 25 years. Other PIs also said that *"the availability of funding is irrelevant"* to them when they consider starting a new project because they are willing to use parts of funds allocated for other projects or they think that they would find the money to finance the project.

The collaborators participating in a project was the second most mentioned argument for getting involved in a project. *"I have written projects to work with friends"* said one PI, but he was not alone in mentioning that human relationships, the opportunity to build collaborations may trigger a project. One PI said that most projects have existed in her head for some time before she can start them, but often interacting with other researchers gives her the push to start a project. Collaborations have another motivating effect: one PI said that he likes to combine projects with other labs because he thinks of 1–2 projects, but if he combines them into a big one with other labs, and he can have a much bigger impact!

Besides these filters, PIs go through a set of restrictive parameters (do a *"reality check"*, as one of them put it) to decide whether they will pursue a project or not. Feasibility was a frequently mentioned filter: is the technology and the manpower required to do the project available to the lab or is it obtainable? *"I take the ideas I want to work on with me to the pub to talk about them with my friends"*, said one PI. First, he wants to find a solution, however impractical it should be, then he wants to find how he can make it practical, which sometimes requires a leap of imagination. *"It is important to see a path to find out the answer"* agreed another PI, *"without a way to get to the answer, there is no project"*. Other PIs mentioned that the *"time has to be right"* for the project. Some meant a technical component by this, e.g. has some new technology became available that makes the problem tractable? Others meant a scientific component: *"like aeroplane carriers, scientific fields can have a lot of inertia, and once there is enough information about a topic in a field, it is hard to change the direction"*, explained one PI. If you want to change the direction of a field, you either need to act early or have blockbuster results.

Several PIs said that they could not study something without a translational link, although it may not matter to them if the translation is far away. One of these PIs, an MD-PhD with 30 years of experience as a PI, said that his filters are: *"Who cares? Who suffers? How would my patients be helped? Are we in a good position to do this? Do we have an edge? Can we do this before tens of others will complete it?"* He reads up in complimentary fields, mulls it over, and looks for *"the intersection of opportunity, novelty, and feasibility"*.

The availability of expertise is an important factor, too. *"Do I know enough about this, or can I find the people who are competent to do a good job?"* asks himself one PI and another said that when he starts thinking about a project, one of the first questions he asks himself is *"Who should we get in the room to figure out how to do this?"*

How Do You Know If a Project Is Going in the Right Direction?

Once you've started a new project, you have to be able to gauge whether it is going well, whether it would be worth the time and money your lab invests in it. The indicators PIs use to decide whether a project goes well fall into three categories: the project outputs, the people working on the project, and the reception of the project in their field.

"In scientific questions, there is no wrong direction!" said one PI, and he added, *"it is easier to see if a project is not going in the right direction: when it is going in too many directions"*. If you can't make decisions based on the data, if the results do not allow you to say yes or no, the project is going badly. These projects go around in circles without getting anywhere.

The most often mentioned indicator if a project is going well was getting solid data out of it. Most PIs want to see as early as possible that the project is technically feasible, the model system they chose gives relevant answers, and produces reproducible results. The majority of the PIs evaluate projects that fulfil these criteria as well going projects, regardless of whether the results are confirming the hypothesis put forth or not (actually, most are even happier, if the data is unexpected and go against the hypothesis because such data opens up new possibilities). As long as the project generates a steady flow of data that is reproducible, can be interpreted, and seems to be telling a coherent story (*"something that can be presented"*, as one of them defined it), most PIs are happy with the project.

The most often recurring motif was that if certain components start to fit together, there is a pattern emerging, the project is going well. In some cases, deciding what path to take may pose a challenge. As one PI said, *"sometimes we do not take the right path, but we can always backtrack and find the right path again"*, and she added, that *"sometimes those detours lead to very unexpected and exciting findings, so they are all worth the effort, in the end"*.

A minority of PIs, said that they want to see results that are congruent with the hypothesis, and use the milestones stipulated in the grant application to gauge success because *"there was a theory behind the experiments: is it going in that direction?"*, as one of them said. These PIs point out that most grants nowadays are written to be feasible because the funding agencies want a guarantee that the project will deliver what was promised. These "safe" grant applications are written backwards and contain a lot of experiments that had already been done. Therefore, if you are getting different results, then there is indeed something wrong.

Unless you are working on one of these "safe grants" when you already know the outcome, the beginning of the project is a critical time. This is when it becomes evident whether there is a clear phenotype, if you were able to design an experimental setup to challenge the hypothesis with experiments and whether the data obtained refute or help to refine the model. One PI told me that he never goes for a single parameter as a readout (his lab uses about ten readouts to assess a disease phenotype). He always looks at the full battery of the results: if all of them go in the same direction, he knows that something is going on. Another said that he is *"sniffing for clues in the data"* because he has developed a *"nose for finding hints of something interesting in the data"*.

Some PIs factor in the personnel involved in the project to evaluate whether it is going well: are they dedicated? Do they plan well? Are they getting experience, a knowledge that benefits the whole group? They also pay attention to the interest of the researchers in the project: it is possible that the project is good but the wrong person is working on it.

Although many PIs emphasized that the pace of how the results are rolling in is important, they expressed varying attitudes towards controlling the personnel working on the project. Some tend to be on top of the students to make sure that they are not losing months struggling with something. These PIs said that adhering to the planned timing is essential—if the timing of the project is not respected, they conclude that the project is not going well. *"It has to be moving at an acceptable speed, because you are in a competitive environment"*, as one of them said.

Others tend to give their people more freedom, let them *"stumble a bit"* and lose some time before they interfere. If you like the hands-off approach, you may want to follow the PI who insists that her students write up registered reports. In case you are not familiar with registered reports, these are summaries containing the research question and the methodology of a planned study. Registered reports are peer-reviewed, and if they are accepted, they ensure publication of the results before any data are collected for the study (Chambers 2019). The registered reports written by the students in the lab of the mentioned PI are not always submitted for peer review, but they serve as a study plan for the students that they can refer to during their research.

Some PIs give projects a certain amount of time to be fruitful, they generally give projects six months to a year before re-evaluating them. One PI said that he loses motivation if nothing happens within 6 months, another said that getting the *"take-home message"* of a project should take less than a year, and then he allows another 2 years for working out the details. Similarly, a third PIs also said that *"everything has a shelf life"* and she is motivated to work on a project only for a limited time. She takes on *"projects that can be solved realistically in three years"*. She arrived at three years as the ideal length for projects by retro-planning: the funding is usually for four years, she leaves one year for publication, so there are three years remaining to do the project.

Also, keep in mind that your assessment of whether a project is going well or not may be subject to change. One PI said that it happened that in the morning he thought about a project that it was going fine, and by the evening he thought that it was going badly—and the opposite can happen, as well. Several PIs mentioned having the experience that the partial results *"don't seem to make sense"*, they don't seem to be telling a coherent story, and then something happens that puts all results in a different light and suddenly everything seems to *"click"*, everything becomes a piece of the same puzzle. You may want to consider the advice of a PI who prides herself as somebody who always manages to make projects work: *"If you have the feeling that it is a dead-end: it is never a dead end!"*

This reminded me of a parable one of my supervisors used to tell us about a little mouse trying to get through the tough crust of a wheel of cheese: it is hard for the mouse to chew through the outer crust, but if it concentrates on a certain spot, it will eventually breakthrough. And once the mouse is inside, it can go in any direction and find cheese (exciting results) in every direction!

Top Publishers

All Top Publisher PIs talked about wanting to see that results are coming in, and both PIs who put a definite time limit on when the project has to produce certain results belong to this group. Most of them emphasized generating data that can be interpreted and seem to be coherent, regardless of whether it confirms the original hypothesis or not—there were only two out of 25 PIs who wants to see the hypothesis confirmed.

What Keeps You Motivated to Continue a Project?

As we talked about it, the results coming out of a project keep PIs interested. One PI even compared himself to a rat getting food pellets: a steady stream of data keeps him going! Another PI said that he keeps pushing the project forward if he stays excited about the answers he wanted to get from the project. *"This can happen two ways: the data either confirm the hypothesis (this is good for the ego), or they are clearly against the hypothesis"*, he finished—the latter usually makes for good publications. Learning new things and seeing causal relationships (*"starting to see a story"*) is the main motivator for most PIs.

What to do when things are not going that well? First of all, it is important to not even start a project you are not invested in, or, as one PI with over thirty years of experience summed it up: *"without passion: forget the project"*. You cannot afford to lose your motivation mid-project, so what can you do if you should find that your enthusiasm for a project is waning?

Most reasons PIs listed for keeping their motivation had to do with the personality of the PI, and many were very similar to the reasons that motivate PIs to initiate projects—they just have to remind themselves why they decided to start the project in the first place.

> *"… you can't 'half-finish' it!" (professor, PI for over 15 years, over 200 publications, H-index over 50)*

The intrinsic reasons for keeping up motivation included personal curiosity about the topic, about the question they want to answer, the PI's passion for learning or love of science that would not let them stop until they found out the answer. Personal perseverance helps some not to step out too soon, and others said that they were used to things taking long. Other PIs said that they are just simply stubborn: *"even negative results motivate me because they make me want to prove that it can (still) happen"* said one of these *"result-driven"* PI who works even harder to obtain the goal when things look grim. *"It was a well-considered project, the hurdles are technical, not conceptual"*—reassures himself another PI with over thirty years of experience, and others quoted their personal pride or their need for a sense of achievement that would not let them quit. Another scientist with over forty years of experience as a PI said that *"outsmarting difficulties is fun"* and the conviction that she will find a way to solve whatever problems are encountered helps her keep focusing on the goal—but it needs to be an important goal, she emphasized.

Other PIs (especially those with medical training) think of the individuals and their families affected by the disease they are working on and the benefit of the patients, should their interest in the project dip. *"I do not know if I will get to a cure, but I want to get closer, anyway"*—tells himself one of them who said he is motivated by the imagined outcome for his patients.

The prospect of publication helps many PIs over the difficulties when projects are not going well. *"This will advance the field!"* tells herself one PI aiming for *"game-changers"*, and others hold on to *"the idea that you might push through and get to a point where you have a message you can pass on"*.

As we talked about it earlier, the primary motivator for starting projects is curiosity. Therefore, it is not surprising that several PIs mentioned that they are not interested in the repeat experiments and confirmatory experiments after they got the final piece of the puzzle, since their curiosity is satisfied. In these situations, PIs think of the extrinsic reasons for finishing projects.

The most frequently mentioned *"practical reasons"* is the impact of the project outcome on the career of the people working on the project, or as one PI said, her *"duty towards the students"*. Whereas losing one project out of the several running in the lab may not impact the PI that much, it might be a career-determining disaster for somebody who tries to graduate. Several PIs said that they have no intrinsic interest in publications, but their students need them to graduate or make them competitive for their next position. Therefore, *"you have to find ways to squeeze data out of the project"*. Besides the publications, the training value projects provide for the students motivates some PIs to keep the projects going.

The team dynamics within the lab are also important: while the enthusiasm of the PI may serve as a source of strength to their frustrated students or co-workers, the inverse is also true. PIs reported that the enthusiasm of other people working on the project can carry the PIs over if his motivation dips.

Several PIs keep their motivation up by thinking of the bigger picture, either within their own lab or outside of it. Since many projects are interconnected with other ones going on in a PI's lab, if one of them is not going well, it may have implications for the entire lab. Moreover, since granting agencies are expecting publications, not getting to a publishable endpoint may jeopardize funding for future projects, as well. Other PIs said that the interest of the scientific community motivates them. Some keep themselves motivated by thinking that *"someone out there"* is waiting to benefit from their results, and some said that being recognized by peers when they present the project to the outside world, especially if these other scientists get excited about the project, motivates them to see the project through.

As PIs were explaining how they keep up their motivation for a project, they also gave many excellent tips on what to do when you are feeling stuck in a project. Even if things do not seem to make sense, trust in the facts: there has to be an explanation. One PI said that she *"dissects"* the situation (another called it taking *"an honest look at the project"*) to see where the block is coming from: is the hypothesis wrong or is the block technical? If it is a technical problem, is the technology not working or is there a problem with the operator doing the experiments?

Perhaps the most important question you can ask yourself if the results do not support the hypothesis is whether you can build on the results in a new direction. One PI explained that she has no intrinsic interest in what is written in the grant proposal because *"it does not matter if the hypothesis is wrong, you just make another one!"* She added that she picks projects that study processes that occur in Nature, so she just keeps believing that she will get where she wants to go, *"because Nature gets there"*. Then, when she feels stuck, she reminds herself that she will get there, she "just" has to *"find out what the trick is!"* Another PI expressed a similar attitude: as long as the phenotype is robust, he keeps going. A third PI told me that he likes to have the first and the last figure of the paper already from the beginning of the project, and the last figure has to be something dramatic. When things are not working out and he starts to doubt himself, he just returns to these first/last figures, and he reminds himself where he wants to arrive—the rest is just figuring out how to get from one to the other!

A PI surprised me by saying that he considered that a project was going well when there was a lot of interaction between the project participants. It became clear only later what he meant when another PI explained that when he is working in a large group, other people having great ideas also motivate him. He admitted that he may feel envious of the ideas, but he enjoys them, too, and they often help to revive the project. Another PI goes to her drawing board to release the block by abstract drawing when she feels stuck. She gives projects a form or colour, she experiments with different colours. It is not the end product that matters (although the artwork she creates is beautiful and quite elaborate), but the process, because it helps her to find a solution to the block. After drawing, she is ready to discuss things.

When struggling, PIs recommend setting realistic goals, and checkpoints: *"If I can answer this question, then ...."* You may have to take a step back and develop the technique you need, and *"come back to the biology later"*. As long as you are making progress (even if it is slower), you are moving the project forward. *"A project is the accumulation of those small successes; each success helps to go on to the next success"*, said one PI. Sometimes getting new people and new expertise helps, added another PI.

Getting robust data after a lot of difficulties is a motor, a great motivator. So is when all the pieces of the jigsaw puzzle are fitting together. Several PIs warned that the last piece is usually the most difficult, but there are strong reasons not to give up: if you can produce a finished story including a mechanism, you will have a higher impact paper than publishing just a phenotype.

How Do You Know When to Stop a Project?

As we talked about it before, having an important output in mind at the beginning of the project is essential. In addition, several PIs recommend staying critical and continually evaluating projects by *"zooming out"* and asking questions like: *"Is this still an important question?"* or *"Does the project still fit the priorities of the lab?"*, *"Are there enough hands to do this project, is there enough funding for it?"*

If the data is not agreeing with the hypothesis, your job, as a PI, is to either find a new hypothesis or if you cannot make a new hypothesis based on the data, find a side way, a lateral where you can get to an interpretable end point. As we will also talk about it in the section on publications, reporting negative results is (still) very difficult. A PI told me that when every result is negative, he tries to go in another direction first because he does not see the value of reporting a negative study. *"I am willing to change the PhD jury, title, even topic to make sure the project becomes a positive study"*, he said. In many cases, you will have to be less ambitious, but you will still be able to get something out of the project. Nevertheless, you may fail to get the project to an interpretable end point and start wondering if it was better to stop the project.

> *"The key to success is not to pursue what will not succeed" (professor, PI for over 20 years, almost 300 publications, H-index of 50)*

Several PIs admitted that they stop projects too late and those who said that they learned to do it earlier, admitted that it is still not early enough. The truth is that stopping projects is often tough. People working on a project get invested in it and they may resist the decision, and some PIs said that they feel guilty about stopping projects. At the same time, as one PI pointed out: *"you need to recognize the sunk-cost fallacy: do not run after that is already gone"* or as another put it, *"cut your losses"*. Instead of delaying for too long, trying to wait for things to get better, it is better to take steps to kill the project.

Some PIs mentioned "external reasons" for stopping projects: *"when the money or the time is gone"*, or *"when the person doing the project leaves"* or is not up to the task. But at the same time, other PIs in such situations decide to seek new funding or hire new personnel—therefore it seems that these "external reasons" just give PIs an excuse to stop a project they no longer want to pursue, anyway.

Losing Interest in the Project

The most cited reason for stopping projects is losing interest by the PI. One PI said that she needs to have a gut feeling about the project, it needs to remain *"personal"*—without this, she loses her interest in it. Although there was another PI who said that even if there are no new results, discussions about the results can be motivating, most PIs lose interest when *"the good pellets stop coming"* (in the words of the PI we already mentioned), when no data is coming out of the project for a long time or the data is uninteresting.

Sometimes projects stop automatically: when you are working on several parallel projects, you focus your resources (money, personnel) on the ones that are the most rewarding. Several PIs said that they stop projects because they get interested in something else. There are always so many other things to do, there are usually more projects than the lab can carry, and in these cases, it may not be difficult to stop the less productive or less interesting ones.

Some PIs have clear cut-offs to decide to stop: they try three or four times or they give sleepy projects a deadline to become productive (typically 6 to 12 months). Other PIs just develop a gut feeling that *"it is not going to happen"*. But this way of stopping projects seems to have more to do with frustration and hopelessness than a rational decision based on a cost-benefit analysis. One PI even told me that although he also does an analysis, *"that is mostly only the official ending, the rationale to end the project"* after he has already made his decision.

Fortunately, some PIs offered a bit more objective ways to decide whether a project should go on or not than frustration or "gut feeling".

Is the Topic Worth Pursuing?

We all have been trained to not give up, and you do not become a PI by being a quitter. However, my recommendation is to re-train yourself to recognize situations when *"it is better to start again than to continue a project"*, as one PI put it.

As we talked about it before, the beginning of the project is a critical time: this is when you obtain data that validate the importance of the process you are investigating and confirm that the foundations of the project are solid. If several preliminary experiments are negative, you have to put the project aside because *"in science, it is necessary to be productive in a short period of time"*, as one PI said. *"If all results are negative, time to stop"*—said one PI and another PI also recommended stopping both projects and collaborations quickly if they are not productive.

> *"When you realize that you are riding a dead horse, get off!" (professor, PI for over 20 years, over 250 publications, H-index over 40)*

If you can get data, the next question many PIs ask is if the outcome will be *"incremental or interesting"*? *"Is it a leap or a small step?"* asks another PI to make the *"GO/NO-GO decision"*, and other PIs also design experiments to decide whether the outcome will be very important (=worth continuing) or not. *"I want to do these experiments as early as possible in the project, 4–5 different questions to decide. If these fail, the project is stopped"*, said one PI. Another PI also said that she drops projects when the assumed relevance of a certain process turns out not to be true. *"The review process is not worth for a mediocre paper"*, added another PI. *"It takes almost as long and almost as much energy to take a mediocre paper through the review process than an excellent paper"*.

There has to be a validation of the importance of the process you are investigating. If there is no phenotype, or if the effect is not novel or important or interesting, it is best to stop the project. If you cannot obtain clear data (*"black and white data"*, as one PI put it), if it is not clear what the effect is, then it is not worth expending a lot of effort to arrive at inconclusive results.

If the data are invalidating the original hypothesis, but let you make an alternative one, you are in luck. Some PIs actually like this element of surprise and the new hypothesis is often more interesting than the original one.

The Tools Are Not Working

Besides verifying the importance of the project and the reproducibility of the effect you are investigating, another hurdle is technology. One PI told me that he *"kills* *projects when the tools turn out not to work as expected"* and there is no technically straightforward route to get the answer. The failure of technology to address the problem is a common reason to stop projects—and it also happens that old projects are re-started when new technology becomes available or affordable.

PIs have varying tolerance to overcome technological hurdles: some said they try 3–4 times the same way and then they change approach, some are willing to spend between 1 month and 6 months to try.

Personnel

Besides having the right technology available, you also need competent personnel operating that technology to obtain data.

Several PIs shared their experience that the success of a project is dependent on the attitude of the person driving the project. *"Everybody can contribute, but it is the person doing the project who will make the project work"*, said one PI. Although, *"it does not mean that it will the original project"*, he finished. Another PI also said that in his experience, the most common reason for a project not working technically is that the person working on the project cannot make it work. Others also said that some projects turn out to be too challenging for the person working on the project and they have stopped projects because the student working on them was not up to the task. So, if you are running into technical difficulties, but you don't want to stop because the project is important to you, involving other personnel may be a good idea.

Even if the people are competent, repeated failure may eat up the motivation of the personnel. One PI said she stops a project when the people working on it are not motivated and she can't motivate them anymore. After a long time of failure, stopping the project may come as a relief to the people working on it. If it is an uphill battle, one PI said to consider *"what would be the best for the person working on the project?"* Another PI said that he may rewrite the project to fit the person better if the project turns out to be too hard for the student, and another said that he may stop a project completely if someone *"is suffering too much doing it"*.

Stopping a Project Later

Unfortunately, even after a promising start, there is no guarantee that you can take the project all the way you imagined.

One of these reasons can be hitting a dead end. Several PIs said that they stop projects *"when they are not learning much anymore, when they keep doing the experiments and not getting any further"* or as one of them said: *"the data obtained does not justify the spending"* anymore. *"If you can't focus the data, if you can't see where to go next, or if you can't take it further"* the best is to stop, said another PI. A *"fatigue"* with the project can hit even when there is data coming out but the new data does not lead to learning any new concepts. *"I am not a cataloguer of facts"*, said one PI, *"whatever I work on has to be new conceptually"*.

When you reach a dead-end, it is better to shift to something else that may be going better. Several PIs reported that if the data remain indecisive, despite turning around it many times, especially when this is combined with the money/time running out, it is not difficult for them to stop the projects.

Getting scooped (i.e. learning from a publication or hearing at a conference that others have already reached the goal of the project and are publishing it) is a nuisance to all PIs, but not all take it as a signal to stop the project. *"Sometimes you can go much further than what has been published and save the project by giving it an extra angle"*, said one PI. She tries to do something different, and be innovative to get around the scoop.

"You need to study phenomena with intrinsic repeatability", said another PI who stops projects if they become too complicated or there are so many parameters to control that he can't challenge the system in a reproducible fashion. Another kind of project stopping event mentioned was if the project leads to an arena that is not of interest to you or where you can't compete. It may also happen that your collaborators lose interest and stop their activities or change their intentions to something that is no longer in line with your goals. Finally, one PI said that once she had abandoned a line of research because she had felt excluded from that particular scientific community, everything was a struggle with them. She got one publication out and then she stopped.

The Best Time to Stop a Project

When the money or the time runs out, that is a natural stopping point for a project, but it may not be a good point to stop. Most PIs qualified their response to the question about when they stop projects with *"after a publication"*. Your job, as a PI, is to get the project to some point you understand and can report in a publication.

One PI told me: *"I learned it from setting up my first spin-off company to never make a plan without preparing an exit"*. He said his industrial experience taught him risk analysis, and if a project is running out of time or money, all he has to ask himself: *"what was the exit I had in mind?"* Others also said, that even if the results are interesting, but getting to the end would take too long and too many experiments, they decide to cut their losses. The important question to ask in such a situation is *"Can we use what we already have to make another project?"*

Several PIs said that you stop when *"the project is nicely rounded up and you can't take it any further"*. Without time constraints, however, it may be hard to stop a project because there are always more and more details to discover. A PI offered this analogy as advice for such cases: *"How do you know when a painting is finished? You remain critical and ask what would adding the next detail matter, would it have any added value?"* When the answer is no, the project is finished. Bear in mind that you may have to make this determination for your co-workers, because *"some* *people like to do only experiments and not think about the results"*, as one PI warned.

On the other hand, some PIs reported that they were *"not interested to solving questions to the last detail, rather in finding new questions that arise from the new understanding discovered"*. These PIs, once they found out the answer to the problem they were interested in, may not have the patience to drive the project to completion. As a consequence, they have to settle for publishing the results at a lower impact than what the full story would deserve.

Publications are milestones that give an excellent chance to re-evaluate if the project should be continued. *"Does it contribute to the overall goals of the group?"*—asks herself one PI when she considers whether she should continue a line of investigation.

Top Publishers

None of the Top Publisher PIs mentioned being scooped as a reason to stop a project—one expressly said that it is not a reason to stop because you can always find a different angle. *"Competition does not matter, because there is always competition. If there is no competition, it is not a good idea!"*

Top Publisher PIs seem to be good at the continuous cost-benefit analysis of projects. They exhibited an interesting mix of being invested in a project and being detached from the project (the warning about the sunk-cost fallacy came from a PI in this group). They prefer to get a publication out of every project (as one of them said, the first question before stopping a project should always be: *"Do we have a story to publish?"*), but they are not reluctant to stop projects if the foundations turn out to be not solid, if the tools required are not working as expected, the people working on the project turn out to be incompetent, or if the project is not productive (if the project goes in circles instead of progressing).

Top Publisher PIs are even willing to stop productive projects if another, more interesting project comes along, despite the resistance of the staff who may resent the decision to stop the project because they are also invested in the project.

Now, that we have an idea of how PIs manage projects of their research program, in the next chapter, we have a look at what they think about grants that are the fuel to power that program and how they approach publications that are the output of their research. Grants and publications go hand in hand: having publications helps to get grants, and getting grant money helps to produce more publications.

Reference

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The Two Cornerstones of Academic Research: Writing Grant Applications and Publications

2

Abstract

Grant writing is as certain in most PI's life as taxes and death—only a few of the PIs I talked with did not have to write grants. What you think about the task of writing grants will influence the way you perform this task (for example, if you hate it, you may postpone it), therefore I wanted to know what thoughts PIs had about this topic. We will discuss PI's views on grant writing (few remained indifferent about this topic), the ways PIs make the current grant system work for them, and some best practices for writing grants. The chapter also contains PI's suggestions to reform the funding of science.

Publications also elicited very wide-ranging and passionate comments from PIs. In the second part of the chapter we discuss the ambivalent relationship of scientists with publications, what they think about the reviewing process, and some practical advice on writing publications.

Grants

The question about grants elicited the most passionate responses from most PIs, there were only a few PIs who stayed neutral and said that grant writing *"needs to be done"* or *"I have the same opinion of the grant system that Churchill had about democracy: not ideal, but there is nothing better"*.

Many PIs expressed frustration about grants—there were complaints even from people who have had a good track record of getting money, and certainly more from those who have had a series of rejections. Calling grant writing a *"pain in the neck"* or a *"waste of time"* was just the beginning. One PI called grant writing *"the most intense and least rewarding part"* of his job, another said it was a *"necessary evil"*. A third PI called writing grants *"an exercise invented by bureaucratic people"* which is *"getting more and more difficult"* because *"people not involved in science add more and more limitations"*.

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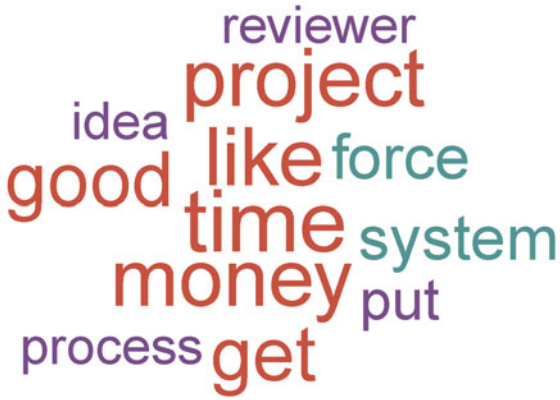

In one PI's view grant writing *"is not the best investment of time"* which is why he seeks out industrial involvement in his research to find other sources of funding. Other PIs also agreed that the granting process was inefficient: *"even for internal funds, 75% of the people will not get the grant, yet they spend their time and send their research ideas around"*, as one of them put it. Another PI said that *"a lot of time and money is thrown in the trash because if you add up all the time and effort that goes into unsuccessful applications, most of the available grant money has already been spent before the applications are even evaluated!"*

One PI thought that *"everybody who is not native English has a big disadvantage in grant writing"* because *"the style of writing is very important"*, and finally, many had opposition towards the review process saying that grants were *"frequently reviewed by people who have no expertise in the field"* and the outcome depended more on *"politics"* than what's in the application.

There were, however, PIs who supported the grant system. *"The actual act of grant writing equals doing science"*, said one proponent of the grant system. *"Getting other people excited about my work is my way of living science"*, said another scientist who has been a PI for twenty years, and he added that *"science would be a disaster without"* grant writing because you need *"to have an exact purpose for spending other people's money and be able to communicate it"*. He also said that paper writing gets boring during all the revisions. Similarly, another PI also said that she likes writing grants more than writing manuscripts because they let her dream. A third PI called grant writing *"the fine part of science"* when you have not done any experiments, you have not failed, when *"the possibilities are great, and there is no ugly data yet to dirty your vision"*.

> *"It is amazing that you can get money for something that exists only in your head." (professor, PI for over 5 years, almost 90 publications, H-index of 45)*

The most frequently cited benefits of writing grants were forcing you to organize your thoughts, structure your project, helping to discover the holes in your thinking.

And, perhaps most importantly, grant writing forces you to read up on the subject. Many PIs complained that they do not have as much time to follow the literature as they would like, and grant writing is an opportunity to catch up and read in-depth. One PI said that writing down her ideas *"forces [her] to read more in detail to make sure [that the grant] is based on facts, it is solid"*. Another PI found that writing grants had another benefit: she said that when she is *"forced to write a project, it helps [her] to run a good project, even if things turn out differently"*.

The Evaluation Process

Many PIs had experience with reviewing grants and they shared their opinion of the evaluation process. One PI who has been a member of committees evaluating grants for eight years said that *"the excellent grants always get funded, the poor grants are rejected, and then there are the grants in between. For these, communication decides: what type of show the authors put on, how they played the reviewers"*. Others have also expressed opinions that for those grants in the middle, the evaluation is a lottery, based on many factors, some of which are outside of the applicant's control. One of these factors is the applicant's track record (this one at least has something to do with the applicant). Many people have said the applicant's CV *"may matter more than the project"*.

The reviewers receive guidance on how to rate the grants from the funding agency, so spend time on discovering what kind of grants the funding agency you are applying to likes. I almost said "know your enemy", but thinking of the funding agency as your enemy will not help you to put the effort in trying to please them.

The reviewers are people like you, except a little more senior (even this may not be true since some senior PIs rely on the members of their team for helping them with reviewing grants). Some PIs (perhaps soured a bit by rejections of their applications) simply called the evaluators *"mediocre scientists"*. This may or may not be the case: one PI thought that the ERC grants are reviewed by excellent scientists, but some funding agencies seem to be short on reviewers and the bar to become a reviewer is not very high. Therefore it is quite possible that the people who decide if your brilliant ideas get funded or not do not have any better ideas themselves. Especially because your grant may not be reviewed by the most visionary scientists, it is important to keep in mind this advice: *"grants have to be written at the right time: if your concept is too new, it is less likely to be accepted by the reviewers"*.

As one PI said, the high rejection rate *"makes researchers try to guess what will please the reviewers"*. Grant writing *"becomes more prostitution than science"*, she added—nevertheless, pleasing the reviewers is a must.

Unfortunately, the practice of rewarding *"safe grants, not [] the ones that will find something new"* places *"more and more pressure [on scientists] to be deceptive in grants"*, said one PI. This does not mean that they lie in their application, but, because of how the process is set up, applicants *"game the funding bodies: they do not put their best and most exciting science in their application lest the project is* *deemed too risky, instead they write "safe", incremental projects"*. Some said that they write their applications *"backwards"*: they write about *"the last 5 years instead of the next 5 years: they put in things that they already know"*, to make sure that they can deliver on their promises.

Many PIs mentioned the role of politics in the decision of funding or not funding a project. One PI said that *"on the national level, people who have European grants are penalized. On the EU level, money begets money"*.

Receiving shallow feedback on your grant is frustrating (for example, being *"too ambitious"* was one of the most cited *"easy, but useless"* comments). Unfortunately, the goal of the review process in most cases is to sort grants out, not to make them better, and this means that the applicants who submitted the 2nd best 10% receive no guidance and they are left wondering if *"the reviewers [are] not interested in the topic, or was something wrong with the grant?"* You have no control over this as an applicant, but I hope you will remember this complaint when you review the applications of other scientists and give real feedback.

"It cripples research how short term is everything", said one PI who thought that funding agencies want a quick return for their money. You need to be aware that besides a few funding channels that invite *"blue-sky research"* and are very supportive of innovative ideas, most funding agencies appreciate *"middle of the road"* projects.

Best Practices

Although many PIs called grant writing an art, they also said that it was *"an art that can be learned"*. They mentioned two ways to learn the art of grant writing: getting lots of practice by writing many grants and learning from other people's mistakes by reviewing grants.

If you are lucky to have a supervisor like the PI who said that *"I teach my people how to write grants by osmosis: I give young people the opportunity to write important grants if they want to"*, make sure you take advantage of the opportunity.

If your PI does not offer you a chance to write grants, he or she is probably reviewing grants. Some PIs said that they involve their people in reviewing grants, but if you have not been asked to do it, be proactive and ask your PI if you can help. You will get no credit for this work, but you will learn a lot from it: what grants look like, how they are structured, what kind of language they use. If you are serious about becoming a PI, your time investment will pay dividends when you will be writing grants yourself.

Should you write small or big grants? The question is not trivial, and I cannot give you a definitive answer. Some PIs prefer to write larger grants so that they need to spend less time writing grant applications. But, considering the very low success rate and the slow re-submission cycle (many funding agencies let you re-submit only a year later), focussing on large grants carries the risk that the funding of your lab dries up. On the other hand, writing many small grants (that may have slightly higher success rates) can be draining, and, as one PI put it, *"can be treacherous"*, because writing many small grants makes you *"bend your ideas to fit the available money"*, and this may make you deviate from what you really want to do. It may be needless to say that she likes writing big grants.

Whether you'll write small or big grants, here's some advice collected from PIs and some from me, since I have been involved with quite a few grant applications in recent years. I hope you will find them useful:

- Start well in advance, grant writing is an iterative process. *"You have to question yourself constantly. The page limits force you to distil the best of the project, to crystallize the vision"* said one PI, and several PIs mentioned that they go through several cycles of writing.
- Make sure you read the entire application (often a website) and know what you need to "produce" to have a complete application. Do you need any documents signed by officials at your host organization? As the instructor told me at one grant-writing workshop: *"You work seven days a week but they [the administrators] don't"*. Moreover, your application is not a priority for them, so allow plenty of time to get those things signed. Once you get the signed document, check if it was signed properly.
- Do not underestimate the administrative part of a grant. This is why it is important to look over the entire application first so that you have an idea of everything that you will have to submit. The science (the project description) is an important part of a grant application but it is only a part of it. *"The project part is fun, but the administrative burden added to it increases every year"*—lamented one PI. There are many parts in a grant application that have little to do with the project you want to do, but you will have to fill them out and it can take an enormous amount of time because there are things in there that scientists usually don't think about. Realize that there are people specialized in doing the administrative parts, involve them. Get in touch with your organization's grant office and ask them if they have templates of successful grant applications, or with people who have successfully applied for the grant and use their application as a template. If you don't know anybody who has gotten a grant like the one you are applying for, check the website of the organization that sent out the call for applications because they may advertise who was successful in the last round or call them and ask.
- Grant reviewers are people. They may be smarter than you, but they may not be. They are certainly not paying as much attention to your research as you do, and they are probably very busy, have a stack of applications to evaluate, and they may read your application in small instalments. Make it easy for them to understand what you want to do and why. Make things simple, use indentation, break the text up into small paragraphs. It is better to introduce two thoughts very clearly and even repeat things at different parts of the grant than introduce four thoughts and not have enough room for clarification. Some redundancy is good.
- Involve other people in the process. You need to keep in mind the obvious truth mentioned by one PI: *"it will be other people who score your grant, not you"*, so show your grant around. I think it is best to be selective about with whom you share your grant, but I want you to know the opinions of the PIs who said that *"if*

you have a new idea, the best thing is to tell someone" and *"do not be afraid that others steal your idea, they will give you other perspectives, they will improve it"*. A third PI echoed this sentiment: *"show [your application] around to a lot of people: although it can be demoralizing to get it back with bad feedback, listening to the feedback will make the grant better!"* Another PI said that he wrote in team: the first draft gets sent around, he receives feedback from his team, then he moves on the second draft... etc. Involving other people makes it even more important to give yourself plenty of time since you will have to wait for other people's feedback.

- Think of a grant as the *"reverse of a paper"*: you need to make it as promising as possible. Although some PIs did compare grants to fairy tales, make sure your vision is rooted in fact (this is why it is very important to read up on the subject).
- We already mentioned the role of pleasing the reviewers. But reviewers ultimately get their instructions on how to evaluate the application from the granting agency. Therefore, it is *"important to understand what kind of research they [the funding agency] are looking for and pitch to that audience"*.
- One PI called *"grant writing an exercise of taking an exciting idea and turning it into a dense, totally boring document"*—but it does not have to be that way. *"The way you tell the story is important"*, as one PI mentioned, and she said that you are allowed to bring your excitement in the grant: *"be colourful, include schematics, graphs"*. Somebody with decades of experience with reviewing grants said that he starts by looking through all the figures of the grant, and by the end of his first pass through the application, he already wants to have a good idea of what the grant is about—so make sure your illustrations stand by themselves.
- I liked the way another PI called grant writing *"imaginary science"* when you have to know everything about the project from all possible angles. Be aware that this is amazingly time/energy/emotionally consuming.
- Many grant calls force you to apply as a consortium of several groups. Although putting a consortium together and coordinating a project is an enormous amount of work, one PI felt that he was *"standing on the shoulder of giants by involving the best partners"*.
- What you write will help the partners to have confidence in you (again, make sure you know what you are talking about), and you will get further input from partners.
- Explain the bigger picture: why are you doing this?
- Admit risks. In general, most PIs advised to admit risks and thought it was important to tell the reviewers about the difficulties. The opinions on contingency plans were divided. One PI who likes to be systematic and dissect the steps said he thinks of contingency plans, anyway, and found this very useful for writing grants. But, many other PIs found providing elaborate risk mitigation plans "*a useless exercise"*, because *"if the experiments are predictable, they are not interesting to do"*. *"All breakthroughs came from unexpected results"*, said one PI, so the most important thing for scientists was *"to be open to first see the*

strange data to later make sense of it". One PI found the expected results section of grant applications absurd.

- Make it interdisciplinary! There was one caveat mentioned, *"if you are working on the boundary of two fields, you may end up with no or the wrong the reviewers, that can be problematic"*. If you are writing an application at the intersection of two fields, make sure you educate experts of each field about the other field.
- Re-use earlier grant applications: editing is always easier and faster than coming up with entirely new text, and if you were lucky to receive in-depth criticism, you will know exactly what could be improved. In this regard looking at successful earlier applications can be very useful, as well. Your institute's grant office may have some applications on file that you can use as a template.
- Since the applicant's track record seems to be an important factor in deciding whether the application gets funded or not, make sure you allow enough time to polish your resume. Your track record is what it is, but you can make sure you include and accent all your achievements relevant to the project.
- For societal impact, you will need more than publications, you will have to interact with patient organizations, clinicians. and the lay public.
- Just as with manuscripts, the quality of the writing is key. Make sure you use spell check, and I would recommend some kind of grammar-checking application, as well (basic versions are available free), to make sure your text is as perfect as you can get it. The reviewers will perceive you as highly competent if your writing is excellent and your goals are formulated clearly. Pericles may have been a little harsh saying that "Having knowledge but lacking the power to express it clearly is no better than never having any ideas at all"—but I find this very true for grant applications.

Dealing with the Rejection of Your Grant

Considering that the success rates of most grants fall in the 10 to 20% range, it is likely that some of your grant applications will get rejected. I would like to arm you with some wisdom to help you deal with those rejections.

As we saw when we were talking about the evaluation process, for the grants in the middle (not excellent, but not bad, either) the evaluation process has a stochastic nature. Therefore, it is useful to keep in mind the advice of one PI: *"the more you play, the more chance you have"*. *"He hears it from great scientists that their grants were not funded"*, said another PI. *"They just re-write them"* he added, and so should you. The success of your grant may have depended on trivial things like misspelling words or minor mistakes, it does not mean that it was a bad project.

"I know people who went to Howard Hughes or other institutions where they do not need to write grants", said one PI, *"but I would not like that, I want to write [grants] to organize my thoughts"*. Similarly, several PIs said that they found even unsuccessful grants useful because the process forced them to read up on the subject and to structure their thinking.

"We all go through roller coasters with funding", said another PI—*"this does not mean that we do not write good grants or do good research"*. Another PI who used to be very stressed about rejection said that now she thinks that *"whether she gets the money or not, writing the grant is a worthwhile exercise"*. *"Have fun with it! If you get the money, that is a bonus"*, she added.

Since more and more grants are written by consortiums, it is good to note that putting the consortium together may have a greater benefit as a starting point for collaboration than the money itself.

And finally, keep in mind the words of the PI who said that *"there are two kinds of people in science: a lot of people do science without joy, and there are those who do it for enjoyment"*.

The Suggestions of PIs to Improve the Grant System

You may or may not find the expressly negative opinions about the grant system correct, and you probably have very little control over the grant process now. But when you become a successful and influential scientist you may be able to do something to shepherd in some change, so I thought I would share some of the suggestions PIs had to improve the grant system.

PIs mentioned that they found the grant system inefficient: several suggested that at least some of the funding should not be competitive. Several others suggested a two-tier system that would guarantee that the applications that are invited for the 2nd stage have a higher chance of being granted—therefore fewer people would waste their time with applying. The *"fund the person, not the grant"* approach was also suggested by several PIs. This makes sense since the track record of the applicant already seems to matter as much or more for the success of the application than the project itself, as we have talked about it just before. Finally, several PIs thought that the Howard Hughes system (evaluation every five years and leaving researchers alone in the meantime) allows researchers more freedom.

Another complaint was that budgets were not realistic. As one PI put it *"you are forced to promise things that are not possible to do within the time frame or budget. Projects cost much more than budgeted"* (2–5× more in his estimation).

Other suggestions to improve the system were that granting agencies could pay the reviewers for their work in exchange for a more thorough evaluation and allow re-submitting unsuccessful grant more quickly instead of the yearly cycle.

Publish or Perish: The Ambivalent Relationship of Scientists with Publications

Many PIs mentioned that publications fulfil a double role both as a way of disseminating knowledge (the original role of publications) and as a means of evaluating a scientist's work (the current practical use of publications), besides serving as a source of accomplishment for the scientists themselves.

The External Functions of Publications

Most PIs view publications as an important way of sharing their results. Several expressed that as academic scientists they are paid by society and publications are their output. They felt that publishing is their way of letting society know what they have been doing and giving back to the people who paid for the science done by making the gained knowledge available.

I think few taxpayers understand the scientific publications and I tend to agree with those PIs who view publications more as a way to communicate their results to other scientists to advance science. *"Knowledge has to be distributed otherwise it is not science"*, said one PI. Many went even farther saying that unpublished research is a waste of resources: *"any observation not documented and published is just air"*. One PI who likes to *"both write and read [publications]*" said that an *"adverse relationship with papers would be like a butcher not liking meat!"* On the other hand, another PI complained that *"we are putting too much effort into publishing not important things"* and *"he feels obligated to publish papers that are not worth the time because his students need papers for their careers"*.

The majority of PIs expressed that they liked publishing *"complete stories"*, although graduation requirements as a pressure to publish smaller papers have come up several times. Not everybody felt negative about smaller publications that do not explore the "complete story". One scientist said that he had never done an experiment that he did not publish. *"Many clinical publications are important, even the small ones"*—said another PI and a third PI said about incomplete publications that *"people like to own ideas, but it is good to give away ideas so that other people can go off working on it!"*. Finally, PIs mentioned that there are pieces of data that never end up even in small publications, but they may serve the role of preliminary data in grant applications: they can take the knowledge from it and develop it further.

In the scientist-to-scientist communication function of publication, we need to bear in mind an obvious feature of publications: they are written after the fact. *"A publication is the synthesis of a whole project, and ultimately the only reality of a project, but publications do not capture how the project really happened"*, said one PI. He added that publications are not a truthful way of how science is conducted, they are *"constructed"* afterwards. I find this very important to bear in mind because we know most other scientists work only through their publications, and it is easy to think that other people do science so much better than we do. It may be downright discouraging to compare the very clean but "constructed" line of reasoning presented in a publication with the twists, turns, and dead ends we experience during our work.

Two different PIs from different continents called publications the *"currency"* of scientists, and this expresses very well the present practical use of publications: a measure of a scientist's worth. Many PIs were torn about metrics, especially the recent heavy focus on journal impact factors. The reality is that careers are decided based on the impact factor of the journal you publish in. As a result, *"a lot of people are more invested in where they publish instead of what they publish"*—as one PI observed. *"Does publishing in a high-impact journal make the work better?"* she added.

Apparently, it does. Determining the value of a scientific contribution is almost impossible for those who are not experts in the field (which is most of us), so we (several PIs also admitted this) assume that *"discoveries published in high-impact journals are more important than those in low-impact journals—especially if we are not experts in the field to judge for ourselves"*. Impact factors are easy to compare, just have to look at who has the higher number. This is certainly advantageous for administrators and HR specialists who are not experts in the subject matter. I cannot fault them, I do the same.

The supremacy of journal impact factors is relatively recent. Before, it was more important how well cited a paper was. Several PIs mentioned that they preferred citations to impact factors as a metric. But accumulating citations may take years, whereas the journal impact factor is instantaneous. If you publish in Nature today, you can immediately take credit for it on your job application!

The focus on journal impact factors is worsened by the custom of taking only the first-author and last-author publications into account when judging somebody's work. One PI said that this *"me, me, me (publication-based) culture destroys large platforms"* because publication credit can't be split. Although nowadays many publications have two or even three "first authors" and more than one "last author", these distinctions get often lost and it is hard for those authors "in the middle" to take credit for their contributions—however important it may have been for the success of the publication.

Another PI also said that we are *"ruining science by the way we are trying to measure and quantify it at the moment"*. *"We can't necessarily quantify how good a scientific contribution is—we are trying to measure the unmeasurable!"*, she added.

The Internal Function of Publications

Publishing the results of a series of experiments gives many PIs a *"sense of completeness"*, it marks the end of the project. *"Without publication, the project is not done"*, said one PI who thought that the publication *"is as important as doing the experiments themselves"*.

Although the publication is not a goal, publishing is *"the act of closing a story before moving on"* for many PIs. Publication does not only close a chapter of life for many PIs, it is also a signpost that lets others know that *"we have accomplished this"* and summarizes what has been done.

Another PI said that publications were *"required, but not sufficient for happiness and feeling productive"*. *"My goal is to deliver good data"*, he added.

A PI said that she had *"mixed feelings about publications because she does research for herself"* to find out the answer to a question. Publishing was less interesting for her because *"when you tell others, you already know the answer!"* But even she thought that publishing the results helped her to organize her thoughts and get feedback from other scientists. This interaction made publication worth it for her. Another PI expressed a similar emphasis on the importance of the feedback of other scientists when he said that *"you are not correct until someone confirms you!"*

The Volume of Publications

There was great disagreement amongst PIs (and some PIs seemed to contradict themselves) about the number of publications. Everybody feels the pressure to publish, down to the graduate students who have to produce a certain number of publications to receive their PhD degree (one PI told me that this number can be as high as four first-author publications in certain countries). This leads to people wanting to publish more "small papers" that don't necessarily explore every angle, don't tell a "complete story" but show that work has been done. Being able to publish negative data would also help in this regard (to publish more) because you often generate data that do not fit your hypothesis but several PIs complained that it is hard to publish negative data because journals are either not interested or require a lot of extra data. *"I agree with Karl Popper that the only reliable pieces of information are the ones that do not fit our hypothesis since we can only believe the falsification of the hypothesis. Such data do not bother me"*, said one PI. *"What is insane"*, he continued, *"that negative results are not publishable!"*. Other PIs also remarked that during face-to-face conversations at meetings scientists do admit that they have explored some avenues and got nowhere, but you don't see such data published. This leads to duplicating research which is a poor use of resources. For all the listed reasons many PIs called for easier publishing and more publications.

At the same time, many PIs expressed negative feelings about the *"diarrhoea of publications"*: they said that there were too many publications which makes it hard to separate the wheat from the chaff. Some called our time the *"age of mass-produced data"* when quality is not considered and many publications are of poor quality. Many PIs said that (if they were not under such a heavy pressure to publish) they would prefer to publish only when they have *"something to say"*, some information to transmit, when they have a complete story they are sure of. One PI even said that she favours the idea that all scientists would be allowed to publish a certain number of papers (e.g. 20) in their lifetime so they would think twice about what to publish (perhaps this could help with the reproducibility problem of published results, as well), and another PI cited the policy of her institution that encourages scientists not to publish all their data but only the best.

The Reproducibility of Publications

Concerns about the reproducibility of publications were frequently mentioned by the PIs: *"published does not mean 100 % true"* as one of them said. Most PIs felt that the pressure forces some researchers to publish before the paper is *"perfect"* (meaning that the authors are fully convinced that the results are correct). Besides the rush, many other sources can contribute to irreproducibility: drift in the cell lines used, the (in)stability of the samples, biological variability, etc., and, in a small minority of papers, fake data.

One PI pointed out that she had more success reproducing the work of labs she knows personally and found it harder to reproduce the work of unknown groups. To me, that just reinforces that a lot of "irreproducibility" is due to information lost during the publication process. If you know (and trust) the source of the information, you take the effort to find out these details, but if you don't, you just chalk your different results up to "irreproducibility".

PIs had varying degrees of tolerance towards irreproducible data. Some were passionate about it and said they hated having wrong information in the literature because it can distort the field. Others were more philosophical about it and cited the self-correcting nature of science: papers that contain wrong information get cited less and less and slowly fade away. *"Anyway, the validity of papers always has to be considered in terms of the state of the art at the time they were published, and this changes over time"*—added another PI.

The Reviewing Process

Many PIs talked about the flaws of the review process. Even a PI who said that she enjoys the interaction with the reviewers because it makes the story stronger added that the review process usually drags on so long that she already would like to move on to the next thing. Others also said that finishing up papers can be frustrating because it can take such a long time sometimes that the lab has already moved on to other projects. Another PI said that the revision process forces authors to go out on a limb and put in less robust data.

Nobody called for eliminating the peer review, but there were plenty of suggestions on how to improve the system. One of these frustrations was that it was *"hard to control whether the reviewers looked at the manuscript objectively or even if they really looked at it (sometimes revision comments reveal that the reviewer did not really read the manuscript!)"*. Since publications are an important way to communicate our results so that others can build on them and our publication record plays such a deciding role in our career, publications should be evaluated very carefully. Others said that the review process should not be anonymous.

One PI said that she had serious doubts about how the publications are evaluated and said that she would rather have independent people, full-time professional reviewers with certain areas of expertise, look at them. Another argument for professional reviewers was that it might reduce the present influence of personal networks and contacts on the review process. Another PI who was convinced that the source of the publication (the submitting authors and their affiliation) is a major factor in the decision whether the manuscript will be accepted said that she often tells herself when looking at publications that *"this would not have been accepted from me"*.

"The verbal and aesthetic component plus the selling capacity has a great influence on success", said another PI. He thought that his job as a PI was to boost the chances of the publications of his people by trying to influence the system. *"Exaggeration helps, overselling helps"*, he added. For this very reason to *"not contaminate [his] mind with what other people want to sell [him]"*, another PI said that when he is reviewing papers he looks at the *"only real thing"* in the paper, the raw data.

But even the fairest and most conscientious peer reviewer can only review papers that are sent to him by an editor. Several PIs talked about another layer in the peer review process that they thought was flawed: editors decide what will be peer-reviewed, and this decision may be influenced by *"business considerations and the reputation of their journal, and not what is out of the box thinking"*.

Several people complained about the topic bias of the journals. One accused high-profile journals of *"double-dipping"*: *"the editors of big journals put pressure on science"*, he said. *"Journals not only publish, but they also determine what will be published—therefore what will be researched!"* He thought that editors are influenced by what high-profile scientist think the most important trends are. This introduces bias, and science is losing its neutrality. He likes the Peer Community Initiative, a bottom-up approach. With the online system it is possible now to get rid of journals but still keep the review process. This does not eliminate reviewer bias but gets rid of the topic bias, at least. In the regular publishing stream, he targets second-tier journals, because they are read by a wide community of scientists, he added.

He was not the only one who was bothered by topic bias. Another PI also said that it bothers her that *"some things are not considered interesting, because most important discoveries were not done intentionally, because they wanted to discover something"*. A third PI said that *"only novel and sexy data get published"*. *"Sometimes we should publish data contesting the established model"*—he thought.

Practical Advice

One PI summarized the publishing process this way: *"you have to do good work and publish it at a time when it is interesting to others, and have it reviewed by people—a lot of luck is involved"*. This is true, but other PIs had a few pieces of advice about writing papers that may improve your luck. We will have a more careful look at how PIs put together the project results in a story for publication in Chap. 5.

"Say what is the core thing that you are trying to do: issue—approach—result—discussion (historical perspective and potential)"—was the straightforward recipe from one PI. Others emphasized that the quality of writing is crucial and complained about the poor quality of language in many publications and argued for well-written papers—although this introduces a bias, again, since native speakers of English are at a distinctive advantage. I would suggest re-writing papers professionally, employing science communicators who would work with the authors to produce better papers. This may not be feasible for all, but at the minimum, everybody should ask some native speakers or people with very strong writing skills to go over the paper and improve the language—it will improve the chances of getting into the review process.

Do not underestimate the importance of language, several PIs talked about their love for language and clear writing. *"You have to write well, clearly, with simple words to have an impact"*, said one PI. *"Writing clearly to share ideas is as important as the ideas themselves!"*—she added. Another PI (with a very impressive H-index of 86, I might add) who *"absolutely loves writing publications"* said that finding the right way to present the results is essential. He said he can help his students a lot by working on their manuscripts. He loves to *"take a story from the students, re-shuffle it until he finds the best pitch"*. He can also appreciate other people's well-written stories, but he regretted that *"not a lot of scientists take care of their writing"*.

Many PIs expressed frustration about the slowness of the publication process. *"It would be better to get the results out sooner so that they can push the field forward"*, said one PI who said she is *"in favour of new and more flexible publication formats, open-access publication"*. An alternative mentioned by several PIs was bioRxiv (pronounced "bio-archive") which is a free online archive and distribution service for unpublished (not peer-reviewed) preprints in the life sciences, operated by Cold Spring Harbor Laboratory, https://www.biorxiv.org/).

Finally, one more piece of practical advice: pay attention to acknowledging your funders. This seems like just a courtesy or a minor detail to many people, but not including all relevant funders in the paper may come back to bite you in the behind later. When the time comes to assemble your report to the funding agency about what you did with their money, you will want to be able to claim all your publications as output for the grant—but many funding agencies let you include only those publications that actually mention the funding agency or grant. Correcting the acknowledgement section of a paper is very difficult or impossible in many journals.

Top Publishers

Top Publisher PIs called publications *"a must"* and a *"measure of a scientist's talent, ambition, organizing capability"*. *"Write up your work—the work is not yours anymore, it belongs to the field"* advised one Top Publisher PI, and another said that *"publication is part of the scientific process"*.

At the same time, they were very critical of publications, emphasizing that not all are true. Despite having a better publication record than the rest of the interviewed PIs, Top Publisher PIs were not less critical of the publication system, either. One simply said that *"the whole evaluation system needs to be reorganized"*.

Talking about the dangers of the *"'impact fetish"*, one mentioned that *"some of his most cited papers came out in low-impact journals"*.

Several Top Publisher PIs said that a publication was *"a story you sell"*. *"The human mind is geared to hear nice stories"*, and the review process forces authors to present a *"story"*. *"Nice data"* are not enough, they are required to supply a mechanism. When we read publications, it is important to detect the flaws in the nice stories, because *"most of them are just not true"*.

Now that we have an idea of how PIs approach grants and publications, in the next chapter, we will have a look at how they build up the group that will help them to perform the work proposed in the grants and reported in the publications.

3 Setting Up a Successful Research Group

Abstract

This chapter describes the process of choosing team members and also contains recommendations on the composition of the team. The inside look at what PIs expect from candidates will be useful to those seeking a position in research labs, as well.

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
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How Do You Know, How Do You Decide, that You Want to Hire Someone?

Hiring is difficult. *"This is the worst part of the job; it is difficult to pick!"*—said one PI. Many PIs admitted that they have been wrong about people and have had bad surprises. *"Hiring is very hard, I still make mistakes"*—admitted one PI who has led his own lab for 27 years.

Although one PI said that picking an administrative assistant is even harder than deciding about scientists, hiring researchers is *"difficult, and it is the key thing for building your group"*, as one PI put it. A lot hinges on your decisions because your team members are your hands and eyes in the lab. PIs go by what their team members tell them, and you have to be able to trust that your team does the experiments to the same high standards you yourself would do them and that the information you receive is correct. The interactions among team members are also very important. Can they function together as a team? *"A bad person can spoil the entire lab—unfortunately, it does not work in the other way, one good person does not turn the entire team to be good"*—warned another PI.

> *Recruitment is the single most difficult thing at the start of a lab (assistant professor, PI for over 5 years, over 30 publications, H-index of 19)*

PIs said over and over that the most important trades they look for in a new person to the lab are honesty and an ability to get along with others. Unfortunately, both of these traits are hard to assess during the short time frame of the hiring process.

According to many PIs, the best way to make hiring decisions is to avoid having to make them on the spot! You may be able to rely on the experience of other PIs with a person: one PI said that they *"shuffle students around according to lab needs and funding opportunities"* within a network of colleagues that she knows well and takes their recommendation very seriously. Others also said that they have trusted colleagues whose endorsement is enough for them to hire someone. One caveat of this method is that certain people function well in one environment and not in others—in the end, it seems that the best way to find out if a person is a good fit is to have them in your lab for a while.

"My favourite method is to take people as BSc students, and if both sides are satisfied with the other, I keep them around for MSc, and PhD", said one PI and many other PIs also prefer taking students to do a Master's thesis or an internship in their lab, because *"past performance is the best predictor"*. *"The best is to work with them"*, said another PI, as well, who likes having MS students in his lab because he can observe several aspects during their rotation, like how they communicate data and how they work with the other people in the lab.

A PI who *"9 times out of 10 hires former interns"* warned that even if you can get a feel for somebody's personality during an interview, *"it takes time to figure out how resilient they are in face of failure, how is their scientific/creative thinking, ability to assess if experiments are technically okay or not, their critical thinking, and the shape of their learning curve: do they learn fast or slow, do they keep* *learning or do they plateau low?"* Therefore, she likes to hire people she has interacted with for a while, and many other PIs mentioned that it is best if the person can spend 1–6 months in the lab before hiring. One PI said that she likes to protect herself by offering a contract to new employees that includes a 6-month trial period with the understanding that there will be an evaluation at the end of the 6 months—but it depends on the policies of your university if this is possible or not.

Besides an extended first-hand experience with the candidate, many PIs mentioned having good experience with "ad hoc" hiring. One of them said that she most often hires people through a spontaneous application if the applicant has the appropriate experience or is interested in a question she is interested in. *"These applications show that the applicant clearly knows the field and are self-motivated on what they want to do next!"*, she argued—although I would suggest subjecting these applicants to the same scrutiny as those who apply for a job opening.

Many PIs said they had learned over the years that it is worth listening to their gut: *"there are a lot of metacommunicational cues that do not become conscious, but inform my general decision"*, said one of them; others said you *"have to be lucky"*. On the other hand, a veteran PI said that *"gut feeling influences the decision, but you have to do better than gut feeling. Do your homework"*. Let's see what you can do to increase your chances of hiring the kind of people you need.

The Procedure

Now that we established that just taking the first person who applies may not be a good idea, let's see how PIs clear this hurdle. There are some individual variations, but the procedure usually looks something like this: advertising the position in some way, making a shortlist of candidates (this can be as few as three and as many as ten), initial contact using telecommunication, narrowing down the list of candidates to 3–5. Then the top candidates have a personal meeting with the PI and usually with lab members. After this, most PIs go through some kind of vetting process and they make the decision.

This procedure may seem complicated already, but several PIs said that they have learned to increase the aspects in recruitment, not the opposite. Considering the importance of picking the right people for your lab, it is worth investing time in hiring.

University policy may dictate how you advertise an open position. In case it does not, you can put ads in major journals or their career websites, but some PIs avoid hiring through ads and rather ask colleagues for people with a particular skill-set, so you may want to send flyers to colleagues in your field.

The location of the lab also influences the pool of applicants you can choose from, e.g. PIs in Australia mentioned that moving there can take a while to get the visa. Another PI in Europe said that she usually does not get that many applicants because the city where she lives is extremely expensive and the salaries are not adjusted accordingly. Others also mentioned that they get a limited pool of applicants to choose from because they work on campuses that are less attractive than others in their city.

Pre-filters for Shortlisting

If you get a lot of candidates for the opening, you need to decide whom you would like to focus on. PIs mentioned using different pre-filters to make their shortlist: have the candidates won any awards or scholarships, where have they published, do they have first-author papers? How many years of experience do they have, how quickly do they change positions? One PI mentioned that he loves to work with MDs who want to do a PhD because he knows *"that they do it for the love of science since they can get a better paying job easily"*.

Having a specific interest in what the PI does as opposed to *"just looking for a job"* was a frequently mentioned pre-filter. *"Candidates need to take the effort to find out what my group does"*, said one PI. She expects candidates to be able to articulate why they want to work specifically with her, and how they think they can contribute to the activity of her group. Others also mentioned that the motivation letter counts to them, and it needs to be personalized and say why people want to come specifically to their lab, what they know about their work, and what they think they could do in his lab. One PI likes if candidates *"mention their long-term career goals to have an idea if this job is long term for them or just a stepping stone"*.

The opinions on the importance of technical expertise were divided: for PIs who work on highly technical topics (e.g. for the PI who said she was building new types of microscopes), this was a major concern, whereas others thought that they do not need to hire a person with all the experience but rather someone who can be trained. They emphasized the importance of other personality traits, for example, flexibility, how the candidate can adapt to change. *"Techniques can be learned, but the character cannot"*, said one of these PIs. *"If somebody has previous experience, this may be good or not—sometimes it is hard to change their way of thinking"*, said another PI who prefers taking PhD students to more senior people. She said that although students take longer to start up, she prefers in the end if they are trained (to think) by her. Another PI said she sorts the CVs based on experience and skills because she likes variety in her lab and hires people who have broad backgrounds (like engineering + biology).

Most PIs also look at the candidate's track record. *"They have to have published something, demonstrated that they can do publishable science"*—said one PI. In the case of students with no track record, one PI said that he gives them a paper and tells them to come back in a week and tell him what they understood from the paper and tell him everything that they did not understand. Finally, there was one PI who outsources the pre-selection process to the top people in his group, because *"he immediately starts thinking about the possibilities in the particular person that is in front of him"* instead of narrowing down the circle of candidates.

What to Look for During the Personal Contacts

Repeated Contact

The CV, skill-set, track record, or whatever other criteria you decide to use for shortlisting are only pre-filters: *"they have to be right for the candidate to be even considered, but the real selection comes afterwards"*, as one PI said. *"The candidate has to be a good fit for the team, the project, and the PI"*, said another PI, and you will have to invest the time to talk to the candidate to determine if this is the case. PIs admit being misled by *"convincing people who turned out to be not as good as they advertised themselves"*.

Several PIs said that they invest the time in talking with the candidates more than once. Repeated contacts with the candidate and probing several aspects of his/her personality will help you to avoid bad surprises later on. Multiple discussions also help to ascertain the honesty of the candidate. As one PI said, she does *"two rounds of interviews, asking similar questions, and if the answers do not match up with each other or with the opinion of the reference, it is a no-go"*. On the other hand, the interview is a two-way process, and meeting the candidates more than once gives them more chance to get to know their future work conditions so that *"they can also see what they are getting into"*. And, as one PI warned, *"the candidate also may have a bad day"*, seeing them several times gives them a chance to redeem themselves, should they make a less-than-optimal impression the first time.

As a first step, most PIs use some kind of telecommunication tool (Skype, Zoom, etc.) as an inexpensive way to find out more about the candidate. *"Sometimes the application is written in perfect English but then I have difficulty communicating with the candidate—that will obviously not work out"*, said one PI. A quick teleconference may not only make such language or communication problems obvious but also start to give you a feel for the personality of the candidate.

Establishing a Connection

The main function of the personal meetings is to give a general impression about the candidate's personality to help PIs to decide whether they would like to work with the candidate. The initial question PIs are looking to answer is very simple: *"Can we get along?"* Or, as another PI put it: *"there has to be a 'click'"*.

First impressions are very important in this case, too. Many PIs said that they know very soon after meeting the candidate if they are interested in learning more about the candidate. *"Sometimes there are obvious bad feelings about some candidates"*, said one PI. Several of them said that regardless of how good somebody looks on paper, they want to feel a connection with the candidate. *"There should be a connection after two minutes"*, said one PI. *"The question I ask myself is: do I want to hear more? If there is no connection, I don't hire the person"*, he continued.

"The personality has to fit: the candidate may be a great scientist but a horrible person to work with! One rotten apple will spoil the lab atmosphere" warned one PI. *"I look for smart people, but they should not be too difficult—one difficult person can destroy a group"*—agreed with her another PI. A third PI said that he suffers if

there is somebody in the lab that he does not like—hiring such a candidate will not work on the long run. Another PI also said that he would not necessarily take the student with the highest past scores because social abilities are also important. *"The person has to be able to collaborate, however smart he is! The social aspect will decide if it is a yes or no. I will not hire a person that is socially incapable"*, was another opinion. *"I look for the feeling that this person will be able to help me with what I need to have done: both at the level of competencies and the level of communication—there needs to be a good interaction between us"*, said another PI.

Most PIs love talking about their work and you might be tempted to explain all your lab's projects to the candidate. However, several PIs said that they learned to do *"more listening than talking"*. When PIs talk to the candidates they watch the way candidates talk about things. Are they open? Other PIs said that they also pay attention to how easy communication is with the candidate. Are there constant misunderstandings? One PI said that she likes to let the candidates talk about their previous work for two reasons: *"First, it lets you see in there is a 'spark' in the candidate. Second, it gives confirmation that they really did the work and they understand their project"*.

"I used to try to excite people with my projects, but now I let them talk", said another PI. *"I ask them: Can you think of a stressful point in your life, what did you do?"* She wants to hear practical examples about how the candidates have dealt with difficult situations before and listens to whether they go deep into the details or if the examples are fake. Stress resistance and creativity are the most important for doing a PhD. *"I learn a lot about people"*, she said, *"for example, when a candidate was talking to me about making jewellery, I knew she'll be able to sit at the microscope for hours"*.

The honesty of the candidate is very much on the mind of PIs during the interviews. *"I want to see genuine answers, not general ones"*, said one of them, and several PIs mentioned being *"allergic"* to overselling people. *"I am looking for the following during the conversation: are they vague?—especially if the question was precise and specific"* said another PI. *"I don't like bullshitters, I value an honest 'I do not know' more"*.

Most PIs also want to see indications of motivation, a passion for the work, because *"science is not a 9–5 job"*. *"Are his eyes sparkling when talking about science?"* scrutinizes the candidate one PI, *"Is he enthusiastic?"*. Motivation and enjoying what you do is important *"because then you will want to do it well. If you can't stand what you are doing, you will do it badly and you will do as little of it as possible"* as one PI said. *"I cannot handle people who do not want to be there"*, she added. *"That is, of course, the enthusiasm the person shows"*—warned another PI. *"If they are enthusiastic, but they don't show it, they will not get hired. The only exception may be if they have a really exceptional record because they must have enthusiasm for science otherwise they would not get that record"* reasoned another PI.

As we have already talked about it, some PIs screen the candidates based on the motivational letter, and they expect it to be personalized and indicate that the candidate has looked up their work. This remains true for the personal meetings:

PIs want people who *“choose to come to their lab and not people who are desperate”*. Several mentioned that they expect the candidate to know what the lab does and like it if people read up on their lab’s work. They take this as an indication of how much initiative the candidates take and how exploratory they are. One PI said that he asks candidates directly why they want to come to his lab. Another PI also said that he not only asks candidates how they found him but goes even farther and asks them: *“When you leave here, what do you expect to have learned, what do you expect from us . . . what do you think you will have learned?”* Then he watches how long they have to think about it.

Specific Issues to Discuss

There is a lot to observe which is why some PIs choose to have a lengthy discussion with the candidates to assess the compatibility of the personality of the candidate with their own, their honesty, level of motivation, how much initiative they take, etc. Besides these general characteristics, many PIs like to ask some specific questions.

For example, one PI poses the question *“What are you reading now?”* to the candidates. Another PI asks the candidate *“why do you want to do this, what are your passions?”*, and a third mentioned asking candidates why they want to be a scientist? *“I want to know how they imagine the life of a scientist if they know what they will have to forgo and what they will get instead”*—she explained.

All PIs want to see curiosity and an intellectual spark in the candidates, but one PI specifically mentioned flexibility as a requirement: *“People have to be willing and able to learn new things”* she explained. Flexibility is very important when hiring technicians, as well; they have to be flexible to do different things as the needs of the lab change. Another PI also said that she watches if candidates mention their long-term career goals to have an idea if this job is long term for them or just a stepping stone.

One PI mentioned asking the candidates whether they have questions for him. This may seem like a common courtesy at the end of an interview but it can be revealing of how much thought the candidate has given to working with you.

How to Conduct the Interview

The schedule of the interviewing day varies from PI to PI, but most of them include a presentation by the candidate. If it’s a postdoc position, PIs usually ask the candidates to present their previous work. Some PIs dispense with the seminar for PhD positions but some like to give students one of their publications and ask them to present it in 10 minutes. This serves not only to assess the presentation skills of the candidate, but PIs also want to see that the candidate can answer questions, is critical and self-critical—all crucial aspects of being a scientist.

Usually, there is also a lengthy discussion with the PI. The university may require that a representative of HR be present and they may even dictate that the same set of questions is asked of all candidates. Whether this is the case or not, many PIs like to have members of their team present, especially the person who will be directly supervising the recruit, and their opinion helps the PI to decide.

One PI said that she sends the candidates questions ahead of time to prepare for the interview. One of the questions is what their expectations are towards her, their future PI? She explained that if the candidates do not prepare or if they can't speak up, that is a red flag for her. *"I do not want blind followers. I want people who are willing to confront or challenge me: this way there will be two brains working on the project instead of only mine"*.

Most PIs also have the candidates meet members of their team in their absence. This helps the candidate to get more information about the future working conditions and many PIs ask for the opinions of their colleagues before deciding. One PI said that he has a round-table discussion with his team members to get their feedback and then spends some more time alone with the candidate. Another PI said that she has the candidates speak with all the members of the team, and when they come back to her again, she asks them for their thoughts on the projects going on in the lab.

Vetting the Person

After the presentation, the interview, and getting feedback from your team members, you already have a lot to go on to make your decision, but most PIs take the time to check other sources than the candidate.

The opinions on the value of reference letters varied widely among the PIs. Some PIs read the reference letters with great care, one PI even said that the references are much more interesting to her than the CV, and some believe that reference letters are useless and don't even read them. Whether your university obliges you to ask for letters of reference or not, most PIs agree that it is a good idea to collect them from your top candidates. Besides, they can also serve as a paper trail in case you ever have to back up your decision.

The reference letters can vary, as well. Sometimes they are general without much detail, these are indeed useless, but one PI reported that sometimes reference letters contain some bad surprises, things that the reference shares with her privately. Whether it is good or bad, you should bear in mind that one PI pointed out: *"the expectations of the author may be different from yours"*.

Whether they give much credence to reference letters or not, many PIs said that they call previous supervisors for an informal chat to go deeper because *"former employers speak more freely on the phone and tell them more good or bad"*.

One PI suggested to *"do a lot of listening during these calls"* and she said she listens especially for the *"pauses"*. Another PI was remembering his experience with an unsuccessful postdoc and said it should have raised a red flag that the former supervisor recommended the person but could not back his opinion up with an anecdote that the candidate was good. In any case, it is *"best if you know the former PI well and can interpret what they say"*. In case the previous supervisor does not say much during your phone conversation, one PI recommended emailing the person—she said sometimes she gets back long answers.

Some PIs insert another step in their decision process after the interview: they ask the top candidate(s) to write a brief for a project (2–3 pages) they choose based on what they know about their lab (for students, some give them a paper and ask them to write an abstract). This step may be especially useful if nobody is giving a testimonial for a candidate. As one of these PIs said, she does not expect the candidates to do the project they propose, but this is a good filter: *"some never respond, and the ones who do respond, I can see how much effort they put into the task, how well they can leverage what has been done in my lab, and how well they write"*.

Finally, some PIs said that they check social media platforms for *"silly posts"*.

Making the Decision

After collecting all this data on the candidates, you will have to decide who you will hire. As we talked about it at the beginning of the chapter, this is a decision with far-reaching consequences that should not be made lightly.

Several PIs said that *"the lab has a say in the hiring decision"* and can veto candidates. Some PIs may reject a candidate they like because of the opinions of lab members. One PI said that she has found the team members' opinion more reliable than her own—she is either easier to convince or the candidates are more guarded with her than when they are with the team, she said. The opposite also happens, some PIs found that their team members are too nice instead. The bottom line is, that when you are unsure about a candidate, do not hire that person.

It may happen that there is not a clear favourite among the remaining candidates, then you will have to use additional criteria to choose. One PI, for example, said that processing the results into papers has been a bottleneck in his group therefore he chooses people who can write well in English and can organize their ideas into manuscripts. Others said that they want to have a diverse team: different backgrounds and personalities, introverts and extroverts, males and females, therefore they take these qualities into account when choosing. *"Sometimes the lab needs a very social person who organizes birthday parties and outings"*, said one PI and another PI said, *"I don't want clones of myself"*. A third PI said *"if things get too hectic, it may lead to a situation when I say: accept my ideas, because I hired you"*, therefore he chooses people who will stand up to him to keep the science honest.

The Composition of Your Lab

How should you set up your lab in terms of personnel? You may unconsciously model your lab on the labs you have worked in, but that may not be the optimal composition (or the optimal composition for you). I asked PIs how many technicians, MS students, PhD students, and postdocs they have to find out the composition of the "average lab". As I found out, the proportions may have as much to do with the availability of funding as with what PIs think is optimal.

There were many labs without technicians but most labs have between one and three technicians (the median number of technicians per lab was 2). Since group size was quite varied (from 2 to 27 people, the median group size was 9 people), perhaps it is more informative to know that technicians comprise most commonly 10–20% of the group (median: 17%). Lab members share the support of the technicians (most of the time, there is one technician for two MS Student/PhD student/Postdoc) and many times technicians are shared between two or three labs or work part-time. Several PIs mentioned that they keep some trusted technicians who know all the methods in the lab to ensure continuity of expertise. Often, people working as technicians have advanced degrees (MSc or even PhD) and do much more than assist with performing experiments: some fulfil the role of lab managers, they train new personnel, maintain animal colonies, give feedback about how things go in the lab, or may even have their own projects to run.

Most labs have one of two Master's students although not all PIs have them around. They typically represent 10–25% of the group (median: 17%). Some PIs like to keep a young group and have a Master's student for each PhD student, although the median ratio was one MS student for two PhD students. As we have talked about it in the hiring section, Master's students spend a relatively short time in the lab, but enough to give both sides a thorough idea of the fit between the student and the lab, therefore many PIs like to bring in students to the lab as Master's students and then keep them on for a PhD and even as postdoctoral researchers. *"They grew up in the lab, started as Master's students. They teach each other"* said one PI about his PhD students. The number of PhD students per PI varies much more widely, between one and five and they give 15–50% of the population of the typical lab (median: 40%).

The number of postdoctoral researchers per lab showed an even wider distribution (from 0 to 11, the median was 2), making up 10 to 50% of the group (median: 20%). This reflects the widely varied opinions of PIs on hiring postdoctoral researchers, depending on their personal outlook, management style and previous experiences. One PI called senior postdocs the *"rocks"* of the lab on whom she builds her lab and several PIs like to have postdocs around to help them with the responsibility of supervising the students. I have talked with several PIs who lead their lab in cooperation with another researcher as co-PI, and the co-PI is sometimes a former student who stays on to help with managing the lab.

Postdocs may run projects of the lab and enjoy a lot of freedom or may work as technical experts. One PI said *"I always run the lab with postdocs, this is what makes my hands-off approach possible"*, and another also mentioned that she has to do *"micro-management again"* because she had lost a postdoctoral researcher who used to be her *"supervising partner"*. On the other hand, another PI had the opinion that postdocs are not independent enough and he *"may well hire two technicians for the same price"*.

The number of postdocs is not always the result of a deliberate decision: *"it is mostly due to the funding available—but it is working out fine"* said a PI who has seven postdocs in her lab. But it was more common that PIs said they would like to have more postdocs. As one of them said, *"unfortunately, there is no structural funding for keeping postdocs around"* and added that he has a conversation with postdocs that they will have to move on. One PI mentioned that MD-PhDs bring an interesting perspective to the lab in her opinion and she likes to have a mix of MDs, PhDs, and doctoral students.

How big should your group be? That is dependent on many variables (your funding situation is an important one), but even if you had all the grant money and lab space you would like, the size of your lab should fit your leadership style, your managerial and organizational skills, and your capacity to follow up your projects. For example, one PI said that he has a bigger group now (12 people) and they generate more results than what he was used to in the past, so it is hard for him to remember the details—he gets by remembering the conclusions they reached. It is probably a good idea to increase the size of your group gradually so that you have time to adjust to the increased needs of the group. Another argument against increasing the size of your group too fast is that training your personnel thoroughly may help your long-term success, as we will talk about it later (Chap. 7).

In the next chapter, we will have a look at how PIs manage their personnel, how they distribute the work, and how they keep up with the results produced by the group.

Leading Your Research Group as a Principal Investigator

4

Abstract

In this chapter, we will summarize how PIs relate to and communicate with their group, how they deal with underperforming team members, how they like to distribute the work among group members. We will also discuss PIs' thoughts about the ideal balance between reading and performing experiments, and their preferred meeting schedule with their team.

The Relationship between PIs and Their Group

It may surprise people outside of science (and maybe even you), but most PIs are quite fond of the members of their lab. When I asked PIs to think about a work situation that made them very happy and then pick what aspect of that situation made them happy, about as many PIs said that working and being together with other people was the most rewarding aspect of their work as those PIs who answered that they were happy because they learned something new or figured out how something worked. As we talked about in Chap. 1, most PIs are interested in the relationship of facts (and not the facts themselves), therefore it is not surprising that understanding some systems is important to them. But PIs also enjoy exchanging ideas with the members of their lab, sharing their team's excitement about the results. They appreciate not only the intellectual interaction with the members of their group but also value the long-term relationships that they form with them. The answer of one PI was especially revealing: he said that although he used to be really into instrumentation (he went to the other end of the world to learn some advanced technique) and his primary goal is to find out how things work, but it is the long-term relationships with colleagues what brings him to work day-to-day. He said he could earn more money working as a doctor, but he enjoys *"being a mentor, finding clarity in the data with other people"*. Another PI also explained a similar change in his attitude: he said that when he was still in the lab, he used to prize learning new

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things most highly, but now, as a PI, when he thinks that the people are the most important. A third PI said that the moment when her first PhD student graduated was one of the happiest moments of her life at work.

Among those who emphasized the importance of learning new things, there was one PI who said that he remembers *"about ten moments in his life when he saw the data for the first time and told himself, this will make a difference!"* when he knew immediately that this new information *"will lead to papers, grants, drugs"*. Another PI said that he gets *"a kick from situations when a breakthrough happens, when they see something for the first time that nobody has seen"*. Even those who prize most finding out how things work said that doing this in a team makes the process enjoyable for them. One PI said, *"I want to contribute to science, but I want to do it surrounded by good people"*. One PI said that, unlike the typical scientific talks that have a slide of the group at the end, he starts his talks by introducing the people who did the work to emphasize that it is not him with an army of hands, but colleagues who work with him.

Now that we know that PIs enjoy working together with their team members, let's see how they would like to be thought of by their team members: would they like that their team members think of them as a fair, caring, sensitive person or a reasonable, logical, objective person? Surprisingly to me, only a quarter (26%) of the PIs answered that they want to be thought of as a reasonable, logical, objective person, a third of them (34%) answered that they want to be considered as a fair, caring, sensitive person, and the rest (40%) said that they want both.

"You get no respect for being sensitive", said one of the PIs who wanted to be considered as a reasonable, logical, objective person. Other PIs said that they stick to this in their professional life, although it may take an effort for some of them. One of the PIs who answered that being fair, caring, and sensitive was more important said that he is thinking of himself as the *"coach"*. The PIs who answered "both", gave various rationales for trying to mix the two approaches. Most said that they want to strike a balance for the sake of fairness: consider the person when judging in a rational way.

Top Publisher PIs acknowledged that the people they work with play an important role in their lives, but they were more likely to choose to find out about systems and how things work as the most rewarding part of their work-life and mentioned some breakthrough moments when they saw some important discovery for the first time.

Focus on the Self Versus Focus on Others

Managing a core facility was part of my job for a while and I remembered how distracting I found that people came to me with various problems throughout the day and how difficult this made it for me to make progress with other things I wanted to get done. I was wondering how PIs manage this conflict between focussing on themselves and what they want to do and focussing on helping others during their day.

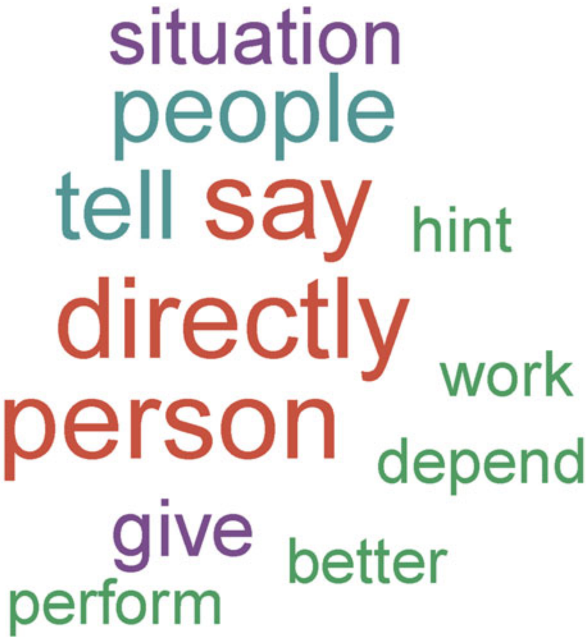
One PI said that he focusses neither himself nor on other people: *"I do not focus on people, proteins come first"*—but he also noted, that his wife complains about this (perhaps not surprisingly). Only a quarter (24%) of the PIs answered that they focus on themselves, and they were often apologetic about it. Some of them were even saying that they were trying to correct this character trait in themselves, but I agree with the PI who said that *"it is impossible not to focus on yourself, you can't achieve anything without focusing on yourself!"* One of these PIs pointed out the irony of trying to focus on herself and at the same time *"ignoring herself by working 80 hrs a week because somebody always needs something"*. Many PIs made a distinction between their behaviour at home and work—being more self-centred at work and more altruistic at home. But even this distinction is blurry for some PIs, who said that they consider members of their team kind of a family.

About half of the PIs (47%) said that they were focussing on others, but most of them meant focussing on their team members. Several mentioned that this was the *"nature of the job"*: they do not have time to think about themselves because there are always people who need something from them. The rest of the PIs said that they alternate focussing on themselves and others. I think the closest to the truth was the PI who said that *"I think of group members as part of my career path, helping them is not selfless. Even helping junior colleagues is not entirely selfless, because it increases my network"*. Another PI said a similar thing, *"I consider the team . . . an extension of myself"*. A third PI said that *"it is a circle: if I am successful, I can help others, and the success of my people helps me, too!"* Top Publisher PIs were even more likely to say that they focus on the members of their team whose success will increase their own success.

Dealing with Underperforming Team Members

"Management issues can be soul-destroying stressful", said one PI, and several other PIs also mentioned during the interviews that problems with members of their team can be very hard on them—this is why it is so important to choose new members for your group carefully. Nobody is looking forward to these conversations, so I asked PIs how they dealt with situations when they felt that someone around them was not performing as well as they ought to: do they come to the point and tell them directly or do they use an indirect approach and give these team members hints and clues or imply some other way that things could go better?

More PIs (44%) answered that they prefer addressing issues with performance directly than those that answered that they prefer to be indirect (33%) or those who said that they vary their approach depending on the situation (24%).



Some of the PIs preferring the direct approach said that this comes naturally for them, and others indicated that they are more disposed to the indirect approach intuitively, but they have learned that a direct approach works better. One PI said that hinting can lead to frustration on both sides and she has emphasized the importance of making a plan, scheduling feedback sessions, and checking off what has been done. This enforces communication and also helps to determine if there is a reason for the lack of performance: is the person having a problem that prevents them to perform or is it due to a real limitation of the person?

Labs are usually international and multi-cultural environments, and one PI emphasized that exactly because of the presence of different cultures, being indirect may not be helpful. *"If the person is from the same culture as me, I may try to hint, but if the person is from another culture, I have to be direct, because hinting may be worse than useless"*, he said, but he also emphasized that he tries to give people feedback the gentlest way they can hear and understand. There can be lots of reasons for not performing well: personal or external. If it's an external problem and has to do with the circumstances in the lab, that should be fixed by the PI.

PIs may, like many other people, be aversive to confrontation and may postpone giving negative feedback. One PI said that he tends to *"give people time to develop, and they usually do"*, although sometimes he has to adjust his expectations. He added that he has a big lab, he can afford some people that are not so great, and he knows that the others will bring the underperforming person up. Most PIs, however, are not in such a luxury position, since many labs are constantly dancing on the edge of the knife financially. One PI said that *"having people in the lab that do not perform to the best of their ability is not an option"*. She said she wanted to *"understand their motivation: why are they there, that is their aim? Do they want only a degree, do they want a Nature paper, do they want an academic career, or are they there because of their mother?"* Another PI said, *"I learned never to leave these situations long because they get worse"*. He admitted that he is always anxious when he is starting such a conversation to give people negative feedback, but in the end, *"these are usually not bad conversations"*.

Some PIs have little patience for underperforming team members. One PI put it this way: *"it is fine if people want to fail, but they should fail somewhere else, not in my lab"*, and another PI said, *"I do not bother trying to motivate people: motivation should be intrinsic, I do not want to waste my time on people who are not motivated"*.

Several PIs emphasized that although it is best to be direct, the way you provide feedback is important: be gentle and consider the person in question—some are more sensitive than others. Others said that they make sure to find a good time and place for giving such feedback. One PI said that in the absence of time sometimes she postpones giving direct feedback to people, but she is still getting impatient with the person—when she catches herself making remarks, she knows it is time to sit the person down and talk to him/her.

Following the feedback up immediately with suggesting some ways the performance could be improved is helpful. One PI said she implemented a *"buddy system"* in the lab: she pairs up underperforming (*"lost"*) people with senior people in the lab to get them up to speed, and it seems to be working well (she pairs up all new students with a postdoc, as well).

One of the proponents of the indirect approach said that *"with more experience, I find that some people take more time to realize their potential than others"*, and another PI said that she *"learned not to be direct, because people may break"*, and now she tries to find out what the underlying cause is for not performing well.

Most PIs who answered "both" start with indirect feedback, and if they do not get the desired change with hinting, they may resort to a direct approach, and others change their approach on a case by case basis, depending *"on the situations and the personality of the person involved"* or their *"feel for people"*. But even one of these PIs said that she thought *"in general, the clearer you can make it to the person, the better"*.

Overall, whatever way you choose to tackle the problem of someone underperforming in your lab, do not wait long before you address the problem.

Distributing the Work

As we talked about it before, the size of the groups of the PIs I interviewed varied widely, from 2 to 27 people, therefore it is not surprising that the number of projects running in each lab was also quite different (ranging from 2 to 45, the median was 5).

Of course, this number also depends on the PI's definition of a "project", on how much overlap they allow before they consider two projects separate.

The methods of PIs on how to organize work was split: the majority prefers to assign each project to a single person who is responsible for performing the experiments needed for that project but about one third organizes a group around the projects so multiple members of the lab contribute their technical expertise to the project. There are good arguments for both methods and the strong focus on individual publication output is a factor, as well. Even in the labs where there is a single person responsible for each project, usually, more than one person are working on each project (the median was about 2 people per project).

Teamwork

The short time I spent in an industrial lab was a departure from the experience I had in academic labs where I had to do everything myself, most of the time without the help of a technician. I found it refreshing that I could perform the techniques that I was skilled at and did not have to learn all the little details of the other methods that were required to advance the project because other people in the team were good at those. I found this a much more efficient way of making progress and some academic labs also encourage this kind of teamwork. *"Everyone in my lab is a team player as well as an individual worker—this is essential for being a member of my lab"*, said one PI. Another said that there is a common theme to all the projects in his lab because they all look at different aspects of the same enzyme, therefore collaboration comes naturally. A third said that he sits his people down and explains to them that they can't be a *"one-man orchestra"* and they talk about possible pitfalls and how they could be circumvented. He also believes that such a team approach also enhances the chances that the results will be further used by others.

Some PIs take an active hand in the division of labour: they require everybody's participation in big experiments or on special occasions, e.g. they want to focus on getting a publication out to make sure things run quickly and smoothly. Other PIs find out what specific technique people are good at and expect them to perform that activity for everybody. If you decide to run your lab in such a "division of labour" system, take to heart the advice of a PI who said that he makes sure that at least two people in his lab master each technique that requires specialized skills, to make sure he does not lose that expertise should somebody leave the lab. Another PI also builds teams of 2–3 people for projects but he puts the members of the teams together by their interest, not by technical expertise and makes sure that people of different levels of seniority are involved.

Setting up teams consisting of people with different technical expertise or with the same interest, however, can be tricky in academic labs because everybody needs publications for their survival in science. As one PI who prefers teamwork said, open communications is very important, especially if there are overlaps between projects because this can lead to problems at the time of publishing. She discusses the publishing arrangement early on and very often they publish with shared co-authorship (she has had papers with three shared first authors). Her experience has been that although PhD students may worry about authorship, they accept this system if it is discussed openly.

Individual Drivers

But not every PI is a fan of organizing the labour of the lab around projects so that each member of the lab contributes different technical expertise. *"I hate assembly-line science"*, said one PI, and others have also argued for assigning projects to one researcher who performs all necessary experiments herself or himself, instead of organizing a group.

Motivation

Some PIs assign each person a project that is optimized to their expertise and interests to make them *"feel ownership of their projects"* because this makes them perform better and they are more likely to enjoy what they do than if they are *"merely a piece of a factory that gets one project done"*.

Education

Others expect students to perform all experiments in their projects personally to help them with their education and believe that the students become independent and more well-rounded scientists by doing many things.

No Internal Competition

One PI said that he knows large labs where there is intentional overlap between people's projects and this often creates tension. He and others assign each person his or her own question specifically to avoid internal competition.

Pros and Cons of Individually Driven Projects

Assigning projects to one individual requires less involvement of the PI in the nitty-gritty of the everyday operation of the lab. Moreover, it makes it easier to get an update on a project or track responsibility for a project. These are considerable benefits for the constantly busy PIs plus this structure maintains the one-to-one relationship of each member of the lab to the PI that is desirable for some PIs. Besides, some PIs reported that amazing teamwork can arrive spontaneously in the lab without their intervention (although I suspect that this is not very frequent).

There are, however, downsides to individually driven projects, most notably inefficiency. All methods have a "learning curve" involving technically failed experiments. Making all members of your lab take the time and effort to master certain techniques is duplication or multiplication of effort. Besides, not all people have the same level of technical aptitude, so it also may lead to some frustration. Several PIs mentioned this, although they believe that the advantages offset the loss in efficiency. *"Sometimes it takes longer to get the data out but it is more rewarding for everyone involved"*, said one of them, and *"everybody has a specific project in my lab—this makes work less efficient, but more interesting for the individuals"*, said another PI.

Another downside is that when people leave the lab, you may lose some specialized expertise developed in your lab that may make continuing the project difficult. This is why one PI said that he promotes the team approach in his lab because it will also make the results more usable later on. There, are, however, PIs who think that driving projects individually is worth losing expertise: when people leave my lab, said one of them, *"they either take their project with them or the project ends"*.

Hybrid Methods

Some PIs use some kind of hybrid method between organizing teamwork themselves and driving project individually to mitigate the mentioned downsides.

Dedicated Persons for Difficult Techniques

Several PIs try to assure the continuity of know-how in the lab and cut down on training time by maintaining technicians who take care of certain things for everybody (e.g. mouse breeding or embedding precious human samples). One PI said that in his lab the technicians do most of the technical work: although he requires the students to learn the techniques and pitch in during big experiments, it is generally the technicians who perform the experiments.

Other PIs keep dedicated technicians only for techniques that require specialized skills and extended training. Others may require people who are good at certain techniques to help others or they make each of their postdocs responsible for a certain method/technique and require them to help out the junior people—but this may not mean that they work on the project together.

Dedicated Responsible for the Project

Some PIs make one member of the team working on the project the *"owner"* of the project, generally the PhD student in the group. These PIs feel that it is important for the education of the PhD students that they have their own projects and bear the responsibility to be the main driver for that project. They either assign some senior people to the group who can contribute their technical expertise or provide guidance in some other way.

Often there are senior postdocs or even faculty members in the group who supervise the students and look after many projects but having each project assigned to a dedicated person seems to cut down on internal competition. Several PIs said that they expect their senior people to coordinate several projects and some PIs incentivize their postdocs by making them the corresponding author of the expected publication.

Other PIs have a more hands-on approach to address internal competition. *"I noticed that some people tend to grab a lot of the time of the technicians while others are less aggressive"*, said one of them, and she added that she sometimes intervenes by redistributing the effort of the technicians as needed. Others may readjust the personal dynamics of the lab by requiring people to do certain things together or for others.

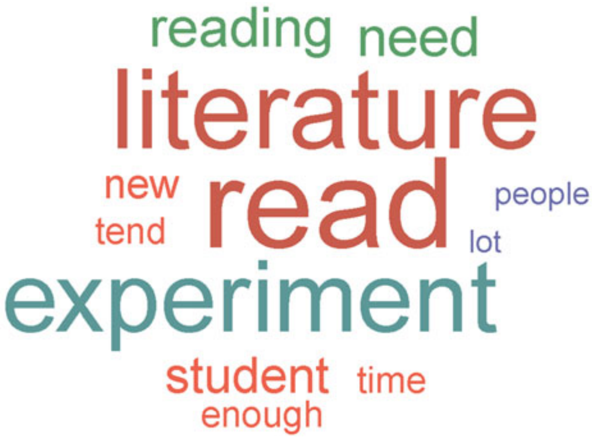
Most PIs give one main project to each graduate student and postdocs usually oversee more projects, and there was one lab where each person has 2 main and 2 side projects. One PI said that she often starts new students with two related projects in case one doesn't generate exciting results since "*it is always more motivating in research if your data are leading to an exciting story rather than getting negative data all the time*". If both projects generate interesting results then one project becomes more dominant and assures that the student will meet graduation requirements. They may keep the other project if they wish to continue with it and have the time to do so or it is given to a new student/staff member to continue.

The size of the question and the risk level of the project may depend on the career stage of the person. More senior people have more projects and are more likely to have at least one risky among them—some PIs mitigate risk for their lab members by carrying out a few side projects either themselves or by maintaining a *"personal technician"* and then passing the project to a lab member once it looks promising.

Reading or Doing Experiments?

One PI said, *"reading the literature is essential to prepare the experiments, and performing a lot of experiment is essential to understand the literature"*.

The members of your team will produce the data you need for your grants and publications, but at the same time they may perform the experiments better if they understand them more. I think it's safe to say that reading and experiments complement each other and there should be at least some reading before designing your experiments and after getting the results. However, it is not trivial how to find the right balance between reading the literature and performing experiments, therefore I asked PIs opinion on this matter.



It Is Hard to Keep Up with the Literature

"There are very few people who read enough, and neither do I", said one PI. Another PI observed that *"the time investment is [even] greater if you are not a native English speaker"* which makes keeping abreast with the literature harder.

Several PIs admitted being *"bad at keeping up with the literature"* and not setting time aside for reading regularly. One PI said that *"reading is the first thing [he] drop [s]"* when things get hectic. *"There are too many publications"*, making it *"impossible to 'read the literature' anymore, it is so overwhelming"*, said other PIs. Instead, PIs try to cope with doing *"purposeful reading"* which usually starts with an Internet search to *"see what happened in the particular field [they] are interested in"*, and one PI mentioned that they try to keep up by organizing their journal club in a way that each person has 5 minutes to discuss a paper so that they can get through 12 papers in an hour.

Depends on the Career Stage

Many PIs recommend more experiments at the beginning of one's career and then slowly changing the balance to more literature later. They brought up several reasons for this. *"When starting, you have to do a lot of experiments to develop your skills for being able to design experiments later. Once you have developed your hands, you can read more"*.

People who produce data at the bench need to read around their own project(s) to know the background of their project, but doing experiments should be combined with *"reading the right literature. Literature that was done right, not just papers that support their hypothesis"*, as one PI warned, because *"many students can't distinguish what is important and what is not"*. Students need to learn how to read the literature and the guidance of senior people in the lab and journal clubs are very important in this regard.

PIs *"have to think much more connected"* and for this, they need to read more widely. PIs, therefore, generally tend to spend more time keeping an eye on the literature, although not all of them do that. Some mentioned that they rely on hearing talks at conferences to know what is happening in their field because at a meeting they can *"see the field at a glance"*.

Depends Also on the Project, Work Stage, and the Individual

The reading needs also depend on the project. *"If the model is well supported but new, reading is not helpful"*, said one PI. And, the need for reading can fluctuate during a project, *"the correct balance is determined by daily problems and their solutions"*, as one PI said, and it also varies during the life of a project. *"You need to read before doing the experiments to get the state of the art, get a list of questions.*

Then you need to read when you are already doing the experiments and you get something unexpected: has anybody seen anything similar? You go through cycles of reading, doing, reading again", explained one PI. At the end, *"you need to go back to the literature to interpret new data and find the right position for the paper"*, said another PI, *"you use the literature a little bit like a mirror"*.

Usually, *"there is no deadline for reading articles so it is easy to put it off"*, said one PI—which is true, except when you are writing a grant and you have to produce something concise by a very strict deadline. Several PIs said they like it about grant writing that it forces them to read because *"to get to the model, you need to read a lot and widely"*, as one of them put it.

The "right" balance can depend on the person, as well, but many PIs thought that *"PhD students and [postdoctoral] fellows have the tendency to do too much practical work"* and not read enough. On the group level, *"the trick in putting a lab together: getting a balanced team together. Some people naturally want to do things, others naturally tend to read"*. You need to put together *"a complementary team to have both enough reading and doing"*, echoed another PI.

With all the caveats we have mentioned, it is not surprising that one PI said that *"there is no right balance [between reading and experimenting]"*, and only about a third of the PIs volunteered to put a number on the proportion of time that should be spent reading. The numbers they gave ranged from 10% to 60%, and the median of the recommendations was 40%.

Reasons to Read

Some PIs like to *"just jump in and do it"*. As one of them said, *"I do first and then figure out what is happening"*, but she added that she should spend more time reading at the beginning because she often realizes later that the hurdle she bumped into has already been described in the literature. Reading can prevent repeating other people's research, or as one PI put it, *"some naïveté is good, but not so much that you reinvent the wheel"*. *"Having read a lot will help you to design the best experiment"*, said another PI, and third added that *"you need to know what has been done to do something new"*. Having read enough to have a solid foundation in your field also helps you to understand the technical limitations of the current methods as well as take advantage of new technologies that become available.

Several PIs said that reading helps *"to put things in context"*. "*You have to read to get the context, without context you can't understand your own results"*, as one PI said, and another pointed out that even if you are in a new field making entirely new discoveries, *"you are always connected to what has been done"*.

My first supervisor used to say that he got his best ideas reading other people's papers. As we discussed it in Chap. 1, PIs use reading not only *"to get an idea about how to perform the experiment"* but also to get experimental ideas at all. *"Publications have to make it sound like it is a complete study, but this is usually not true"*, said one PI, and he suggested being critical when reading: *"the authors may be wrong—re-interpreting the data may lead to discovery!"* Another PI said that *"the more [students] read, the more creative they can be. Technical competence does not correlate with literature reading, but creativity does!"*

Prioritizing Reading

With all the mentioned virtues of reading, it is not surprising that some PIs think that *"there should be more reading"* because most people tend to spend more time with their experiments and not read enough. *"Afterwards, you always regret not reading more"*, said one of the advocates of more reading. She also added that if you *"get the impression that you are not doing anything when you read"*, you should *"accept that reading is also part of the job!"*

The field you are in may make reading even more important. One PI involved in clinical research said that she finds literature more and more useful because she *"can find out much more reading the literature than doing the experiments: the data are available, they just need to be assembled. You can do more and more by mining the literature, you do not have to do everything yourself by hand"*. You may make progress without lifting a finger!

Prioritizing Experiments

Many more PIs, however, said that *"people should spend more time on their experiments than literature"* because *"it is more important to do"* than read about, science. Most PIs are doers who feel that experimentation (and not reading about experiments) is at the heart of being a scientist. One PI said that experiments were more important for him because he was *"not interested in writing reviews"*, and another said that *"without experiments, you are a reader, not a scientist"*. Besides, many of these PIs tend to believe their own experiments more than others'.

Several PIs thought that performing experiments has to be dominant since the literature is not reliable (see more on this in Chap. 6). As one PI put it, *"the literature is often a polished version of the actual biological phenomenon, they include only the best representation. To get all the details, you need to do it yourself"*, and another PI said that although *"one should be aware of the closely related publications, you can find everything and their opposite in the literature. Sometimes you do a project despite of the literature!"*.

These PIs recommend reading the literature *"to see what has not been done yet"* and to discover new tools. They don't read the literature to see how other people do science because they do not care about that, the question on their mind is *"where are the holes?"*, they want to know where to go. *"Reading is important, but not almighty"*, as one of them said. They may not make a huge investment in searching the literature at the beginning of a project, instead, they prefer going fast with the experiments—and they go to the literature when the findings get interesting! *"It is important to know where we stand, what is accepted at the current time, but I don't stick to it too much"*, as one of them said.

A Partnership of Researcher and PI

Since both keeping up with the literature and performing experiments require a lot of time, you need to be selective in what you read. *"The science needs to be done right, that makes the paper worth reading"*, as one PI put it. On the other hand, selecting which papers are worth reading requires some experience, therefore many PIs suggested that the most efficient way of making progress is if the PIs do a lot of reading and focus the attention of the younger researchers on the right papers, as mentioned before. *"For me, more literature, for the younger ones, more experiments—I do the reading for them!"*, summed it up one PI.

This model, however, was not universal. Other PIs told me that they had very little time to read. For example, a PI who directs an institute of more than 300 people said that he relies on his network and going to meetings to hear about anything new. Other PIs implement a similar system on a smaller case in their lab and give the responsibility to their students or postdocs to prepare *"a reader's digest"* of the recent literature for them. One PI said that he motivates the students to summarize the recent literature, which ultimately becomes the intro to their thesis, and he gets a review, which he may also try to publish.

Literature Bias

Several PIs were concerned with *"literature bias"*: they thought that reading too much at the beginning of a project narrows the thinking and limits the creativity of the researcher. *"If you have an idea and it does not match with what is accepted in the literature, you can always read yourself to kill a project"*, said one PI. *"There is a danger in reading too much: you end up doing what other people are doing"*, said another PI, and third thought that *"if you want to be a successful, but average scientist: read a lot and you will produce results that confirm the literature"*.

"I use literature for getting new data and technology, but I do not follow other people's ideas. The only thing is your own data", said one PI and another thought that it is *"better to think about how you would answer the question: it is a better way to be innovative"*. One of these PIs thought that the best combination for creativity was a PI who knows the literature (to prevent reproducing somebody else's research) and a *"naïve"* researcher with no literature bias, because, as another PI said, *"people who read a lot develop the feeling that everything has been done, and they either do not do the experiments or they follow the fashions in the literature. You have to have original ideas and read the literature with those in mind, otherwise, you just follow other people's ideas"*.

Communicating with Your Group

The overwhelming majority of PIs said that they had an open-door policy and people could *"always come with burning questions or new data to show"*, as one of them put it. But, as their lab grows, their responsibilities multiply and their agenda becomes too busy to have longer unscheduled meetings, many PIs come to a point when they feel the need to minimize interruptions. Although some still allow short interruptions, most install various solutions in case team members want their undivided attention for longer than a few minutes. Some require that team members make an appointment by email, others have a regular period during the day when their group members can come to them or they make their rounds in the lab every day to touch base with people. Many like a low-tech approach: if their door is open, people can drop in and they signal that they don't want to be bothered by closing their door.

Most PIs have one scheduled meeting with their entire group each week, and typically they have an individual meeting with each of their team members every two weeks. My next question was how PIs like to spend the time of the meetings, do they prefer that people communicate the literal facts of the matter to them or they rather hear stories and analogies?

"Spare me the editorial", used to say one of my supervisors during meetings to people who were presenting their results with excessive explanations of what the data imply. He preferred to make up his own "big picture" about the results. Clearly, he was not an anomaly, because almost half of the PIs (46%) said that they preferred hearing the literal facts and only 29% preferred stories and analogies (the rest were interested in both).

Those who want the literal facts acknowledged that their preference may be situation-dependent and stories and analogies can be very useful in communicating with non-scientists or even with other scientists who are not experts in the field. A story helps to grasp the facts—this is why papers present the research in a story. Those who want stories and analogies mentioned that a story can serve as a framework for the facts and helps to understand and retain them. This is why stories are important teaching tools (one referred to lectures as *"5 minutes of facts stretched out to 50 minutes"*).

Those who want both talked about how they reinforce each other: stories make the facts easier to digest (stories, especially patient stories, can help to draw in the audience during a lecture), and the facts give credibility to the story (this is why, for example it is good to pepper your grant application with facts and numbers). Some PIs warned that stories can also be misused: they get suspicious when there is a big story and no facts are presented. Some want to hear a story to see if the presenter can critically assess the data and put them in a framework, and it also indicates what they want to do with the facts. The preference may be also situation-dependent, several PIs stated that when they are short on time, they prefer to receive the facts.

Top Publishers had an even stronger preference towards hearing the literal facts. Although they acknowledged that stories or analogies are useful for conveying a complex set of facts, they also emphasized that they want to see the facts: *"you have to pull the story out of the data"*. Moreover, one PI cautioned that analogies can backfire since they may not have the same frame of reference as the set of facts you are trying to communicate.

In the next chapter, we will look at how PIs go about the daily business of scientific research.

The Daily Work of Principal Investigators

5

Abstract

This chapter discusses how much time PIs spend working, where they find the motivation to work that hard, and what they think their most important daily tasks are. It also talks about how PIs evaluate data, remember experimental results, and how they decide on the interpretation of results, as well as how they deal with unexpected results and build a cohesive story for publication. Finally, it discusses when PIs decide to reach out for help, their ways of communicating with others and reaching decisions.

Hard Work

If you have been around biomedical labs you know that biomedical researchers work long hours, many of them take their work home to continue in the evening and they often work during the weekend. The same is true for PIs.

The median time PIs reported working when they are not busy was 55 hrs per week and five hours more (60 hrs) when things get busy, e.g. during grant submission periods. Top Publisher PIs seem to work even more: they work about 60 hrs per week even when there is nothing special going on (Fig. 5.1).

Although being a PI involves many different kinds of activities, most of these run on a yearly cycle and there is not a big change from one year to the same time next year. Only a fraction of the PIs said that what they are doing at the time of the interview and what they were doing the same time the previous year was different, and they usually cited some change in their circumstances: promotion or stepping down from a major position, retirement, being on sabbatical, starting their new lab, getting some major grant, or some major illness. Research projects evolve, the lab may be using different technologies for an old research question or apply the same old techniques to different research questions, but as one of the PIs put it *"by large, [the work] is similar, but in the details, it is different!"*.

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
https://doi.org/10.1007/978-3-030-85571-0_5

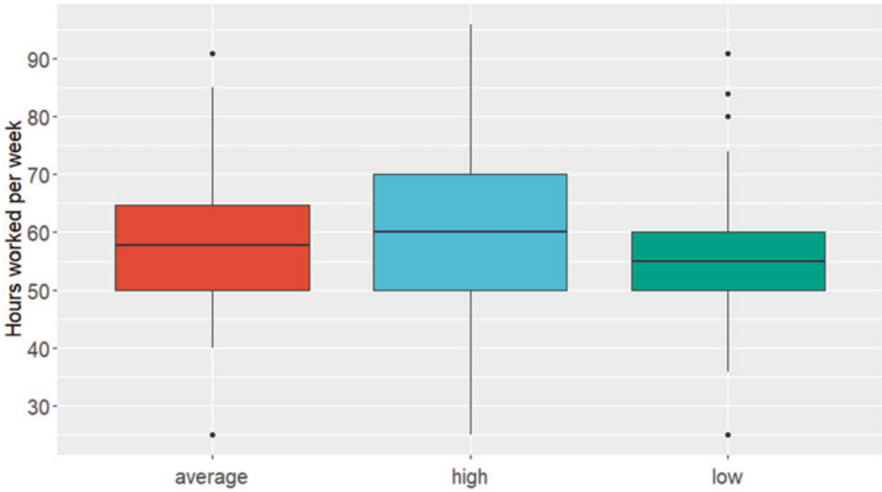


Fig. 5.1 The median of how many hours PIs work per week on an average week is 57.8 hrs ($n = 102$)

The Sources of Daily Motivation for PIs

Being a PI is a very demanding life. *"The reward is not immediate, [it is] fragmented"*, said one PI, which makes keeping up one's daily motivation even more important. Another PI said that *"Science is a spectacularly negative career, there are much more failures than successes"*. But, he continued, *"when I get something right, when I make a conceptual leap, it gives me an injection of motivation that sustains me over the next six months of failures"*. I was curious what keeps PIs going, are they already thinking of the lab when they get up in the morning, what gives them the motivation to go to the lab and work as hard as they do every day?

A good illustration of how busy the life of a PI is that one of them shocked me by answering that his first thought of the morning is a swear word, when he realizes that he has to leave his bed, and another PI said that *"I don't think before getting out of bed, I sleep as long as I can"*. A third PI said that his first thought of the morning is *"how can I survive this day and do all I need to do?"*

Fortunately, there were more inspiring answers, as well. One PI said that she prepares a to-do-list for the day the evening before so that she is ready to go in the morning, and other PIs use those few minutes before waking up and getting up to mentally prepare their day: some make a (visual/mental) to-do list, others run a little movie in their head about how they would like the day to unfold, thinking of which projects they want to move ahead today. Finally, if you are a slow starter in the morning, you may want to try the method of the PI who said he gets his brain going in the morning by reading the sports news.

Excitement

Curiosity or a passion for discovery was an often-cited reason to get out of bed and go to the lab. PIs feel a desire to either see the new data or hear new ideas or find out if their gut feeling about something was right. One PI put it very funnily: *"Science has always been a gut feeling for me. It is like a temptation: I really want to find out whether it is correct!"*, and other PIs also said that their motivation is kinaesthetic (gut feeling). One PI called this *"the joy of creation!"*, the joy of *"creating new knowledge, seeing, understanding something for the first time"*.

Another PI said that she loves being a PI because it is a work of passion, not just a "job". It is like being an artist: she loves the projects she is working on because they are coming out of her brain, and once another said that *"she likes the constant ability for inquiry"* because it makes her feel that she makes a difference, and another said that he feels like he's *"looking under Mother Nature's skirt and discovering the biology that drives the processes"*.

PIs seem to have an unquenchable curiosity that has to be fed constantly with new information, especially with pieces of data that nobody has seen before. *"I need interesting things to do, and the interesting things are going on in the lab"* explained one PI why she loves to go to the lab and another PI said that she only has to think *"tonight, I will get in bed knowing a little more than I did yesterday!"* and she wants to go to the lab instantly.

The best part about being a PI is that you don't only get new information but you get new information about the topic you want since you can shape the activity of the lab. "*I get to decide what is interesting and go after it, it is a real privilege"*, as another PI put it.

Another PI said that he only has to think over what happened the previous day and he feels motivated to go to the lab to find out how things worked out. Others also said that continuing the work of the previous day motivates them. *"I am so convinced that it will work that I want to see the results"*, said one of them. Of course, not all experiments turn out as expected, but *"if it does not work, that is okay, I regenerate my excitement every day. I am always confident that it will work"*, he continued. Another PI pointed out that his excitement of the research can have different levels: it can either be an intellectual excitement or excitement about overcoming a technical challenge (more of an engineering problem).

Also, PIs are curious about the novel technologies being implemented in the lab, even if they do not do any experimental work anymore. For example, one PI said that he likes to go into the wet lab when somebody is implementing new technology because he likes to learn new things and wants to know how it is working out." *Not for controlling but just for knowing"*, he added.

"The promise of new things happening" is a powerful force drawing other PIs to the lab. Or, as another PI put it, *"the hope that today something very interesting will happen"* gives them the motivation needed every day. *"This is not true for 99% of days, but the 1% when it does happen, it makes it worthwhile"*, he finished.

Team Members

"The daily motivation is that 20 people's pay depends on me", said one PI, and other PIs also mentioned the members of their team as the reason to go to the lab. Interacting with their co-workers, discussing scientific questions, thinking about the results together was a very frequently mentioned source of day-to-day motivation for PIs. One PI said that one of his thoughts every morning is *"I wonder for whom I go to work today? Whom I will help?"* As one of the PIs put it, his motivation comes from *"the mixture of what is going on and the people"*. Another PI said that she enjoys *"feeling part of the community, mingling with the students"* and seeing *"what interesting problem/solution the students will come up with"* and others mentioned making a difference in their students' careers as a source of their motivation.

"I like to walk around and show my appreciation to my people", said one PI, and others also expressed that they are excited to meet their team, find out what the students did the previous day and interact with their team members or other people during the day. One said that he wants *"to be contagious of enthusiasm, to infect people with enthusiasm, to find enthusiasm in the people he is coaching"*. As a former researcher who had such a supervisor on whom I could always rely to pick me up, I appreciated that.

The Big Picture

Some PIs can translate the big picture driving their research into day-to-day motivation: one listed her excitement about the story they are working on and another wanting to repay the medical community for helping him when he was a child. Others cited the *"desire to change the world"* or the feeling that they can make a difference in their field of research, or being excited about creating a new medication, helping a group of patients, or creating a new industry,

Immediate Tasks

Although it's great to enjoy working towards e.g., curing a disease, a long-term goal like that may be too far away for some people to provide the motivation they need to get through the day—and some parts of the job (certain meetings, admin duties) can actively drain one's motivation. *"I am not thinking about 'curing arthritis' all the time but inside that, I have smaller goals"*, told me one PI and another PI said that *"there need to be challenging short-, middle-, and long-term goals"*.

Some PIs have a specific task in mind that they want to tackle as they are getting out of bed, like a grant application, submitting or revising a manuscript, getting ready for a specific meeting. *"There is so much to be done, the lists are waiting!"* explained one PI why she feels motivated to go to the lab but many others also cited *"some short-term commitment, some 'urgency'"* as the source of their motivation each morning, like teaching duties, a manuscript to be finished, or the patients they are caring for, in case of physician-scientists.

One PI who said that he is motivated by *"getting stuff done"*, seeing a problem right in front of him, explained that he has a list of things to be dealt with but he resists the impulse to do tasks according to the deadlines: *"Deadlines do not stop, I rather ask: does it impact something else on my list? If it can wait, it gets pushed down on the priority list"*. Another PI, on the other hand, said that she likes procrastinating until things become urgent because the stress of upcoming deadlines motivates her (although I would not recommend this method).

One PI said that *"lots of people talk, but few get things done"*, and many PIs' motivation seems to be that they want to be the doers, who accomplish things. One PI said that she sets milestones for herself for the day and she does not go home until they are accomplished. Another list-crosser said that he likes to write down things to be accomplished and ticking them off! On bad days, he puts some things on the list at the end of the day so that just he can cross something off!

Keeping a Finger on the Pulse of the Lab

Although some PIs work from home one or two days a week or go to the lab only once or twice a week, most PIs prefer to be in the lab every day. The answer of some PIs reminded me of a Hungarian adage expressing that it is the constant attention of the owner that makes things develop smoothly ("A gazda szeme hizlalja a jószágot" ≈ The farmer's eye makes the livestock grow). Several PIs mentioned that although they could do a lot from home or they have senior people in the lab who can progress projects in their absence, they still prefer to *"see the day to day effect"* in the lab. One PI told me that she worked from home for a while because of the excessive noise from the construction going on next door but she started missing the contact with the lab and knowing what was going on.

"I like to be present because people can ask me questions and tell me about stupid mistakes, I get better information this way", said one of the PIs. *"I have a maternal feeling: the students grew up in my lab, they are my scientific children"* explained her need to be present in the lab another PI. A third PI said that she is *"a control freak who wants to know what is going on, what the data are like, what we have learned"*.

Another PI, head of an institute, also said that he goes in every day because he wants the interaction with people, talk to people in person, look at results together. *"I find that direct interaction is much more efficient, the management aspects of my job are much easier and quicker if I conduct them personally"*, he explained. Other PIs also felt that they can move the projects forward more efficiently if they are present personally and, for example, can be part of the excitement in the lab caused by new data.

Some PIs mentioned that the responsibility they feel towards their people and projects even makes them skip conferences. *"Going to meetings and networking is* *okay if you have a lot of postdocs you can trust to keep the lab together while you are away"*, said one of them but he prefers to stay around.

The Lab Environment

The lab atmosphere grows on people. Many PIs said that they don't find it hard to come in because they like being in the lab environment very much. *"There is usually at least one item on my agenda that I must do"*, said one PI, *"but an empty agenda is also motivating: I can read all day!"* He said that although he could do many things at home, *"the atmosphere at work is different from that of home"*, and he likes to keep the work environment separate.

Especially for people who have been heads of a lab for a longer time, going to the lab becomes part of the rhythm of their life. Several said that they enjoy regular activities and going to the lab is *"just what they do"*. *"It is my way of connecting with the rest of humanity"*, said one emeritus PI, and she added that she has friends who are retired, but for her, *"not going to work would be hell"*. Other emeritus professors also told me that although they are not obliged to come anymore, the lab became their second home and they still go in regularly because it was their routine. *"Earlier, when I was home during the weekend, I did not stop being a researcher"* explained one of them.

What Is the Most Important Activity of a PI?

The work of a PI is very diverse. We have already talked about several of their activities: thinking up new projects, writing and reviewing grants and publications, meeting with their team, but there are many others, including teaching duties, administrative duties, participating in the governance of the university, etc. *Therefore, I asked PIs what they think the most important thing is that they do on a daily basis as a scientist.*

As it turned out, the most important daily activity for a PI may change depending on the period (e.g. an approaching grant deadline definitely bumps grant writing up on the list) and it may also change with the days of the week because some PIs like to set aside different days for different activities. Nevertheless, the list below will give you an idea of the general preferences. One PI advised that *"every day there should be something that is good to think back about: a good discussion, making a good figure, writing a good sentence, seeing a new result"* because it will help to keep up your motivation and drive. This is especially important to remember since whatever you decide the most important activity of the day is, you will have to do that activity on the backdrop of *"constant interruptions and routine things needed (e.g. administrative duties originating from the fact that the lab is part of a big machinery called the hospital/university)"*, as one PI put it.

Communication

In his answer to another question, one PI said that doing science was a good thing for him because he did not like to interact with people. This surprised me because most of the biomedical scientists I interviewed indicated that communication with their co-workers (be it their students, postdocs, fellow PIs) was the most important aspect of their day-to-day activities. As a PI, you will have to do a lot of listening to and talking with people and if you don't like to do that, being a PI will be difficult.

Your interactions may not be limited to discussing data with team members, either. For example, one PI indicated that her most important duty related to her scientific work was *"communicating with the outside, the families of the patients"* suffering from the disease she is working on.

Interpreting Results

"I would like to say that 'to think' is my most important activity but I don't have time for that. Scientific discussions are the most important", said one PI. *"Time-wise, I spend the most time with (very much needed) planning and coordinating with other people"*, said another PI, *"but impact-wise, my most important activity is discussing experiments"*. Indeed, discussing experiments is at the top of the list for many PIs. Discussing how experiments were conducted is important to make sure that the experiments are technically sound, especially in the case of inexperienced co-workers. These discussions will also be important for troubleshooting, solving

technical problems so that your staff can do their job, especially if the lab does not have a middle layer and students come to you directly with their problems.

Many PIs said that going through the data with the students is not only important but it is also the favourite part of their day. *"I love seeing something in the data"*, said one of them. Discussing experiments also includes looking at the raw data together, comparing interpretations. Deciding together what the interpretation will be and what we can learn from the results is not only necessary to plan the next steps but it is also a teaching opportunity. *"Teach your subordinates, always explain, to make them appreciate the feeling of thinking forward"*, advised one PI.

Managing People

Discussing experiments is also a great way of getting an overview of all the projects and problems in the lab. *"I follow up with people and I know what everybody is doing or should be doing at all times"*, said one PI. These personal discussions require a lot of time but are important for managing your group. For some people you may have to lay out clear plans and others will require less detail. One PI said that he has taken on too many responsibilities and it did not leave him sufficient time for managing his group. He resolved not to take on new responsibilities because he wants to go back to guiding PhD students and postdocs, analysing results, discuss new possibilities with the team.

Steering Projects

You will have to do a lot of communicating to steer the projects. *"The most important for me is to be really, fully present with full brain capacity when projects are discussed"*, said one PI. Some days steering projects will involve communicating not only with your team but also talking with companies or the technology transfer office of your University. *"Move something forward every day"* is the motto of one PI.

Steering projects also involves keeping the timeline of the project. One PI said that she uses a lot of retro-planning in her lab, and *"if someone has agreed to a deadline, that is a deadline: someone has to die for it to be violated"*. She involves people in setting the deadline, but after that, she keeps them to it (it is them who said it would be done by then, after all). *"It is the manager's responsibility to keep people straight"*, she said, and she added that she likes it *"when people say that they cannot take on some task, it shows that they think about their responsibilities and take them seriously"*.

Motivating People

As we talked about, a motivated team can pull the PI through when a project is stuck, and the PI's enthusiasm can motivate the members of the lab. *"I have two jobs"*, said one PI, *"being a scientist, and being a manager of science. As a PI, the most important is to encourage people to do good work and competently"*, she finished. *"My main activity is to motivate my team"*, said another PI, and many other PIs also said that their most important daily activity is keeping their people motivated. For some PIs this means encouraging all members of their lab, others prefer inspiring the top tier (postdocs) in the lab and let them pass it on. Encouragement does not mean strictly talking about projects or results, it also includes discussing other topics (e.g. how the baby is doing). *"I like to say something nice to my team every day"*, said one PI. *"It is important to discuss with students, give them energy, be supportive to them"*, said another PI, because few students are confident. Another PI also said that he finds that talking to his people is important to the well-being of his group, and a third said that *"some days, pepping up depressed students is the most important"*.

Creating the Vision

As we talked about in Chap. 1 ("Carving Your Own Path": Shaping Your Scientific Identity), you are responsible for sculpting your scientific identity. As a PI, it is your privilege and your duty to create the vision, the path forward for your entire lab and many PIs listed *"thinking about the projects and what directions they should be going in"* as one of their most important daily tasks. *"Never lose track of where you want to go, what questions you want to tackle. What is the whole purpose? What is the next exciting thing?"*, said one of them.

"Unfortunately, I can spend very little time on important things, most of the time I spend at work is spent with management, people and projects", said one PI and probably you will also spend much of your time communicating. Nevertheless, you will have to invest time in determining the path forward for your team because your and your team's scientific future depends on it. *"The trick is to configure one's team correctly and to keep them motivated"*, said the same PI—we have talked about how to set up your team in Chap. 3 ("Setting up a Successful Research Group") to make sure that it functions well and you will have time for other things besides managing your group.

When you are thinking about what goals to set for your team, it is useful to review what you have done to know where you are at the moment. As one PI said, she spends time *"being very auto-critical, decide what piece of data is good or not good"*, and she added that *"you need years of experience for this"*.

"Think, imagine!" said several other PIs. I found that rather generic and preferred the advice of those PIs who suggested asking yourself questions as a good way of deciding where to go next. One PI had a very interesting way of using self-questioning to direct his science: he imagines himself giving a talk about the topic and then he asks himself *"if I was giving a talk, what would I like to talk about next?"* It is important to be *"asking the right questions, that can be answered"*, warned one PI, and then she added that you will have to re-define those questions for the students.

Writing

Several PIs listed writing (papers, grant applications, editing theses, etc.) as their most important daily activity. *"Putting together and making stories"* helps to see the holes and will help with creating the vision for your lab, as well. *"Thinking and writing—the two help each other"*, as one PI put it.

Unless you isolate yourself for creating the vision for your lab, you may not have very long chunks of time to do this. I found the advice of the PI who said *"the key is to be able to write a project 10 minutes at a time and keep focusing on it. It will be incubating in the back of my mind"*, very useful. Writing regularly is also important to show progress: *"Write up results—otherwise you have nothing to show for your work!"*, warned one PI.

Others

Besides these three principal activities (communicating, creating the vision, and writing), some PIs also mentioned reading and learning new things as their most important daily activity. *"If you do not learn anything, it was a waste of a day"*, said one PI and added that this is why he likes teaching because he learns a lot of new things. As mentioned above, informal discussions with your team are also an opportunity to teach them, and some PIs also have a strong commitment to teaching in a formal setting: *"All top researchers should teach undergraduates to share their passion for research"*, as one of them said.

Top Publishers

57% of Top Publishers mentioned talking with their team members as their most important daily activity and the rest was split between interpreting data and planning.

Evaluating Information

As we talked about it just a little bit before, interpreting results is a very important daily activity of PIs. I was curious, how PIs weigh the information presented to them, and how they decide whether a piece of information is reliable, that they can believe it? Their answers revealed that PIs consider several aspects when they evaluate information besides the data itself, including the source of the information, how reproducible it is, etc.

The Person

"The source of the information is key", said one PI and it seems that the first thing many PIs consider when presented with new or unexpected information is who that information is coming from. *"Judgement is very difficult to learn: you have to know something about the person"*, as one PI said. This is especially true when they do not know the topic well enough to judge the veracity themselves and need to rely on the judgement of the source.

The factors that play the greatest role are their history with the person, how well they know and how much they trust the person providing the information, how reliable the information provided by that person has been in the past, as well as their assessment of how careful the person is performing experiments in general. They also consider the experience of the person: how much they have mastered the technique used to obtain the data. *"If something unexpected is produced I ask: does the operator know what he is doing, and why he is doing it that way?"*, said one PI with over forty years of experience leading a lab.

Some PIs said that they like to see the raw data themselves. *"Students do not see everything! Sometimes students are too insecure and they do not see everything that there is in the data"*, said one PI, and this reminded me that it has happened to me, as well, that I dismissed small differences as a lack of an effect. Other PIs mentioned that they have had people in their team who were less critical of their own data or were prone to over-sell differences. One PI said that he trusts the students to do the initial analysis correctly and does not always check the raw data but he gets suspicious if a student produces all the data he asks for, or if the student is *"selling the data"*.

Two PIs mentioned that they tend to trust people—until the trust is broken. *"It is very difficult to come back from that"*, said one of them. *"I am very black and white about this"*, said the other PI, *"I confront people early, which can be difficult. If I get the gut feeling that something is fishy, I end the interaction"*.

Reproducibility

Reproducibility was the most often mentioned aspect PIs take into account when deciding whether a piece of data is reliable—but different PIs mean different things when they talk about "reproducibility". They distinguished several levels of reproducibility: repetition (independent biological replicates), repetition by another person, and confirmation by another method.

At the most basic level, PIs mean by a result being "reproducible" that if you repeat the experiment several times you consistently get the same or a similar result. How similar the results will be *"may also depend on the solidity of the method"* or the experimental system used but this is a good way to assess the size of the effect and how *"noisy"* the result is. Most PIs want to see that the same result can be produced on multiple occasions using different animals or biological replicates and one mentioned that she finds the results even more convincing if the experiments are *"separated in time"*. *"I find 3 repetitions compelling enough if the results are in agreement"*, said one PI whereas others like to use some statistical method to decide if there is an effect.

The next level of reproducibility PIs mentioned is testing if different experimenters arrive at the same result. This may mean checking if other people in the lab can repeat the experiment and get the same result. *"I usually bring in another author whose role is to independently reproduce the experimental results in a blinded way"*, said a PI. *"We can't underestimate the influence of human bias"*, he added.

Other PIs said that the ultimate test in this regard is if another lab can reproduce the result. *"If you realize that some other people (your competitors, for example) have the same result"* then you can believe it, said one PI. *"If somebody tells me a result, I repeat it in my own lab or look in the literature if others have seen similar things"*, said another. A third PI also mentioned that he takes pride in the fact that other labs can repeat his results: *"It is the ultimate reward for me that other people are using my models"*, he said. Just as a side note, it is strange that although PIs put such a high value on independent replication, it is very hard to publish data confirming earlier reports.

"I often confirm results by another person", said one PI, although he admitted that *"this slows things down and can create personal conflict"*. Perhaps this is why that some PIs skip repeating the experiment by a different operator or leave it for a later stage and instead prefer obtaining multiple readouts to see if they are going in the same direction. *"Confirmation is always needed by another method"*, said one of them. *"I was taught to check from a different angle, using a different technology"*, said another PI." *You need repetition of the original experiment, also, but more convincing is if you can confirm it from a different angle"*, he continued. *"I ask if the result is dependent on the method"*, said one PI, as well, and many other PIs mentioned that they cross-check the validity of results with other methods to make sure there is nothing in the experiment that can give them an artefact. If they can show that they come to the same information using two or more different approaches, it's a good indication that the phenomenon itself is reproducible, not only the original experiment. *"If the same result can be obtained by two different approaches that do not have the same risks and biases, I tend to believe it"*, said one PI about unpredicted results. *"I don't believe any single piece of information separately"*, said another PI explaining that she wants to see that the same information can be derived by several experimental approaches.

Technical Quality

I heard about a PI who would not even look at the experimental results of his students if the controls did not outnumber the experimental samples. This may have been warranted (since they were using a notoriously finicky functional assay) or may have been a bit of an overkill, but the message is pertinent: controls are always important. Many PIs emphasized that the technical quality of the data (were the appropriate controls included in the experiment and was the technique properly executed) is an important factor determining whether they believe the results. One PI even had this scathing remark: *"many scientists do not understand the importance of technical controls, but they still reach a high level of success"*.

"I first look at results from a technical point of view: if the variations are too big or controls are missing, I ignore the result", said one PI. There was one PI who said that if the system is very well known to him a result even without the controls may be reliable, everybody else said that they want to see the positive and negative controls included in the experiment. Skipping controls may seem like saving time and effort, but, as one PI said: *"It takes less effort to do an experiment right the first time than to do it over!" "The worst experiment is the one that did not work and you do not know why"*, said another PI, and a third summed up his criteria to take a result seriously in the following: *"Controls, controls, controls, and technical quality"*. Several other PIs also said that the technical quality of the raw data (e.g. how clean an immunoblot looks) influences their judgement.

A veteran PI said that he goes to the lab and looks at the instrument producing the data and how the actual work is performed if the data are unexpected, and another (junior) PI said that she has a hard time trusting the students and needs to see it with her eyes how the experiment was done, what settings were used to trust the data produced.

Finally, several PIs consider the method used. *"The reliability of the experiment always depends on the tools used. Each type of experiment has its limits"* said one PI, summing up the opinion of many PIs that the method used also determines how strong your conclusion can be. *"Having experience in techniques has taught me what type of systematic error is built in a method"*, said one PI, and if you have personally performed all types of experiments that the members of your team do, you will also know already the strengths and weaknesses of each method. But it may also happen that some members of your team perform types of experiments that you have never done. In this case, you will need to familiarize yourself with the method, what the results are supposed to look like, what the pitfalls are, what the limits of interpretation of the results are so that you will be able to judge the results.

Statistics and Size of the Effect

"If I see perfect controls and a big effect, I may believe a single experiment!" said one PI—although most PIs insist on multiple repeats of the same experiment before concluding. Most PIs want to see the repeats only as a test of reproducibility and to

assess the spread of the data. Several PIs said that they look at the size of the effect because they are interested only in robust phenotypes, but they do not use statistical methods to draw a conclusion. Although some PIs do use statistics to decide whether there is an effect or not, even one of these admitted that if the differences are minor (albeit statistically significant), she becomes more critical of the data.

Consistency with Other Results or Earlier Experience

"There are no miracles", said one PI, explaining that he expects new results to fit with other results his lab has produced. *"This is why a good memory is essential!"*, he added. Another PI also said that she relies *"on her past experiences, past mistakes"* when judging if a new piece of data could be for real. Other PIs also said that they either try to consult independent sources or try to place new information within the framework of what they know and tend to accept data that can be inserted in the current hypothesis. *"I cross-reference several sources, publications, and accept only things that are common"*, said one of them. *"If it does not make sense or if it is not in keeping with other data: it is a red flag that it may be wrong, we need to be critical of it"*, said another.

"I have a hard time to believe results that do not connect to any previously seen results, the bar is much higher [for such results]", said one PI expressing the wariness of totally unexpected results shared by many PIs. On the other hand, we should keep in mind that sometimes our knowledge is advanced by information that overthrows the dogma, or as another PI put it: *"if it does not correspond to other previous knowledge, it is either garbage or it is new"*. Indeed, it may be either totally new knowledge or something that has not been noticed by anybody before. As one PI related, when somebody approached him with some very unexpected results, he suggested going through an old image base to try to find similar structures. *"Indeed, they were there, they just have been ignored previously"*, he said.

Results Coming from the Literature

The aspects we have talked about so far are mostly relevant to data produced in the PIs lab. But what about published studies? Some PIs said that first, they ask such "big picture" questions when they look at a publication as *"was the right question asked"* or *"did they pose an intelligent question"* and they only subject the paper to further scrutiny if the answer is yes.

"You cannot dissect the process, you don't have a lot of information", said one PI, expressing what many PIs mentioned: they trust data coming from their own lab more, mostly because they have access to more details and have more insight into how the data were produced. Yet, PIs have to decide somehow if they take the paper seriously. Several PIs mentioned repeating the key experiments in their lab before further acting on published results. But are there other criteria you can apply to help

you to decide whether you should commit your lab's time and resources to repeating somebody else's experiments?

"The source of the information can make a difference", said one PI and indeed the source of the information was the most often mentioned criteria when considering whether to believe a piece of information or not (just like with results produced in their own lab). One PI said that the impact factor of the journal makes a difference to him: *"if it is a journal with a good reputation, I believe that the results are more reliable"* while others dismissed thinking that the number of citations (the basis of impact factors) means something about the reliability of the paper as *"an obvious mistake"*. The list of authors seems to matter more: PIs may know one or more of the authors or may have had previous experience with data coming from them and that does help to establish trust. *"There are a few trusted people whose information I would believe without reproduction"*, said one PI; *"If it is a publication from someone else, the author, the institution does matter to me"*, said another.

"I do not care what journal it was published in or who the authors were", said another PI, *"I look at the data"*. She and several other PIs mentioned that they try to treat published data similarly to data coming from their own labs: they want to see all individual data points so that they can judge the variability for themselves and they do look at the supplemental data. Although these PIs cannot tell the authors of a published study that they would like to see more replicates of an experiment, they do look at *"their controls, number of repeat experiments, their methods, and their statistical analysis"*. *"The more supporting data there is, the better and more believable [published data is]"*, said one of these PIs. They also scrutinize the experimental setup and whether the methods used in the paper are suitable for answering the questions posed. *"When I read the literature, I check it against my own experience and read the fine lines: sometimes methodological details explain why the results may be weird"*, said a PI.

Another PI said that she looks into the paper to see if the introduction convinces her that the authors are experts in the field, if the experiments are described carefully, how thoughtful the discussion is, how many aspects they discuss, and how critical they are with their own results. Consistency with earlier results is also a factor for publications, as one PI mentioned: *"if I can see similarities between publications by different people, that increases my confidence that the result may be real"*.

As you can see, PIs look at many aspects of papers for deciding whether to believe them or not, and the decision is not all-or-nothing. They may accept some parts and reject others: *"sometimes I write my own conclusions"*, as one PI said, *"when I think it is not covered properly in the paper"*. Keep these criteria in mind as you are publishing because they will serve as the "scoring grid" as other PIs are reading your publications and if you score high, it will help you to establish your reputation at the beginning of your career as a trustworthy scientist.

Reliability

As one PI pointed out, the reproducibility and reliability of a piece of information are different things. PIs check the different aspects we have just discussed (one of which is reproducibility), and they deem a new result reliable if a combination of different aspects all gives green signals. As one PI put it, *"if something is clearly reproducible, it can be exciting, but not reliable yet. 'Reliable' includes that all the relevant controls are present, reproducibility, reproducibility by other operators or labs, it can be corroborated by different experimental techniques/approaches, and the results can be put in context with other information"*.

Some PIs gave rather philosophical answers when asked about how they know what information they can believe: *"I never believe anything fully"* said one of them, and *"I can never be sure"*, said another, expressing that they treat their hypotheses according to what they are: mental constructs based on the probable interpretation of the available (incomplete) data. Another PI who said that *"we can draw conclusions, but certainty is not reachable"* likes to flip the question: instead of asking whether the data are reliable, his main question is how they would be able to detect fraud. He likes to ask his team how they would fake certain results and if nobody can tell him what would be necessary for fraud, he is more prone to accept the result.

Top Publishers seemed to rely less on the source and tend more to dig into the details of the data.

Remembering Experimental Results

The collection of experimental results produced by your lab is a great resource since it is combined with detailed knowledge of how the experiments were conducted. Many of these results may not be published, therefore having this "knowledge base" in the back of your mind can not only be very useful when you are interpreting new data (some phenomena may pop up again later) but they also put you in a unique position to make new connections. I have been in the embarrassing position that my supervisor had to remind me of some piece of data I had produced but have forgotten about. Even if you have a great memory, you may find interesting the various ways PIs utilize to remember experimental results—and if you don't, you may pick up some ways that work for you.

Most PIs Remember Results Visually

About four-fifth of PIs said that they remember experimental results as images. Some PIs have the amazing ability to keep in their head results from 15–20 years back and pull out a mental picture of it when they want! One PI said that she can even remember several versions of the same experiment and knows exactly which blot she wants to put in the paper!

About a quarter of the PIs who remember visually retain equally well raw data (like images of blots, microscopic images, the curves on a FACS graph, etc.) and processed images derived from the data (these can be either the results of computation like a graph or a boxplot or they may remember them like a publication-quality figure), and the rest is split evenly between PIs who prefer to remember raw data (*"as raw as possible"*, as one of them said), and those who remember processed images.

What these PIs can recall varies: some can "see" clear, detailed images in their mind's eye, and others said that what they retain is not a clear picture, just something they *"have in mind"* or may even be something abstract that conveys the main result to them. One PI, for example, stores a visual memory of the project in her head that looks similar to a visual abstract of a paper, with graphs and charts. The exact nature of the image may also change over time: one PI told me that raw data he has seen recently stays in his mind for a while (especially if he finds the data striking) but in the long term, what sticks is the finished, processed figure, because he uses it in talks, presentations.

One highly visual PI told me that he finds lab meetings inefficient because what he wants to see is the image of the data. Since sharing the results is not an issue anymore with easy digital access to the results, you may want to use an electronic lab book in your lab that lets you see the results and you just need to have an ad hoc meeting with the person who generated the data to get a verbal summary.

Some PIs Remember a Combination of Images and Something Else

More than a quarter of PIs retain a combination of the image of a result and some "metadata" associated with it. The "metadata" can be also visual but it can also be something they hear, an internal dialogue (what we often call "thinking") or even a feeling.

When the "metadata" is also visual, it can be an image of actual written text: one PI told me that she takes the new data and adds explanations and conclusions to it, and that is what she remembers. For some PIs, this kind of memory is not limited to remembering results coming out of their own lab. For example, one PI told me that when he pulls out a paper to read it, he writes his own conclusions on the paper and what he remembers is where the results were on the page and his own commentary going with it.

But this accompanying text does not need to be ever written down: one PI with photographic memory retains the individual images of the results plus remembers a *"figure legend"* as text, guiding him through the panels. Another PI said that he remembers results like graphs, with bullet points describing them, similar to a slide, and a third PI explained that she can see the graph showing the results along with the explanation of the conclusions.

Another PI who can retain images well said that he remembers, for example, the image of the gel (what the bands looked like compared to each other) combined with what the person said about it during the presentation. Several PIs can remember raw data along with the conversation they had about it. Another PI with good auditory memory said that she sees the figure that was produced (often linked with the raw data) and hears the comments out loud.

The most common combination seems to be retaining images combined with an internal dialogue. For example, the PI mentioned above who stores projects as visual abstracts in her head links this image with an internal dialogue that guides her through the project. Several others mentioned remembering images in combination with an internal dialogue summarizing the outcome or a conclusion (*"this was the result"*).

But the "metadata" does not have to be the conclusion: some PIs remember other kinds of context like who showed them the data, the circumstances that led to the result, the relevance of the result to the hypothesis, if they saw an opportunity in the result or if it gave them any ideas, what could be the next step, and sometimes how they felt at the moment they saw the result or the feeling about the outcome.

Some Remember Little Movies

For some PIs, remembering certain results is a multi-sensational experience, like a little movie, watched through their own eyes. One PI told me that she remembers the talks she had with the students when the results came in and another PI said that he remembers the experiments with the context of receiving the information: where he was sitting, the phone call he received, but also the feeling he had when he heard the result.

Internal Dialogue Only

About 15% of the PIs retain only their internal dialogue (their "thoughts") about the results. These PIs do not remember raw data or even figures but rather the general outcome or summary finding. One of these PIs who said that he keeps *"the message more than the picture"* explained that he remembers the result itself (e.g. *"this correlated with that positively/negatively…"*) and he remembers his conclusion separately. There was another PI in this group who remembers results because of their connection to each other or something else: she imagines the individual results on a big Velcro block (although not as pictures), connected by an internal dialogue about their meaning.

Remembering Numbers

If you have trouble remembering numbers, you are not alone. Although many PIs can retain detailed visual information (immunoblot pictures, images of staining) many seem to be biased against remembering numbers and only a couple of PIs told me that they retain numbers easily.

Changes Over Time

What PIs retain may change over time. Several PIs said that they used to remember the raw results visually when they were doing experiments themselves and now they tend to remember the conclusions more. For example, one PI said that she used to retain a visual memory of the results (*"the ELISA plate was darker"* or *"there was more haemolysis"*) of her own experiments, but now that she does not do any experimentation, she remembers the summary findings—nevertheless, she likes to go into the raw data. Another PI, who leads a group of 12, said that his people generate more results than what he was used to in the past so it is hard for him to remember the details—instead he remembers the conclusions they reached. Other PIs also said that they tend to remember summary results like graphs or plots better.

Results Coming Out of Your Lab or from Publications

Naturally, PIs know much more about the experimental circumstances that led to producing a certain piece of data and have much more access to the raw data if the experiment was conducted in their own lab. This is also reflected in the way many PIs remember data collected in their own lab or data seen in publications, especially for those who prefer remembering the raw data. One PI told me that it is harder for her to remember published results because she does not spend as much time with publications as with their own data. In this latter case, she remembers the "*top line: the title of the publication and the big picture*".

Some Don't Remember Results!

There was a minority of PIs who said that they do not remember experimental results. One PI told me that it happened that he got reminded by his lab that he had published something! For some, this tends to happen as their group grows or as they move into a more managerial role. Different PIs deal with this in different ways, some try to keep up by making notes (although they may never actually look at their notes later), and some just ask people to show them the results again.

Some PIs are not at all apologetic about not remembering the experimental results: "*I don't want to remember them. All I need to know is where they are*" said one of them. He said he has his PhD students re-define their goals every two weeks which is not only a good resume of the results but also forces them to arrange their thoughts. "*Why should I remember the results? With a good archiving system, I can look them up whenever I need them. That way, there is no danger of misremembering*" said another PI, and she's not the only one who prefers not to keep the results in her head but instead looks them up regularly in the lab books.

Remembering Experimental Results that Do Not Seem to Make Sense

62% of PIs said it was easier for them to remember experimental results that did not seem to make sense at the time they saw them, and about half as many (29%) said it was harder for them to remember such results. The rest (almost 10%) said it was about equally easy to recall experimental results whether they matched their expectations or not.

The majority who said it was easier to remember the results that do not make sense quoted that these results "*stand out*", they find these results more interesting. If the results fit, they feel that they can just move on, but these results "*nag*" at them or bother them, annoy them, or they trigger wonderment ("*Why don't they fit? It is a technical issue?*") that makes them think more about them.

One PI said that *"results of technically solid experiments that I do not 'get' are fixed in my mind". "Those results pose the next big question that I want to solve!"*—exclaimed another PI, and a third PI said that he has a good memory and keeps such results *"in the back yard"* of his mind. Because he designs his experiments for a specific purpose, expecting something to happen, he ponders why it did not happen and later he thinks: *"this could be the explanation…"* Another said that he *"keep [s] results that do not make sense in a separate drawer because as you learn more, things may make sense later. Solid data that does not seem to make sense means that the model has inaccuracies, you have to keep an open mind!"*

An important condition is that the data are robust, the experiment is technically sound and contains the proper controls. As one PI said *"If the results are striking but technically clear and solid, they become the fundamental observations to follow in the future. They are especially memorable if they are clear and do not fit the current dogma."* Another also said that *those [unexpected data] are the most memorable, especially, if properly controlled"*.

"You have to go back later with a different approach. Research is always grey, never black and white. This is the most important part that is blocking the path/stimulating new research. Never discard these results, always keep in mind, they can turn out to be very important", advised another PI, and some PIs reported that they only found an explanation years, maybe a decade, later.

Several PIs who said that it was harder for them to remember results that do not fit their model said that this was a weakness they were aware of and they made a conscious effort to remember or store these results—but they found the results that *"fit"* a logical framework easier to remember. One of these PIs called results of experiments that did not fit his expectations *"failed"* experiments—it is easy to understand why he had trouble remembering them.

Finally, some PIs said that it made no difference to them whether the results fit their expectations or not, they remembered both kinds equally well. Some of these PIs were lucky to have an excellent memory, and one of them said that he remembers all results because he does not believe there are *"failed"* experiments. Another PI who said that *"it is about the same"*, explained her thinking process this way: *"you do not know what is right and what is wrong, anyway. If it is an expected result, it fits with everything else I know, so I can remember it. If it is an unexpected result, I think* *'it's not right', and spend time trying to understand it"*. She also emphasized the importance of pondering unexpected results. Said that *"it has happened to me that I could not explain an unexpected result for months, then I read something, that explained the unexpected result—and then it also explained a bunch of other things!"*

Arguments for a Good Filing System

Several PIs who have excellent memory admitted that sometimes they have found out that what they remembered was not correct! Other PIs pointed it out that remembering becomes more difficult during pregnancies, during certain medical treatments, and memory tends to decline with age. This is why some PIs prefer consulting the data again instead of risking that what they remember is not reliable.

It is worth, therefore, to invest time and energy in setting up a good filing system that works for you (depending on what you tend to remember best) and makes it easier to consult the body of work performed by your group than flipping through the pages of your students' notebooks. I have already mentioned the PI who requires biweekly summaries from the PhD students and the lab that shares digital images of all their results. A third PI, who called herself *"very visual"*, said that they have standardized workbooks in the lab and she teaches her students to save the worksheets containing the raw data and then write the most important points down separately as well as save a visual representation of the most striking results.

Revisiting data may have other benefits, as well. Several PIs said that it is good to see the results again with fresh eyes because they often discover interesting clues in the data that they missed earlier, and data that did not look exciting the first time you saw it may become striking later as your understanding increases or as you can put other data next to it.

One PI said that the reason she remembers raw data visually, even different versions of experiments, is that she goes back and looks at data frequently. She also added that she has noticed that many students do not go back to re-evaluate their own experiments. My own experience is that looking at the data you have produced does not only refresh your memory and gives new ideas but it also gives you a sense of accomplishment and boosts your morale—very useful during difficult times.

Ways to Help Yourself Remembering

Remembering results, therefore, is good—admittedly, you need to cross-check your memory against the records so it does not play any tricks on you. There are ways you can help yourself to remember, should you not be blessed with an excellent memory.

An obvious way to help your memory is keeping notes, done by many PIs. Although some PIs admit never looking at their notes again, just the act of taking notes may help to remember the result. In the same vein, some PIs make notes next to important images. Putting a summary heading on the conclusions helps with retrieving your notes later. One PI says his conclusions out loud as he is analysing the image to help himself remember them. Other PIs help themselves remembering by simplifying the results or creating an overview. One of them told me that she simplifies the result to remember: *"in my field, the result can be 'not much happens' or 'wow!'—the details are for the publications"*, she said. The "wow" effect also helps to remember. Even PIs with average memories mention remembering certain visually striking results. One PI who can *"vaguely remember trends, and the most important observations"*, said that he distils the important things from the result like if there is an opportunity in the result to improve the process he is working on.

Spending time with the data is also a good way to help yourself remember it. Some visual PIs make drawings or plot the data several ways until they find the best representation. Making summary figures derived from experiments also helps to extract the essential information from the data without the noise. And, one PI said that although he uses visual representation, talking a lot about the project is very important and helps him to remember the result.

Although most PIs report remembering better the results that do not seem to make sense, as we have discussed above, others remember results by putting them in a story. One of them said that he regularly goes through the results and tries to put them in context and another also said that he can remember things that he can integrate into a narrative. As mentioned above, the "story" does not have to have any text, some PIs store images of results like puzzle pieces of a larger picture.

As with remembering anything, emotional charge helps. For example, this is how one PI remembered one of the breakthrough moments of her career: *"I still remember crying with happiness when I was a postdoc over 20 years ago, running my samples on a FACS machine and recognizing that I had solved my first big research puzzle! It ended up in papers for which I have become internationally recognized"*. Anything you are closely involved with will stick better—another good reason to choose projects that you can connect with on an emotional level, as well, as we discussed in Chap. 1.

Interpreting "Grey" Results

As we saw a little bit ago, interpretation of results is one of the main daily activities of PIs, yet it is often not straightforward. For example, two people looking at the same image may focus on different features and draw different conclusions. Therefore, I asked PIs how do they know which interpretation to choose when the results are not clear-cut, or in other words, "black and white"?

As many PIs pointed out, we should not draw conclusions based on one experiment and neither do the results have to either clearly match the hypothesis or be clearly against it. Nevertheless, finding out how PIs go about drawing conclusions from an experiment is an important question since your resources will be limited and your decisions about what to spend your lab's time on will have serious consequences. The question here is: how careful do you have to be without hindering yourself? How to help yourself with proving your hypothesis and publishing your work and still not miss the "grey zone": signs of things not matching the hypothesis—because that is where the interesting discoveries lie.

There were a couple of PIs who said it straight out that this is not a straightforward procedure and depends on the situation: it can be difficult to draw a conclusion from experimental data and decide what the next step should be. There was not a single predominant method used by the majority of the PIs, instead of a plethora of different approaches, and about half of the PIs listed using more than one approach.

Preamble

Your approach will depend a lot on the discipline you are working in. For example, PIs expressed quite different views regarding the use of statistical methods whether they were doing structural biology, immunology, or human genetics. All the following answers assume that the hypothetical experiment we are talking about was performed by a competent person and is properly controlled (otherwise, all bets are off). I also would like to mention that many PIs seemed to intuitively take "white" in my question to mean "supports the hypothesis" and "black" to mean "contradicts the hypothesis".

Hypothesis-Driven Science

When we are taught about the scientific method, we are told to design experiments to test the predictions of our hypothesis and then draw a conclusion based on the results of those experiments. We are also taught that since testing our hypothesis in "all circumstances" is not possible we cannot really "prove" our hypothesis; we can only rely on the pieces of data that show when our hypothesis breaks down. Despite all this, one PI said that *"in science, they like to say that we should disprove things, but nobody does that"*. And he was almost correct, only a handful of the PIs said that they *"tend to see experimental results as black or grey"*, meaning that they are looking for signs in the data invalidating their hypothesis. One of these PIs said that he likes to play the Devil's advocate, another said that she makes a conscious effort to be cautious: she is *"trying very hard not to over-interpret the data, especially when they match the hypothesis"*, and a third PI said that he hates this pessimistic streak about himself.

It makes sense that very few PIs tend to see experimental results going against their hypothesis: publishing negative data is very difficult, and your survival as a scientist depends on publishing—so looking for signs in the data to knock down your own hypothesis is counter-productive. About 10% of the PIs said that they are *"geared towards their own hypothesis"* and *"tend to think biased towards the positive, tend to think that there is something there"* in the experimental results that confirm their hypothesis. *"We all like to be right"*, said one of these PIs. PIs in this group tend to take *"the most optimistic"* interpretation of the data, a way that will fit logically into the hypothesis and they tend to think that differences are meaningful. These *"inherently optimistic"* PIs look for clues in the data that allow them to interpret the data in a way that fits the hypothesis.

Some of these PIs call a meeting and ask other people's opinions to test out their interpretation in the community, some design follow-up experiments to confirm their conclusion immediately, but they tend to take the interpretation that supports their hypothesis. One of them said that as he is getting older, *"all results look white"*. He said that he had learned in the business world to *"limit damage, cut losses, and move on—do not aggravate the situation"*.

It is important to realize that even if you are not actively looking for signs in the data that confirm your hypothesis, the hypothesis itself may influence your interpretation of the results. As one PI (professor, PI for over 30 years, over 200 publications, H-index over 45) said, *"a well-designed experiment is so attractive aesthetically that it influences the researcher to see what he wants to see"*. Since our interpretation of the results may be subjective, *"it is important to be aware of this and it is best not to be invested emotionally in the results"*, he suggested. *"Sometimes you are geared towards your own hypothesis and tend to push conclusions towards the positive, the conclusion that supports your hypothesis"* explained another PI. This is why one PI called the hypothesis *"the prejudice"*, and another PI told me that she looks at pictures together with other team members when she needs to evaluate a picture to make sure that they see the same thing, to guard against her own bias.

Despite this biasing effect of the hypothesis, many PIs function within the black or white dichotomy of results: *"the result either follows the hypothesis, goes with the hypothesis or it is the exact opposite"*, as one of them said. *"In this latter case, I design extra experiments to disprove the hypothesis and to support a new hypothesis"* she explained her process. Be prepared that you may have to completely scrap your hypothesis, as well. *"It's possible that ten years old published results are false"*, as another PI said, *… make a new hypothesis and re-check"*.

"The models are based on several approaches, by several labs—assumed to be right. I tend to report confirmative data and put the data not fitting in a separate box—some of these become obvious by themselves in time" said a *"hypothesis-driven"* PI. The practice of not reporting data not fitting the hypothesis is probably not limited to this one PI and it is quite understandable, knowing the extreme pressure PIs are under to publish. It is much more rewarding to publish a neat hypothesis, supported by the data provided than turning around and around to find a hypothesis that can incorporate all the data. Nevertheless, another PI said that she likes to leave the door open, rather than dropping sets of results. *"This is not the best way to sell your story, but it is important to me"*, she said. Dropping results may hurt your reputation in the long run if your fellow scientists start to doubt everything you published and it is also wasteful, because other people building on your work may reproduce experiments that you have already done.

Another way of dealing with results that your hypothesis cannot explain is to *"keep on digging, repeating, looking at it from another angle, turning around it"*, as one PI put it. His advice was: *"You can have an idea about what you would like to see, but you will not decide on a grey outcome—you have to keep digging!" "If the result is black and white, it means that your assumptions were correct. If the results* *are grey, repeat until it becomes black and white"*, said also another PI. Other PIs also agreed with this way of proceeding: *"if it is not black and white: not interesting. If you can't make the effect black and white: you need another lens to look at the issue"*, as one of these PIs said. *"Look at the trends and optimize the experiment until the results are black and white. If that can't be done, you are on the wrong path"* advised another PI.

However, it may take a long time to rebuild your hypotheses to get to something publishable. Time pressures put PIs in a difficult position, therefore it is not surprising that one PI said that she often drops a task if it is too much effort to get a clear answer. *"If it is something highly interesting, we will look for more evidence using another approach"*, said another PI, *"if it is not interesting, we just say that we do not know. I am not afraid to say that we do not know something"*, he added.

Appreciating Greyness

One PI said, *"I would never interpret a set of experiments that were not giving a conclusive answer"*. At face value, this seems sound advice. Many PIs try again and try another way, and they keep looking for other evidence that would help them to come down on either the white or the black side of the divide. The problem with the "do the results support or invalidate my hypothesis" approach is that many times the experimental result is hard to interpret. There were more PIs (about 20%) who suggested paying attention to the greyness of results than the "black or white PIs".

> *"Science is based on the experience that nature answers intelligent questions intelligently, so if she is silent there may be something wrong about the question." (Albert Szent-Györgyi, The Living State. With Observations on Cancer. Academic Press, 1972)*

As you look for the explanation or hypothesis that explains, covers all your results, I would suggest considering the words of the PI who said *"[when the results are not black and white] I think about why it is not black and white: is the experimental design wrong, the experiment is not answering the question you had in mind, is it a technical issue, or is the answer indeed not supposed to be black and white?"* In other words, it's worth stopping for a moment and considering whether not getting a black and white answer means that either you are looking at the outcome of a stochastic process or you are asking the wrong question.

"We tend to think of error bars as errors, but they may reflect the plasticity of the system", said one PI and she suggested to *"go back to the 'beginning' and re-design the question"*, if we have trouble interpreting the results. Therefore, she teaches her students that *"experiments start with a question, not with the answer"*. The hypothesis may be so far from reality that questions formulated based on the hypothesis cannot give intelligible answers (see the quote from Szent-Györgyi above).

The definiteness of the answers may depend on your discipline, as well, but even a PI working on protein structure told me that although he is doing *"quantitative science"* since a structure is a very defined thing, he never says that something is black or white. Instead, he tends to *"appreciate apparent definitiveness"* and go in the middle of the black/white divide: he concludes what is definitive and asks new questions. *"The results are grey, I am quite sure"*, said another PI. He explained that most probably only a part of the hypothesis is true therefore he focuses *"on the common parts to find out the overlap between the hypothesis and reality"*.

Different PIs have differing approaches to deal with the grey zone and find a middle ground between publishing and endless research. *"Everything is grey, very often. The black and white part comes in the telling"* said one of them. *"I present the data for both interpretations, but I insist on the white in the publication. . . . I tell the community: this is my interpretation"*, he said. Another PI seemed to have a very similar approach: *"Discount the black and white"*, she said. *"It is never black and white in biology. In papers you explain what your 'preferred' explanation is, and what needs to be done in the future to clarify"*, she added. A third PI said that *"[if the results are not clear] I repeat the experiment with a larger sample, but if it is still inconclusive, I publish the dilemma, admitting the limitations. . . . If the results are inconclusive, it means that you need to continue the research*".

"First build a theoretical concept, then do exploratory analysis"—suggested another of the "grey PIs". *"You can shuffle things when you put the story together. You do not know what will go where until you have the full paper—but it is still only a stupid guess!"*, he added. *"I am a grey person: there could be other interpretations"*, said another PI. *"Doubt is a source of strength. Shades of grey are more challenging but make research more fun too"*, she added and suggested limiting the possibilities. Finally, another PI said, *"I do not want to force the results into one or the other box, I keep both options open"*. She added that the outcome does not need to be binary, *"we are not forced to make a decision!"*, there can be several options. Her results can also be a good starting point for somebody else.

Relying on Experience

About 10% of PIs said that they rely on their experience when they are interpreting experimental results and deciding how to proceed, what to do next out of the hundred possible experiments.

"My decision is based on my 'gut feeling', which is the sum of years of reading and experience. I mull the results over and accept that my subconscious can process difficult situations differently" said one of these PIs trusting her intuition. Another PI said that he already had a *"good hunch"* when he was a medical student and he keeps using his intuition. He loves reading the literature and seeing the big picture, making connections, including relationships with other fields, using his broad training as a medic.

Relying on your "gut feeling" (or your intuition derived from your past experiences, if you like that term more) has some advantages. It increases your self-confidence (assuming that things turn out favourably) and it lets you make very fast decisions that cement your role as the leader of your group. *"Dominant people take decisions quicker, that is why they come to dominate groups"*, explained one of these PIs. *"Having good visual memory helps in this regard if you have had relevant experience ('this is what it looked like in the past. . . .')"*, pointed out another PI.

Other PIs' reflex is to use the collective experience in the literature to guide them. *"I look in the literature: has anyone published something like this in another field?"* said one of them and another PI also said that when in doubt, he tries to find data in the literature to help him to interpret the results one way or the other.

Finally, some of these PIs prefer to discuss the data with others before deciding. They consult either members of their group or colleagues outside of their group—although one PI said that she prefers talking the results over with other people who are not interested in the result, to compensate for her own biases.

More Repeats

For other PIs, the first question when they see the results of a new experiment is not whether it supports or invalidates the hypothesis but whether the results are reproducible. This "confirmation by repetition" approach seems quite prevalent: about 30% of the PIs said that there has to be sufficient replication of the experiment before they draw a conclusion.

These PIs repeat experiments several times (they mentioned three to seven repeats). For some of them, repetition is necessary to get convinced and they want the results to look perfect. For critical results, some even have the experiment re-done by another person to make sure that it is robust, reproducible (especially if the result is conflicting with the literature). For others, repetition is a way of testing the system: are the results really grey or are they going in a direction? *"Sufficient repetition may be needed to see if the results are going in any direction"*, said one of them. If the difference seems to come and go, they want to find out what conditions make the difference not consistent. What could be changed? They repeat the experiment until they find the key factors.

Depending on the discipline, PIs may repeat the experiment with a larger sample, and with larger datasets comes the possibility of using statistical tools to find differences between, e.g., healthy subjects and patients, as well. Some PIs find using a statistical cut-off to decide if there is an effect absurd, but others see value in using statistics because of the high variability inherent in biological experiments. *"We use statistical tools in science"*, said one of these PI, *"you take a data series, then apply a properly selected statistical probe, and then you can say that within the probability dictated by the statistical probe, the conclusion is X"*, said another PI. Interestingly, these PIs have different ways of proceeding if the results turn out to be inconclusive, despite repetitions. *"In the absence of statistical evidence, I put the results aside and think up a better experiment"*, said one PI, whereas others conclude that there is no real change.

The Size of the Effect

For many PIs, besides reproducibility and signal to noise ratio, the size of the effect has a lot to do with their decision on how to proceed. *"I am not a fan of small effects"*, said a PI, one of several PIs who do not encourage their people to pursue small effects. One PI passes the advice of her postdoc advisor to her students: *"You are not looking for minimal differences. You want effects of fold changes that can be easily measured and reproducible, effects that will stand the test of time"*. She said that deciding if an effect is worth pursuing is part gut feeling and part not wanting to fool herself.

"If I need statistics to see if there is an effect, I am not interested", said another PI. *"I make exceptions sometimes based on the investment already and the underlying hypothesis, making a cost-benefit analysis. But in general, my enthusiasm is proportional to the effect size"*, he added. Another PI also said that he tends to be dismissive of small effects and does not encourage his people to pursue them. Sometimes he may be induced to follow up if the effect is reproducible. *"Although we are forced to provide p values, the difference has to be obvious"*, said a third PI, and he added that *"if you do it 5–6 times, there may be a variation in the size of the effect, but not in the direction of the effect"*.

Follow-up Experiments

The most popular approach (more than 30% of the PIs mentioned it) to decide how to interpret "grey" results is "complement and confirm": doing more experiments that tackle the question from a different angle. The follow-up experiments are set up with the goal of either testing the hypothesis further (if this happens, then this should happen. . .) or discriminating between the highest-ranking hypotheses on how to interpret "grey" results.

Many PIs use the complement and confirm approach in combination with repetitions and PIs seem to have different views on which one to do first. Some prefer to do the repeats first like the PI who said that she wants three repeats to have a solid result, but then to lock in the interpretation, she devises another experiment and looks if the results match. Another PI said that repeats are only useful to get more statistical power once the experimental setup is perfect, but if the results say that *"there may be a trend"*, she first likes to look at the question using another method.

For some PIs, complementing means using a different experimental system, for others, it means asking a similar or tightly linked question. We have already mentioned that no PI draws conclusions based on a single experiment, but many PIs said that they never rely even on a single type of experiment. Although some experimental systems are more reliable than others, all experiments have their limitations. *"I confirm everything by repeating the experiment and doing something similar or complementary, or opposite"*, said one PI. *"The crucial experiments have to be supported by more than one technique"*, said another PI, and others also mentioned that they *"tend to believe a conclusion if more than one approach supports it"*.

"Repetition, the magnitude of the effect, fortified with complimentary approaches" enumerated his *"1–2-3 method"* one PI. *"Without using other approaches, you are just spinning your wheels repeating the same thing over and over"*, she added.

Weight of Evidence

If you have data generated using several approaches, all having their strengths and weaknesses, you can use what some PIs call the "weight of evidence" approach. This involves not advancing straightforward but following kind of a circular path. As one PI explained, if she's in doubt about the interpretation of an experiment, she makes a hypothesis based on one possible interpretation and designs the next experiment. Then she goes back and re-evaluates the first experiment, taking into account the results of the second experiment.

"The hypothesis needs to be tested over and over. If the results do not fit other results, I don't draw a complete conclusion" said another PI. The trick is *"asking the question in many different ways and concluding only afterwards"*, explained a third PI, which is very different from the way many people are working who want to make sure of every step before proceeding further.

Another PI explained her thinking process this way: *"I focus on one interpretation, then on the other interpretation. My first intuition is not always the best so I adapt one point of view, then I force myself to adapt the other one. Which one fits better my knowledge of the subject?"*

There can be, of course, more than two interpretations, and PIs said that they put forward several hypotheses and then carefully consider each of them. *"It is often difficult to interpret one experiment: I look at the results of several experiments together, and try to find an explanation or hypothesis that explains, covers all the results"*, said one PI. Another suggested that if you have many possible explanations, a good question to ask may be *"What do the results exclude?"*, and a third said that when she imagines alternative answers she asks herself: *"Which one is the simplest?"*

Independent Confirmation

Although this may seem like distrusting the member of your team who supplied the data in the first place, several PIs mentioned confirming results by asking other people to repeat the experiment. One PI said that this is a way of protecting himself, but he likes to suggest this as *"I give you a student…"*. Another PI who also likes to *"try another pair of hands"* said that it is important to do it in a way that does not make the original person feel not trusted, so she tells her people that she is *"looking for robustness"*.

Not every PI seeks independent confirmation, but many PIs think that for critical results, having the experiment re-done by another person is an important step, especially if the result is conflicting with the literature. One PI told me about a paper she published in Cell, for which she has given the reagents blinded to somebody else to reproduce the key findings so that she can be absolutely sure of the result.

Top Publishers

Top Publisher did not have a "one size fits all" solution, either. More repeats and follow-up experiments using a different approach were the most frequently used approaches by Top Publisher. None of the PIs who mentioned using statistics tools or the size of the effect to guide them in how to interpret the results belonged to the Top Publisher group. With one exception, all PIs who mentioned independent confirmation of the result belonged to the Top Publisher group, and two-thirds of the PIs who mentioned approaching the results from the viewpoint of the hypothesis were Top Publishers, as well.

Dealing with the Results Not Fitting the Hypothesis

Some scientists change their hypothesis more readily than others. I remember sitting in the office of a legendary biomedical scientist (astronomical H-index, close to a thousand publications, founder of several companies, benefactor of the University, etc.). I have to admit I felt intimidated and all my questions suddenly seemed banal. He was rather sombre during our discussion but when I asked him the question what he does if the results do not fit the hypothesis he literally laughed out loud and said: *"Change the hypothesis!"*. And that was it, he added no qualifiers.

Not Good for the Ego

Changing the hypothesis, however, does not seem to come so readily for many scientists. Many are fond of their hypothesis, which is understandable. After all, there was a reason for the hypothesis, it was made based on previous data. The answers of some PIs even reminded me of the stages of grief (denial, anger, bargaining, depression, acceptance) which may not be surprising, since, as we saw in Chap. 1, many PIs are emotionally invested in their work.

"I hate them!" said one PI about results not fitting his hypothesis. He eventually does say to himself: *"let's go have another idea"* and reconsiders his hypothesis, but his first reaction is anger. He is not alone, other PIs also said that it can be hard for them to adapt their hypothesis and sometimes experience some pain and anger at having to do it. *"It is tough sometimes to part with your favourite ideas"* admitted one PI, *"but you can't be married to a hypothesis"*, he continued. *"They are an*

'itch'", said a third PI about results not fitting the hypothesis, *"I know that something has to be done, I can't ignore them"*, although she also acknowledged that *"they usually lead to very interesting results"*.

Reasons to Hate Them

"The majority of scientists are attached to being 'right'" stated one PI as the reason for PIs being bothered by results not fitting their hypothesis, but there are other, more rational reasons for not jumping to modify the hypothesis besides bruised egos. For example, if your hypothesis questions the current paradigm of your field, the reward for proving it can be considerable. *"If you can disprove a hypothesis embedded in the field, that can also make for a very good publication"*, as one PI put it, and another said that *"I don't mind to be proven wrong. Of course, I like to be correct, and surprise everyone in the field!"*

Another frequent reason for healthy scepticism is that *"disproving a hypothesis with [low quality] data is easy"*, as one PI put it (actually, he used another qualifier, but that is not fit to be printed), summarizing why PIs may need some convincing when it comes to data that seemingly falsify their hypothesis. *"I ask: 'is this new or is it unreliable?'"* said another PI. Also, such detours throw a monkey-wrench into the tight schedule and can have a major impact on the project. *"They are annoying"*, said a PI about data not fitting the hypothesis. *"You have a plan, a time constraint, and it takes a whole lot more time to figure out what hypothesis do these non-fitting results support"*, she added.

"You also have to do a risk-calculation: if you have a wild hypothesis, and it proves out to be right, you have a good paper, but if turns out to be false, you still need to have a story for the PhD student to graduate", said one PI, and another said *"I consider how important the original question was. If not that important, I let it go, if it is important, I keep going"*.

Collecting Them Separately

Several PIs mentioned collecting data that go against the hypothesis separately. *"I put them in the mental box of stuff I can't make sense of now. Together, they may point to the same thing"*—said one of them but others also mentioned putting such data temporarily aside and coming back to them from time to time to see if they can find an explanation. Holding on to these pieces of data is a good idea, because *"if the data are skewed, but you are not aware of the skewing, you may draw the wrong conclusion"* as another PI warned. *"If the evidence is not clear, and I cannot make sense of it: I keep it in mind and wait for an explanation"* added another PI.

"It is extremely important to remember the results not fitting the hypothesis", said one PI who admitted that he tends to forget such data. Since he is aware of this weakness, he makes great efforts to remember these results and *"write[s] them down with exclamation marks"*.

Are We Doing It Properly?

The first question most PIs ask when confronted with data going against their hypothesis is *"are we doing this properly?"*. Many PIs start by assuming that there was something technically wrong with the way the data were produced and want to see the experiments repeated (*"is this a one-time result or consistent?"*), sometimes by another pair of hands, and sometimes approaching the question from another angle. *"I am aware of the possibility that the hypothesis can be wrong, but I do not accept it too soon"*, summed up one PI what seems to be the attitude of many.

"I don't throw them away", said one PI about data that do not fit her hypothesis. *"I keep them in mind and think 'we probably do not know all the details'. My action will depend on how much of the data don't fit and what technique was used to obtain the pieces that do not fit. Some methods are more trustworthy than others"*.

As one PI pointed out, the timing of the results also makes a difference: *"if you know the result from an earlier experiment, it introduces bias"* explains one PI. This bias is probably why many PIs are sceptical and go through troubleshooting steps to find something *"wrong"* with the experiment that would explain the discrepancy, find the reason why the results are not what was expected.

"There was a reason for the hypothesis, so I check if the result is correct. Then I check if the result actually does not fit, or it doesn't fit because the result is context-specific. If all checks out, then I change the hypothesis", said one PI. *"It is usually one third, one third, one third for each scenario"*, he added. Several PIs include in their troubleshooting changing the conditions, changing the method to find out if there is another, unappreciated layer of complexity that influences the results. If the result is not consistent or shows up with only one of several approaches, they conclude that it is not necessary to change the hypothesis because those results are "context-specific".

As we have already talked about it, it's a two-way street between experiments and the hypothesis. Therefore, a couple of PIs said that they tend to revise the hypothesis, but before doing so they also *"consider whether it was the right experiment to tackle the issue"* or whether the experiments were properly designed.

Detail or Cornerstone?

Another issue many PIs consider before scrapping their hypothesis is how wide the impact of the result is. Does it invalidate the entire hypothesis, does it only limit its applicability or is it a minor detail?

"Sometimes it is a detail that does not fit—students may be blocked by the mismatched detail, without realizing that it does not affect the big picture" explained one PI. He added, nevertheless, that *"sometimes the not fitting result says that the whole edifice that we have been building may be wrong—in this case, I try to take these results into consideration"*.

Such results can present a real dilemma to PIs, as one of the PIs described: *"Let's say I have 7 experiments confirming the hypothesis and 3 not confirming it: what do I* *do, show the 7? Is that correct? I make the following compromise: I look at the 3 more attentively to see if there was a technical problem. If not, I include them"*.

An important question raised by one PI is *"Does it [the not fitting result] invalidate the positive results?"* Another PI gave this example to illustrate: *"if there are several potential mechanisms, and the one I am investigating sometimes shows up and sometimes not, I focus on the results that show the involvement of the pathway I am interested in. I can't investigate all possible mechanisms at the same time. It is important not to overestimate your findings: the negative results do not mean that the positive results do not exist, they can be a potential mechanism"*. He added that *"I can't explore everything but this does not mean that I disregard experimental results. E.g. if a drug sometimes inhibits and sometimes promotes tumour growth, that is very important. I like to be very careful"*.

The Fails Are More Interesting

Despite all the mentioned difficulties unexpected results can cause, many PIs find them exhilarating. *"I love them! This is why you do science!"* exclaimed one of them, and *"unexpected results are far more interesting than expected ones"*, said another.

Several PIs mentioned that they enjoy the challenge such results pose. *"This is when you have to think, rethink. These are the most interesting results, they allow you to re-evaluate the hypothesis. If you achieve confirming your hypothesis, that is not interesting"* said one of them, and *"these are more exciting than the ones that do fit. Changing the hypothesis is the fun part"* confirmed another—although she did add that sometimes she is fond of the hypothesis and resists changing it. *"These results are what excites me the most in research! I love having new puzzles to solve, I love a challenge!"* said a third PI, and several others mentioned that they think more about unexpected results. *"You lose time, but this is science, this is part of the process. I would be bothered if everything worked as expected: no research would be needed"* explained another PI why she is not bothered by unexpected result. But, besides the intellectual challenge, unexpected results can also let you know if you are not on the right track: *"These are usually the most important results! I am a fan of the method of trying to design the experiment that breaks your hypothesis to invalidate it as soon as possible"*, explained a PI why she likes unexpected results.

Unexpected Results Can Lead to New Projects

Importantly, unexpected results can make you pivot in directions you did not think of before. *"The hypothesis can bias us. I like results that go against the dogma because they lead to innovation"*, said one PI. *"These 'fails' are more interesting: follow up to find out what they are telling you"* advised another. *"I like those a lot. My best work originated from results that were not fitting the hypothesis"* said a third PI.

Hypotheses Are Only Tools and They Are Made to be Falsified

It is important to keep in mind that hypotheses are tools to help us design experiments. *"If the evidence goes against the hypothesis and it is clear, I am fine with changing the hypothesis: the hypothesis exists to be changed"*, said one PI. This is how another PI explained it: *"I am Greek: the hypothesis is proposed as a possibility, but it is not the answer, it is a tool. The very point of the hypothesis is that you do not know the answer! The results do not have to fit! I do not expect the data to fit the hypothesis. The hypothesis is only a starting point to investigate the problem"*.

> *"The most important thing is to be always ready to kill your own hypothesis." (assistant professor, PI for over 5 years, over 30 publications, H-index of 19)*

"We always have to be aware that the hypothesis is only a tool", reiterated another PI. *"If the experimental results support it, fine, if not, we have to rethink it"*. A third PI also said that it happens very often that the experimental data don't fit the hypothesis. His advice was: *"Rethink your hypothesis, try another method: you could be overlooking something. It is like a difficult jigsaw puzzle: it often looks impossible [until it's almost finished]"*. So, treat your hypothesis as a tool, like a leveller: using it you can tell if something is horizontal or vertical, but if you find that something is neither horizontal nor vertical (or at least not close to one of them), it still exists, you can't just ignore it.

Much Better than Uninterpretable Data

Some PIs pointed out that although unexpected results can sometimes be disappointing, they would much rather have data not supporting their hypothesis than uninterpretable data. *"I treat results not fitting my hypothesis the same way I treat results fitting the hypothesis! Either way, it is good to have an answer—at least, we can make a conclusion and move on"*, said one of them, and *"I am perfectly happy if I get clear-cut data one way or another"* explained another, and a third PI said, *"if the data negate the hypothesis but they are consistent: I am happy"*.

Keep Your Students from Despair

Whatever your attitude is towards unexpected results, keep in mind that they can be frustrating to those producing the data. If you don't like them, *"it is important not to let despair and disappointment filter through to the students and postdocs to keep them motivated"* warned one PI, and another said that "*courage and honesty are both needed to remember the drive you had at the beginning to solve the puzzle"*.

Another PI who likes unexpected results said that although *"the lab people"* may get frustrated, by unexpected results, she tells them that *"something more interesting is going on"*. "It is a reality check", she continued, *"the theory is getting challenged by reality. It would be boring if everything turned out as expected"*.

It's Normal

The best is to accept that having to modify your hypothesis is normal. One PI expressed this point a little more strongly: *"The hypothesis needs to be data-driven, and not the other way around. Insisting on providing data supporting the hypothesis is dumb"*. Don't be bothered by data not fitting your hypothesis (however fond you may be of your creation), quickly make a new hypothesis and get new results. You need to keep an open mind. *"I am very flexible: I try to forget all and look at the data with a different hypothesis in mind and ask: 'does it fit better?'"* explained her process one PI. She also said that instead of accepting failure, or you can *"try pushing on the door until you get in"*.

Do You Really Need a Hypothesis?

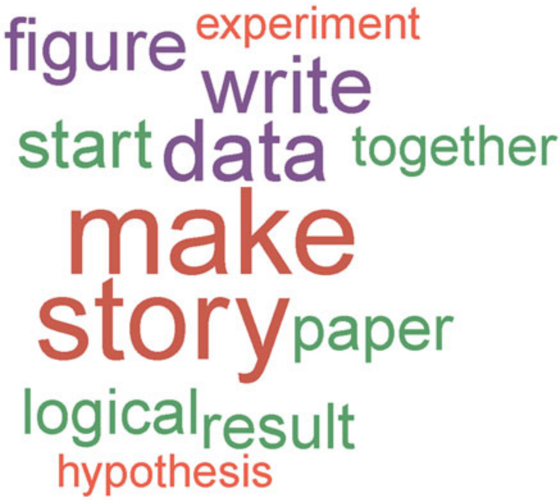
Although there is a strong push for doing "hypothesis-driven" science, not all PIs do that. Unexpected data are *"not a problem for me because I don't work so much with hypotheses than questions. I change my mind easily"*, said one of them. Whether you can work without a hypothesis may also depend on your discipline. A genomics researcher told me that they generate global data and they never have a detailed hypothesis going into a project, they are usually between not having a hypothesis and having a mechanism in mind. They adjust the hypothesis as data come in.

Piecing Experimental Results Together

We have discussed how PIs evaluate information, how they interpret results that are not clear-cut, how they deal with results that do not seem to fit their working hypothesis. In this section, we will discuss how they integrate all these activities to build a cohesive story that will end up in a publication.

Scientific Storytelling

Humans have a strong affinity for stories. We have probably been telling each other stories for tens of thousands of years—compared to that, biomedical science is a recent invention. As we do research in biomedical science, we produce data but our "currency" is not data, but publications—based on that data, but containing a narrative that presents the data as part of a story. *"Look for a story. No story—no publication"*, said one PI, and another PI, who used to write stories, also said that she thinks of writing a manuscript as putting a story together: she keeps images of the results in her head and arranges them in a storyline.



Scientific papers are a genre of storytelling, and science is advanced by the stories scientists tell each other. These scientific stories need the same ingredients any story needs: characters (e.g. ligands, receptors, signalling molecules), a plot (which character does what, where, when, and how), and a narrative that provides the writer's point of view (what this means and why this is important). *"There has to be a story behind it and a future ahead of [the data you present]"*, said one PI, and he added that even if your data are observational, you will have to find a way to present it in a way so that they fit with a story.

Although there are written and visual ways of telling stories, storytelling is a verbal tradition, and many PIs mentioned an intermediate step between getting the data and writing publications: making presentations first to find the best way to structure the data. *"If you can present it in 10 minutes: there is a story. If it can't be presented in a 10-minute presentation, there is no story"*, said one PI. Others also said that they approach manuscripts as if they were planning to give a talk about the data: how can I explain this to other people, how can I make my findings logical to other people? One PI said that first *"everything goes into a presentation"* and then he tries on various schemes before settling on the best way of explaining the story. "*I present at conferences to get feedback and to come up with a logical way to present it"*, said another PI. *"I discuss the story during lab meetings, and it is also shaped by the questions I get during presentations"*, said a third PI, because the questions from other scientists help her to see the story from different perspectives. Then, PIs are ready to write the paper. *"It is easier to write papers after giving talks about the topic"*, observed one PI.

Your Job as a PI

"Being good at synthesizing facts is a quality of a PI", said one of them, and another PI also said that although other people in his lab are more skilled at acquiring or analysing the data, his "added value" is that he is very good at piecing the results together. A third PI said that his strength is *"seeing connections and combining results into something greater"*.

Producing a manuscript is not a trivial task (Fig. 5.4). One PI described the process this way: *"I distinguish three phases in producing a paper: the what, the how, and the what is the story? In the what phase you explore whether there is a direct link emerging (e.g. receptor-ligand interaction). Then comes the how phase, the hypothesis testing phase, when you test one idea at a time. Once the mechanism seems to be clear, we enter into the what is the story phase. In this phase, you start looking into the consequences, and check how far you can go away from the original observation and still predict what will happen with reasonable accuracy"*.

Your talks and your grant applications are ephemeral but your publications represent a lasting scientific legacy and they may be read long after you are gone (if you are lucky). This is why one PI said that *"it is the duty and the right of the person whose hands produced the experimental data to write up the manuscript about it and try to shape the story as he sees fit"*, but he also added that *"it is the responsibility of the PI to edit it"*. Most PIs seem to agree with this and involve their team members in producing manuscripts. One PI said that she has the people in the lab make presentations about the data early on, and that forms the basis, then she orders the presentations logically and it becomes the script for the paper. Another PI said that he asks the student/postdoc to write up the paper and then there is a lengthy interchange between him and the first author about how best to shape and tell the story. Such involvement is also great preparation for your team members to become independent investigators later on. One junior PI lamented that it would have been great if her previous supervisors had let her write more papers because now she has to do it on her own with having written only two.

Although you need to arrange the data in scientific publications into a story, it needs to be an honest story. *"I will say as much in the paper as much I can say based on all the available data"*, said one PI, and another also recommended to *"never hide data"* and *"be completely honest about the truth, limitations, failures"*. However, writing a paper is not the same as documenting your experiments. One PI called producing a manuscript an artistic process because *"you never write the paper how the research actually happened—although you do not lie, either"*, and another PI also said that the best way to tell the story is not necessarily the order the results were generated: *"The last figure of the paper many times was the first to be made!"* He explained that he does his science *"backwards"*, filling in the details afterwards.

On the other hand, some PIs prefer a chronological account, if possible. One of them said that he wants to tell *"a story of discovery"*: he starts with contrasting some data from his lab with the current view in the literature to demonstrate that there is a problem somewhere. Then he describes the process they went through to arrive at the new conclusion.

Producing a manuscript is difficult, don't worry if you are not a natural at it. *"This takes time and learned with experience!"* said one PI about the process. *"I am better at it now than I was five years ago"*, she added.

Building the Big Picture

Many PIs used the jigsaw puzzle analogy to describe how their research works and how they approach putting manuscripts together. But there are at least two ways of completing a jigsaw puzzle: you either know what the picture is or you don't. If you know what the picture will be at the end, you can already place the pieces approximately as you find them. If you have no idea what the final picture will be, all you can do is check if the pieces you have fit together or not.

Similarly, PIs seem to fall into two categories when it comes to building a manuscript: those who use the picture on the box of the puzzle as a guide (they work from the hypothesis laid out beforehand in the grant application) and those who take the pieces they have and turn them around until they find interlocking ones and make up a picture that way.

Deduction

Having a hypothesis helps to design experiments and to organize the work—plus, you already have an idea about what you want to communicate with the paper even before the project is complete. Several PIs said that they use the original experimental design as the framework for the paper. *"You know where you intended to go"*, said one of them, pointing out that you have already done the work of devising experiments to prove your hypothesis in your grant application. *"There was a purpose, a plan to begin with. Do the results fit? If they do, then it's easy"*, as one PI put it. If the data agree with the framework laid down beforehand (not necessarily in all the details but in general) then the paper will be an extended version of your grant application, filled in with the experimental results you generated during the project. You hang the data generated during the project on the original framework like you'd hang decorations on a Christmas tree.

One PI described his process like this: *"First, there is a concept, a thought, then we compose, devise a well-formulated question. This question guides the construction of the hypothesis, which leads to devising ways the question can be answered. At this point it becomes like an algorithm: if the result is this, we go this way, if something else, we go the other way..."* Depending on your "algorithm", things may get complicated, though. Another PI said that although she always starts with a low complexity paper in mind, as the analyses come in and she plans more experiments, things may branch out in several directions. *"It may get complicated at the end"*, she said.

If the original framework turns out to be not correct, things will take longer. *"In this case, I have to consider more facts and have to read more literature to find out* *what could be the alternative framework"* explained one PI. *"This usually involves a lot of reading"*, he added, and he reads not only in his discipline but in the neighbouring disciplines, as well, to find analogies.

Induction

Not all projects start with a detailed hypothesis in mind and some PIs prefer to manage projects more organically: start with a question, get data to answer it, formulate the next question based on the answer. . . etc. The pile of results (questions plus answers) you get, however, also need to become a logical story for publishing them. You will need to come up with something that explains all the experimental data and binds everything together. *"This happens in my brain"*, said one PI, *"I have pictures of all the different results, and at a certain point when a new incoming result arrives, it all suddenly starts to make sense"*. She added that such "aha" moments can also happen during lab meetings or informal chats about the results: *"somebody says: 'if you look at it this way', . . . and it suddenly makes sense"*.

"We look at the overall big picture. Many different things connect to make a story, even if they don't initially seem to be related. It's all part of a complex jigsaw puzzle!", said another PI. I have witnessed a PI producing a brilliant paper because he realized that by recycling the results of a project that were otherwise not very exciting, with some additional analysis, he could demonstrate much broader principles than the original project was about. Because of its general significance, the paper was published in a journal with a much higher impact factor than what the original project could have hoped for.

"By the time of writing up the paper I have regurgitated all the data many times to have a good feeling of what the story is" described one PI the hard labour of giving birth to a story. It is worth it, however: *"When I have a pile of results, it takes some time until I see a story! But when that happens the paper or story becomes unstoppable"*, as another PI said.

Start Early

Whether you will produce your story top-down or bottom-up, you will need well-documented puzzle pieces. Several PIs recommended starting to organize the data early. One PI had this advice: *"I tell students to start to make figures early, [. . .] Start with the hypothesis, the hints that if may be true (patient data, e.g.), then start organizing the results in a logical way as early as possible—this guides the next experiments. It is nice to be chaotic, but it does not help—be systematic as early as possible." "Coming up with a figure proposal is the best exercise: can you make a figure out of the results? It shows you what is missing"*, said another PI. A third PI also said that he is making figures from all data from the start of the project. *"This is also a great way to remember data because you get a constant visual refreshing"*, he added.

The opinions of PIs about when to start the actual writing process varied, on the other hand. One PI said that she already makes bullet points of what the results section of the paper would look like from the beginning even when she has only partial results. Another PI, however, said that he does not encourage his students to start to write the paper from the beginning of the project, because he thinks *"this is dangerous: it may narrow down, constrain imagination"*, and manuscript writing should start at a later stage in his opinion. A third PI seemed to take the middle road: *"somewhere in the middle of the project, we start writing the manuscript (either in our head or on paper)"*. Whether you are concerned about biasing yourself by writing down your hypothesis or not, several PIs said that it is a good idea to structure what you know already because it helps to see what is missing. *"I tend to doodle, draw relationships"*, said one PI.

Even if you have a firm idea of what you want to communicate, you may realize that there are holes in your story, warned several PIs and you might realize that you need more data as you try to write it up. *"It gets more concrete when I start writing: I like to outline the paper when I have most of the results, then I see how to complete it, what additional experiments are needed"*, as one PI said.

Shuffling Things

Whether you work deductively or inductively, you may need to re-shuffle the pieces to adjust the storyline for two reasons: you either find a better, more logical way of telling the story or you realize that you made a mistake when you were putting the story together, be prepared that the picture may change during the writing process. As one PI put it, *"the story does not arise from the data by chance but by trying on several stories, re-shaping them. It is possible that you end up with a different beginning and end and the same middle!"*

If we go back to the jigsaw puzzle analogy: if you think you know what the final picture will be and are already placing pieces approximately in the frame, be ready that you may have to shift some of them either because your original placement was not correct or because you mistook a blue piece of a pond for a piece of the sky, for example—or you realize that you were looking at the lid of the wrong box and the picture is not at all what you thought it would be.

One PI gave this fascinating description of how he is working the storyline out: *"I shuffle the data around in my mind until I find an angle that ties everything together. It is like a puzzle, it floats in my mind until it all clicks together. When it is done in my mind, it is hard to change the order, so I sit down and start writing"*. Sometimes this is when he realizes that a certain element is needed. Another PI also said that finding the storyline is like solving a puzzle, it keeps him awake until he solves it.

Consistency

Eventually, you settle on a storyline. The big picture told by your story may be off but you cannot help that because nobody knows what the big picture is supposed to be, or as one PI put it, *"these are riddles that nobody has the answer for"*. You can ensure, however, that your story is consistent within itself. This is how one PI described how he ensures consistency: *"I stare at the results, I ask a question and stare again at the results and repeat that until I run out of questions. Then I discuss with everyone involved"*. Another PI's advice was: *"Hang results on the theory, the interconnection of the data makes the theory: if it is waterproof, you are on the right track"*.

When to Stop

The PI who compared building the story to an algorithm also said that *"... except, this algorithm has no ending because when we answer one question, several others pop up"*. Another PI said that "*the difficult part is to know when it is enough when to stop and publish"*. She added that *"sometimes this becomes a practical decision because the student needs a paper to graduate or is leaving the lab and would like a publication before leaving: in these cases, we look for the minimum publishable unit that could be made from the existing data"*.

Even in the absence of such pressures, it is important to know *"when to stop and publish that story because stories can be never-ending and we need publications to be able to continue to get funding to continue those stories"*, as one PI warned. You will have to decide where to draw the boundary of the story.

The PI who divided the process of producing a paper into *"the what, the how, and the what is the story?"* phases offered this advice: *"You go 2nd or 3rd degrees away from the original observation to see where to end the story. You continue building the story to the point where things get shaky, that is where you stop"*. This seems like a way of determining the boundary of a paper from within the context of the paper itself but there was another PI who likes to consider the paper in the context of the body of publications coming out of his lab. He said that *"we close the paper at a point where it can serve as a foundation of further publications"*.

The Process

Many PIs described not only their intellectual approach towards constructing the story but the actual mechanics of how they work on the paper, as well.

Some PIs said that they start with the "punch line" of the story. *"[My mentor told me to] always work on figure 7 first and make it into a detective story"*, said one of them, and another said that *"the process is directed by the rules of storytelling, it is not linear"*. He takes the main figure (*"the jugular figure"*, as he called it) which may be *"discovery out of context"* then he asks himself and his lab: *"How do we tell this story? What do we open with and why?"*

There were a few PIs who start with writing text (these PIs usually said that they are not very visual). They either write the results section or the introduction to establish the main flow of the paper. This first version may not be very elaborate, it may consist only of a few lines that the PI wants to convey as the conclusions of the paper or it may be full-fledged text describing the results. One PI said that he may ask the first author to come up with a first draft of the text, depending on the writing skills of the person. Although this is great training for the team members, he admitted that *"sometimes it is more effort to re-write a bad first draft than do it from scratch"*.

Most PIs, however, start with producing the figures. They may produce the figures themselves (one of them said that she loves *"the precision of graphic design"*) or they may collect the figures made by their team members.

Some PIs start with a chronological order of the data. Starting with a visual reconstruction of the history of the project does make sense since there was a logic behind the succession of experiments but PIs often conclude that this is not the best order to present a logical storyline. There is usually a shuffling process to find the best way to structure the results.

As we discussed before, some PIs start with asking themselves *"what do I want to say?"* and they arrange the data to tell their story. *"Sometimes I go back and redo the figures to show the new message I want to convey"*, as the story emerges and sometimes changes, said one of them. Others start looking at the data and ask themselves *"how do you make this into something interesting?"* Some PIs maintain the same logic in all their papers (e.g. *"First in vivo, then in vitro. First similarities, then differences. Big to small: mouse, then organ, then tissues"*, as one PI delineated it). Whatever way you construct your story, at the end *"it has to be a complete story with a beginning, middle, and end—in crescendo!"* as one PI put it, or as another PI put it, it needs to be like *"a man goes into the café…"*.

Many PIs use hard copies of the figures that they spread out on their table or on the floor to have an overview. Two PIs said that they print out all the data and write "headlines" (little titles, containing partial conclusions) or the question that the data are answering on each sheet—this becomes their "story board". A third PI also said he has an *"old-fashioned writing style: literally cutting and pasting data on a big board"*, shifting things around until he is satisfied with the flow. There are, however, PIs who prefer to do this process electronically, they put each piece of data on a separate slide or board and they move them around and group them (like panels in a complex figure) on the screen.

One PI said that she tries different orders together with two or three colleagues, other PIs do the shuffling process by themselves and then consult colleagues. You will have to consider not only how to order the data but also how each one of the figures contributes to the story—you may decide that some hard-produced data will end up as supplementary data because their contribution is not that strong. In such cases, it helps that *"as the distance from the bench increases, you get less emotional about the data"*, said one PI.

As I mentioned, there are few PIs who start with writing the text even before settling on the order of the figures but most PIs “fill in the dialogue” once they have settled on the most logical order of presenting the pieces of data. They usually proceed with deciding what claims they can make based on the data and write the results section. Some adjust the storyline even during this process as they find even better ways of telling the story and even re-doing some figures may be necessary. *“The figures can change but not the data”*, said one PI.

After the results, PIs write the methods and the intro section, leaving only the discussion to be written. The discussion represents the narrative component of storytelling, it is the point of view of the author that puts the results into context. One PI said that she likes discussing each result within the results section and not presenting a discussion only at the end of the paper but if they write a separate discussion, most PIs leave this for last. As one PI said, she likes to write the discussion *“at the very end to make sure it is timely and addresses open questions in the field at the moment”*. Another PI said that he stops writing the manuscript for two weeks to two months before tackling the discussion. He finds the rest period very helpful because *“it sediments the value and order of the results”*.

Unfortunately, *“there is no perfect recipe: put things down on paper and spend time with it!”* as one PI said. With a few exceptions when the *“paper writes itself”*, most PIs report that the story emerges, evolves gradually. You will just have to try to write the results up and see where they take you.

Reaching Out for Help

Nobody is an expert in everything, sooner or later we all need to ask somebody else for help. I know that I tend to delay asking for help from others, and this causes me to progress slowly with some problems, therefore I asked PI how they decide when they ask for external help.

Always Collaborating

For about a quarter of the PIs, collaboration seems the default way of working. *“I always seek help! I have not published a single paper without outside help”*, said one of these PIs. *“I have no barrier whatsoever to ask for help—if I did, I would be a hindrance to the lab”*, said another one. *“All the low-hanging fruit is gone, things are very complex, you need a team to work”*, said a third PI.

For these PIs, collaboration is *“not a question of needing it, but wanting it”*. They could make their own decisions, but they see value in discussing everything before they make their own decisions. *“I believe that we have to talk about what we are doing. Not for being reassured, but to find the most efficient way to find the answer. You have to read, read, read, and go to meetings to find the most elegant and efficient way. The pressure to publish is so great that you have to be efficient”*, summed up her motivation to collaborate one of them. *“I do not hesitate to seek help,* *collaboration, I am very extrovert about this. The time of individual science is over"*, added another PI, and third said, *"it is insane to do everything yourself"*.

Some PIs mentioned that they are happy because they work in a very collaborative environment. One PI even pointed out that the institute he is working in is deliberately designed to lower the barrier for collaboration: there are over 100 labs on top of each other, not even organized in departments. He goes to the next lab or contacts outside labs immediately when he wants to collaborate.

Going It Alone

On the other hand, some PIs usually do not get external help. *"The only case is to help students to get up to the task: I hire English teachers for them, [I organize] statistics classes"*, said one of them. He hires people to perform any task that is not necessary to have within the lab (e.g. sequencing). Another PI also said that he is reluctant to ask for help. *"I like helping people but I do not like to be helped, because I do not want people to think that I am weak. I want to show that I am strong and able to solve problems myself"*. A third PI, on the other hand, said that although naturally she also wants to solve everything herself, she came to the conclusion that it is really important to seek external help therefore she forces herself to do it. Being a PI, she has more of a network to ask now. *"I have learned that it is okay not to know something"*, she finished.

The reasons mentioned for hesitating to ask for help had to do with keeping the project in control, especially avoiding major delays. *"You can't always be dependent on other labs for everything, since everybody has their own timelines"*, said one PI. *"Collaborations are interesting, but also problematic: sometimes there is a lot of enthusiasm at the beginning, and then no follow-through"*, said another PI. Perhaps this is why several PIs said that they prefer collaborating within their institute: it is easier to put pressure on another lab if they are on the same campus than if they are halfway around the world. Ironically, keeping control over the timeline of the project was also one of the reasons listed for collaborating: some PIs said they resort to approaching someone else for help if the data is needed but they have not been able to produce it for a long time.

There Is a Trigger

Most of the PIs were somewhere between these two extremes and they described themselves as having *"a medium barrier against going to others for help"*: first they try to resolve problems themselves and when they reach a certain threshold, it motivates them to seek outside help. They have mentioned various "triggers".

The most often mentioned reason for asking others for help was lacking the technical expertise needed. *"When people have a specific expertise, it is so much easier and more efficient to ask, it saves time"*, stated her reason for reaching out to somebody else another PI.

For other PIs, the trigger that motivates them to ask for external help is related to the time spent trying to resolve the problem or a feeling of "being stuck". The thresholds varied widely: several PIs said that they would not spend more than a few weeks before asking for help, but one PI said she might go 6 months trying if she feels that her lab should be able to resolve the issue. But even she said that if she had the feeling that the issue is beyond their expertise, she would be quick to ask for help.

It may surprise you, but sometimes PIs feel overwhelmed, too. *"When I am not capable of managing everything, when I notice that I am forgetting things: it is time to delegate"*, said one PI, and others also said that feelings of overwhelm can drive them to ask for help. *"I am quite self-reliant, I work at getting along by myself quite a lot"*, said one PI, but when she feels overwhelmed or she is stuck about finding a solution, she looks for somebody to help with the project. *"I feel it when I need help"*, said another PI, as well. *"There are warning signs like negative feedback or assessment from colleagues or evaluators"* he continued.

New Methods

PIs seem most comfortable with reaching out to others for technical expertise. *"If it is something I have never done before, nine out of ten times I ask someone for help"*, said one PI. If the technique turns out to be vital, she transfers the technique later on to her lab. *"The questions to ask are: 'what would it cost us to set this up?', and 'do we need this expertise once, or are we going to use it in the future?'"*, said another PI about deciding whether to set up the required new method in her lab or ask a collaborator to analyse the samples. *"If it seems to be a one-time need: I send the samples out to another lab or I send one of my people to do the measurements at another lab"*, agreed another PI. But if he thinks that he will continue to need the method in the future, he tries to set it up in his lab, because *"it is better not to be dependent on anybody else for core activities: the basic things have to depend on us only"*. Other PIs also said that if they think that the technique will benefit the lab in the long term, they get the capability inside their lab. *"Whatever I consider core business, I like to keep it in the lab, even if it is available next door"*, said one of them.

Even if they want to install the method in their own lab, many PIs prefer going to an expert for help instead of struggling on their own. Many mentioned sending their people to other labs who are experts in the method.

Guidance

It seems easier for PIs to reach out to others for technical help. *"For thinking, it is more difficult because it needs lots of investment from others"*, said one PI, *"and it also hurts my pride"*, she added. It does happen, however, that PIs need guidance not for performing a particular experiment but for conceptualizing a problem. *"When I do not understand something, when I do not have experience in something, when I* *have difficulty interpreting the data or when I hit a bit of a roadblock"*, listed his reasons for asking for help another PI. A third described his method for deciding in the following way: *"I rely on the same awareness that is the core of leadership: when I can't back my own opinion with data, I need external help"*.

We, as scientists, figure out things that nobody has figured out before us and this can give us the feeling that we can do anything. But, as several PIs pointed out, *"it is important to know what you know and what you do not know"*. The problem with taking on issues out of our expertise is that we may spend a lot of time on them, time that could be spent more efficiently. *"Physicians are trained to recognize the limit of their competence, and I am bringing the same attitude to my science"*, said another PI, an MD-PhD. *"I know what I know and understand—if it is beyond, I contact somebody immediately, preferably here on campus"*, said a third PI.

The most often mentioned request for guidance was getting second opinions on grant applications—although this may depend on the overlap of interests: one PI said that she still asks her mentors to read her manuscripts—but not her grants! *"I usually think that I need external help"*, said another PI, *"I ask people: 'is this a good enough question?' and count on the opinion of my colleagues—not only elder ones but juniors, as well"*. A third PI said that she consults the strategic advisory board of the meeting she organizes about her research plans.

Sometimes *"the data will tell you to enter a new field"*, said one PI, and he suggested asking for help *"when you want to follow your data, when you have no experience in a field, when the data seem to make no sense"*. He added that one of the keys to the success of some research institutes is that they have *"a critical mass, a set of researchers that represent a wide range of expertise"* which makes it easy to find expert advice within the institute. Other PIs also said that they look for an expert when they come in a new field and they feel that they do not know enough about it. They may even call people up to ask them "what does this mean?" if they are not sure about the interpretation of results.

Keep Your Threshold Low

As we have seen, PIs have varying degrees of collaborative spirit in them. Several PIs regretted not asking for help more often. *"I ask for help only if it is really serious. I should do it more. I mostly think that we can tackle problems alone: 'we, the team, can do most'—this is not always wise"*, said one of them.

Another PI said that she was surprised that people did not ask for help more often. She thought that the two main reasons why PIs did not ask for help were insecurity and not knowing that help was available. In agreement with this, others said that they learned to collaborate more during their career. *"I am getting better at it"*, said one PI. *"I used to want to do it all by myself, but as I gained confidence, I can see it more clearly what I can and what I can't do"*, she added. Another PI also said that *"it used to be harder to ask for help"*, but now he collaborates easily and goes out readily to seek help. *"I see the big picture better and seeking out input is easier"*, he finished.

"I like to stay independent", said a third PI, *"but sometimes I need help to maintain my independence!"*

"Don't work alone. You have to have a good team and good collaborators. Make as many collaborations as you can", was the straightforward advice of one PI, and another said that she teaches her students that being able to find help is more important than being able to figure out the problem themselves.

Addressing the issue that people may not be aware that help is available, one PI said that *"if you want to do something and you don't have the expertise: look around what people are doing, especially in your immediate surroundings. Go and ask! Collaboration is key in most projects. Successful people are able to take advantage of their environment and avoid isolation. Collaborations are helpful and fun!"* He said that he benefited a lot from getting advice from more experienced people, and he continuously seeks advice: how to get ahead and how to avoid pitfalls.

How to Ask for Help

It may feel intimidating to go up to the Big Professor at a meeting to ask for her or his help. *"Face to face is not that comfortable"*, admitted one PI about asking for help. But she finds it easy to approach people by email, and you don't have to ask in person, either. *"I think better in writing, gives me more security because I can prepare myself better"*, she added. Also, remember that *"people sometimes are busy, have a lot of other things to do, so you need to pursue help until you get it"*—the first person you ask may not be the one who ends up helping you.

Top Publishers

Collaboration may be good for publication output, too. Two-thirds of the Top Publishers said that they tend to collaborate and none of the PIs who indicated that they were reluctant to seek outside help belonged to the Top Publisher category. The number of co-authors also contains clues that a collaborative spirit may increase publication output, Top Publisher PIs amass a bigger network of co-authors. They publish with several-fold more co-authors each year of their career: the median values were 128 vs. 21.9 if we normalize by the years they spent as a PI, and 30.7 vs. 15.7 if we normalize by the number of years they spent as a PI, and a postdoc combined for Top Publisher and Non-Top Publisher PIs, respectively (Fig. 5.2). Top Publisher PIs tend to have more co-authors per publication, as well (median values: 5.88 vs. 3.48 for Top Publisher and Non-Top Publisher PIs, respectively, see Fig. 5.3). Although there can be other interpretations of these differences than more collaboration by Top Publisher PIs, the mentioned differences in the size of the co-author networks is not explained, e.g. by the size of the group of Top Publishers. The median size of the groups of Top Publishers was only slightly higher than that of Non-Top Publisher PIs: 9.4 members vs. 8.5 members, respectively, see Fig. 5.4).

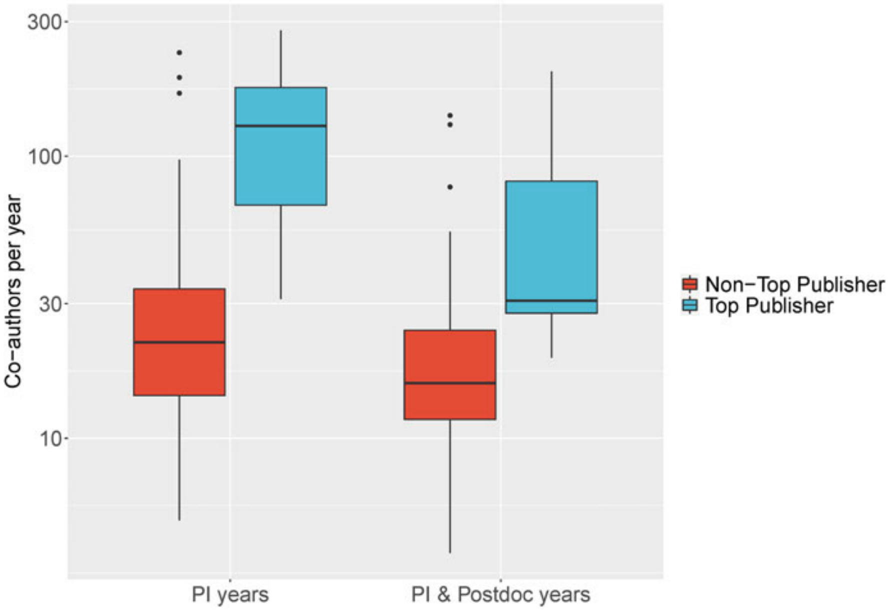


Fig. 5.2 Top Publisher PIs publish with more co-authors each year of their career. The number of co-authors was normalized by either the number of years they have been a PI ("PI years") or a postdoc and a PI combined ("PI & Postdoc years"). $n = 25$ for Top Publisher PIs, $n = 81$ for Non-Top Publishers. Please see the Methods for details

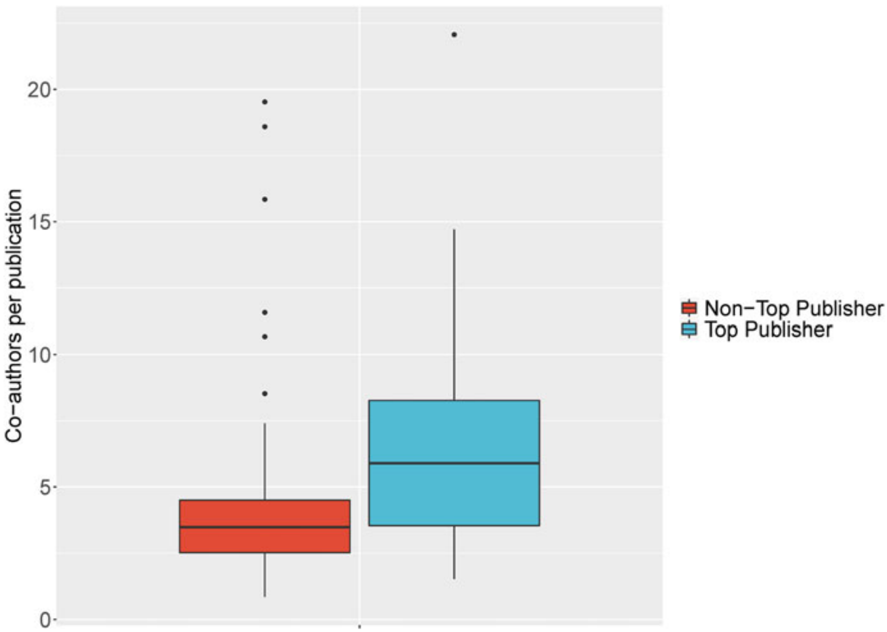


Fig. 5.3 Top Publisher PIs have more co-authors on each publication. $n = 25$ for Top Publisher PIs, $n = 81$ for Non-Top Publishers. Please see the Methods section for details

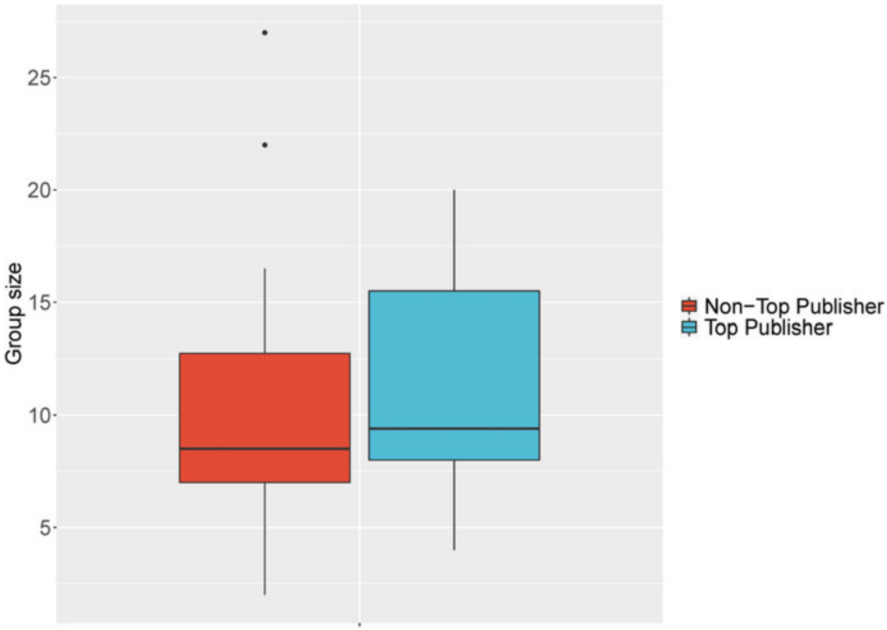


Fig. 5.4 The teams of Top Publishers PIs are only slightly larger than those of Non-Top Publishers. $n = 15$ for Top Publisher PIs, $n = 47$ for Non-Top Publishers

Planning Collaborations

As we saw above, collaboration is a must. But it is not obvious how to harmonize the activity of the labs of two PIs who may have very different interests, goals, and styles. Therefore, I asked PI that if they start a project together with somebody else, would they prefer that the project was outlined, planned and orderly or would they prefer that they were able to be more flexible in the project?

Very few PIs (6%) preferred outlined and orderly projects, almost half (44%) preferred being flexible, and the rest (50%) wanted both an orderly outline and then flexibility to adjust the project.

The people who chose flexibility emphasized that it is very hard to plan in science. Some admitted that they are disorganized and not like planning, but most said that the outcomes are unpredictable—this is why we are doing the project in the first place, and projects can take unexpected turns very early on. They wanted to see the outcomes and follow them wherever they lead (as one PI put it, she preferred when projects could *"grow organically"*). Another PI said she was very naïve and very positive minded: she believes that she can pull off things others cannot. *"When I hit the wall, I know that it is time for new ideas, but a positive attitude wins!"*, she said and added that in this kind of project management, the most important factor is trusting your collaborators.

Other PIs mentioned that they do not like that currently, grants need to be perfectly structured—the written plan is only useful for outsiders to judge the project. When at the end you compare the grant as it was written and the project as it was performed, usually there is very little overlap. One even said that *"if in the next five years you do exactly what you planned, it is a bad project"*. Others said that as long as you have a global plan and good people to work on the project, it will be successful (as we already discussed in Chap. 1, the people working on a particular project have a great impact on success).

The people who wanted both a plan and flexibility had the most comments—this may be an indication that the most thoughtful people are the ones who are not on autopilot, doing things a certain way just because that is the way they have always done it, but those who can adapt their behaviour to the situation. These PIs said that projects need a focus, a clear aim, and a structure of how we get there. Many said it is important to have a clear plan at the beginning, especially when several partners are involved: describe the roles of the partners clearly, decide beforehand who will do what and decide publication arrangements, e.g. who the first author of the paper will be. It is important to fix these details because if one party should not deliver, others get frustrated. One PI, who was very focused on publications, said that an outline is needed at the beginning already, like *"What would be the title of this paper?"*. *"One weird result can change the paper"*, he admitted, *"but the goal is the paper!"*

The bigger the project, the more planning is needed—otherwise nothing will happen. Having a good plan is also useful at the start to convince others whom you want in your consortium—so have a plan, then be very open. A good trust relationship is essential, but it also helps if you define the role of all partners beforehand to avoid problems of collaboration later: this way, nobody takes advantage of the other. Since the data are unpredictable, decide that you will publish together in any case, for example, whether data provided by a certain partner ends up in the paper or not!

Start with a good outline (*"you have to aim to hit something"*, as one PI put it) but keep in mind that the plan will change and you should have no problem with following an interesting path later. Since rarely anything works out the way you expect, you can plan out only to a certain point. It is useful to have some what-if trajectories, but on the other hand, as one PI put it, *"the hypothesis is a sum of multiple smaller hypotheses, which all can turn out to be wrong, and the hypothesis becomes a tree of possibilities"*. One PI said her lab moves by an iteration of the two approaches: they revise projects periodically and depending on the data, they reconsider the goals, as well, sometimes changing them. One PI pointed it out that there is tension between her duties to the postdocs (requires flexibility) and her reporting duties to the funding agency (requires sticking to the plan).

The amount of planning needed also depends on the previous relationship with the partners: the more they have worked together and the more trust there is between them, the less planning is needed (building the relationship takes time, though). Overall, the advice was to start with a plan and then be flexible to change it, depending on the data you obtain. It is important to leave some wiggle room because science is unpredictable.

Communicating with Others

We have already discussed the preference of PIs regarding communicating with their group (meetings and talking with underperforming employees, see Chap. 4), but PIs will have to communicate with others in many other situations, like talking with colleagues, collaborators, or the higher management of their institutions. I asked them, whether, in general, they prefer direct communication, laying their cards on the table, so to speak, or they are less direct, more hinting at what they want?

Similarly to addressing the problem of an underperforming colleague, most PIs (76%) preferred the direct approach in general. The people who prefer laying their cards on the table (in their professional life) said that they do this either because this is their nature (one said that *"I can't keep things to myself"*) or because they find this advantageous since communicating directly is faster and leads to fewer misunderstandings. One PI said that his favourite phrase is that English is not his mother tongue, therefore he will just say it simply, and another of these PIs said that *"I do not like to play games because I do not trust my tactical sense"*.

There were several PIs, however, who, although they prefer to communicate directly, may choose to say nothing in certain situations. One PI said that whether he will contribute to a conversation "*depends on what I think the impact will be: if I think what I say will make a difference, I speak up directly. If I think that my comment will not make a difference, then I will not say anything or only give a hint"*. Another echoed this saying that *"I have learned to keep silent and listen more. When scientists promote their results too much, it comes back as a boomerang"*.

Actually, several PIs who communicate directly saw this as a fault in themselves and thought that it might be advantageous to be *"more mysterious"*. One PI said that *"I am too open: I tell people unpublished data. This has proven dangerous because the data could be wrong or other people can run with the idea"*. Both have happened, he added.

A minority (14%) who preferred the indirect approach said that they do this to let other people around them *"have a sense of ownership of the project"* or they find being less upfront a better position for negotiating. A few PIs (10%) said that they use either approach, depending on the situation. For example, one PI said, *"[when] I am negotiating with a junior colleague I am upfront and I hint when talking with senior colleagues"*, and another said, *"I lay my cards on the table with people I trust and am indirect with people I do not know or do not trust"*. Finally, one PI said that *"sometimes I delay relaying certain information to my team because I do not want to overwhelm them"* (e.g. their lab will have to move).

Top Publisher PIs were more likely to use a direct approach to express what they want but emphasized the importance of being kind. There was no Top Publisher PIs who answered that they use the indirect approach exclusively, and they mentioned that their approach may depend on the topic or the level of trust they feel towards the persons present,

Talking Things over

As a PI, you will have to make decisions, big and small, all day long (like anybody else). Since many PIs told me that they make quick decisions with their "gut", it surprised me that most PIs include talking problems over with someone else in their decision process.

Only 17% of PIs said that they make decisions based on thinking about the problem solely by themselves. 22% indicated that they talk problems or challenges over with others, and 61% said that they do both—although the order could be either way: first talk things over with others and then think about it themselves, or the reverse. Some even do several iterations. . .

The PIs who include talking things over with somebody else in their decision process indicated that this is like *"thinking out loud"* for them that helps them to *"get the picture sharper"* and it is also a good way of testing their ideas and tapping into the ideas of others. One PI emphasized that this is his way of expressing that he *"does not see his employees as subordinates"* but as partners.

As mentioned, only a minority of PIs said that they consider their decisions by themselves only. When we look at their comments, it seems that even fewer PIs decide things this way by choice. Some mentioned that they decide by themselves either because of time constraints or because they do not have the right people around them to discuss things with.

> *"Nothing clears up a case so much as stating it to another person." The Memoirs of Sherlock Holmes by Sir Arthur Conan Doyle (1893)*

The majority answered that they both think about the solution by themselves and talk the problem over with others. There was no consensus about the order or the number of cycles: some start with mulling things over in their head (*"playing mental chess"*, as one PI called exploring all the possibilities in her mind) and others start with discussing the problem with others. The reasons for involving others were various: *"I reach the limits of my own knowledge quickly"*, said one PI, and another said that *"on your own, you go nowhere"*. The people they most commonly use as a *"sounding board"* for their ideas can be their team members, fellow scientists, spouses (especially if the spouse is also a scientist). One PI said that he likes to do "verbal sparring" over grants with somebody in his department who is from a different field, not a scientist.

Some people may be concerned about sharing their ideas with others, but this is the advice one PI offered about that: *"Do not be afraid that others steal your idea, they will give you other perspectives, they will improve it. After all, it will be other people who score your grant, not you!"*

Moreover, for some decisions, *"it does not have to be an expert in the topic, but someone I trust and knows me"*, said one PI, adding that he sometimes gets advice from his wife or a friend. This may be especially helpful when you need help with management issues. Another PI also said that *"it is hard to know whom to ask"* in such cases, and he added that seeking the help of a career coach can be a good way to clarify the issues.

Top Publishers were even more likely to talk to others before making decisions.

The next chapter is dedicated to dealing with things not working out as planned and other stressful situations. Although such matters occur daily in the life of PIs, managing them is so important for PIs that it deserves a chapter by itself.

6 Dealing with Failure and Stress in Academic Research

Abstract

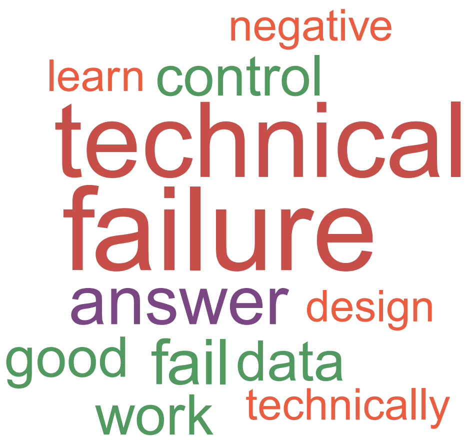
You know by now that the daily work of a PI is extremely busy, full of stressful situations and the nature of doing science is such that failure is the rule, not the exception. In this chapter, you can find the answers of PIs to questions about experiments not working out as planned, their attitude towards published, but irreproducible results, as well as how PIs handle stressful situations, and how they recover from all of this so that they can do it all over…

What Is a Failed Experiment?

Everybody who has done experiments in biomedical science knows that things often do not turn out as planned. *"You need to be frustration-resistant"*, said one PI, *"the reality is that success is rare"*. Another PI said that *"the public is not aware of the amount of failure and the effect of failure on the morale of scientists is underestimated"*. She added that *"to the students, even technically sound experiments may feel as failures if they do not produce the desired results—I train them to make the distinction"*. Since your definition of failure will play a great role in keeping your (and your group's) motivation up, let's have a closer look at what PIs consider a failed experiment. The answers covered a wide range from *"there is no failed experiment"* to *"experiments that do not give the expected answer"*. I attempted to group the answers but you will see that the groups add up to more than 100%—that is because many PIs gave multiple definitions for experimental failure and the definitions were partially overlapping.

> *"My least favourite phrase is: 'the experiment did not work'—What does that mean? Did somebody make a mistake? Is it irreproducible? Do we need to change the experimental conditions? It can't be measured? Or did we not get the result we expected?" (professor, PI for over 15 years, over 200 publications, H-index over 50)*

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
https://doi.org/10.1007/978-3-030-85571-0_6



No Such Thing

A few PIs (5%) saw value in all experiments and one even said that she was *"allergic"* to the expression *"failed experiment"*. As one of these PIs put it: *"the students say that 9 out of 10 experiments fail, but I say no: you are building experience to create a better experience!"* These PIs believe that all experiments contribute to the training of scientists, as one of them said, *failure is part of learning"*, and another of them put it like this: *even if the experiment is technically wrong, even if the student did it for the first time, she learned something from it"*, and a third PI also said that *"there is no failed experiment, you always learn something"*.

According to these PIs, failure is possible only on the part of the experimenter: *"A failed experiment is one where we don't learn from our mistakes"*. As several PIs pointed out, doing experiments better is not the only thing failures teach students: they also prepare them for their life in science. *"If you give up on an experiment because it did not give you the results you were expecting then you are not learning from it and that is a huge failed experiment"*, said one PI, and another put it this way: *"frustration is part of the job. If you can't tolerate frustration: you are no good for science"*.

No Information

A little more than a third of PIs defined an experiment as failed if *"no information can be squeezed out of it"* either due to a *"total lack of data"* or because the absence of certain controls precludes interpreting the results. *"I regard only experiments that say nothing as failures. Very few experiments say absolutely nothing"*, said one PI. Another PI also said that *"failure is when there is no output"*.

These PIs had a minimalistic view of experimental failure: *"even if all you learn is that you have to repeat, that is not a failure. Failure is when you get no novel* *information"*, said one of them. As another put it, a failed experiment is one *"that really does not give you any insight. If there was a technical problem, we may still learn something from experiments, total failure is when there is no output"*. "*All results are good"*, said another PI, and a third PI who regarded only experiments that gave no interpretable results as failures said that *"all the rest are facts"*.

Technical Failure

The most common definition of experimental failure was "*technical failure*", a little over half of the PIs mentioned it. This definition of failure includes things like the instrument breaking down, buffers going bad, contamination, as well as mistakes in the way the experiment was carried out (losing samples, pipetting error, forgetting to add a reagent etc.), events resulting in getting either no data or data that is uninterpretable. Most PIs said that they were tolerant to operator error, as long as mistakes are recorded and they didn't suspect that the experimenter was just careless.

The most often-mentioned type of technical failure was a problem with the positive or negative technical controls necessary to interpret the results obtained for the experimental samples. *"If the controls did not work for some reason: this is not even an experiment, this is a waste of time and reagent"*, said one PI. *"I look for robust positive and negative controls—you can't trust data with poor controls"*, said another PI but a third was more lenient: *"an experiment failed completely if there is nothing in it that you can trust. Even with some controls missing, an experiment can give you an idea, it is not garbage*".

Another type of failure mentioned was the poor experimental design: when the technical controls are present but you still can't interpret what the result means because *"the experiment was not thought through properly and some other important controls are missing"*. *"This is a personal failure"*, said one PI—*"if you had thought about it more carefully, it would not have failed"*.

Unexpected Data

Eleven percent of PIs said that they regard experiments that give unexpected results failures. One of these PIs said that a failed experiment is "*when I get very enthusiastic about a new idea, and it turns out to be junk—it happens very often"*. Another PI said, *"I do not make a clear distinction between uninterpretable experiments and experiments producing unexpected results"*, reflecting the view of most of these PIs.

I have been avoiding expressing an opinion regarding the interview answers, but here I make an exception: I do not find it a productive practice to bundle together experiments producing unexpected results with technical failures, for several reasons. First, dismissing experiments producing unexpected results as failures will make it harder to look for and find the clues in the results that would help you to learn from them and modify your hypothesis. Second, repeated failures do wear down your motivation, and even if you have a very high threshold for failure and can handle frustration very well, your students doing the experiments may not be so lucky. And third, some students may just end up giving you the results you expect—and you may never find out that the result was "cherry-picked" to please you.

Failure of Hypothesis

"When the results tell you that you are wrong, this can be difficult to accept, especially if it happens after years of believing in a model", said one PI. Despite this, 43% of PIs said that they do not regard unexpected data as failures. As one of these PIs pointed out, as long as *"the experiment was technically okay, you can learn from it"*. Another PI said that *"if the positive or negative controls are correct, the experiment did not fail, we just do not understand the results—that's what makes science fun!"*

I recommend considering the words of the PI who said that *"an experiment can fail only technically. When you have a big theory, you think you have it all figured out, and then you try to do something definitive, and the theory turns out to be wrong—that is a failure of hypothesis"*. Distinguishing failures of hypothesis from experimental failures will help you to handle them as guide rails that are shepherding you away from unfruitful directions. *"If a direction does not give you the expected results, you need to change the experiment"*, as another PI said, and she added that *"in a way, the more you fail, the more you learn. Unexpected results are interesting and urge you to look for another way to attack the problem"*. As the leader of the lab you will need to guide your people. As one PI said, if *"you get unexpected results, you have to change the system. I feel a personal responsibility to my people in this regard, to guide them to use the correct systems"*. *"Failure is not about an inability to reach milestones or adhere to timelines but about content"*, said another PI. *"If 3–4 assays do not give positive results, it is time to stop"*, he added.

"You always learn from negative results", said one PI and others added that *"robustly negative results are fine, those are not failures"* because *"they rule out something"* and *"they are good to negate the hypothesis"*. *"An experiment is designed to answer a question"*, said another PI. *"If the experimental design in itself is capable to answer the question, that is already a success. If the answer is negative, but the experiment is technically sound, it was successful"*. A third PI said that students need to realize that *"if the hypothesis turns out to be wrong, it's not a failure, only part of the process"* and another PI said that she keeps telling her students not to mistake failure with getting negative data or unexpected data.

Other PIs said how easy or difficult it may be to handle unexpected results may also depend on your field. *"In the past, I worked a lot on molecular interactions, trying to get something to work, and used to think that unexpected results were a failure"*, said one PI. *"With the kind of work I do now, I more interpret the results than anticipate them. I do not have expectations and I am more open to the results. Now I regard technical failures more as failed experiments"*.

Many PIs find unexpected results inspiring. *"The result is the result! Students are bothered by not getting the expected results, I find them fascinating! It makes me* *think of alternatives"*, said one of them. *"If the results are unexpected, it is even better! It is new!"* said another PI, and a third PI reminded that *"we study complex biology, it is normal that we cannot predict what to expect"*. He added that *"some findings stick as rules although they are far from being general: e.g. in genomics, hypermethylation downregulates the expression of only 30–40% of genes yet science has jumped to the conclusion that the hypermethylation is a downregulation signal!"*

Another PI said, talking about a situation when a result is different from the results of all the other experiments, that *"these anomalies need to be examined carefully because they may hide some interesting reason for the differences, and that could lead to new projects"*. Taking negative data seriously can pay off. One PI told me that he has published negative data several times and proudly added that he had become known in his field for publishing such papers. He admitted that publishing such data is very hard, but he thought it was important to invest in it because *"reasonable wrong theories can hurt a field"*.

Did Not Answer the Question

A little more than a third of the PIs had a more restrictive view of experimental failure and considered an experiment a failure if it did not let them make a conclusion: *"If a conclusion cannot be drawn as to what the answer to the original question is, it is a failure"*, as one of them put it. They meant situations when *"you challenge the model but you can't validate or invalidate the hypothesis"* because *"the result is inconclusive: neither yes neither no"*, as one PI put it or *"when you have to say 'I am not sure what that means because...' when you try to interpret the data"*, as another put it.

This is frustrating, of course, since the goal of most experiments is to get an answer to a (specific) question and provide guidance on how to proceed with elucidating the research topic. *"There was a question, there should be a yes/no answer, but there is none"*, as a PI put it. Such impasse could arise because of problems with the experimental design, e.g. some controls are missing that would let you interpret the data (we've covered that above) or *"you are completely off on the dose: you treat mice with something and all of them die; you are in the wrong range"*.

But uninterpretable results can indicate more profound issues with either the hypothesis or with the experimental approach, as well. As one PI put it, *"if the results are unexpected several times: it was not a good question!"* Another PI said that *"if the experiment was properly designed, controls were present, and the experiment does not give you an answer: there is a problem with the thinking"*. He added that during his training he was taught that *"if you can't bring the experiment to be black and white, you do not know what you are doing"*. *"Just looking at the results should be enough to know what the answer is. If you can't get a yes/no answer, you do not understand the assay!"*, he finished.

Another PI had similar advice: *"Experiments can be well designed or badly designed. Failed experiments were badly designed, they failed by your own fault because you did not think it through well enough, e.g. you do not have the right controls"*.

Irreproducible Results

Some PIs consider experiments that do not give the same result reliably as a failure. As one of them put it, if an experiment *"gives you a result, then you repeat it, and you never get that result again: you have to conclude that the first experiment was a fluke. If an experiment is not reproducible, it is a failure—regardless whether it was done in my lab or published by someone"*.

If such an experiment makes it in your publication, that can indeed feel like a huge failure. A PI mentioned having to retract a paper because the results turned out to be not reliable: *"I do not know if it was just a lapse in my oversight or a malignant act. That is a big failure for me. I think it may kill part of my career"*.

Other PIs, had a more nuanced approach to irreproducibility. One of them said that irreproducible results tell you that *"your goal is experimentally inapproachable, [. . .] there are too many parameters that you do not master"* and another PI also said that she considers experiments failures *"when you can't identify some flaw that prevents the experiment from producing a reproducible result"*.

Dealing with Experimental Failure

Whichever definition of a "failed experiment" you adopt, not all experiments will "work". Therefore, I asked PIs what goes through their mind in such situations and how they deal with failed experiments.

It Is Disappointing

While there were (a few) PIs who accept that *"failure is common"* and don't seem to be bothered about failed experiments, most PIs reported having some kind of emotional response to failed experiments. PIs reported going through emotions including disappointment, frustration, anger, feeling depressed or discouraged, feeling annoyed, feeling stressed. Although several PIs expressed that *"it is best to be detached from the experiments"*, I think it's important to acknowledge that having an emotional response is normal, considering how involved PIs are in their projects. *"It is devastating that you are stopped on your tracks, you can't make progress"*, as one PI put it. *"Failed experiments are annoying because you are stuck for no good reason"*, said another PI.

You may also stress over the lost time. *"It is still hard on an emotional level because I am focused on getting publications needed for my students to graduate or* *to put into grant applications"*, as another PI put it. For some PIs, the amount of time and resources that went into the failed experiment make a difference, and as one PI put it, *"one or two failures are okay, . . . if it's longer time, it gets hard"*. Finally, I would like to mention that there were a couple of PIs who said that failures challenge or motivate them to troubleshoot—which I would say is the best kind of emotional response you can have.

Move on

I assume that you will have an emotional response but you need to move on and start thinking about the next step. Refocusing your attention will also help you get over whatever emotions you may have. *"I go through a series of troubleshooting steps that occupy me and keep me from getting emotionally trapped"*, said one PI and many other PIs also confirmed that the worst part of a failed experiment for them is if they do not understand the reason for the failure. Therefore, it is good to *"just stop to think about the reason"*, as another PI advised.

It's Hard on the Experimenter, Too

Before you kick into full troubleshooting mode, I would like to point out that experimental failure is hard on the people who are doing the experiments, as well, not only on the PI who is expecting the results. Several PIs remembered their own experience. *"This used to be very difficult when I was doing experiments"*, said one PI. *"It happens to all of us and it takes courage to do it again"*, said another. *"When I was a PhD student or young postdoc, I was quite sensitive to failure (technical or other) but I was trained to keep on fighting"*, said a third PI.

Therefore, I suggest following the advice of the PI who said: *"First, empathy!"*. *"I express to the experimenter that it is not the end of the world"*, she continued. Also, remember that you are dealing with people in training. As one PI said, *"if the experiment failed because the experimenter is still in the learning process then failure is not a problem—persistence is part of doing science"*. Other PIs also said that they try to support people in their lab *"to not feel guilty about failed experiments"*.

In case you are not the nurturing/sentimental type, I would remind you that taking good care of your experimenters is also part of finding the solution to the problem: you will need their full cooperation to get all the information you need for troubleshooting, and it is a good idea from the viewpoint of promoting replicable experiments, as well (as we will talk about it in Chap. 6).

Several PIs mentioned that they try to uplift the experimenter by diverting their attention to other things going on. *"To the fellow, I point out that we have other things we can do to re-focus attention so they are only disappointed for a day or two"*, said one PI. *"There is always failure—that is why it is important that PhD students plan several experiments per week. Depressing, but multitasking can help.*

Some students are slow: if they do a single experiment, the failure can drive you crazy", said another.

Part of the Business

As many PIs pointed out, failure is part of doing science. *"If you try interesting things, it is normal that you fail sometimes. If you never fail, you are not doing interesting things"*, as one PI put it. You don't have to like it, but *"a scientist has to deal with frustration very well because it is very common. We have a lot of expectations and then we do not have confirmation"*, as another PI said. *"Things always take longer than one would like. Endure and repeat!"*, advised a third PI.

Gets Easier with Time

"At this stage in my career, I have so many lines of research going on that failures are always compensated by successes in other fields", said one PI. *"It has gotten easier, it is not as 'soul-destroying' as it used to be"*, said another PI, and she also added that leading several projects in parallel helps to be fine with experimental failures emotionally. Another PI said that as she's getting older, dealing with experimental failure is getting easier. *"Now I know that I will survive. I 'give time to time'"*, she finished.

Several PIs remarked that being farther away from the bench makes it easier to tolerate experimental failure. *"I am not the one who has to repeat the experiment"*, observed one PI. On the other hand, several PIs said that other types of failures, like grant rejection or paper rejection, can be more difficult to deal with for PIs because they feel closer to them.

You Can Still Learn from it

There was one PI who said that he completely ignores the data coming from failed experiments because he thinks that considering these data would just confuse him. Several other PIs agreed that they can learn from failed experiments and said that trying to learn from failed experiments also helps them to "pick themselves up". This also depends on your definition of "failure", of course, and what kind of output the experiment generated. She added that *"if you can follow through experiments that had technical problems or weird results, you can often learn new things—some of my best work comes from experiments that did not seem to work or gave weird results"*. Another PI said, talking about the kind of "failures" that do not provide the expected result, that *"if the experiment has a valid result but the result is negative, that is important information. This kind of failure provides information"*.

Another important piece of information you can get out of failures is that you may be asking the wrong question. One PI said that if things fail repeatedly, she may have to change the angle she is getting at the problem, slightly change the question she is asking. *"If it's just not possible to answer the question with the type of experiment done: at least we learned that much"*, said another PI.

You Have to Learn from it

One PI said *"I don't deal with experimental failure, it is not my job"* and there were others whose motto seemed to be DIA (do it again) but many other PIs mentioned that they do investigate what went wrong. Simply repeating the experiment may do the trick (e.g. if the reason for failure was operator error) but there are problems with this approach: the experimenter may not draw this conclusion by himself and it will be your lab's resources that are being wasted if the repeat is not an improved version of the previous experiment. Therefore, unless you have people in your group who can do this for you, I suggest you get involved and make sure the next experiments are done correctly when they are repeated.

"It is important to know what went wrong before", said one of these PIs. *"I insist on both better designing and better conducting the experiments. I challenge people to do better, I state that in clear terms"*, said another. As another PI put it: *"I teach my students: if you do not make mistakes, you don't do experiments . . . but you have to learn from your mistakes!"* He and many other PIs discuss the experiment with the person performing it before they move on. They *"dissect the experiment"* starting from the experimental design (e.g., "were all the appropriate controls included?") through the protocol and how the experiment was performed in reality. *"Try to find out as much about the experiment as possible, look at every step. Do not consider only the protocol, but the actual hand-performed procedure"*, was the advice of one PI.

"If you know why it did not work, it's okay", said one PI and this sentiment was shared by many other PIs. Unfortunately, even detailed discussions with the experimenters do not guarantee that the next experiment will be successful but at least you can make sure they know what the critical steps are in the protocol. One PI quoted Walter Fiers (Belgian molecular biologist) who said: *"never get angry about a failed experiment, instead ask what do we do to avoid this in the future"*.

Patience

Troubleshooting will require patience. Several PIs mentioned that although they may be stressed about experimental failure they do not let it show. *"I want to de-stress people, I want to make sure that I know about things not working"*, said one PI. *"Mistakes happen all the time but I want to understand the technical reasons and make sure it does not happen again"*, he finished. Also, putting people under too much pressure, making them afraid to tell you that they made a mistake will not help with ensuring reproducibility in the long run.

Technical Problems

"Most failures are technical, not that difficult to solve", said one PI, and indeed things sometimes come down to simple causes like *"an expired or malfunctioning kit"*. How you deal with technical problems will also depend on how familiar you are with the technique. One PI said that if it is a technique she knows (something established in the lab), she repeats the experiment with the student. Several other PIs mentioned that they find somebody who does the techniques well, either in their own lab or in another lab. *"If it does not work with even external help: I find an alternative [approach]"*, said one PI.

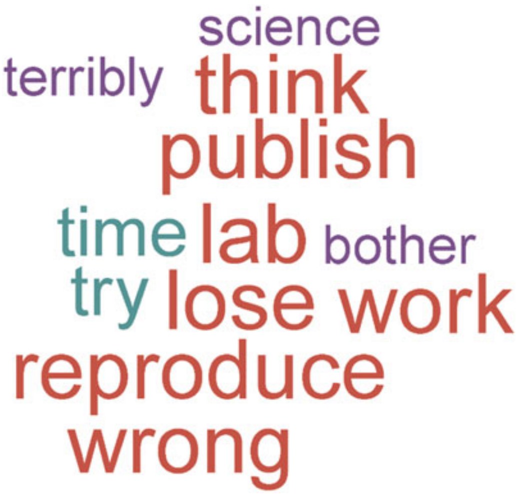
Incompetence

"Either the general design was wrong or the technical performance was botched", said one PI about the causes of experimental failure and many PIs mentioned *"human failure"* as a frequent cause of failed experiments. *"When humans are involved, there will be always technical mistakes"*, said one PI and most PIs are tolerant to *"honest mistakes"*—unless they keep happening. If *"somebody makes really stupid mistakes three times in a row, I get annoyed"*, said one PI and several PIs mentioned that they take action if they suspect carelessness, sloppiness, or sabotage. *"[Some people] always have problems, can never get some experiments to work"*, said one PI, *"they either are not good at designing the experiment or they are bad at bench work"*. In such cases, PIs may find an alternative experiment to perform, re-assign the person to a less challenging project or be more severe: one PI said that *"if the person doing the experiment is not up to the task, I get rid of them"*.

Irreproducible Published Results

Eighty-five percent of the PIs answered a resounding "yes / definitely / of course / absolutely" to the question of whether irreproducible published results bother them. *"30% of publications are rubbish"*, *"up to 50% of the data are not reliable, misinterpreted, or fake"* and *"80% of published results are irreproducible"* were some of the most startling opinions, and many other PIs said that there are just too many irreproducible results. *"They are out there and people believe them: although they are nonsense, some people who are not expert in the field will take the information at face value"*, observed one PI. *"These results can cause a lot of damage, especially, when they make their way into reviews"*, said another PI. *"Every good scientist knows that one publication means nothing but some people can be tricked by these publications if they were published in Nature or Cell"*, observed a third PI.

Some of the PIs are bothered by irreproducible results but they do not get emotional about them. *"I am not a crusader"*, said one of these. But some other PIs are quite bitter, like the one who said, *"the problem is money: money is killing* *science, scientists want money and not the truth, the publishers also want money"*. Irreproducible results can be an especially charged topic for PIs who have tried to use unreliable results as a direct input for their own research or irreproducible results have affected them personally some other way. *"It bothers me that a lot of people publish crap"*, said one PI who was fighting a case over irreproducible results at the time of the interview. *"They are terribly annoying because they can break the novelty of a project and journals and funding agencies use the incorrect information against you"*, said another PI. A physician–scientist PI also said that he is *"terribly irritated"* by them. *"As you move from bench to bedside, you are confronted with it that 90% of the published work is a waste of time"*, he added.



They Are Wasteful and Frustrating

"Irreproducible results are worthless", said one PI, and other PIs pointed out that publications containing irreproducible results are wasteful on several levels: not only was the money spent on producing such publications wasted, but such results are also actively damaging because they set people on the wrong path. *"You assume that there was a competent review before publication and published results can serve as the starting point for other results, projects"*, said one PI. *"We build our projects on what the community has built and when the premise is not true we are in trouble"*, said another one. *"You can end up spending a lot of time and energy going down the wrong route"*, said a third PI.

"[Irreproducibility of published results] causes a major issue in the industry and wastes a lot of time, money and resources that could be better spent elsewhere", said another PI pointing out that the damage is not limited to the academic field. Another PI said that she is part of an initiative of replicating key findings before they are

passed on to the pharmaceutical industry. They do this because, according to her, the pharmaceutical industry is losing so much money on following up findings that can't be replicated that it may cause them to pull out of certain fields. On the other hand, a third PI was not bothered by the inability of the pharmaceutical industry not being able to reproduce most academic results because she does not think they put in the time and effort needed to optimize the systems. She was more concerned about academic labs like hers that spend a lot of time to optimize the system to reproduce somebody else's results, and if they fail, it is a lot of wasted time and money.

"People remember the first publication about something", used to say one of my supervisors, and, unfortunately, this is true even if that publication is wrong. That first publication, even if it is wrong, raises the burden of proof for the subsequent publications. *"Unfortunately, the statement is already out there, and you need to produce more proof to disprove it than you would normally do"*, explained one PI. This is the third level of damage caused by irreproducible result: scientists have to spend more time and money on debunking wrong published results than they would otherwise have to spend on publishing the correct results in the first place.

"Sometimes you have to clean up other people's messes", said one PI lamenting the wasted energy and work required to correct unreliable publications. *"When I have results contradicting published results I know that they will be hard to publish"*, said another PI, because "*it usually takes a lot of time to figure out what the reason could be. We need to figure out why the other lab saw a different result"*. A third PI said that she has just published a paper rebutting somebody else's *"sloppy work"*. *"I lost 1.5 years by doing it and one PhD student quit during it"*, she added. Fortunately, she was in a stable funding situation. *"This could have ruined my career"*, she finished.

Besides causing direct damage by wasting lab resources and people's time, irreproducible results also cause less tangible damage: they are frustrating researchers. *"Researchers who fail to reproduce results usually think that it is their own fault"*, said one PI. *"Most team people are not that confident as they should be and they waste a lot of time trying to reproduce results"*, he added. *"Earlier in my career I was convinced that it was my fault if I could not reproduce something, that it was me who was doing something wrong"* confirmed another PI. *"But not anymore"*, he added, *"now I try to reproduce results and if it does not work, I change direction"*.

They Erode Trust

Another way irreproducible results are damaging is diminishing the trust in the work of fellow scientists. *"I don't start corresponding with the authors or confront them, I just draw the conclusion about them to be careful with what they say in the future"*, said one PI about situations when she cannot reproduce somebody else' results. *"If you can't reproduce, you lose trust in their previous results, as well"*, said another PI.

Unfortunately, the loss of trust can go even beyond the scientific community. Although *"every good scientist knows that one publication means nothing"*, as I have already quoted one PI, the general public can be tricked by these single publications and they will inevitably be disappointed when the results turn out not to be true. Since much of science is done using public funding, it is important that the public feels that they receive reliable information in return. Communicating solid results *"is also important for the public perception of science"*, said one PI. Otherwise, *"laypeople may think that scientists do not think they are accountable"*.

They Are Part of the Business

After this litany of the damages irreproducible results can cause, I have one more piece of bad news for you: irreproducible results are part of research and some of them are just not avoidable. As one PI said, *"there are two kinds of irreproducible results: some of them are just sloppy, bad science (there is a lot of these in the clinical fields that get more money for certain diseases) and there are results that are hard to reproduce. In this latter case, something crucial is missing from the description. It is possible that not even the authors know what it is"*.

Several PIs stated that we need to tolerate irreproducibility. *"Sometimes irreproducibility is due to the reagents, this does not bother me"*, said on PI. *"Sometimes [irreproducibility] is not due to sloppiness or intentional falsification, there is some unknown factor or artefact in the background that the authors are genuinely not aware of—this is part of the business, you need to tolerate this"*, said another PI. A third PI said that *"it is easy to criticize others: if you do things, you will make mistakes. If you go for novelty, you will make mistakes. It is part of the job, you just have to live with it"*. Another PI went even further: *"Real breakthroughs are always stochastic. In any study, there are always weak parts, that is just part of the business"*.

PIs are usually less bothered if some mechanistic detail turns out to be irreproducible. However, "*if the key experiment is wrong, that is bad"*, as one of them said. *"I care less if the 'decoration' (the supporting stuff) is wrong"*, he added. Also, if you are trying to reproduce older findings, keep in mind what this PI said: *"It is also possible that previously published data may have been correct according to the technology it was produced with, but it may be incorrect with newer technology"*. As another PI pointed out, there can be also non-scientific reasons for some results turning out to be unreliable, e.g. the experiment is so expensive to do that nobody will repeat it.

Therefore, if you encounter irreproducible or unreliable results, don't jump to the conclusion that the authors were sloppy or they are knowingly misleading you. The reason can be an honest mistake, it is best to give the authors the benefit of the doubt. As one PI said, when she gets a different answer, she thinks: *"who's to say that who is right? It may be a genuine mistake. We have to acknowledge it but hopefully, it is not deliberate"*.

It's Built in the System

Many PIs said that the way science functions is partially responsible for the publication of so many irreproducible results. Below you can see the summary of the opinions of the interviewed PIs, and you can read about this elsewhere, as well (Fitzpatrick et al. 2018; Bishop 2019).

Lack of Standards

Some PIs identified the problem as *"lacking standards"* in scientific research. *"It usually means that the publication was done quick and dirty"* thought one PI, and another warned that *"the ultimate test of scientific advance is reproducibility"*.

Pressure to Publish

Several PIs blamed the pressure to publish for unreliable publications. *"The system forces scientists to create visibility"*, said one of them and another PI thought that *"when the stakes are high, people over-simplify"*, and another PI said, *"we are ruining science by forcing them [scientists] to publish anything!"*

Too Much Focus on Positive Results

Some PIs said that there is too much focus on positive results in science that forces researchers to find differences at any price. Irreproducibility *"probably means that the effects are subtle"*, said one of these PI. *"Negative results do not bother me, they can carry important information"*, said another PI, *"but scientific results can only be called results if they can be reproduced"*, he finished.

No Penalty

As we mentioned before, high-profile publications can help the career of the scientists who publish them even if the results prove to be wrong later. *"Lots of people make a career out of stuff that is simply wrong because people are evaluated on the short term. Scientists have a standard, and some people breach the standard and get an unfair advantage"*, said one PI.

In addition, there is little to be gained from owning up to a mistake if the authors realize that the information is wrong. One PI told me this story: *"I have also published some results that later turned out to be not reproducible. I thought they were correct when I published them, but later they turned out not to be reliable. On the advice of my peers, I did not retract the paper (it came out in a high impact journal). It is unfortunate that if you publish something you can't correct it without losing face, not even if you have figured out the source of the problem"*. The result is that *"nobody says anything about [irreproducible results]"*, as another PI said it. *"They can disrupt the field but scandals are not acknowledged willingly"*, said a third PI. Another PI said that he is bothered by irreproducible published results a lot, *"especially when people know that the published results are wrong, but they make no effort to correct the error"*.

It Can Happen to Anybody

The truth is that publishing something that later turns out to be wrong can happen to anybody. Many PIs expressed trepidation about this. *"When I see corrections and retractions, I do think: what if this happened to me?"*, said one PI. *"I have never had to retract a paper but I have retracted a manuscript because I was misinformed about the identity of a cell line. This issue is on my mind all the time"*, said another PI. *"I don't lose sleep over [other people's irreproducible results]. My nightmare: something I published is not reproducible!"*, said a third PI. She used to think that irreproducibility was scandalous, and it was a direct responsibility of another lab. But now she thinks that it may be due to cell culture conditions. *"The longer you do science, the less it bothers you. If a work is poorly presented* <u>*and*</u> *cannot be reproduced: that bothers me"*, she finished.

There Are Cheaters

Don't think I am naïve, I know that some scientists do behave unethically. A meta-analysis of studies on various forms of scientific misconduct said that about 2% of scientists admitted to a serious form of misconduct (Fanelli 2009), although the paper indicates that this is probably a conservative estimate.

PIs said that irreproducible results bother them much more if they suspect scientific misconduct (e.g. hiding data or publishing wrong data). Considering the tight academic job market, it is not surprising that PIs get particularly upset if people publishing irreproducible results get ahead. *"The job of a scientist is to try to disprove his own model, after all"*, as one PI said.

But even if the 2% is a several-fold underestimation, the occurrence of intentional scientific misconduct is low compared with the proportion of publications assumed to be wrong (PIs gave me numbers between 30% and 80%, published figures also range from 50 to 90% (Prinz et al. 2011; Bustin 2014; Freedman et al. 2015)). I suspect that the gap is made of papers that made "an honest mistake" or their only mistake is not being aware of all the factors influencing the results.

What to Do about Them?

The high prevalence of results in the literature that cannot be replicated makes it very likely that you will encounter such results in your career. What can you do about them?

If You Cannot Reproduce Other People's Results

"We often are too quick to jump on the irreproducibility conclusion", said one PI. *"When we are struggling with reproducing the results of another lab, I get in touch with them, and often it turns out that it is due to lack of sufficient information in the paper. We simply need more information to reproduce it"*. Another PI also said

that *"the scientific literature of today does not let you separate well"* irreproducibility from insufficient information to reproduce, and he added, "*I get to the bottom of it, I go to the source because I am aware that the information provided in the paper is typically not enough"*. A third PI said that science has been scolded too much about irreproducibility due to insufficient information. *"The answer would be more collaboration"*, she finished.

"In biology, the devil is in the details", said another PI. She added that she had moved the lab twice and experiments stopped working both times, therefore she appreciates that small details (e.g. was the serum heat-treated or not?) can make a difference. She works in a field with a lot of controversies so she adopted the practice that if she can't repeat a result, she invites people to her lab to reproduce it (it has happened twice). They do a student exchange to figure out where the difference is coming from. *"THIS is science!"*, she finished.

Therefore, in most cases, all you need to do is contact the authors for more information. Most PIs expressed that they deeply care about their data being reproducible so you should not be apprehensive about asking other scientists for their help to resolve the discrepancy. Their reaction may also tell you if they are careful or sloppy. Sometimes you may have to collaborate and troubleshoot together but this is not different from any other troubleshooting you have to do regularly, anyway. Start rationally, try to dissect the experiment. As one PI said: *"you are either not doing the same thing or the starting material is not the same"*. Of course, the amount of resources you spend on this troubleshooting will depend on how important the result is for your future research. *"Sometimes, you never find out"*, he admitted.

Educate Your Students

"[Irreproducible published results] do bother me somewhat but I accept that not everything you read is true", said one PI—transmitting this simple lesson to your students will go a long way to teach them to read papers critically. Another PI also said that her students often do not understand how this can happen, and a third PI said that she decided to teach a class on critical reading of papers because of irreproducible results.

"The problem is usually with the interpretation and not with the actual data", said one PI, calling attention to another distinction you need to teach your students: whether the data is wrong or if it has been misinterpreted. PIs listed as common reasons for misinterpretation that the experiment was not well controlled or the interpretation was stretched beyond its limits. *"People forget that their interpretation cannot be general, it pertains to their system only. Over-generalization bothers me"*, said one PI. Another PI also said that he teaches his students how to recognize unsubstantiated claims.

Prevent it

As we talked about it earlier, many PIs are much more worried about their own published data turning out to be not reproducible than the publications of other scientists, and several put in place mechanisms to reduce the likelihood of producing irreproducible results in their own lab as much as possible. *"If you put people under too much pressure, you increase the risk of misconduct. Pressure takes away the feeling of trust and freedom from people"*, said one PI. He encourages people to talk about experiments not working because he thinks that the risk of misconduct is lower if people don't hesitate to report negative results. *"If you have any doubt, look at the results again to see if there is any little sign that something does not fit"*, said another PI.

Fixing the System

Several PIs offered suggestions on how they think we could modify the way we do science to improve reproducibility. *"Common standards are important"*—said several PIs. Some mentioned that we should include more detailed information in publications about how the results were obtained. Several journals have already made efforts in this regard, they have adopted STAR (for "structured, transparent, accessible, and reproducible") protocols and supplementary information is much easier to include and is more comprehensive than it used to be. *"Open data and publishing negative results are very useful in this regard, I am happy that there are more and more journals for this"*, said one PI.

"It is important to not just write a protocol, but make it clear what is critical and what is not critical", said one PI about what authors could do. Other PIs recommended publishing datasets, the scripts used for data analysis (usually a requirement now at high-impact journals), and some thought that the review process could be improved—especially in filtering out unsupported broad claims.

There were calls for more independent replication, as well. One PI thought that high-impact journals should have another lab reproduce important results. *"This would shift the blame from the people who can't reproduce something to the authors"*, she added. Another PI thought *"[it is] worrisome that you can't get money for reproduction, not even using a new technology for an old question—there is funding only for new studies"*. A third PI also said that *"publishing repeats is very difficult—there should be a government initiative for this"*.

Finally, there was one PI who said that although she does not go out of her way to correct mistakes in the literature, she may go as far as mentioning it in her publication that a certain author may have seen something different for this or that reason, *"I try to state it softly, though"*, she added.

Not a Problem

It surprised me first, but 15% of PIs answered that they are not concerned about irreproducible results, or they are concerned about them only if they are due to misconduct.

Science Is Self-correcting

Several PIs said that the irreproducibility problem is *"not such a big problem as it is talked about"*. *"It is important that we do not overestimate the problem: science is* *self-correcting"*, said one of them and many others said wrong results *"get left behind"* or *"they get lost in time"*. *"Science will prove itself, this is the beauty of science"*, assured me another PI. Although this is mostly true in the long term, it offers little solace to scientists surviving on short-term funding.

They Can be an Opportunity

Some PIs see irreproducible results as a challenge. *"They 'trigger' me: I always wonder, what the difference is"*, said one of them and said that she enjoys finding out what the source of the discrepancy is. *"I sometimes manage to use them for my benefit"*, said another PI. He has published 5 papers completely disproving other people's results and showing why they got the wrong results.

"Conflicting results are information. They provide an opportunity to find out why the results differ", said another PI. Once another PI said that conflicting results *"can be intriguing and informative"*—especially if she knows the people who produced the results. If she knows and trusts the source *"slightly different results can be intriguing"*, she finished.

Reacting to Stressful Situations

When a group of people is working together, conflicts are bound to occur from time to time, or you, as a PI, may have to make some unpopular decision that affects your entire group, or you may perceive some injustice in your Department, or somebody may give you a bad review of your grant application or manuscript. Sooner or later, some such problem will come up, therefore I asked PIs how they deal with situations at work that give them trouble. Do they get caught up in their feelings or are they able to look at the situation objectively, without being bothered too much? Or perhaps, they can make a choice whether it is appropriate to the situation to express their feelings or not?

Most PIs do experience their feelings when things do not go as expected at work—only 12% answered that they can look at situations objectively without being bothered by them, at least some of the time. The remaining PIs experience their feelings—although most of these PIs are able to evaluate whether expressing their feelings is helpful in the given situation.

One PI said that she does not get emotional about research, but other University roles can get to her. Another PI mentioned that he *"knows this about himself, therefore never takes a decision on the spot—he likes to sleep on it"* because he often finds that *"a problem is not a problem after a day or two"*. A third PI said, *"I have to overcome my feelings so that I can define the problem"*, therefore *"removing the feelings is essential for solving the problem*" for him.

Most PIs (57%) answered that they were able to make a choice whether expressing their feelings is appropriate for the situation. Some of them admitted that this may be difficult sometimes, and several of them mentioned that being able to make a choice was a result of a learning process and it is getting easier as time passes. They also said that they *"pick their battles"*, and they may refrain from expressing their feelings to achieve certain goals. Some answered that they either make a distinction between private and professional situations (being more restrained at work) or they strive to be able to make a choice, but they don't always succeed.

Interestingly, Top Publisher PIs had a little higher tendency towards being emotional. The comments said that they may not like this, but *"science is very personal, emotional"* for them, as one of them put it. Their feelings may also be important for firing them up for a response, for example, *"[let's] show them that they are wrong!"*

Dealing with Stress

"Stress is difficult to manage in science because it is such roller coaster", said one PI, mentioning not only the uncertainty of funding, but also the *"intellectual uncertainty: you are betting to work on something (in a grant application), people give you money for working on it, but if it does not work out, all of you, including the people you hired, who believed in you and followed you, you are in trouble. It is a lot of responsibility"*. Other PIs also confirmed that getting enough money to run their lab is *"the most stressing thing"* for them. *"Finding money gives me sleepless nights. I am easily worried and can't turn worries off at night"* said one of them. Another veteran PI who has since mastered the pressures of the job, also said that he *"used to have sleeping problems, even nightmares"*.

> *"Hitting the tennis ball really hard helps" (professor, PI for over 15 years, almost 80 publications, H-index over 35)*

Other PIs said that becoming a PI put them on a whole new level of stress: *"being on the tenure track is the most stressful time in my career so far"*, said one PI. *"When I was in training, events caused me stress"*, said another PI, explaining why this would be the case, but *"since I am part of the faculty, events do not stop, ... all the separate events merge together into a constant stress, there is always a deadline looming"*. *"The weekend used to be for preparing for the week ahead"*, said another PI, *"but now is it for catching up, at the expense of sleep and long-term health. I am always tired"*.

Other PIs also mentioned having a disturbed work-life balance. One PI who has had his lab for 30 years said that it has happened to him 3–4 times during his career that he became physically ill with fever after some career shock (e.g. once it happened when he had realized that two year's work was based on a mistake and he had to redo the research). But lab finances and problems with research are not the only source of stress for PIs, one of them said that having to give lectures was the most stressful aspect of her work, *"I am better at one-on-one tutoring than classroom teaching. I am never satisfied with my lectures"*. Besides such *"science-specific"* stresses, being a PI involves all the regular stresses that can occur at any workplace, including personal conflicts. *"Personnel issues stress me out, I even* *wanted to quit"*, said one PI. *"If I lose sleep, that is due to people problems"*, said another. *"Unfair situations or bad atmosphere, ... like departmental problems that I cannot solve, do stress me out"*, added a third PI.

Not Stressed

About a tenth of the PIs surprised me by saying that they do not get stressed by their job. *"There are deadlines, but they do not stress me out"*, said one of them. *"I am usually very busy, but not stressed. In general, I tend to see everything in a positive way"*, said another, and a third said that although she is always juggling a lot of things that is the way she likes it!

It May Get Easier with Time

Even if you should not be as lucky as the PIs who do not get stressed or manage to *"just accept stress"*, there is hope! Several PIs said that it gets easier to deal with the pressures of the job. *"I stopped having [stress]! Maybe not entirely, but I have less and less"*, said one of them. *"I do not feel that I have to prove myself anymore on a day to day basis ... I am confident in the skills I have gained"*, he added. *"I have been successful enough to have confidence in myself, I do not stress as much as I used to"*, said another PI, and he added proudly that he set up a career development centre for the entire school when he was dean to teach postdocs/fresh PIs about time-, people-, and financial management.

"The older you get the better you get at avoiding stress", said one PI. *"I have learned not to blame myself"*, explained another PI why she thinks she can deal with stress better than before. *"When I was younger, the responsibilities bothered me"*, said a third PI, but experience taught him to *"neglect certain problems and people"*. *"Sometimes you have to pour out a lot of work in a short time, which is trying, but not stressful"*, he finished.

Stress Can be Helpful

"There is eu-stress, and there is distress", said one of the PIs, explaining that a certain amount of stress is a source of motivation, positive excitement for him. *"I thrive on it! Stress can drive me"*, said another PI, and others also mentioned that the stress of, e.g. deadlines, improves their performance. *"I never submit early, I would feel that I did not make the most of the available time"*, said one of them. However, *"be selective, pick what you stress about"*, warned another PI.

What Can You Do?

"If you can't deal with stress, you can't do this job" was the brutally honest assessment offered by one PI. Therefore, if you are not one of those lucky naturally stress-resistant people, you will have to adopt certain habits to keep stress at a level acceptable for you. Let's see what PIs do to achieve this.

Accept it

Some PIs just accept that stress is part of their job. *"The worst is being stressed about being stressed"*, said one of these PIs. *"I do the thing that worries me first thing in the morning so that I do not have to think about it anymore"*, she added. *"Stress is there all the time, you just have to live with it"*, said another one of them. *"Don't try to get rid of it. Every job has stress"*, said a third PI.

Others remind themselves that the stress is temporary, it will pass, and one PI said that she *"embraces it"*. *"If you can't deal with stress, tough to be in this profession! Science is a tough existence—but there are alternatives if you don't want to do it"*, she added.

Working More

"When I am stressed about finances or grants, I get into action", said one of the PIs who responds to feeling stressed by working harder. *"Stress only stops for me by getting something finished, done. Sometimes I wake up at 5 and start working"*, said another PI. *"Sometimes I have to increase my work rate to cut through, then I can scale back"*, said a third PI about situations when stress *"comes in little doses"* and he just needs to push through (you may remember when we talked about the cyclical nature of a PI's work in Chap. 5). This may not be sustainable in the long run, however. As one PI said, she used to be able to deal with stress very well when she was younger by working longer (she said that she also used to work faster when she was younger), but she can't do it anymore.

Being Organized

"I become very pragmatic when I am stressed: I have an excellent agenda (lest I forget anything), I make a primary list, and everything non-crucial has to wait", explained one PI. She was not the only one who said that *"being able to tick items off the list"* relaxes her.

"I deal with stress very badly, this is why I am so organized, it is a necessity to combat stress", said another PI, and she added that she thinks a lot during sleepless nights. Another PI also said that he likes to prevent stress by doing things according to plan: he plans difficult days carefully, to make sure that tasks do not pile up. If something unexpected comes up, he asks for help. Careful planning is also the basis of the method other PIs use to *"slow things down"*: *"I reflect on things and prioritize tasks, and I really start doing the most important tasks"*, said one PI. Another PI called her method *"living in the moment"*. She focuses on the now, on each separate task to get them done. A third PI said that he deals with stress *"by doing one thing at*

a time, and completely ignoring other things", although he warned that *"this can get other people angry"*, and picking well the one thing you focus on is the key.

"Since grant deadlines stress me out, I like to work in advance", said another PI, and others also said they generate deadlines for themselves to avoid being stressed out by the real deadlines.

Putting it in Perspective

"Compared to what the patients are going through (losing their entire life within 2–5 years), these things are nothing", reminds himself an MD-PhD PI who works on a neurodegenerative disease. *"My husband is a cardiologist and reminds me that life can be over in a second"*, said another PI. Other PIs also said that they reduce their level of stress by *"trying to put the item giving stress in a broader context"*.

"A good sense of humour and self-relativization helps", as one of them put it, and *"think about what you can influence and what you can't"*, advised another PI. If you manage to put things in perspective, you may agree with the PI who said: *"stress: a lot of it is minute"*. Others said that *"being detached"* or *"getting some distance"* from the lab helps them to put things in perspective (and also helps to deal with failure).

Taking Time Off

"When I'm saturated, I take a long weekend", said a PI with over forty years of experience, and others also said that taking breaks regularly helps them deal with stress. Changing your environment and putting some physical distance between you and the lab can help to put things in perspective and disconnect from the lab, as we have just mentioned. Some PIs take long holidays, travelling to exotic places and others take more frequent breaks, usually on the weekends, going to a vacation home or travelling with their family or on their own.

But you may not need to go very far from the lab to unwind a bit. One PI said that when she reaches her cut-off and needs to take a break, she just goes outside to take a coffee for a few minutes to a couple of hours—until she feels guilty about not working and goes back. Other PIs said that they limit further input by *"disconnecting from phone and internet"* or going to bed early and reading in hiding in her bedroom for hours. *"I take time to myself to sort things out"*, said another PI.

Taking time off when you are stressed by all the things you have to do is hard, but several PIs mentioned taking time off especially when they are stressed. *"Even when going through a very stressful time, I take time off"*, said one of them. Another way of preventing yourself from working all the time and possibly burning yourself out is setting the times when you work and when you do not work. *"The job is very stressful, I try to offset it by setting boundaries: not working all the time and setting time aside for other things. It is a conscious effort to stay away from working all the time"*, summarized her method one PI. Other PIs also said that they keep one day a week (Saturday or Sunday) when they do not work and do not even think about work.

Distractions

Some PIs can draw the boundary between their work and their private life easily. *"I can compartmentalize very well. For example, when I am visiting my elderly parents, I only worry about them"*, said one of them, and another said that *"I switch off when going home, I never work in the evenings"*. A third PI said that he had *"developed the skills to leave the lab and forget the lab"*. Others, however, find it very hard to switch their brain off and employ the same kind of distractions to stop thinking about work as any other people: they read books (not about science), watch a football game, listen to music, go to the pub for a few drinks, watch television, stream movies or go to the movie theatre to completely forget about the lab. One PI said that she has *"a ritual for finishing the day"* with a glass of wine.

Talking it Out

"Once I have talked about it with someone, I feel better", said one PI, summarizing the experience of many others that discussing the issues stressing them lessens their stress. *"My wife helps me, she's very good at putting things in perspective, and helps me focus on the essential"*, said another PI, and a third said that *"when I have a problem, I share it with someone, it helps"*.

Different PIs have widely differing preferences about with whom they like to discuss their problems. Some like to talk to colleagues who may have similar problems themselves and *"can mutually unload their problems to the other"*, others prefer talking with people outside of science, be it their friends, partners, or family members (not only husbands or wives but also their children). If there is nobody available to talk with, you can follow the example of the PI who goes walking and talking to himself in his head to calm himself down.

Life Outside the Lab

"Having a life outside of the lab helps" to deal with stress, said one PI, and many PIs mentioned that planning fun activities, meeting nice and happy people for a drink, or having a nice dinner with friends, helps them to unwind.

Family

"Family helps: you realize what is really important", said one PI, and others also mentioned that having a family helps them to deal with the frustrations and stresses of their job. *"I am glad to have a family to fall back on when I am down by failures"*, said another PI, and others also said that the time they spend with the children or grandchildren takes their focus away from the lab.

Physical Exhaustion

One of the many benefits of exercise is stress reduction, and exercise was the single most mentioned activity as a way of dealing with stress. *"I run 3–4 times a week—without it, I have anxiety"*, said one PI, and *"I exercise religiously"*, said another. PIs mentioned various forms of exercise from going on walks (some with their dog), jogging, running, and cycling through going to the gym, doing Pilates or playing team sports to using exercise machines in their home. Several mentioned that they found yoga beneficial.

Being Outside

PIs said that they found outdoor activities, like going on hikes or do gardening, helpful to deal with stress. *"I do everything on bike, I hardly ever get in the car"*, said one of them, and others also mentioned that they commute to work riding a bicycle or walking. Commuting to the lab on a bicycle, like a good chess move, accomplishes several things: it is an outdoor activity, gives you exercise, and (hopefully) takes your focus off of your problems.

Stress-reduction Techniques

Several PIs mentioned using stress-reduction techniques. One tells herself *"this is stressing now, let's think about this tomorrow"*, and another PI also said that he uses self-controlling self-talk to keep himself calm. *"I used to be quite stressed, but not anymore. I have a nap every day"*, he added. A third PI simply tells herself: *"breath!"*

Others use meditation. *"I isolate myself and focus on a single topic"*, said one of them, and several mentioned Mindfulness practice. *"I am in the moment, I stay grounded and present"*, said one of them. *"I put my full mind on doing science, and when I am having dinner, I have my full mind on that"*. She learned mindfulness from a friend who is working in intensive care but others mentioned learning it from books or taking a course.

Others

Besides the most-mentioned stress-reduction techniques listed above, there were some brought up by only one PI each, but I thought they may be useful to complete the list.

"It's a combination of relaxing, reading and cooking", summarized her anti-stress regimen one PI. *"I do some washing up together with my husband"*, said another. Others take anti-stress medication, paint portraits, cry or pay meticulous attention to their *"sleep hygiene"* (going to bed and getting up approximately the same time, not watching movies in bed etc.). Finally, there was one PI who said that she complains directly to the people pressuring her. *"I hate it that stress is expected to be part of the job"*, she said. *"Motivation is better than stress"*, she said. *"Stress may lead to irreproducible data and narrow ways of thinking. I get involved . . . and take it up to people why they think applying stress on me is a good idea"*, she added.

Not Passing Stress on

I have known PIs who were prone to making a scene in the lab as a way of relieving their frustration. I found that extremely stressful, therefore I was happy to hear a couple of PIs mentioning that they take care not to share their stress with the members of their lab. *"All they may notice is that I am more silent than usual"*, said one of them. The other related the story that once he discovered a huge mistake during the review process of a manuscript—and the person who made the mistake was not available. Instead of making a great fuss, he gathered three people from his lab, quietly explained the problem to them, and asked for help—they solved the problem! *"PhDs thank me for not passing my stress on to them"*, he said.

Recharging Your Batteries

You will spend a lot of time working as a PI, and finding the best way to relax, recharge and recreate yourself will be very important. As we discussed above, PIs spend most of their time talking with their team or with other colleagues. How draining this can be was illustrated by the remark of one person who said *"when I feel that my batteries are chronically low, I limit the size of my group"*. Perhaps not surprisingly, when they are tired, most PIs (62%) prefer to be either alone or with a significant other. Only 18% of PIs indicated being with other people as their sole preference for relaxing, and the rest does a mixture of relaxing alone or with a group of other people.

The ones that want to relax among other people said that they are either *"very extroverted"*, or they want to spend time with non-scientists to relax. Another reason one PI cited for relaxing with other people was that she sometimes finds switching off mentally hard, and it happens quicker when she's with other people. The ones who prefer to relax alone or with a significant other, these select people are often their family members. One called himself *"a real family man"*, who works a lot during the week, but not on the weekend. At very busy times he spends 3–4 hrs with his family and then he works again until 1 am (although he tries to do this not more than once a week).

For their *"alone time"*, PIs named different activities: hiking or biking alone, other physical activity, travelling alone, spending time with their hobbies (learning about history and social sciences, being a radio amateur, repairing electronics), or mindfulness practice. Finally, one PI said that she could *"be alone together with her husband: occupying the same space but not bothering each other"*.

Top Publisher PIs were more likely to say that spending time with other people was their preferred way to relax (32% of Top Publisher PIs chose to be with other people as their favourite way of unwinding compared with only 14% amongst non-Top Publisher PIs).

In the next chapter, we discuss the relationship of PIs with their work (in general, and with science in particular), why they think they are fit for their job, how they measure their own success, and why they think they have been successful.

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7 Thoughts of Principal Investigators about Work, Science, and Themselves

Abstract

By now, we have had a comprehensive look at the main activities of PIs and have discussed where PIs find the motivation for their day-to-day activities. In this chapter, we will zoom out a bit, and discuss what PIs think about work in general, why science is important to them and what they think about the role of science for society in general. We will also see what PIs think of themselves in terms of what qualities of theirs make them fit for their position, how they evaluate their own success, and what factors helped them to succeed.

Most PIs (91%) said that they worked as a scientist because they liked the possibilities and options they had and not out of necessity. Despite all the pressures and deadlines, they appreciate the freedom they have, and they are having fun directing their curiosity in any direction they want. Also, many consider being a scientist a luxury—they feel privileged, fortunate to be doing science and it is not a job for them, it is a lifestyle. *"I love to play, I am bored of routine"*, said one of them. Another PI pointed out that although he works long hours, he enjoys the freedom that he could take time off if he wanted to—although he does not use this option. A third PI said he likes the *"delusion"* that he is helping other people by doing science.

Some PIs said that they did science out of an internal necessity: they wanted to be a scientist since they were children and could not even consider doing anything else. *"I wrote it in my diary when I was eight years old: I want to be a biologist"*, said one of them. Another PI said that he was heading a drug discovery program because he wants to pay back the medical community for developing a medication that helped him to get over a debilitating condition when he was a child.

For others, becoming a PI was a mixture of inclination and luck: it was just one possible path in life they could have taken. *"I can't do anything else than science,*

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
https://doi.org/10.1007/978-3-030-85571-0_7

and this is where I ended up", said one of them. Other PIs also said that becoming a professor was not part of a grand plan for them, they rolled into it by taking advantage of the possibilities put in front of them—and then they stayed in the role because they enjoyed it.

Some PIs acknowledged that there were elements of necessity in their career: one stated that he was in his position due to a combination of circumstances, including his supervisor leaving the research team for an administrative job much earlier than he expected, and he felt he had to stay there to fill his shoes, others felt bound by the stable nature of their position and others thought they could not change the theme they have been pursuing in their research. Others mentioned the sense of duty they feel towards their lab, their people. *"I like my job, but I could not stop it even if I wanted because of the responsibility for my group"*, said one of them. PIs also admitted that there are aspects of the job they do not enjoy and sometimes they do get fed up. *"Sometimes I wonder how easy life would be without thinking"*, as one of them said.

What Is Important about Work to PIs?

Now that we know that most PIs do their line of work out of a conscious choice, I asked what aspects of work in general and scientific work, in particular, are important to them.

Pays for Life

PIs need to eat, too, and most of them have a family to support, children to raise, a mortgage to pay, and they like to enjoy life, as well. Being a PI is a way to make a living (although some did also mention that scientific work is greatly underpaid considering its contribution to society), but *"research is not the type of work you do for money"*, said one PI. Another PI said, *"most people just work for the money, but this is not ideal"*, explaining that PIs expect more from their job than earning enough money to pay for life. As a third PI said, if you are in science, *"this need [to make a living] can be transformed into an opportunity to do what you like"*.

Enjoyment

The number one aspect PIs are looking for in work is enjoyment. *"Work is such a large part of our lives that we should enjoy what we are doing. If we are not, then we should rethink what our priorities are for work, and move towards achieving those goals"* said one PI, expressing the opinion of many PIs.

One PI quoted Mark Twain (*"Find a job you enjoy doing, and you will never have to work a day in your life."*), and another PI said that indeed his mother tells him that he has never worked a day in his life because he enjoys his work too much for it to be a "real job". A third PI said, *"Life is short, you better enjoy what you do, do what you like!"*, and he added that he would stop doing science when he does not enjoy it any more.

Work-Life Balance

Because they enjoy it so much, *"some people cannot find the right balance between working and other parts of their life"* said another PI. *"There is nothing wrong with working a lot but work should not absorb you totally or make you sick!"* She added that *"work can also be a drug for people"* acknowledging that she can also *"fall victim to this"*.

For other PIs, blurring the boundary between work and the rest of their life is intentional: *"my work is my life"*, said one of these PIs. *"It is not the case for a lot of people, but for me, it is hard to separate my work from the rest of my life"* she continued. *"Being a scientist is a privilege and a curse"*, she finished. *"For scientists, there is no separation between life and work"*, agreed another PI, and a third PI plainly called himself a *"workaholic"*, although he added that he does not impose his work habits on others.

Other PIs take a more nuanced view of work: *"my work gives me a lot and I like it very much. It is 99% of my life, but not my entire life"*, said another PI. *"You need to love it because you do it a lot. But it is important to know what is work what is not work"*, said another PI, although she added that working can also be relaxing for her: she works at nights because seeing items ticked off of the list of the things she wants to have done relaxes her! Finally, some PIs emphasized the importance of work-life balance: *“only working is not efficient, you have to refresh”* said one of them and another added that work should not compromise your mental or physical health.

Know What Makes Being a PI Enjoyable for you

Most PIs are passionate about their work, but this does not mean that PIs enjoy every minute of every day they spend working. Some of them did point out that they do not enjoy time and money pressures, *“administrative silliness”*, additional duties on top of their scientific work, and sometimes they do feel just simply overworked and long for work where *“now thinking is required”*. Fortunately, being a PI is a combination of many activities (which is one of the aspects many PIs love about it), and most find the overall mix of what is happening at work enjoyable. One PI said that he has trained himself to like those additional duties that come with the job. *“If I have ten things to do, 2 of them I really love, 2 of them I really hate, and 6 I have learned to love—at the end, 8 out of ten tasks I love!*”, he said, and he added that *“work is like a wife: you have to learn to love everything about her*”.

It is important to know what aspects of the work you really/particularly love (or as one PI put it, *“it is important to know where you get your energy during work”*) because these are the activities that will maintain your drive when doing tasks that you are not that keen on and help you to persevere, to overcome difficulties. *“There should be a balance between the amount of energy it costs to do the work and the amount of energy it gives you”* advised one PI.

Let’s have a look at what aspects of being a PI make work enjoyable for them!

A Challenging Game

“Science is just a game, an activity” stated one PI and he was one of many that likened being a PI to participating in an intellectually challenging game. PIs love the excitement their job brings them and they find being a PI so engaging exactly because it is challenging. *“At work, I feel that my brain is active”*, said one PI and another said that *“if it was always easy it would be boring”*, summing up the feeling of many that although they do want to find answers to their questions, they appreciate that the road leading to the answer is often rocky and involves learning new skills.

Contributing to Society

“I find my work completely absorbing and fascinating, this is my selfish reason for doing it”, said one PI (although she added that she also wants to make life better for the people with the disease she is working on). Many scientists explained that their science is not *“l’art pour l’art”*. Although gaining knowledge through doing a

variety of interesting things is important for enjoyment, the output of their work in itself is also important to them. *"Making a contribution to something bigger than yourself"* was the way one PI expressed his need to contribute to society through his work and other PIs also emphasized that scientists should *"always do work with a purpose"* and *"do important things"*. *"In the end, one's work has to help other people and society, it has to contribute to society—if it does not, it is not work, it is a hobby"* summed up another PI. One PI mentioned that one of his personal reasons for wanting to contribute to society was paying back what has been invested in him during his education.

But solving societal problems is not the only contribution to society PIs care about. *"Training young people is one of the most important goals of my work"*, said one PI and she proudly added that four of her former trainees serve now as heads of a research institute in two continents. Others have expressed that they particularly enjoy guiding students and *"passing the knowledge and excitement on to young people"*.

Social Interactions

One PI's answer to the question of what is important about work was: *"a motivated, good group who likes to work together"*. We have also talked about this in Chap. 4 when we discussed the relationship of PIs with their group, that most PIs enjoy working together on problems with other people. Many PIs said that interacting with the members of their group is very important to them and makes them look forward to going to work, and pointed out the importance of a good personal connection with co-workers. *"You spend half of your life with them, you have to like with whom you work"*, said one PI, and *"you need to enjoy the presence of your colleagues"*, said another.

Some PIs also mentioned that they try to provide a safe and nurturing environment to the members of their groups. *"You should feel safe at work. Not oppressed, not bullied, you should feel appreciated, not judged. There are no silly questions. You should be able to be yourself"*, said one of them. *"The end does not sanctify the means"*, said another PI, talking about installing a culture in the department she is heading where there is respect for all people, including students. *"We can work with people with different backgrounds. Open communication, but respectfully: no bullying, the Nature paper at the end does not absolve bad behaviour"*, she said.

Self-Realisation

"I could reverse your question: what is the importance of laziness?", said one PI. In his view, shared by many other PIs, accomplishing something worthwhile, producing something appreciated by society gives them satisfaction and defines one's value. For most PIs, their work is part of their identity and some PIs said that the feeling of satisfaction and self-fulfilment provided by their work is even more

important to them than enjoying their work. *"Work defines me. I am also a husband and a father, but work is what provides me with the definition of 'me'"*, said one of them.

"A sense of purpose is needed for everybody, and work can provide this", said one PI, and doing creative and purposeful work, achieving things, moving forward makes PIs feel good about themselves. Work not only saves them from boredom (as mentioned by several) but accomplishing something, or at least trying to accomplish something provides a meaning to their lives so much so that some said that they could not live without their work. *"Raising a child and gardening would not satisfy me. I find challenges and satisfaction at work"*, said one of them.

Some PIs see work as a human need and their reason to be alive. *"Work is vital to humans and the lack of work is detrimental—this is obvious from people who are not able to work or are retired"*, said one of them.

Being at the Cutting Edge

"Being continuously at the front of the field. Doing or thinking about things that have not been done" is one of the most important things about work, said one PI, and many other PIs also mentioned that continuously learning new things (and to some, working with new technologies) is important to them.

Ethics

"We are all very lucky in this part of the world: we should not just sit back and relax, we should do something!" said one PI, and others also emphasized the importance of a rigorous work ethic: *"It is important to work with all devotion, you should not take it easy"*, said one of them. *"You need both diligence and talent, neither is enough without the other"* he continued. Another PI emphasized that a good work ethic also involves utilizing resources and time efficiently, organizing work to be productive. *"I always ask: how much time is this going to take?"*, he said (I should mention that we were doing the interview over lunch to be efficient).

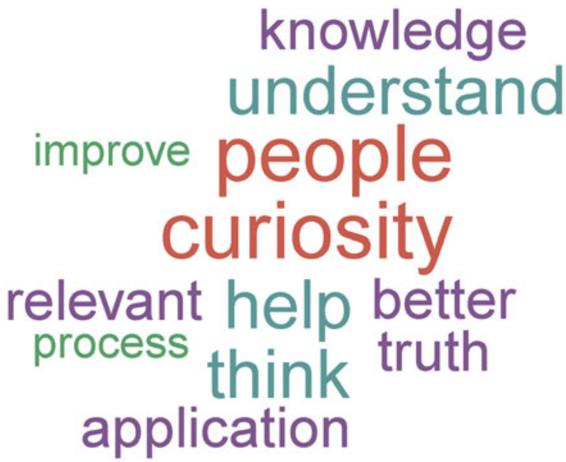
A PI said that *"doing it honourably, thoroughly, and precisely"* was the most important thing about work, and another PI said that *"as a scientist, the most important is to be trustworthy"*. She added that *"people cut corners, there is a lot of manipulation and falsifying data"*, but instead *"we have to look at the raw data and be truthful"*. "*Strong ethics is important"*, said another PI, *"you can't cheat or disrespect the data"*.

Self-Determination

Many PIs appreciate the variability of the job. *"Flexibility and freedom"* are the most important about work, said one PI and she added that she *"would never want to* *do the same thing every day"*. To many other PIs, it seems even more important that they can determine their own path. *"I value the unique independence I am given by the University, that I have a free choice of projects"*, said one PI and he was not the only one who felt that working in academia gives them more independence than they would have working in industry or business. *"I like that I can run my lab the way I want"*, said another PI. In my opinion, the appeal of the academic career lies right here, in the way you have the power to determine your own path, in the almost perfect alignment of personal and professional goals, in the overlap of personal and professional development that is rare in occupations.

Why Is Science Important to PIs?

When you will be a PI, you will constantly have to ask "society" (funding agencies) for money to pay for your research. I think you will be much more effective at that if you believe that your activity is important, so I asked PIs what they believe about science in general, and about its role in society. It may not be a surprise that most PIs believe that science is a force for good that advances the world for the benefit of humankind.



What Science Is to PIs

It was clear from the answers from the PIs that science was not only an occupation for them, but part of their identity and they felt quite passionately about it. *"Science is life"*, said one of them simply, and many other PIs said that science was a vocation for them (like, e.g. being a monk), they felt that science was *"the most noble of* *human endeavours"*, and *"[science] discriminates humans from everything else on Earth"*, and doing science was an expression of their humanity, because science is *"an unalienable reflex of humankind, just like breathing"*. Many PIs said that science is a career of passions and it is a privilege to be a scientist and work in this area. This does not mean, however, that doing science is all joy. On the contrary, it is a very demanding vocation and the satisfying moments can be few and far between. *"Genius is 10% inspiration and 90% perspiration"* quoted the saying (attributed to Goethe, Thomas Edison, and Kate Sanborn) one PI, and he added that in science this means that *"you can have an insight quickly, but it takes years to grind it out." "Doing science squeezes everything out of you"*, said another PI, *"the question is: do you have enough passion to make it through?"*

PIs, however, feel that the overall mix is enjoyable. *"[Although] I am no Michelangelo, I feel like him: I have a job that I can be creative in, get paid for using my talents, while I can be my own boss"*, said one PI. Many others PIs said that they got into science because they enjoy finding out how things work, how things are put together and they find science a great way to structure and satisfy their inner curiosity. PIs find science very attractive because it is always novel, there is no routine. *"Science, falsification of hypotheses by trial and error, is, in my opinion, the best way to acquire non-dogmatic knowledge about the world"*, said one PI, and another PI called science a *"fantastic way to move society forward"*.

Contrary to the common perception of a dichotomy between science and art, many PIs felt that they were complementary and even alike: *"science and art are both ways for humans to understand the human experience: science on a mathematical basis, art on an emotional basis"*, said one of them. *"Science is a beautiful mix of unbridled creativity and rigorous fact",* said another, and he continued that*"[science is] imagining and then testing: confronting the theory through experiment"*. A third PI said that "*[science is] a mixture of art, aesthetics, facts, cross-validation—art and craft combined"*.

Science is also a community activity. One PI described her work as *"resolving problems through knowledge gathered from other people's work"*, and another said that *"science is an incremental exercise"* because each scientist contributes only a small part of the puzzle. *"Science done by an individual can be great, but it is required to share the results, otherwise they are lost"*, said a third PI, and another said that the exchange of ideas is the best way to move science forward. Therefore, a culture of sharing is extremely important for science. It is a great paradox that whereas science is moved by individual passions that can make coordinating the work of different labs difficult, at the same time interaction is essential for moving science forward. Although science can get messy because people do not always achieve impartiality, and not everything is true in science, "*on the long term, we are making progress"*, said one PI. *"Science self-corrects itself, fake stories disappear"*—confirmed another.

Although PIs repeatedly said that their curiosity or passion for solving problems or answering questions led them to science, they have also remarked that science has become a career field. *"We need to distinguish 'real' scientists from 'politician-*

style' scientists", said one of them, *"the first type is driven by passion, the second type is driven by a desire to be recognized"*.

The Role of Science in Society

Whereas one PI remarked that *"science is completely irrelevant in humanity's history, in the light of evolution, it is only a bleb"*, most others thought that science was important for society. *"Science is good for society in many ways, not only if it saves lives, it can improve people's lives by training, providing them with a job"*—said about the importance of science one PI. Other PIs also said that science is a driver of the economy: it provides employment, wealth for the country (Sahin 2015; BiGGAR Economics 2017), and the way we live (at least in the industrially developed countries) is based on science, a lot of our comforts are based on scientific findings—even if few people realize the extent scientific research has moulded our world.

Engagement with the Public

Besides acquiring information, science has a second function, teaching people. Science contributes to the education of society indirectly since people who engage in scientific research or work in research environments acquire critical thinking skills that they can use in other areas of their lives besides their work. But scientists also need to engage with the public directly. Several PIs expressed frustration that the general public does not get the importance of good scientific research or that not even their educated relatives understand what they are doing. At the same time, only a few out of the one hundred and six PIs I interviewed said that they like engaging with the public. It is not surprising, because PIs are already over-burdened and anybody who has tried to write a "lay abstract" about their research knows that it is very hard to explain what you are doing without using the jargon you are accustomed to (and the background it requires to understand it).

Scientists have a lot to do in terms of educating the public about science. The "general population" is not aware of the high failure rate in science, for example, because they see the tip of the iceberg only. But how would they know when failures are rarely talked about, even in scientist-to-scientist communication? "*Science should be brought to all levels of society since a lot of decisions show the lack of understanding of the importance of science on the part of politicians",* said one PI, and another PI said he is worried about the *"fact-free world"* some people are promoting. The rationality of the scientific world can serve as an example, especially during the current trend of irrationality. *"The process of using the scientific method makes people more thoughtful and think about all sides of the story"*, which is a general benefit for all society, observed one PI.

Other PIs said that although science can't answer all questions, it would be important to consider the scientific method in many questions of society. Even in questions that could be decided by weighing the scientific evidence, science is being dwarfed by other interests. *"Science has a big role, but it is corrupted by politicians, industry, money"*, said one PI. *"Genetically modified crops or pharmaceutical companies not developing certain drugs because of financial interests"* are prominent examples of this, she continued.

Science is a key aspect of human society and life, and it is important on many levels. Scientists, however, have a lot of ground to cover to explain to people how and why science is important for everyday life as well as transmitting already existing knowledge to people (e.g. one PI brought up as an example that there are still people who do not know that malaria is spread by mosquitoes). The opinions on the importance of disseminating scientific results to the general public were variable: some did not find it important, others said that science should never be detached from daily life, and scientists need to break down the importance of their results to make them relevant to laypeople. *"Dissemination is important"*, said one PI and added that detached science that stays abstract to laypeople is not good. Another PI said that *"science is not a 'light' subject, it should get more respect"*, but this will probably not happen unless scientists engage with the public more and make it more obvious to laypeople that science is more than academic info, that science is important for them.

Basic Science and Applied Science

Science is *"a toy, amusement, a fantastic game, even if we work on a problem that is not that important, it is still amusing"*—said one PI, and I am afraid that many non-scientists think that people in science are just playing around. But science is not only an opportunity to ask questions about the world but also a means to an end (e.g. curing a disease), it is a valuable exercise. The balance between basic science and applied science has been mentioned by many PIs. Whereas PIs realize that applicability is important to the taxpayers, they also said that there is currently a problem with the way many people expect instant application. Sometimes very basic knowledge is needed for an application that a very focused study would not find: for example, the people working on CRISPR were not trying to do genome editing, they were studying the response of bacteria to viruses.

Other PIs mentioned that in biomedical science everything is supposed to be about the patients now, but we need a constant supply of basic research to have new ways to help the patients later since basic research is the fuel that drives the application. *"It would be a great pity if work that cannot lead to immediate application would be excluded from funding"*—said one PI. The application should not drive the projects because *"nobody can tell what should be discovered"*, as another PI put it. Now, science is pushed towards direct application, and the result is very short projects aiming at low-hanging fruits—which will hamper being innovative in the long term.

"There is too much focus on immediate visibility and application, and creative thinking is less important than it should be. The 'academic freedom' is limited,

scientists are pushed into boxes that fit the funding schemes", said one PI. Science makes the world progress, but novel ideas take time to develop, and scientists do not get the time: PIs were concerned that it will kill the system if there are no more new ideas, there will be nothing to develop for the application. *"Science should be based on the interests of the investigator",* said another PI who also thought that there is pressure on scientists to do applied science. He said he has gotten away with researching what he wanted because he has been always able to find a suitable translational aspect, and most reviewers appreciate good work.

Another PI complained that science has become very capitalistic, very business-like: return on the money is driving it instead of a search for the truth. He said that the current funding structure reminds him of an upside-down pyramid: there is a lot of money spent on translational science, but a large proportion of this money is wasted because the basic science that is to be translated has not been worked out yet.

The Importance of Science on the Personal Level

PIs put different labels on this (*"discovering new things"*, *"closing the knowledge gap"*, *"solving puzzles"*, *"understanding a disease better"*, were a few), but satisfying their curiosity was the most important about science for most of them at the personal level. PIs with medical training or working in a medical department tended to direct their curiosity towards diseases or ways of helping patients, but for most other PIs, curiosity was the motivator and they thought that applications will naturally come from the new understanding (we have already touched upon this in Chap. 1). Whether they called it *"making discoveries"* or *"finding pieces of the puzzle"* or *"linking together previously distant ends"*, several PIs said that they derived immense satisfaction from seeing something for the first time. *"Curiosity-driven science makes the world a better place and we become better human beings by it"*—said one of them.

The value PIs placed on the impact of their discoveries on society was variable: some were only interested in *"blue-sky research"*, some liked to see the application of their discoveries (although they may not want to develop those personally), and others placed primary importance on application and were not at all interested in projects that did not help patients. An MD-PhD PI mentioned that however complex a particular disease is, after seeing a thousand cases, it becomes routine. Science, however, helps him to keep his edge and not go into routine thinking about a disease.

According to another PI, what is of primary importance changes by the age of the scientist: young scientists want to discover something novel, then they would like to be recognized by their peers, to be considered as an equal player, and even later, they are looking for self-fulfilment by making a difference in their field or for the lives of patients.

Science is also a bridge between people: several PIs emphasized that it is important that science remains a social undertaking done together by all genders and ages without borders or cultural restraints. Being part of an international community, interacting with intelligent people, constantly sharing data and ideas, asking for and giving help constantly—these are all important aspects of being a scientist. Students are also part of this community, and one PI mentioned that working with students and being able to transfer her enthusiasm for science gives her energy.

"You never know what application you contribute to", said one PI explaining that the exchange of ideas between scientists can cross-fertilize their brains. He said that he was most surprised when he went to a lecture in another field and the presenter started by saying that it was his review that gave him an idea. *"You may contribute by steering other people's thinking"* he finished.

Top Publishers

There was a strong preference for curiosity-driven science among Top Publisher PIs. *"The most important that science gets ever closer to the truth. Science is unique in that it is a process of constant revision, testing, admitting wrong, getting closer to the truth"*, said one Top Publishers PI. *"In some fields, getting closer to the truth has some extra medical benefits, but the main thing is to get closer to the truth"*—he added.

What Do PIs Believe about themselves?

What does it take for a person to become a PI? I asked the interview subjects what they thought of themselves as a scientist: what are their strong points, do they have any weaknesses?

Most of the PIs said that they were good and successful scientists—although several pointed out that they knew much more successful ones. Many were proud to say that they were careful scientists who may not publish in top-tier journals, but what they do publish is solid and will stand the test of time. It was amazing how many of these (in my opinion, very accomplished) people talked about themselves as *"not top scientists"* (the Dutch speakers even had a word for this "subtopper")—but they were proud to work on important problems, publish solid work and be respected within their scientific community. One explained that, although she could not get into as high impact journal as she wanted to, why she is taking satisfaction in being thorough: *"The rush in modern science makes us all less true than we want to be. I love it when I see a disagreement in the literature, and I know what the source of it is—because I have looked at it in my lab very carefully"*.

Intellectual Capabilities

In terms of their intellectual capabilities, many scientists mentioned that they are *"smart and creative"* or they *"think more quickly than most other people"*. They are hard workers and good learners, as can be expected, and they said they are very analytical, can think a problem through. But besides being able to think things through in a linear fashion, several mentioned being good at *"lateral thinking"*, seeing the big picture and being able to synthesize broad information or *"connect tidbits of information"*. Others called this having *"the ability to think outside the box, connect distant things"*.

PIs are not conceited about their intellectual abilities, though. Several expressed similar sentiments to the PI who said that *"she has seen much smarter people than her, but she is smart enough"*. One who evaluated himself as *"arrogant at times"* said that *"you have to have a mix of thinking of oneself highly intellectually, but still be insecure to re-check ideas"*. Another said that although *"he does not think of himself that he is super smart with brilliant ideas, but once he has an idea and a way to work it out, he goes for it"*. Another PI echoed this sentiment saying that she *"knows more genius colleagues, but she has enough imagination and is organized enough. . . . A lot of people are very clever but not organized enough, the combination is needed"*.

And this leads us to the question: what else is needed besides being "smart"?

Independence, Courage, and Decisiveness

At the Dutch-speaking university I work at (KU Leuven in Belgium) the title of full professor is "zelfstandig academisch personeel" (ZAP for short), meaning "independent academic staff", and one PI drew my attention to it that this title was quite meaningful. The importance of this streak of independence, intellectual courage was pointed out by several other people. Many PIs expressed feelings similar to the one who said of herself that she *"like[s] challenging the current understanding"*.

This intellectual courage has several aspects: on the one hand, you need to be *"fearless about the problems [you] address, not [be] intimidated by the complexity"*, as one PI put it. On the other hand, as another PI said, you need *"the courage to make conclusions—some people just keep collecting data and never arrive at a conclusion"*. To challenge the dogma, you also have to be able to free yourself of intellectual bias, as one PI said, "*I always try to reach the truth without preconceived notions, and this is how I train my students, as well*". Another PI said that *"for me, the most important is to achieve unexpected results. All breakthroughs came from unexpected results. Scientists have to be open to first see the strange data to later make sense of it"*.

Many PIs emphasized their independence from other scientists. Several said that they do enjoy collaborative work, but there are only a few other scientists that they can really work with, who *"really get them"*. You have to be able to go your own way, said one PI, calling this being in a *"PI desert alone"*, and another said that *"if you want to be a pioneer, you have to believe in yourself, and not worry too much about what others think of you"*—which is admittedly hard.

Determining new research lines is one of the things that makes the difference between PIs and researchers. One PI said that "*I have the talent for analysing a problem and turning it into a research line, asking questions. Science is not about* *answering questions: it is more important to determine a research line. Then, you will have to find the answers, of course"*. Another PI said, *"I think: this where important unknowns are, I will invest in this. You have to be going ahead of the curve"*, and a third said of himself that he has *"the capacity to look where science is going and where [he] should go. Best scientists pro-actively re-invent themselves"*. A third PI also said that he keeps reinventing himself: *"I am completely different from what I was ten years ago, and have still enormous potential to grow, as long as I can believe it can be done"*.

One PI had this advice: *"do not go into a fashionable field. If you are serious, and able to find a hypothesis, people will listen. Go to the front of the train (to steer it) and come up with new ideas all the time"*. He did add that *"it takes a long time"*, and many other PIs also emphasized the importance of persistence, resilience: once you determined your new research line, you will need to stick with it until it bears fruit. As one PI said, *"sometimes I do drop questions, but if I pursue something long enough, something interesting always comes up"*. Or, as another PI put it: *"stubbornness is a strength"*.

But besides intelligence and independence, you need one more thing to come up with new research lines: intuition—or, as some called it: imagination. This was mentioned by many, and one PI described herself as *"capable of quantum leap, capable of non-incremental research"* and another said that he is *"a visionary and good at inspiring others"*.

Interaction with the Team and the Institution

It's great to come up with a new research line and design experiments to answers new questions, but you will need people to perform the experiments—it is unlikely that you can do all the research yourself. The above-mentioned independent spirit seemed at odds with this need for helpers and what we discussed before that PIs enjoy most working with their team. I asked PIs if they saw themselves as independent players, team players, or management players. More PIs said that they considered themselves team players than those who said they were independent- or management players. The answers of those PIs who answered "independent player" revealed that they meant their independence from other labs, other scientists—not from their teams! Which fits well with what many PIs said, that they view their team as an extension of themselves.

Since you will need people to perform the research with you, how good you are at convincing and managing people will be very important. A very successful PI (over 170 publications, H-index of 44, PI for 12 years) said *"I probably did fewer experiments than anybody around me, including my PhD students"*, but he added that he is a very good communicator and collaborator. Another PI called herself a *"very good motivator"* and there were several who described themselves as *"good cheerleader[s]"*. Other PIs said that they think of themselves as the *"coach"* or a facilitator, who provides resources and opportunities to people and encourage and expect collaboration between the people in their lab. One PI said that this is why he likes to hire scientists who have done team sports because they are team players.

Many of the PIs who considered themselves management players pointed out a personal evolution from being independent players or team players to becoming management players. Some of them emphasized that playing a management role to direct their lab is necessary for keeping their lab running whether they liked it or not, whereas others said that they welcome the mentoring role and enjoy putting their time into their people. Several PIs mentioned that they care about their people—some even likened the members of their team to family members with whom they keep up with even after they leave the lab.

Many PIs emphasized the importance of *"building a team that progresses"*, meaning that not only the PI makes progress, but their team members, as well. One of these PIs said that he hopes *"to stimulate people in his lab and train young scientists who will continue to do important work"*, and he added, *"I will become dust, but the work continues"*. Other PIs also said that they were supportive of the people in their lab—and one PI who said of herself that she was good at managing her people added that she *"make[s] a point of committing to them and get them enthusiastic without being too controlling or pushy—keeping their own rhythm"*. On the other hand, some others indicated they were selective into whom to put their time and qualified their support for their lab members with an *"if they are good"*. As other PIs pointed out, it is key what kind of people you are surrounding yourself with, and one of them said of himself proudly that he was *"good at hiring the best people"*.

In opposition to the spirit of independence emphasized by many PIs above, one PI said that *"science is interdisciplinary, it is not possible to be an independent player"*. These are, of course, different sides of the same coin: scientists have to be independent to come up with new research directions, and, at the same time, working with other PIs can help with performing the research—and it also can help with coming up with new ideas, as well as acquiring funding, since many funding opportunities require consortia to apply.

Communicating your Results

Communication skills also came up often when PIs were talking about themselves, and several said that they *"present very clearly, be it a grant, a paper, or a talk"* and that they pay attention to who their audience is. On the other hand, several PIs said they wish they were better at communicating. One PI said *"I am not articulate as a scientist. I can write well, but in a person-to-person situation I am not good at thinking on the spot"*. Another said that *"presenting is my weakest point. . . . I am not relaxed when giving a talk"*.

Several PIs emphasized honesty in communicating the results. One said he was teaching his people the right ethical behaviour like this: *"if someone cornered you at a meeting and asked you if you absolutely believe the results you are presenting, you must be able to look that person in the eye and answer to the positive"*. He did admit that it was still possible that they publish the wrong interpretation, but he is *"a believer in pursuing the truth and in rigour"*.

Things that they Wished they Were Better at

There were some characteristics that some PIs would have liked to have—since some of these were mentioned as a strength by other PIs when answering other questions, I thought it was worth including these, as well.

Several PIs mentioned that they wished that they were more focused. One said *"I do not have a real goal, go with the flow [instead focussing on a single area]"*, another called himself *"too much of an all-arounder, not focused enough"* and another said of herself that she *"does not dig very deep"*. One connected her shallow focus directly with her publication record by saying that *"perhaps . . . I do not have very high impact publications because I never pinned down a specific area of interest. I am not focused, do not drill very deep"*. Another PI with a similarly meandering focus called his science *"opportunistic"*: if he sees something that interests him, he looks into it deeper. Although this gives him fulfilment, it also results in scattered activities and prevents him from maintaining a strong focus that would be needed for becoming what he calls a *"big scientist"*.

Some PIs mentioned that they are not as dedicated to their scientific work as they think they ought to be. One said of himself that he was not a *"monkish-style"* scientist who is totally absorbed by the work, he is rather *"the managerial kind"*. An MD-PhD PI said that not being focussed totally on research was built into his job. He had so many clinical-, teaching-, and administrative duties that he can't devote as much attention to research as he would like. But the situation was the result of a conscious decision on his part, because *"a purely academic appointment would have been less certain. A clinical/scientific career offered much more job security"*.

Another thing several PIs wished that they were better at was building their network. One PI said *"I am not the person who has connections with other scientists, I don't pursue other scientists for the interest of the project. I can be in a meeting but not very social, I collaborate with people I already know"*.

Several PIs said that focusing on the connections, the *"big picture"* meant for them that that they were *"less good about the technical details"* or another said that *"sometimes I miss details that could have saved me time or effort"* in the long run. Another said of himself that he is a big-picture guy who reads very broadly but this has a drawback: he does not have the time and interest to go into details. He compensates by working with people who go deeper.

The importance of thinking widely was expressed by the PI who said of herself that she is *"not good at creating a long-term vision. Much better at the here and now, and how to push things farther (instead of coming up with entirely new concepts)"*.

It was most surprising to hear how many PIs struggle with insecurities. Many admitted of having low self-confidence, one PI called this having *"women in science issues"* and others said they were suffering from *"impostor syndrome"*: the feeling that they are not fit for the position where they are, and it is only a matter of time when others find this out.

Several PIs tried to put a positive spin on this by expressing that self-doubt can be useful, like the PI who said *"I am not self-confident enough—but this makes me a better [more rigorous] scientist"* and another said that *"being humble does not always help"* with her career, but it helps her to get good feedback and to push her boundaries. Unfortunately, low confidence prevents these people from *"blowing [their] own trumpet more"* or fighting for themselves, which may hurt their career. *"I am not playing politics enough"*, said one of them, and *"science is a social thing, you need to do a lot of politics, and I should do more"*, said another. One PI complained that other people appropriate her good ideas because she does not stand up for herself, and she wishes that they did not do that! Another echoed this by saying that she *"could have done better by being more selfish…"*.

And finally, several PIs admitted being impatient which may put a strain on their relationship with their team. One PI said that *"holding on to the big vision means that I can be demanding. I do not want to settle for second best, but only for optimal quality"*. She drives her team to do the best science they can do. Since she is forceful and driven, patience and giving things time do not come to her naturally. Another said a very similar thing: *"I have high expectations of people, I often have to temper that"*. She said, *"I always think steps ahead, but it can be overwhelming to other people"*, therefore she often needs to put her breaks for the sake of some of the people in the lab. Similarly, another PI said of himself that his *"timelines are often not realistic"*, and he added that *"you have to learn to accept how much you can advance with the time and money available"*. Apparently, it's easy to err on the other side, as well: one PI listed as a weakness that sometimes she is too soft with her people and they relax a little too much—*"which is not the best for the projects and science"*.

Top Publishers

Many Top Publisher PIs mentioned being creative or imaginative. Surprisingly, many of these very accomplished people complained of low self-confidence or having impostor syndrome, being insecure. The most consistently emerging theme was their connection to their team: they said they regarded themselves as good mentors or coaches to their people who are good at building their team and motivating the members of their lab, and they keep their people around them by treating them well and helping them to grow.

How PIs Measure their Own Success

Since touting PIs' accomplishments is necessary for getting grant money and advancing their career, yet so many PIs seem to struggle with low confidence, I was wondering where PIs get their sense of accomplishment. Do they just know inside that they are doing a good job or does someone have to tell them?

A little over a third of the PIs said they were seeking external validation. They mentioned many sources they seek feedback from, including their publications, e.g. are they able to publish in highly coveted journals, and are the papers they publish cited? On the other hand, another PI said that *"a Nature paper is not the end of the story"*, and he said that the ultimate acknowledgement is if one's results are not only published but also applied. PIs also use their grant applications as a source of feedback: what kind of comments do they receive on their grant application, are they receiving grants? Another source to consult was their lab: is the lab productive, are papers going out, are the students in training developing well, are people in the lab happy and doing well scientifically?

One PI said she measures her own performance also by her family: are they happy? *"No scientific success could make up for family problems"*, she said. Finally, many want to see that their peers and the scientific community appreciate them, e.g. through formal evaluations like a tenure committee's opinion or informal chats with peers (either in their department or more distant ones at meetings or leaders in their field). The Nobel laureate among the interview subjects said that he judges his success by recognition and invitations to participate in meetings: *"if other highly achieved scientists think that you are worthy, that is highly gratifying"*—it is humbling to hear that a person of his stature thinks that!

The answer "I know inside" was selected more than twice as many times as "someone has to tell me" for the question of "how you know that you are doing a good job?" Several of the PI who "just know inside" said that it is rare in science for anybody to tell you that you were doing a good job. *"It would be nice, . . . but it does not happen"*, said one of these PIs—and there were some PIs who expressed discomfort with receiving positive feedback, but welcoming criticism.

One PI said that science is an art for her, and artists do not need approval (as she said, she has always been a PI, she was doing her *"own stuff"* already in kindergarten). She said that although you have to be able to proceed by yourself, it is good to look for mentors (preferable outside of your field) with whom you can check from time to time and who can put things in perspective for you.

Several PIs were squarely against the widely used publication-based metrics: *"In Europe, everything is so H-index driven that the bigger picture gets lost!"*, said one of these PIs. She likes to judge herself by looking at her own CV: *"Is this a creative, independent thinker or rather someone who is just collecting numbers?" "When I feel that I understand things, when I have increased my understanding"*, said another PI about when she thinks she is doing a good job. Another opinion about scientific metrics was that *"the scientific community is schizophrenic about the metrics"*, as one PI said, *"they criticize it, and at the same time, everybody loves to see their H-index or impact factor go up—they are prisoners of the system"*.

Some other PIs also preferred more internal ways of judging. For example, some PIs said that they judge their own performance based on how they evaluate themselves: have they finished a good story that makes sense, did they discover something, have they moved the field forward, are they working on things that they are excited about? One PI judges himself from the results of his lab: *"I know I am doing a good job when things make sense"*. This kind of evaluation can be useful for people who are going against the dogmas or feel like being the oddball in their department.

On the other hand, some of the PIs who do seek external validation mentioned that following your own instincts can be dangerous. *"One has to be confident, but it's best to get validation from other people"*, said one PI. *"I do not want a pat on the back, but the opinion of my competitors"*. Another PI said that for him, it depends on what aspect of his work we are talking about: *"For science: if I am interested, that is enough for me. For performance indication: I need outside feedback to survive"*.

Many people who rely on their own judgement do include some external input to form their opinion like project applications approved, publications widely cited, publishing in good journals, invitations to review panels, invitations to consortia. Another PI said that she measures her own success by how much people (students, colleagues in her department, at conferences, international collaborators) want to interact with her.

"At the beginning, you do not know." (professor, PI for over 25 years, over 150 publications, H-index over 35)

Although some PIs struggle with low confidence, several PIs said that the way they judge their own success changed over their career: becoming a PI was a watershed for many, they gained confidence in their own performance, and many said that the more senior they get the less they worry about external validation. Several PIs mentioned that they are over-critical of or underestimate their own performance, therefore "hearing it from his colleagues that he is doing well is important". This can be especially helpful for those lacking confidence.

Some PIs said that receiving a grant or a good journal accepting a publication may not be directly related to the quality of that particular piece of work since there is a lot of politics involved in these decisions, but exactly for this reason, these are good metrics because they reflect how you are perceived in the scientific community. Such validation is helpful, and *"after enough external validation, you know yourself"*, as one PI said.

Some PIs use metrics a little closer to home: does the lab have enough money, does the group work well together, are the graduating PhD students getting good jobs and are they successful? One PI said that whether the people in the lab are happy tells her if she's doing a good job on the social side.

One PI said that although she looks at citations and metrics, her main way of gauging her performance is against her own milestones. At the beginning of each year, she has a good idea of what she wants to achieve that year: how many and what papers she wants to submit, what grants she wants to apply for, what projects she wants to finish. For these things to happen, she knows who in her lab has to do what, and when. Another PI said that he tracks his performance in several levels: *"1. The science part: other's reactions to my publications and talks. 2. The aspect of running a lab, the obsession with discovery: am I working on important topics—or they should be at least exciting to me. 3. The aspect of helping younger people to reach their potential: how well are my alumni doing? Are they doing well in their career,* *and are they happy?"* He said that helping his people is a tricky balance because he needs them to help his career while he also would like to help their career.

Just to show that even very accomplished people need feedback: a PI who has been leading his lab for over thirty years (almost 300 publications, H-index over a 100) said *"I am not so self-confident that if my students did not follow me, I could not get funding, I would not be able to persist"*—despite being sure of the relevance to his work.

Fewer of the Top Publisher PIs relied on external evaluation alone, rather they tended to say that they had a strong sense of doing a good job, but they also sought external validation.

The Factors Contributing to the Success of PIs

Towards the end of the interview, I posed the following "summary question" to PIs: "What do you attribute your success to?" The answers often included elements already mentioned during other parts of the interview, and, naturally, there is an overlap between what PIs are good at and what makes them successful. But I think these are important things that bear repeating.

The Definition of Success

I set out to do these interviews to find out what I could have done better, what would have helped me to become a PI, therefore, in my eyes, all interview subjects were successful, since they became the leader of their own lab and can determine their own research agenda. Surprisingly to me, several other PIs said they do not feel successful. *"I do not perceive myself as successful. I am more critical of my own success than of others"*, said one of them, and another said that she does not consider her scientific output extraordinary. *"Success is relative"*, said a third PI. I told these PIs that they managed to do something that most freshly graduated PhDs aspire to, but less, than 10% of them succeed to do—therefore, I do consider them successful. *"I recognize that where I am now is an achievement that not everybody can get"*, said one of them, *"but for me, things just aligned this way"*. Others said that they do not think that they have "made it" just because they have their own lab, their success is a process: *"I have learned from playing basketball that even if you play a good game on Saturday, you still have to perform the next week!"*, as one of them said.

Probably no Single Success Factor

"I read the career column and I do not see any pattern", said one PI, expressing that success, and how you become successful, appears to be very personal. Only a minority of PIs (17%) listed a single success factor, but they gave different ones: there were only three that were mentioned by more than a couple of PIs: a passion for

science, being creative in what questions you ask, and collaboration (the rest were their mentors, training, hard work, and luck).

Most PIs said that their success was due to a combination of several factors—hence the extensive list of success factors below. Read this list as a list of possible ingredients. All of the factors listed are valuable and can help you to cook up your own success, but I cannot tell you what combination of them will lead you to success.

Perseverance

The success factor mentioned by most PIs was the ability to continue working towards their goal despite difficulties or failures. Although they put various names on this ability (perseverance, drive, determination, ambition, tenacity, endurance, or stubbornness), 40% of PIs said that it was part of what made them successful.

"People get discouraged too easily, I do not. Sometimes even I do not like the fact about myself that I am persistent, but that is what I do", said one of them. *"I have never given up anything I cared much about"*, said another PI, and added that her *"naivete"* helps her: *"I do not think about the consequences on the long term: can I pull through?"*

"There is lots of uncertainty in science", said one PI, and other PIs also said that they persevere because they can handle uncertainty well, both regarding projects and their own career. One of them said to *"be audacious and take risks—sometimes you are not sure that the parachute will open"*.

"I was more persistent than many MD/PhD colleagues who left science because they reached the tolerance of incertitude sooner, but I stuck it out", said a third PI. You may want to have a look at Fig. 7.1 that shows how long PIs spent as

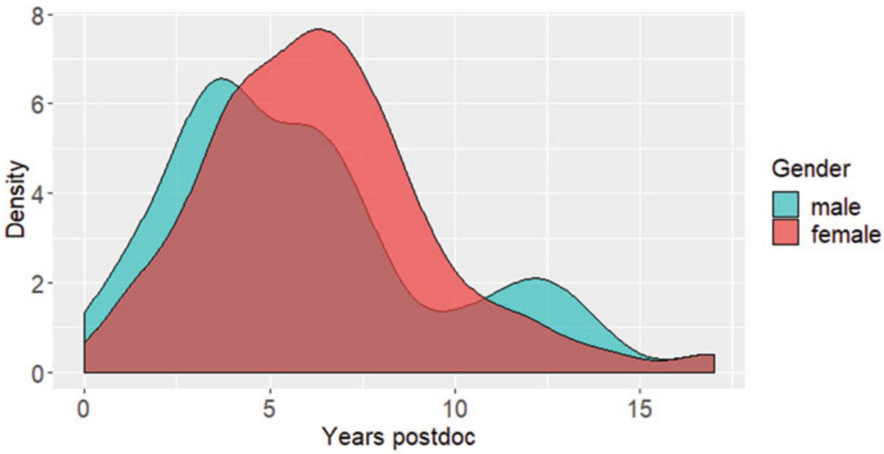


Fig. 7.1 Female scientists seem to spend slightly longer time as postdocs. The distributions are quite different, but both the median and average values for females are about half a year higher. $n = 55$ for females and $n = 51$ for males

postdoctoral scientists before getting an independent position—thirteen of the interview subjects spent more than ten years as postdocs and two waited 17 years!

Don't think of perseverance as some abstract concept, it is the daily process of dealing with things, always finding a way to get past obstacles, even when the reward is far from certain. *"Success comes at a prize"*, said one PI. *"Planning is part of the success, but more important is getting over things on a daily basis, not giving up"*. Another PI also used a sports analogy: *"It is like a football team: even if you lose, you have to play again and again, always doing your best at the next match"*. She added that success comes from endurance, dealing with stress and frustration, rejection, and embracing stress, pulling herself together and motivating herself to come to work with a smile! *"I never give up, just keep going"*, said another PI, *"if everything seems to fail: sleep on it, and do it again!"*

"Self-generated motivation is essential, you can't depend on others to motivate or encourage you", said one PI, and another said that *"the capability to always regenerate enthusiasm, to make efforts day by day"* helps him. A third PI said that *"I always wanted to be a group leader, even as a postdoc I had my own funding"*, she said, *"I just did not take no as an option: I ran around hoping for a crack that lets me in"*.

Sometimes, your persistence will make you seem stubborn, but don't worry about that. *"Have a thick skin, ask for help a lot and don't give up"*, said one PI, and another said that *"be a little bit stubborn: even if people say that something is not the right way, if you feel that that is the correct way, just do it!"*. *"Have a thick skull and never take no for an answer"*, said a third one. You need to be *"tireless and stubborn"*: *"in science, you constantly get criticized and judged, there are endless failures: just keep going"*.

Passion for Science

As we saw in the last section, many PIs seem to agree that you will need to be perseverant and able to regenerate your enthusiasm to achieve success—but to do those, you will need some internal motivation.

Over a quarter of PIs (26%) mentioned their passion for science as a source of their success. As one of them put it: *"passion is my driving force"*.

"I tell my children that it does not matter what they will do, but they need to be passionate about it because that is the only way to be successful", said one PI. *"My advice is: be really convinced about what you do"*, said another PI and she added that she struggled for years to set up assays to measure reliably what she wanted to measure. *"I really like science and knowing things, finding out things, putting things together—both in science and in my private life"*, said a third PI. *"I like picking out and putting things together to form a hypothesis about how the world is"*, she finished. You need *"a real and passionate interest in a topic"*, said another PI. Several PIs even called their love for science an obsession: *"I think a lot about science, it is kind of an obsession"*, said one of them. *"I got my ERC grant because I was obsessed with a single puzzle. I dive very deep. Most people let go too soon"*,

said another. He credited his *"skill to be focused on the same thing for days like a marathon"* for his success. *"I can make a long-term investment in one thing, in the same thing, and put my energy into it"*, he added.

Several PIs mentioned that their enthusiasm for science started at an early age. *"I always wanted to be a physician-scientist (and not a clinician), because this seemed so romantic!"*, said one PI. *"I was always a scientist"*, said another PI. When he was 12 years old, he wrote to the author of a piece in Scientific American about the interpretation of some results—and the author wrote back! *"At 15-years old, I knocked on lab doors at Harvard until somebody let me in"*, he continued. He explained that he has held some high-level administrative jobs within his university but he stepped down to return to science. *"I told the rector that I was hired to be a scientist, so that is what I would like to do"*.

As we will talk about it later, you will need to be able to convince others (team members, collaborators) to help you work towards your goal, therefore being able to communicate your enthusiasm to others is as important as being enthusiastic yourself. *"I am enthusiastic about my work and can bring people to follow me"*, said one PI about the key to her success. Also, your enthusiasm has to be genuine—several PIs mentioned that they are successful because their passion for science has no ulterior motive. *"I have no second agenda"*, said one of them. *"I am not doing science for achieving some other goal, I am doing it because of curiosity"*, and he added that he never intended to be a professor or department head. *"It is quite extraordinary to have become head of a medical department as an engineer, but I was just curious, wrote things up, applied for grants and got credit for my achievements. I got to where I am as a side effect"*, he finished. *"Nowadays, the postdocs are very calculating"*, said another PI. *"I never did that, I just followed where the results brought me. You keep the fun!"*, she finished. A third PI also said that the culture at the places where he trained was that *"the focus was purely on making basic science, there was never an ulterior motive. The only question was: who will make the next great discovery? We were focusing on the excitement"*.

Enjoyment

Besides believing in your topic, you will need to get enjoyment out of doing science—otherwise, you will find it hard to persevere when things get tough. *"I am resilient because I am enjoying my work"*, said one PI. *"I have tried several jobs, this is the one I like most"*, said another PI, adding that although he does not think he's really successful, he is enjoying doing his job and feels lucky to do what he likes. *"Originally, I wanted to be a pilot, but I had a weak eye"*, said a third PI. *"After getting into science, I never imagined to do anything else"*, he added.

According to a veteran PI (40 years of experience), enjoyment can also compensate for having a lower profile career than what one perhaps could have had: *"I could have been more successful elsewhere, but I was dedicated to working on interesting subjects and in my home country"*. He explained that he was invited to work at Harvard, but he decided against it. *"People trust my data, and colleagues know me,* *that is my key achievement. I don't care about decorations. I have generated interesting and trustworthy data. I enjoy my life, I am proud of my citations"*, he finished.

Mentors and Training

One PI (one of those who attributed his success to a single factor) simply gave me his mentor's name as the answer to why he has been successful. This may have been an over-simplification, of course, but having good mentors can help someone's career to take off. Another PI said that her supervisor *"was placed well enough"* to push for her to get the position. I think she was modest about her achievements since this happened after a long postdoc with extraordinary output, but she said that *"the people around you account for more than 50%"*.

One PI finished her list of success factors with "... *plus the environment"*. She explained that she had the good fortune to have mentors who gave her space to grow. Others also mentioned that their mentors played a great role in their success by encouraging them and advocating for them to get some precious fellowships, allowing them to work on what they wanted to work on, or paving their way in other ways.

For example, one PI (the one who said that *"I have always been a PI—in somebody else's lab"* (Schmidt 2019)) explained that he initiated a discussion with his supervisor (who was extremely busy with administrative duties and relied on his postdocs for running the projects) about distributing the projects. As a result, he could be the last author on certain papers when he was still in his supervisor's lab. This helped him to get to the next level in his career. He said, *"there needs to be a discussion between the person who secured the funding, the person who is the head of the lab, and the person who is driving the project on how credit will be divided. In many labs the postdocs do all the work and the PI takes all the credit, but it does not have to be this way. One solution is that the senior postdoc who drives the project becomes the last author, and the head of the lab becomes next to last as the corresponding author. If you have some last-author papers, it is a much better indicator of your potential than just saying that you have done all the work for the paper"*.

Although it may be unpleasant sometimes, working with very strict and demanding supervisors can also help you in the long term. One PI said that she excelled because of the high expectations of her supervisors. *"As they say, 'Palma sub pondere crescit' = the palm grows under the weight"*, she finished.

Your training can prove helpful in other ways, as well. For example, one PI said that her teaching duties as a PhD student helped her: *"doing a PhD is very lonely, often frustrating. Having a teaching activity next to it is useful because all you need to do is prepare well and you are immediately important, immediately a star!"* She added that making a contribution to society early on, *"doing something immediately useful"* besides doing science is important. *"Teaching early is very good, not only* *for society, but for the scientist, as well, and having scientists as teachers is also good for society because teachers would be more knowledgeable"*, she finished.

"Doing something well also takes skill", said one PI, and he explained that for him, writing was the best skill he picked up early. *"I can write a good grant that lays out logical reasons and clarifying schemes"*, said another PI, as well.

Several PIs mentioned that they found thinking ahead helpful in attaining success, so you may want to condition yourself to plan ahead during your trainee years. *"You have to know the system and must outline your choices well ahead"*, said one of them. Others also said that they think 3–5 years ahead about projects and development: what are the important next steps to progress with the projects and their scientific career. *"When you get a grant, you should be already thinking of the next step—it is stressful but very helpful"*, said one of them.

Picking up organizational skills during your training can also prove very helpful. One PI attributed his success to *"being good at breaking down a big project into accomplishable projects"* and another said that "*the ability to do many things in parallel, to connect information and people"* helped her. A third PI also said that she found it helpful *"having eggs in different baskets (slow experiments, multiple projects at once)"*. Organizational skills get even more important as your group grows. One PI said that*"to maintain my group, I needed management skills more. Bright ideas are not helpful for that"*.

One PI said that she actively looked for mentoring advice. *"I have approached senior people whom I trust, asking: 'Do you have any advice for me?' or 'Who would know how to advise me?'"*, she said and recommended writing down the advice of senior people in the field. *"It is much more useful than comments from failed grant applications"*, she finished.

A couple of PIs had some practical advice for shaping one's training. *"Do a PhD in a very good place, then do a good postdoc. Then change discipline with some connection to the previous field: combine the expertise of the old field and the chosen one, see how they combine. Combine all skills in postdoc"*, advised one, and another mentioned that he found mobility useful for his career: he spent a few years overseas that made him eligible for a highly coveted grant that made it possible for him to return to his home country as a PI.

Hard Work

"You do not earn this by sitting and waiting for it to happen", said one PI, and many others mentioned that consistently working hard is the key to their success (29% of PIs mentioned working hard when talking about their success). *"Hard work! I don't think about myself as super-intelligent"* answered one of them to the question of what he attributes his success, and another also said *"hard work, sheer hard work, and the ability to work with people, to collaborate"*. *"Diligence is very important"*, and *"I do not go home until everything planned for the day is done"*, said other PIs.

"[I was] working hard, working insanely when I was a postdoc, being the only person in the lab when everybody else left", said of herself one PI, and things do not

necessarily get easier later, either. Another PI said, *"I also invested a lot of energy in work: for two times seven years, I had labs in two different countries, then I consolidated it to one country and about 1.5 jobs"*.

A veteran PI, looking back on her career said that she can't even imagine how she was able to do all the things she has done. *"I worked diligently, I did not let up, and I had good colleagues that made it possible to make progress"*, she finished. Another PI described himself like this: *"I have a good working capacity. I am very efficient, a kind of machine sometimes"*.

On the other hand, several PIs said that although hard work was part of their success, it is not enough in itself. *"This is not to say that I did not make efforts, but all my competitors made efforts, too"*, pointed out one of them.

Delivering Results

However, it is possible to work very hard and have little to show for it in the end. You need to work in a manner that is focused on getting things done and producing output.

Several PIs mentioned their ability to bring things to a finished product as a contributor to their success. *"I am willing to finish the less exciting or boring tasks, as well"*, said one of them and she added that she is *"not attracted to people who have brilliant ideas but do not follow through"*. Another PI contributed his success to *"a hunger for publications: I knew when to go full steam and when to drop a project"*. A third PI said of himself that *"Whatever I agree to, I follow through with it"*, and others said that they are *"good at both planning and executing the work"*, and are *"very motivated to finish projects"*.

Creativity to Ask the Right Questions

"What is even more important than working hard is working hard in the good direction: go for things with an added value", said one PI and another expressed a similar notion saying that one of the factors of his success was *"being aware of where to put [his] efforts, what would be the most worthwhile"*.

Indeed, what you focus your efforts on makes a big difference in how much the output will help you to succeed. One PI said that she was successful partly because of *"working in the right domain"* (in the intersection of two fields that get a lot of attention: metabolomics and cancer) but also because of *"choosing the right projects"*. One-third of PIs attributed their success to being *"good at asking the right questions"* or having the creativity to look *"outside of the box"*.

One PI explained that *"you can never plan a discovery, you can just ask good questions. It is important to ask big and important questions because working out insignificant questions takes almost the same amount of time"*. Another PI had similar advice: *"work on important questions instead of working well on the questions put in front of you"*. Other PIs also said that they don't just want to do experiments, they *"want to move the field forward"* and" *publish papers that show a paradigm shift"*.

Although one PI advised that you ought to *"do the science you want to do, and it will happen"*, others indicated that timing of your contribution may also determine how much success it will bring you: *"I have contributed quite a bit to a new field. I got interested in a new field at the right time"*, said one PI, and another explained that her first postdoc was not successful at all but her second postdoc was very successful, because *"it was the right plan at the right time"*.

What your fellow scientists think of your contribution will also influence whether it will be hit or not. One PI said that she is successful because she is *"doing things differently, and doing things other people think are interesting and innovative"*. Another said that he was *"doing slightly unusual things"*. He does *"not do the obvious thing—which leads to publishable things!"*

One PI said that she has been successful because she *"dare[s] to enter new pathways"*, and indeed sometimes going into a new field is risky. As one PI said, he moved away from the university where he had a guaranteed position and moved into bioinformatics when bioinformatics was still very new (1988). *"I could do this because I was not worried about my job"*, he said. *"The field then exploded unexpectedly and bioinformaticians came into great demand, so I was lucky, as well"*, he added. Another PI also said that she is successful because *"I am comfortable with doing things that other people are not, because they see it too risky"*.

Of course, not all of your questions may turn out to be as exciting as you initially thought, and reversing the course will also require courage. *"I am willing the pull the plug on something that I have invested in and start something new"*, said one PI about such situations. She also admitted, that although she made decisions she felt comfortable with, she may not evaluate risk the same way as other people.

Being observant, and especially, seeing the non-obvious will help you to ask the right questions. One PI attributed her success to her multidisciplinary background, saying that she *"can take advantage of opportunities other people may not see"*. *"I look for the un-obvious!"*, said another PI.

One PI said that it is important to formulate research questions clearly (this will also help to do your research in a focused way). He said: *"I spend a lot of time interrupting my people and other presenters asking: 'what is the question?', because people often lose track of this. I force my people to write project plans in forms of questions (with a question mark!), with sub-questions and sub-sub-questions"*.

"I am creative, I dream about my topic", said one PI and many others also attributed their success to their imagination. *"I have never done a 'me-too' paper because 'me-too' is boring"*, said one of them.

Other PIs mentioned having a vision for their field as well as for their contribution to it, and acting based on their vision. One of them said that his *"talent is having an idea, a gut feeling where fields of research will merge"* and the other said that his success comes from *"having a vision, being able to see what other people do not see"*.

Collaboration

"Be constructive to other people: collaborate, help others", was the advice of one PI, and many others also listed the *"capacity to interact with people"* and collaboration as one of the sources of their success (33% of PIs included collaboration in their list of success factors).

"I am collaborative with people and build long term relationships with trustworthy people", said of himself one PI, and another PI also contributed her success to the very large community she built with colleagues. She is interacting and supporting colleagues who in return support her.

Being a PI can be a lonely place without collaborators. One PI related to me that she got a precious European grant to realize her ideas—but they did not fit with the department's profile, and she ended up transferring to another department. *"I am bothered that my grant was not welcomed at my old department. I got my independence, but I never imagined to be this alone"*, she finished.

You will have to take an active role in building your collaborative network and you may have to get out of your comfort zone. One PI said that she *"spread her wings in other areas"* by following up her research topic in different tissues and organs than she was working in before. She reached out to others to learn from them, which *"kept things interesting and resulted in a large group of friends and colleagues"*, she said. "People like to help and teach", and showing her weaknesses openly, honestly, and with humour resulted in genuine relationships. *"To be known is very important. Bring hard-working and open-minded people together who are willing to share"*, she added.

Another PI also said that it was important to integrate into the international scientific community, which was not easy from the small country he was from. He overcame this by organizing a conference every two years in his field, and the group of regularly invited speakers became a circle of friends. *"I try to maintain a relationship and collaborate with people smarter than me: things are more interesting this way, I get to learn more"*, he finished.

One PI explained that he studied military history and he is translating his knowledge of strategy and tactics to his own work. *"I can't do a Nature-worthy experiment, but I am good at strategy"*, he said, and he explained that developing research proposals requires involving *"the right people at the right time"*. *"I can be very quick! I respond to offers before others and get involved in consortia—time really matters"*, he added, and he has been successful with grants and consortia.

Several PIs had advice on how to make sure that the networks you build will last. "*I deal with people honestly. I am myself, and not faking it"*, said the previous PI and another had this advice: *"make sure that other people find it fun to interact with you, and they will help you"*. Delivering what you agreed to is also important. Another PI said, *"I am open and collaborative, I get things done. If people trust you and they think you are reliable, they will come to you for help and they will help you"*. Others also mentioned that they are respected in their field because they are reliable and produce solid, reproducible data. Of course, you should hold your collaboration partners to the same standards. *"I am very selective with collaborations"*, said one PI, and he said that he accepts about 1 in five offers to collaborate.

Others had advice on the way you communicate with others. One PI said that she has an outspoken character, always saying what she is thinking, *"but in a polite way"*. *"My EQ is more important than my IQ"*, she finished. Another PI suggested to *"always speak collectively—it develops the common thinking"*, and a third cautioned that *"the key is not to make enemies . . . You always meet the same people: either you win or lose, you lose on the long term"*.

Also, as you are building your network, think broadly (both scientifically and geographically). One PI who said that being collaborative is most important added that she works with somebody on the opposite side of the globe on something that is not even her field, but it became a very productive collaboration!

Character Traits

"All scientists are addicted to discovery. Just go on, if you accept yourself, things get easier!", said one PI. It sounds like good advice, but to stand toe to toe with other scientists (reviewers, grant agencies), you need one more thing besides being passionate about your subject: confidence. One PI finished her list of success factors by saying that *". . . and, most importantly, I believe in myself"*, and other PIs also mentioned confidence when talking about why they thought they were successful. She also added that it helps in this regard that she has a small circle of scientists with whom she has a close connection: *"we encourage each other and have each other's backs"*. We will talk more about the importance of networks later. "*Have the confidence and do science in your own way! You can be successful in many ways",* said another PI.

Several PIs mentioned that not shying away from responsibility also helped them. One of them had this advice: *"Grab the responsibility—or not. But confidence is gained by grabbing responsibility. Learn to work with people, invest in the success of co-workers. Just like in basketball, not everybody can score: long-lasting relationships are more important than the last-authorship"*.

Although I was expecting that most PIs would bring this up, only a small proportion (7%) of them mentioned that being intelligent contributed to their success. Funnily, most of those who mentioned it, were rather shy about it: *"I am not dumb and can focus"*, said one of them, *"I am smart enough"*, said another, and a third said that she *"can analyse problems deeply"*. Several mentioned that it certainly helps to be intelligent, but you need to use your intelligence in combination with perseverance, drive to succeed, focus, and hard work. One PI even said that *"there is no such thing as talent, it is all hard work and perseverance"*. In any case, it's probably better not to get too caught up in your own cleverness: *"I don't take myself too seriously: if people think I'm smart, fine, if they think I'm stupid, that is fine, too, it does not matter to me"*, as another PI said.

Besides intelligence, there were a few other character traits that PIs said to have contributed to their success. *"I always wanted to do well by my superiors, ... I* *always wanted to perform well what was expected from me"*, said one of them. *"Trying to be perfect"* was one of the factors another PI listed, and another PI also mentioned *"thoroughness"*. Several PIs mentioned feeling gratitude for having the opportunity to be a scientist. One of them compared her own life with the harder life of her mother and said that she felt privileged. *"It is important to be modest, not only as a hypocrisy but being frankly grateful"*, said another PI, *"I try to believe that I deserve the success I have had"*.

Finally, having wide-ranging interests about the world (including arts) and good communication skills were also mentioned. *"I am not fearful, I am willing to open my mouth at meetings"*, said one PI, and she added that *"this has had a good effect at the national and the international level"*—although it has not endeared her to her colleagues at the local level.

Good Group

Biomedical science is a team sport. Just as in the case of any team effort, *"you are only as good as the people around you"*, as a veteran PI put it. Many PIs included in the list of the factors contributing to their success are their ability to work with people, having good people in their group, and supporting them well.

As we talked about it a little before, being passionate about your science in a way that is obvious to others helps on the road to success, and several PIs mentioned their *"capacity for working with people and leading people"* as a contributor to their success. *"I am enthusiastic about my work and can bring people to follow me"*, said one PI, and another said, *"I can lead people, people adhere to my projects and accept my criticism"*. *"I know how to work with people, how to put them together in a non-competitive environment"*, said a third PI, a former basketball coach, and he said that he uses the same principles to assemble his group as coaching team sports.

Just like in the case of collaborations, several PIs mentioned that picking the right people for your group is essential. *"I am very selective to hire the right people"*, said one PI, and another PI said that "*people in the lab have to be there to do science and not to please me"*, and she explained that she does not like people who are constantly seeking approval, she wants self-motivated people, and *"the science they do have to be good and reliable"*. A third PI had this advice: *"Attract the right kind of people to your lab: have at least a couple of people at the beginning who are really dedicated—you will need them to establish your lab"*.

Several PIs mentioned that their success is due to being in touch and nurturing their people. *"I am interested in my people and take care of them, I show genuine interest in their problems"*, said one PI. She explained that she wants people around her happy, and people, in turn, recognize and appreciate this. Besides, it also gives her a good feeling.

Another PI mentioned that he thinks that training their people very carefully served him well. *"I had early on a team of people who worked with me, whom I taught everything I learned about the model during my PhD"*, he said, and one of these early people stayed with him in the lab as a co-PI. *"Still, everybody who comes to my lab gets a very thorough training, they do nothing alone for the first three* *months. Better training leads to better outcomes"*, he continued. *"Some people may feel that transferring all their expertise takes away their uniqueness, their edge, . . . but this served me well. . . . You have to trust people to do this since you are creating your competitor, but I believe that sharing knowledge is key to success"*, he finished.

You may question the wisdom of training people carefully if they just go on to another job from your lab, and indeed, most funding is designed to support personnel for doing their PhD and short postdoctoral stays. *"The structure of science failed: science manages to get rid of the people it needs most, the well-trained more senior people"*, said one PI, but it does not have to be that way. This PI said that part of his success came from the partnership he formed with one of his team leaders. *"He can make anything run, we have a complementary relationship: he takes care of practical things, and I take care of ideas, papers, money"*, he said. *"I am willing to pay more for a senior person. I protect scientists from academia"*, he finished.

Supportive Family and Friends

As we saw in the section about stress management (see Chap. 6), many PIs said that their family and friends help them manage the stress of being a PI, and some also mentioned their family and friends as one of the factors in their success. *"I have a wonderful, supportive family, I have many long-lasting friends from my personal life and also through my work"*, said one of them. *"There is a private factor to success"*, said another PI, *"the energy needed for doing science comes from the person and his situation, having a partner who understands"*, and another PI also said that having *"a family that understands what you are doing and supports it at home"* is important.

Luck

"Luck" was also a very often mentioned success factor, 33% of PIs mentioned it. *"You can't have this career without luck in choosing whom to work with and making good choices without being able to make rational choices"*, said one of them.

Other PIs, including the Nobel Prize winner in the sample, attributed all their success to *"good fortune"*. Several PIs said that their career was not at all planned and some described their success story as a chain of coincidences, involving chance meetings, being *"at the right place at the right time"*, some calamity leading to a lucky discovery, publishing something *"just in time for applying for funding"*—stories reminding me of Paulo Coelho's The Alchemist. One very accomplished PI (270 publications, PI for 25 years, H-index of 51) even felt that she has not achieved enough, considering all the luck that she has had, and another PI said that she had *"impostor syndrome"* because luck was involved in her success.

> *"Plus, I had a big dose of luck!" (professor, PI for over 25 years, over 120 publication, H-index of 24)*

Not everybody agreed, of course. One PI said that his success was due to *"not luck, perseverance"*. Other PIs who did think luck was involved qualified their answer with *"but people make their own luck"* or *"at the same time, fortune favours the bold"*. I tend to agree with these PIs because what stood out from the stories of lucky coincidences was that those PIs were successful because of their ability to take advantage of opportunities. *"Things just came up, and I did not let them pass by"*, said one of them, and others had the courage to quit and start over when they saw that things were going nowhere, or changed their projects to follow up on some unforeseen outcomes—instead of getting frustrated.

Although I don't find "be lucky" helpful advice, therefore I like to focus on this other component because that is something you can act on, I got some pushback on this point from one PI. Since she felt so strongly about this, I want you to hear her opinion, as well: *"We need to tell young people how we think things really are. If the reality is 50% hard work and 50% luck, they need to know, whether it is helpful to them or not. . . . I still think that securing an academic position is largely due to luck. I mean luck in a wide sense: having a supervisor who is able to place your work in higher-ranking journals than another would, being interested in a topic that happens to be in fashion, having reviewers that like your research proposals (which is more often a question of taste than not), just being plain lucky in having non-negative research results, having a partner who is willing to move if you find a position in another country etc. Taleb explains in his Black Swan how we underestimate luck as the main factor behind success, and I agree with him"*.

Top Publishers

Top Publisher cited most often their imagination, creativity, asking the right question and luck as a success factor—closely followed by their passion for science, hard work, and perseverance.

Throughout this book, we discussed not only what PIs do, but also what goes on in their head, why they do things. The next chapter will be dedicated to some general thinking patterns of PIs that have not come up yet because PIs rarely volunteer this information and finding it out otherwise is difficult.

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8 Under the Hood: Common Thinking Patterns of Principal Investigators

Abstract

We all have habits. Some of our habits may be a result of conscious choice and we may not be even aware of others (if you think you don't have any habits, just ask your sibling/parent/child/significant other—they will be happy to provide a list). Some of our habits can be helpful to achieve our goals (like exercising regularly), others may be neutral or even impede us in reaching our goals.

Habits can be not only behaviours, things we do, but we also have habitual thinking patterns. Just like physical habits, some of our mental habits can be helpful for achieving our goals and others may not be: e.g. *drawing the conclusion from a failure that we are not good at something and we should stop is not a habit that helps to achieve your goals. I asked PIs about some of their thinking habits because it will be useful for you to emulate not only the behaviour of PIs but their ways of thinking, as well. I think that just as there is a body position that makes it easier to ride the bicycle, for example, there is a "mental position", a way of thinking that makes it easier to be a PI, for example. I also think we can find out what that "mental position" is by looking into the most common ways PIs think. As you will see, not all PIs have the same mental habits (far from it). Although I may not be able to tell you which ways of thinking are more useful than others, I think the more common ways are probably routine because they help them to become and stay PIs. I am also convinced that being aware that there are other ways of thinking than the way you naturally do, and trying out those other ways from time to time will be useful.*

In this chapter, we discuss some of the thinking patterns of PIs, including their information processing and goal-setting habits, how they make decisions, and how they get convinced, and reassure themselves that they are on the right track.

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
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Noticing Similarities or Differences?

If you see the results of the same experiment, performed twice, do you tend to notice the similarities or the differences? Only 19% of PIs said that they look for the similarities, and the rest were split about evenly between PIs who notice differences (40%) and those who look for both similarities and differences (41%). The comments of people who answered that they looked for differences revealed that many of them actually look for both differences and similarities, but they start with the differences.

Those who look for similarities cited looking for reproducibility and said that similarities give them confidence that the experiments were performed properly and give them a feeling of the major trends in the experimental system or they interpret it as the robustness of the result. Those who look for the differences are frequently asking "is the source of error technical or is it biology that determines it, or in other words, what is the effect and what is noise? It also depends on the phase of the project whether PIs focus on differences or similarities: at the beginning of a project (especially when they are optimizing a technique), they tend to look for differences, and towards the end, when they are in *"publication mode"* and are looking for a storyline, they tend to look for the similarities.

"The truth is in the differences", said one proponent of looking for the differences, and he added that if you look at similarities only, you ignore a lot of information, because observing similarities leads to setting up categories, which makes learning easier, but *"we need to dismantle categories to learn more"*. The comments of another PI also illustrated that looking for similarities is a tool to simplify things: if he knows the field very well, he looks at the differences, but if it is something out of his expertise, he looks for the similarities. *"The similarities make it [the result] believable, [but] the differences bother me, they make me think 'which one is true?'"*, said another PI.

Top Publisher PIs picked looking for differences much more often than looking for similarities (65% of Top Publisher PIs look for differences), only a few of them (4%) said they were looking for similarities and the rest said they were looking for both differences and similarities.

The "Big Picture" or the Details?

If we were going to do a project together, would you like to know all the details first or the big picture first? The vast majority of PIs (89%) want to know the big picture first when they hear about a new project, and then they want to know the details afterwards. They said that they want to know the big picture to decide if they want to get involved, or does it even interest them? They ask for details for various reasons: to know if the big picture is accurate, to know if they can deliver what would be expected, and to ensure that the collaborators know what they are doing. A very successful PI (PI for almost 20 years, over 450 publications, H-index over 90) mentioned that he wanted to know the details to ensure that this will be a real collaboration with the complementarity of expertise and his lab making a meaningful contribution and the other party is not only after putting his name on the paper. Some said that they may not go into the details too deeply since *"science is discovery: it can't really be planned"*, and they are not at the bench anymore so they don't need a lot of detail. Several PIs mentioned that the amount of detail they require also depends on the amount of trust in the relationship (the more trust there is, the fewer details they needed). Discussing the details also includes setting the rules for publication beforehand—as we have already talked about it in Chap. 5.

In a similar question, I asked PIs whether they tend to look for the bigger categories an issue fits into or they tend to drill down and dissect the topic? 80% of the PIs said that they look for the big picture. Then they either stop there or they follow up by drilling down—although one PI also pointed out very amusingly that this is context-dependent, since *"one person's details are another person's big picture"*.

PIs said they look for the bigger categories because they always *"want to be a bird who looks at things from the top"*. One pointed out that the details make no sense without the big picture, and you can ask completely different questions starting from the same details if your big picture is different. One person pointed out that her preference has changed over time: now she tends to go up, but in the past, she was drilling down.

About 20% of PIs look for the bigger category first and then shift gears and looks for the details. These PIs said that they want to make sure they have a good reason to do the work (as one PI said *"without a purpose, I don't touch anything"*) and they drill down to make sure that the results are solid (as opposed to *"correlative bullshit"*, as one PI put it). Sometimes this is dictated by the situation: e.g. when they discuss the implementation of a project with members of their team, they need to go into the details very much, or they tend to zoom out at the beginning of the project and drill down later during the end of the project. One PI said that both zooming out and drilling down are necessary, ideally both at the same time: they are synonymous with basic and applied research. Society wants applied research, so drilling down is good for finding funding and zooming out is good for finding new topics for research.

The minority of PIs (27%) who tend to look for the details said that the essence of their field is to find out the minutest details (e.g. structural biology), or they do it to differentiate themselves from other researchers (to find their niche), or this is a way for them to make the results more concrete and honest.

Top Publisher PIs showed an even stronger preference for going towards the higher categories.

Listening Style

If somebody tells you something describing a need (e.g. "I am thirsty"), do you tend to take what you heard as information or an inferred request to meet that need (also called being a literal listener or an inferential listener, respectively)? Most PIs (89%)

are inferential listeners who have it in the back of their mind that there is an inherent need in what they hear and immediately think about what they could do about that need. PIs with medical training, for example, said that they were naturally very empathetic and could not even imagine not fulfilling a need somebody has expressed.

The remaining 11% mentioned that they either like explicit requests or they make a distinction whether to act to fulfil the expressed need based on who makes the request (e.g. are they capable of taking care of their needs themselves?) or they have learned to let people ask for help.

Setting Goals

There are many ways of "thinking": some people have an internal dialogue going on and when they are "thinking" they are actually talking to themselves with their inner voice, others "think" in images, or may have a kinaesthetic experience (a "gut feeling") or hear somebody talking to them. I asked PIs what way they "think" about their goals, how they represent their goals internally.

PIs talk to themselves: the most frequently chosen modality for internal representations ("way of thinking") was internal dialogue, and the next most frequent was visual representation (thinking in pictures). Kinaesthetic ("gut feeling") was about half as frequently mentioned as internal dialogue, and hearing was barely used.

Self-Talk

Self-talk was the most frequently mentioned (54%) way PIs think, and about a third of PIs (37%) use self-talk exclusively as their way of "thinking". Some PIs use self-talk for motivating themselves, others use it in more specific ways, for prioritizing, self-questioning, clarifying the issues, or even steadying themselves in tense situations.

Cheerleading

Some PIs are constantly asking themselves what their schedule is, what tasks lie ahead of them or use self-talk in a general way to motivate themselves. They may tell themselves to hurry up with their tasks, saying things like *"Chop, chop, let's do this now!"* or *"If I just get this thing done, I can move on to the next thing!"*

Prioritizing Tasks

"What am I doing and what am I doing it for?", likes to ask herself one PI to *"help to put the smaller things (everyday management) in the context of the big picture"*. As she explained, she feels lucky to be doing what she is doing and her lab has been well funded so she feels obligated to do an even better job than was accomplished in the past.

Several PIs reported such very practical use of self-talk, e.g. to generate an overview of their goals for the day and the way they are approaching them at the beginning of the day even before getting out of bed. One PI said that she repeats the procedure at the end of the day and she reviews her day in comparison with what she wanted out of the day.

Self-Questioning

Another PI mentioned using self-talk to achieve her goals by questioning herself (e.g. *"I would like to have this student in my lab, how do I go about it?"*) to see if any good ideas pop up that she could develop into a strategy.

Clarifying

One PI said that he wishes he was more impulsive, *"more of a System 1 person"*, as he put it, referring to Daniel Kahneman's work (see Recommended reading at the end), but instead his internal dialogue is constantly going on, he is considering all possibilities and the pros and cons of the different possibilities. Other PIs also reported thoughts constantly percolating in their minds about projects, recent events, how they would have loved to react in certain situations but did not, preparing for future similar situations, etc. Some likened it to a constantly ongoing conversation with themselves that helps them to clarify issues and integrate new knowledge. One PI said that he *"nibbles at problems"* as he mulls them over in his mind, trying to look at them from several angles. Another PI even said that he lets the project mature in his mind before he starts grant writing (although I would recommend more the advice of another PI who said that thinking and writing help each other and it is much easier to achieve the coherence needed for a grant application once it is on the page than as long as it exists only in your head).

For most PIs self-talk seems like an informal conversation but one PI reported that he not only puts his thoughts in words (without actually talking) but also forms complete sentences and he finds it very inspiring when he has a chance to explain to others what he has already formulated in himself.

Steadying themselves

Finally, one PI said that he uses self-talk in tense situations to keep himself focused, grounded.

Visual

43% of PIs mentioned including images in their thinking process (21% uses internal pictures exclusively). Self-talk is very useful for pairwise comparisons, weighing the pros and cons of options or finding a linear and logical order for blocks of information, but it seems to me that thinking visually is better for finding new connections.

Perhaps because I am not good at thinking visually, I found the inner visual life of PIs astounding. What they "see" in their mind's eye varies a lot: one PI said *"I see a path in front of me"*, others talked about associating colours with, e.g. persons or situations, seeing detailed images or even full movies of goals or situations, and any of these can be augmented with sounds and feelings. The images they "see" are in colour and they can be of various sizes, from the size of a page through the size of a mid-sized television to life-size, and they can be either close or several metres away like an image projected on a movie screen.

Some PIs make tangible visual representations, as well, that can be simple sketches and models or very elaborate paintings (one PI showed me the amazing colour drawings she uses to find connections between results, they were veritable works of art).

Not all PIs are naturally good at visual thinking, some said that they are conditioning themselves and are getting better at visualizing, and another said that having lots of discussions about the problem and possible solutions allows her to imagine the outcome.

Expected Results

Several PIs said that they create an image of the end result they would like to achieve, they imagine the data they would like to have or what the experimental data or the figure they would like to have in the future publication look like. PIs often use a combination of internal representations, e.g. one PI who usually uses self-talk for "thinking" said that sometimes she can get a sudden flash of an image, like a figure for a paper showing what she has to do. Another PI said that she visualizes the experimental results and sees the words describing the conclusions on the paper while she is talking to herself about the concepts.

You might worry that having a specific outcome in mind would narrow the PIs vision, but interestingly, it does not seem to matter to them if things turn out differently—the important thing is that in their mind's eye, they already have the solution. Moreover, the imagined result may not be specific at the level of the data: one PI said that she may imagine, for example, what the title of the paper would look like in the journal *Cell*.

Exploring Connections

Besides using images as a goal-setting tool, some other PIs use imagery for exploring connections. One PI told me that he sees colour images (the colours signify various qualities) and his thinking process is like a game of chess, looking for interrelationships and evaluating how changing some relationships would affect all the other nodes.

Another PI also said that he is constantly comparing things in his head and doing some "lateral thinking" by shuffling the various pieces around. He thinks of it as a puzzle: you have to get as close to the truth as possible with the limited information you have by figuring out how the pieces connect. Once another PI said that he "sees" colour images in front of him and talks to himself about them, testing ideas or troubleshooting or looking for strengths and weaknesses.

A couple of other PIs also said that they have an assembly of images and graphs that they are thinking about in their head and try to arrange them in a schematic drawing of the pathway or the mechanism. It starts with a general model with arrows connecting the pages that they can re-shuffle as new data comes in to update the model as necessary.

Teaching Tool

One PI said that he envisions the events he is working on (e.g. a chaperone breaking apart aggregates). He does not find still pictures very useful, therefore he envisions these events as a movie or even as a pantomime. He loves that we have the technology to make good animations now, they really help him to explain to students what he's envisioning—they never forget it!

Finding Solutions

Another PI said he likes to search for solutions to the problems he's working on by entering a dream-like state with life-size images and sound: *"it is like being in another world where the end results are present"*, he said. When he can't sleep, he does this kind of free association—until he finds that he is sleeping!

A PI who described herself as *"extremely image-driven"* said that when she's thinking about how to solve a problem, images often occur to her—although they can be abstract images containing words and colours. When she interacts with people, she sometimes sees them in colours, as well.

As we talked about, many PIs use self-talk to prioritize tasks and one PI mentioned using visualizing similarly: he looks at the possibilities like they were branches of a tree and then asks himself: *"what is the ripest fruit?"*

Lists

Many PIs are list-makers, they make lists of things they want to get done. Having an item on a list is a source of motivation to complete that task and they derive satisfaction from being able to cross an item off their list. For some, the lists are real lists on pieces of papers, stuck on their desks, computer screens, bathroom mirrors, or electronic lists on their phones or computers. For others, the lists are mental lists and several said that they can see the list in their mind's eye because they have a real list somewhere.

The mental list can be a picture of a simple list of their tasks and others have life-size, brightly coloured movies in the back of their head that show the people they will need to deal with in the situations that are coming up. There can be 3–10 such items on the list and the list does not only help them remember their tasks but one of these PIs said that these little movies also help her to explain the tasks to others.

One PI explained that the order of items on his mental list is not set. He *"looks"* at this list frequently in his mind and there is self-dialogue going on, like *"you have to do this thing"* or *"that can wait"*, as things get moved up or pushed down on the list as he is prioritizing.

Preparing for Upcoming Events

Several PIs visualize the favourable outcome of upcoming events. One PI said that if she's nervous about a presentation, she may visualize how she presents, how she handles questions, etc., and may also tell herself: *"this will be well-received"*. Other

PIs also mentioned picturing themselves giving talks, but this use of visualization was not limited to talks: PIs make visual representations of the people they will meet that day or “see” how people will react to what they want them to do. These are usually very realistic, life-size pictures, or movies in bright colours, augmented with their feelings about the situation.

Gut Feeling

16% of the PIs said that they have a purely kinaesthetic experience (gut feeling) when they think about a goal (and another 8% said they have such experience in combination with other modalities of representing their goal). These PIs mentioned having an *“eureka-feeling”* or simply being very happy to go to work or a feeling of responsibility as their source of motivation. These PIs just *“get a gut feeling and get going”* and don’t need or don’t even want other kinds of motivation. *“I need the gut feeling all the time. Other sources of motivation are dry for me”* said one PI, and he added that he does not think about anything else besides his work: everything else is for relaxation and he does not need the motivation to do it (e.g. he likes to cut the grass because he finds it relaxing).

Other PIs also reported being *“super-enthusiastic”* about their field of study or getting a *“feeling of looking forward to doing”* something. But the answer that really gave me goose bumps came from the PI who said that finding simple solutions to big problems is a strong driver for her because she gets the feeling of *“I see something”*. She said she gets the same kind of feeling when she is playing African percussion or looking at 3D pictures: something rises out of the chaos.

Auditory

Some people remember better what they hear or if they also hear what they read. For example, one PI said that when he was a student, he used to mimic the voice of the teacher when he was studying and repeating things out loud still helps him to focus.

In Writing

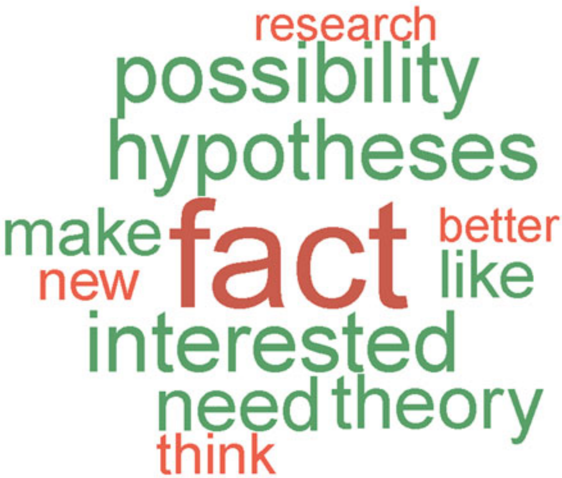
Some PIs prefer doing their planning on their computer—having all the results at their fingertips. Others, on the other hand, said that they prefer to do their goal-setting using pen and paper because it helps them to focus, thinking behind the computer does not work as well for them. One PI said that he is using a calendar because it lets him see the upcoming deadlines as he is asking himself what he can do now and what he can put down the list for later. Having pen and paper around may remain a good idea, e.g. one PI said, for example, that she gets up in the middle of the night to write down her thoughts about the problem they are having in the lab, including her ideas of how the system may operate or something to look up in the literature that may be useful.

Facts or Principles?

Most PIs are not fact-finders. This may sound strange since scientists are finding out new facts about the world all the time—but it seems that for most PIs, the facts themselves are not their primary interest, they are rather interested in what they can build based on those fact (like most people are not interested in the individual Lego blocks in a set but what they can make out of them). About two-thirds of the PIs said that they were more interested in ideas and the relationships between facts and the application of these for the future than in the facts themselves and their immediate application. About a quarter of PIs answered that they were interested in both (*"when I am interested in a topic, I am interested in facts, ideas and their relationships"*, said one of them), but many of these PIs made a temporal distinction: they were interested in the facts for the now, for directing the work of the lab, and in the relationships for the future, for example when they are writing grants. *"You need to have a vision in science. Everybody can do the here and now"*—said one of them.

Some PIs are interested in the application, the translational aspects of their research (typically those who have a background in medicine or work in medical departments), but most PIs prefer to "simply" acquire knowledge about the fundamental processes of life and uncover new relationships between facts. Although many of them mentioned that they feel obligated to think about applications for funding purposes, most are happy to leave working out those details to other people (to the *"engineer types"*, as one of them put it). *"I am more interested in the logic of the circuit, not that much in the architecture of the circuit"*, said a PI with over twenty years of experience. *"I like figuring out the detective story: what is the logic? I enjoy the aesthetic beauty, being able to say: 'in retrospect, that is really clever'"*, he finished.

When asked to choose between facts or the possibilities and hypotheses associated with those facts, only a quarter of PIs said that they were interested in the facts only. These fact-oriented PIs said that they are primarily interested in the facts because they want to make sure of the quality of the results, they do not want to over-promise, or they think that the facts will dictate the possibilities, anyway. 75% of PIs said that they were more interested in the possibilities, hypotheses, or theories based on the facts. But this does not mean that these PIs do not want to be sure of the facts. Many of them said that they were interested in both the facts and the possibilities, although they may have a preference to consider one or the other first. Most PIs want to see the facts first (with their context) because those form the basis from which their imagination can explore the possibilities. *"The facts are needed to evaluate the possibilities"*, said one PI and he continued that he goes in the facts "as deep as needed" to evaluate the possibilities. Others said that they are interested to explore the possibilities only if the facts seem solid, but the inverse was mentioned, too: one PI wants to see the possibilities first to determine if knowing the facts is interesting.



Here, it is interesting to explore what PIs mean by "facts". I asked them whether they think "facts need no other explanation" or "facts support certain principles". The majority (75%) chose that facts support certain principles. The difference between the two choices seems philosophical, but as PIs explained, we need to be aware that the interpretation of a fact depends very much on the context in which that fact was collected. As one PI said, *"facts always need an explanation"*, and you always need to *"dig deeper"* and explore the way the fact was generated. A physician-scientist PI gave me this example: if somebody is bleeding, this may or may not be dangerous, depending on other underlying conditions. Another PI pointed out that since the facts are context-specific, the hypotheses constructed based on those facts are also context-specific, as a consequence.

The more complex a system is, the more opportunity there is for the context to influence the outcome. One PI said it was important to keep this in mind as you are working with students who manipulate complex biological systems—the complexity of biological systems makes finding out the context even more important. You can look at facts from different angles and interpret them differently—it is worth re-reading old experiments and see if you still draw the same conclusion from the results, suggested one scientist with 27 years of experience as a PI. Another PI with over 25 years of experience went even as far as calling biological facts not "facts", but the *"truth of the day or the fact of the day"*. This flexibility in changing the interpretation of a fact may be important for long-term success.

This does not mean that PIs live in some fairy-tale world where everybody creates their own version of reality. They did emphasize that facts reflect the objective reality that they are trying to model, yet our concepts/principles may be wrong or too narrow to include the facts. They accept that facts are always right (*"data is data"*), even if we cannot make sense of them—but the interpretation of those facts may change, as we learn more about the context.

The other reason why most PIs dislike standalone facts was that they find facts more meaningful and easier to work with or remember if they are integrated into a broader framework. One PI called facts *"observed relationships"* and embedding them in a set of principles (putting them on *"hangers"*, as another PI said) helps to retain them. The PIs who emphasized the need for a framework to work with facts said that science is not collecting facts, but finding out what this intellectual framework holding the facts together should be. Facts are the evidence supporting the principles and they are meaningless without an intellectual framework. Another function of the intellectual framework is to guide and improve future experiments: the hypotheses are the *"crutches"* that help us navigate the rough terrain of the facts.

However, it is important to keep in mind that our concepts may be wrong. Don't be blinded by the current concepts or your hypothesis, pay attention to (reproducible) facts that go against the current concepts. Often the underlying principles are not what we thought they were and recognizing this helps to discover the truth—as well as it helps your career since whatever you discover against the current dogma will be very interesting to the entire scientific community. If the facts do not fit any known principle, it is the job of the scientist is to find out the principle the facts do fit.

Despite the focus of most PIs on concepts and intellectual frameworks, most of them (65%) consider themselves as "practical persons". They said that running and sustaining a lab requires being practical—on the other hand, they indicated that they have imagination. The quarter of PIs who said that they are both practical and fanciful said that they believed that both approaches are needed, depending on the situation or the phase of the project. They mentioned that being able to go from being practical to being fanciful is a strength (like being able to zoom out and in), like having two hats on, a scientist hat and a manager hat: imagining projects and then making them a reality. Imagination can help to jump on opportunities or dream up and start projects that are not practical—several of these PIs mentioned having some *"crazy"* projects on the side. The few (10%) who characterized themselves as "fanciful" only emphasized the importance of imagination and creativity—one even said that he is planning to set up a course to teach students to use their imagination because scientists should be artists.

Making Decisions

I asked PIs several questions probing how they make decisions: do they stick to reason and logic or do they let their personal values and feelings influence their decisions? Do they deliberate long before making decisions or do they decide on the spot? How do they make a choice out of several options?

Reason and Logic or Personal Values and Your Feelings?

PIs were about 50% more likely to say that they rely on their logic for making decisions than on their feelings, perhaps not surprisingly. But even those who said they were making decisions based on logic qualified their answer saying that this can be situation-dependent, and they use logic with project-related, known scientific topics—and even in those situations, their "logic" can be informed and influenced by their values and feelings.

The 21% of PIs who make decisions based on their personal values said that they ask themselves *"Is this the right thing to do?"*, and even when they are trying to use pure logic, they often discover that their personal values and feelings are the reason why they follow a certain logic: decisions are personal, guided by gut feeling.

The most popular answer was using both logic and personal values. These PIs admitted that personal values and feeling have a strong effect on their decisions and mentioned compartmentalizing their decisions: for practical matters, project management, money, they try to stick to making their decisions based purely on logic, and for personnel issues or deciding what questions to pursue, they rely more on their personal values and feelings.

Acting Quickly or Making a Complete Study of all the Consequences Before Acting?

At the beginning of the interviews, it surprised me how many PIs said that they make decisions with their "gut", without lengthy deliberation, so I was expecting that the overwhelming majority of PIs would answer that they act quickly after sizing up the situation. Although PIs who said they were acting quickly were in the majority (46%), quite a few PIs (37%) answered they like to study the potential consequences before acting, and the rest said they use either method, depending on the situation and the topic of the decision.

One PI told me that she believes there were no wrong decisions, therefore it was not worth spending too much time thinking about them! Others who act quickly were more apologetic about it and said that this is how they operated, saying that they were *"visceral"*, *"impatient"* or *"impulsive"* or simply too *"enthusiastic"*. They were also aware that they have had made wrong decisions sometimes because they did not consider some detail.

Several of the PIs who answered that they did a complete study of all the consequences and then acted said that this was a learned way of making decisions for them, they used to do quick decisions in the past, but they have trained themselves to *"sleep on it"*. Some were aware that although they study the potential consequences of their decisions, this is not a complete study, and several said that although they give thought to the consequences, they try to do it quickly.

A particularly interesting answer was from a PI who said that hard problems can keep him awake at night and he uses a dream state for searching for solutions. He prepares in his head before deciding, but he usually makes a collaborative decision with his co-PI. As soon as a decision has been made and he has a plan, he can completely let go of the problem, it is completely out of his mind (and can start the executing phase).

Those who adapt their way of decision-making to the situation said that they take a longer time to consider the consequences and consult colleagues when the decision is about people, and another PI said that he takes a quick decision if a clear picture emerges in front of him suddenly (this applies mostly to administrative decisions). If this does not happen, he takes pencil and paper and draws his ideal result, then asks himself: *"How do you answer this question? How do you get ahead if the answer is negative?"*

Although making quick decisions had only a slight edge when looking at the answers of all PIs, it was the clear answer of choice of the Top Publisher PIs (56% chose it), even though sometimes their quickness backfires, as some Top Publisher PI admitted.

Sorting by Elimination or Sorting for the Presence of Attributes

I asked PIs that if they were going to buy a new car (or a new piece of equipment), would they be looking for one that will not break down, that is not too expensive, and not too ugly or would they want a reliable, reasonably priced, nice looking car? The two choices are almost identical, of course (reliable = not break down, etc.), they are just two ways of phrasing the same thing, but this question gets at whether the PIs sort their choices by the presence of positive attributes or they sort by elimination.

Overwhelmingly (67%), PIs answered that they make choices by the presence of positive attributes, and only 20% sort by the absence of negative attributes. Those who sort by the presence of positive attributes are focused on getting a functional instrument that gets the job done. They may be very methodical about it (setting up an order of importance of the different features and deciding based on a score), or they are just looking to select something that will do the job in the least time. Although they may consider long-term value and quality, they will not spend time discovering all the possible features to sort by elimination. Some of those who use both approaches said that they sort by elimination if there are too many choices or if the issue is not important to them.

Judging Competence

Most PIs do not acquire data anymore themselves but use the data generated by their team members (or other scientists). As we saw in Chap. 5, the person, the source of a piece of information, plays a great role in how PIs evaluate the trustworthiness of that information, therefore I was curious how they decide if they should trust somebody and accept them as a competent source of information.

Your Favourite Way of Getting Convinced

I asked PIs what convinces them most effectively about the competence of somebody, if they have to see the person or talk to them, perhaps can read about them or read something they have written, or if they really need to do things together with them. The favourite modality was talking with the person and hearing them talk (60% of PIs picked it), closely followed by seeing them (52%).

Doing the activity with the person was the least popular (31%), perhaps because it takes a lot of time and PIs are very busy, although one PI said that if *"I need to see them do it or need to do it with them to know that they are good at something, it means I do not trust them"*. 45% of PIs picked reading about or from the person as a trusted way of getting convinced about them.

PhD students are often cautioned not to believe everything in publications (when all they have to go on is what they read in the paper), and this bears out in the answers on how successful PIs get convinced. More than two-thirds (68%) of PIs indicated they use a combination of two or more modalities for getting convinced about the competence of a person (as you have already figured out from the percentages).

One of the people who chose "seeing" said that he is a physician, accustomed to assessing people quickly. But it seems that he (and other people who chose "seeing" alone) actually meant seeing somebody in person *and* talking to them or hearing them talk since he said that he told his students *"not to read, but go and listen to a lecture of the person and see him/her"*, and then ask themselves: *"do I trust this person?"*. Similarly, the comments of many PIs who chose "hearing" as a single modality revealed that although they want to hear the person speak, they want a personal meeting, and preferably a two-way discourse when they have the chance to ask questions. Personal contact allows PIs to spot people who blow hot air without much substance. They also mentioned that meeting in person, looking into the other person's eyes allows them to assess whether the person really performed the work he or she was writing about, and they can judge *"their passion and their understanding of what they do"*—this can be a deciding factor for new hires.

One person warned that *"many people are very good at managing the impression they make—but having charisma for giving a seminar does not mean that they are right"*.

I think this is important to point out in general because many people confuse conviction with correctness: even if a person is delivering an opinion persuasively, it does not mean that that opinion is right! I think scientists have a great responsibility here.

The comments of many PIs also revealed that when they evaluate the content, it is very much synonymous with evaluating the person—this is why personal contact is so important, this is why there are still conferences where scientists meet personally.

Using several modalities (whatever the preferred ones are, and whatever order you like to use them: e.g. hear about somebody, then talk to them, then read their papers was a sequence mentioned) is about *"doing your homework"*, not letting appearances or other people's (often biased) opinions guide your judgement.

Although several people mentioned that if they hear about somebody or read somebody's work, the source of that information is very important: if it comes from a previously "vetted" source, they tend to trust the information.

Senior people said that they have learned to evaluate people through their written record and CV by reviewing lots of grant applications.

Top Publisher PIs were even more likely to answer that they want to interact personally with the person who they are evaluating. *"I want to talk to them, not hear about them"* as one of them said.

Repeat Demonstration of Competence

In the previous question, we learned the favourite modalities PIs use to get convinced—but do they get convinced easily or not? Do they want to see good performance a certain amount of times to form a positive opinion about somebody and trust them in the future, or do they want to observe them over a certain period?

The most commonly picked answer of PIs was getting convinced over a period of time (56% of the answers included this option). The length of the period required was most commonly around 3–6 months, although it could be as short as a few weeks and many said they know only after a year if a person is good (one even said she was not sure until the end of the second year!)—hence some PIs hire their people for one year initially, then they re-evaluate after a year.

The second most popular answer (29% of PIs picked it) was "a certain number of times": mostly twice, although requiring 3–5 repetitions was also common. Many of these PIs mentioned that the number of times needed depended on the type or the complexity of the task (e.g. performing or designing experiments, analysing data, writing, presenting), as well as the seniority of the person (they got more readily convinced if it was a postdoc or a PI than in case of a student). Only 10% of PIs said they can get convinced by only one good performance. Surprisingly, over a fifth of PIs (22%) said that they tend to give people a benefit of the doubt (i.e. they trust people without a demonstration of competence)—but many of them also said that one bad experience is enough to ruin the trust. Some PIs gave a hybrid answer, e.g., they want to see a certain number of good performances over a period of time.

One PI said that *"proving competence is a daily affair. You stop proving your competence when you die—but this does not mean that you never fail"*. He added that failure does not mean that he loses his faith in the competence of the person. He also made the distinction of being convinced about the competence of a person or trusting them: this latter requires longer interaction and seeing whether the person tries to hide anything from him—he also added breaking his trust once enough to lose it forever.

Top Publisher PIs (compared with the non-Top Publisher PIs) tend to give people the benefit of the doubt more often and they are more likely to form their opinion over a period of time (as opposed to a given number of times).

How Do You Know that You Have Made the Right Decision?

As you are "carving your path" you may get unsure whether you are choosing the right path, therefore I asked PIs how they know if they had made the right decision, and if/how they reassure themselves.

PIs distinguished two kinds of decisions: when there is a clear, controlled way of getting feedback and "complex" issues when you are choosing one possible way over others but there is no way of controlling what would have happened if you had chosen differently.

One of the more straightforward situations is a scientific decision. As several PIs said, you have made the right decisions *"when somebody can independently repeat your experiment and gets to the same conclusion"* or if you somehow *"realize that some other people, e.g. your competitors have the same results"*. You will face, however, many other choices where you will not have such a clear-cut way to verify whether you made the right decision. In the latter cases, there is no appropriate control because your decision alters reality around you and you can never go back in time to the point before the decision and redo life to see if you get better results.

The Toughest Decisions

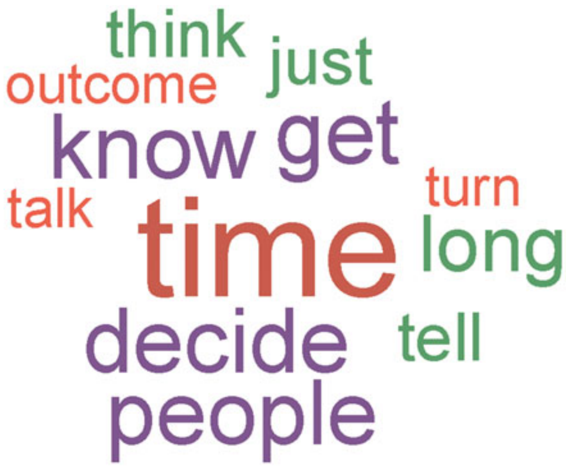
Many PIs find that decisions concerning personnel (e.g., whom to hire or how to deal with underperforming team members) are amongst the toughest they have to make (see also Chap. 3. Setting up a Successful Research Group and Chap. 4. Leading Your Research Group as a Principal Investigator). Others mentioned career decisions (whether to take a position or not) and deciding what reviewers to pick for a manuscript as difficult ones.

The Important Thing Is to Decide

PIs recommended acknowledging that we are making a decision based on incomplete information (which is true for all decisions) and making a choice, nevertheless. As one pointed out: *"if we knew all the facts, it would not be a decision, because the facts would speak for themselves"*. The important thing is to decide because you only move forward by deciding. Since there is no clear control, you cannot know if you have made the right decision: all decisions represent different paths, and by deciding you just follow the one you chose. Another PI also said that as he is getting older he is learning that he just has to make a decision: *"sometimes good, sometimes bad"*. *"If I'm lucky, more than 50% of my decisions are right!"*—he added jokingly. *"You will not know if you made the right decision, but the worst is not to make a decision!"*, said a third PI.

How Do You Know If It Was a Good Decision?

But what if you want reassurance? *"Time is needed"*, said one PI, *"you know only afterwards"*, summing up very well the recurring theme in the answers to this question: the only way to measure whether a decision was correct is by the outcome, evaluating the situation after the decision.



As we discussed above, in scientific decisions you may get independent confirmation as the ultimate control that your decisions were correct. But in many cases, there is no such control therefore it may not be even possible to tell if there was a right and wrong decision. Another problem with the evaluation of a past decision is that it can change with time: sometimes it seems right at first, then perhaps wrong, then right again...

One PI said that he looks for mid-term (3–4 months) success in science because he considers that this much time is needed to get proper feedback, but it's hard to put a general timeline on measuring the outcome. For example, several PIs mentioned that decisions about handling people are notoriously difficult, but they would like to see an improvement of the situation in a much shorter time than 3–4 months! On the other hand, other PIs mentioned that some roundabouts have proven to be very useful in the long run. For example, one PI said that he had taken a chance on a PhD student who was failing in another lab and saw the benefits only years later. Another PI said that he stuck with a project because he stayed excited about it and he trusted his intuition that it would lead to a high-impact paper—but he had to wait seven years for that very nice publication! He could afford to do this only because other projects in the lab were productive.

PIs seem to draw two different conclusions from the uncertainty of evaluating decisions: some make their decision and never look back and others actively seek feedback and re-evaluate their decisions regularly.

"The decision is based on the facts that you have at the time. Questioning yourself afterwards is a waste of energy" said one of the PIs who never look back once a decision is made. Other PIs said that they *"dispense with doubts before making the decision"* and need no reassurance that they have made the right decision. *"I try my best and ignore the rest"*, said one of them. In many decisions, there is no right or wrong way. One PI who admitted that some of her decisions *"may have been unfortunate"* said that *"at the time you decide, you never know about anything how it will turn out, so the best you can do is to just adjust to the outcome"*. Another PI went even farther and said that reassuring himself would be fooling himself, *"since all you can do is to hope that you made the right decision, but you can't know until later"*.

"If we were always right we would never learn anything", thought one PI (associate professor, PI for over 10 years, over 70 publications, H-index of 28), and several others advocated getting past decisions: you either reassure yourself that you did the best you could or you don't reassure yourself at all and *"just accept that you may be wrong and you may have to go to plan b, c, etc."* A third PI said that she just decides and moves on, telling herself that *"you will just have to live with that"*.

Another PI from this group also said that in the case of complex issues (e.g. career decision) he never mulls his decisions over afterwards because you can never arrive at a proper answer: there is no control, you can never decide which way would have been better. *"Re-thinking old decisions does not help and consumes a lot of energy and it can only make you less happy"*, was his opinion. *"I will never know if my decision was correct. I have come to accept uncertainty as a part of life"*—summed it up another PI.

Other PIs are constantly re-evaluating their choices and the more important a decision is the more important it is for them to have feedback. One PI explained that she does not need to reassure herself about her decisions because *"there is always a follow-up"* and a second one said that he tends to go in little steps and waits to be able to change his decision later after he sees the effect. A third PI turns constant re-evaluation of the choices into a group affair by having regular discussions about them. This lets him make quick decisions and see later how they turn out.

The kind of feedback PIs look for varies and depends on the issue, of course. As one PI said, the feedback *"can be anything from citations of his publications to the praise of the cleaning lady"*. He did emphasize, however, that he wants his information only from consistently reliable sources, whom he has never been disappointed in. Others look for practical signs: was the paper or talk well received, did the grant get funded? In the case of personnel decisions, PIs either get direct feedback from the affected party or from their group or they just try to read the general ambience of their group.

If You Want Reassurance

Some PIs (usually the ones who also mentioned being less confident) said that they need to be reassured about their decision at the time they are making it. Since this reassurance happens at the time of the decision, it cannot be based on the outcome, the purpose seems to be more giving the person permission to get past the decision and think of other things than guaranteeing a good outcome.

Some PIs can reassure themselves by telling themselves that they were careful, objective and rigorous, open to thinking of all possible interpretations and self-critical when they were making the decision but others seek feedback from other people like a mentor, co-workers, collaborators, or family members. *"I always have a doubt"*, said one of them, *"I am reassured if people tell me that it was the right decision"*.

Dwelling on Past Decisions

Although revisiting decisions is energy-consuming, it may be useful in two ways: past decisions may inform future decisions no matter whether the feedback is positive or negative (so don't let bad past decisions depress you), and positive feedback can help PIs who are doubting themselves to become sure of themselves. *"Even if you made the wrong decision, hopefully, next time you will get it right"*—said one PI, and she recommended not to dwell on the past, just take the consequences and change direction. *"The important thing is to make a decision. It is sometimes impossible to tell if the decision was right or wrong, because the decision changes the reality"*, as another PI put it.

As one PI explained, she likes to revisit decisions a little later but this is for her only, others may not know that she is re-assessing things. She does this partly because she gains good information for the next time she has to make a similar decision. But she goes even further: if the decision turns out to be wrong, she lets the involved party or parties know that she is aware of making the wrong decision. Although the decision may not be always reversible, such communication can be very good from a management perspective.

Reversing Your Decision

As you suspect by now, you may, you are allowed to, and you probably will be wrong many times. Just prepare yourself for the possibility and keep an open mind. Several PIs mentioned that although they may agonize over other decisions, they find it easier to make decisions or changing their mind in matters of science. *"It is nice to be wrong! The best results are the unexpected ones! It is very exciting and humbling to be wrong and finding out that Nature is so smart, smarter than us!"*—said one PI. *"One has to be willing to change his mind"*, said another PI with over 30 years of experience. *"It can be hard, but as Günther Blobel said 'do not become* *an apostle of your hypothesis—try to disprove it'"*. He said that although he can agonize about personal decisions, in science he usually adopts a *"we'll see later"* attitude and this has gotten easier as he got older. *"You have to follow the truth—unfortunately, not everybody does that"* he finished.

"You have to have humility", said another PI and added that if his decision is challenged, he is ready to revise. Another PI said that although he is usually stubborn and wants to stick by his first choice, he can change his opinion—and he is getting more flexible in this regard as he is getting older.

Intuitive Decisions

14% of the PIs said that they rely on their intuition for making decisions. One of them said that knowing that he has made the right decision is not based on numbers or output, it is an intuition, feeling, a qualitative issue. He does not worry about making bad decisions sometimes, neither does he hide them. Another PI said that she has a very strong sense of her gut feeling and she makes mistakes only when she does not listen to that inner voice. A third PI from this group said that she has an intuitive way of functioning but when she's not sure, she may ask other people.

Rationalizing the Decision

15% of PIs mentioned rationalizing their decisions. These pragmatic people get as much information on the issue at hand as they can in a short time, and try to see the problem from different perspectives—still acknowledging that they will never get the full picture, will never have all the information or options and they are just doing the best they can. As one of them put it: *"You give yourself time, take the decision seriously. You list the pros and cons, and then you make your decision—and you have to live with the consequences. Just carry on"*.

As one PI said, she wants to see if she can explain her position to somebody clearly and logically. Some rationalizers reach out to other people (it can be a partner, a family member, a mentor) either to test the soundness of their position or to get other points of view.

Quick Decisions

Some PIs said that they make decisions quickly. These PIs don't like taking a long time to decide and their position is that if they make a mistake, they can change it later. They also believe that since their past decisions inform their future decisions, their chance to make the correct decisions improves over time.

The Slow Deciders

A larger fraction of PIs than the quick deciders, but still a minority, indicated that they obsess over decisions.

These PIs mentioned that they tend to feel insecure about many things and try to dispel their doubts by going over and over their reasons for their decision and discuss it with other people (mentors, colleagues, family members). As one of them put it, she needs *"to learn to cancel things"* and not go back and forth in her mind agonizing over decisions. Another PI said that because he is insecure about many things and worries a lot about decisions, he tends to delay decisions—and when they become urgent, he decides quickly (the worst strategy, in his opinion).

With this inside look at the thinking of PIs, we have concluded our summary of the advice given by PIs in the interviews. In the Epilogue, we will discuss how you might want to use this information.

Epilogue

9

A PI (with almost 30 years of experience, over 300 publications, and an H-index over 70) told me that he sees three career paths available in academic biomedical science: 1. the academic scientist career: these are scientists who have an impact on students; 2. the medical school career: physician-scientists who have an impact on their patients and students; and 3. the *"high-profile scientific career"*: these care only about publishing in high-impact journals and getting recognized. *"Nobody is grateful to these for mentoring"*—he said about the third type of scientists.

I started interviewing PIs in my network from the four institutes I have worked at during my career then asked those who had given me an interview for referrals to other PIs and worked my way through their extended networks. My sample of PIs may be skewed since not everybody I asked volunteered to talk to me but this kind of bias is true for any kind of poll since you get the opinions of those only who are willing to express an opinion.

You may know scientists who do not operate according to the ways described in this book but keep in mind that this book is not about all scientists, it is only the summary of interviews with the 106 scientists who agreed to the interview. I don't think there are any third type PIs among the people I interviewed. Although there was one Nobel Prize winner among them (and nobody gets a higher profile than that in science), all PIs cared about mentoring the next generation of scientists and were humble about their intellectual capabilities and achievements.

Gathering the interviews for this book was like finding a window into the mind of PIs. It reminded me of the first time I was in the Netherlands and saw houses without curtains on the living room window. I found it fascinating that as I was walking down the street I could see people in their homes going about their lives, eating dinner, having conversations around a table or reading in an armchair.

Many times, after answering a question about how they do something, PIs have surprised me by asking "Doesn't everybody do it that way?" After reading this book, you know that in most cases the answer to that question is "No". There are many ways we think or process information. One of the surprises that working on this project gave me was that for most PIs the way they function is not a result of a

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
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conscious decision, but they do things the way that comes naturally to them. By having read this book, you are now aware that often there are many ways to think and process information and you can try them out to see which one brings you the best results. Don't be paralysed by the variety of choices, just let yourself be inspired to try them out and see what happens. There are many paths to success.

As you were reading about the many ways PIs function, you may have recognized that you do things the same way as some PIs do. In this case, I hope this book gives you more choices and a few tips on how to do things even better. May this book also give you the motivation to persevere and become a PI or become an even more successful PI if you are one already. If you find that you don't do things the way PIs do them, but you are willing to try out the ways that have worked for others, I hope this book will help you to adopt some of those methods that do not come to you naturally and improve your chance of success. Finally, this book may lead you to realize that you are not interested in becoming a PI, after all. There are institutes of higher education that place less emphasis on scientific research, so those could be an alternative, but you may decide to step out of the "academic bubble" completely. Even if you should decide after reading this book that you don't want to be a PI, I consider that a success, as well, because the sooner you come to that conclusion, the better your chances are to be successful in your alternative career Many of the habits of PIs described in this book can help you on your path in whatever else you decide to pursue. Whichever the case will be for you, I sincerely hope that you will find this book useful!

Another thing that kept surprising me during the interviews was how many of these very accomplished people struggle with insecurities and low confidence. One PI suggested that insecurities may help PIs to become successful. I don't know if that is true, but I agree with those PIs who said that their insecurities urge them to be more careful scientists—which, in turn, may help them to succeed.

As mentioned in the introduction, I also wanted to become a PI and I started this project because I was wondering what I could have done better. I regarded all interview subjects as successful because they managed to do what I did not. After all the interviews, however, I have to admit that my original criterion for success (landing a "permanent" position by either getting on the tenure-track at a university or becoming a staff scientist at some research institute) is not a very good one. It became obvious that for the most inspiring, successful PIs (those with whom I would like to work with or would like to imitate), the positions they occupy were not the goal. Getting their "permanent" position was only a stepping stone, the vehicle they use to fearlessly go towards their real goal: discovery and satisfying their curiosity. One PI said, *"all fibres in my body are directed towards discovery"*. As you are deciding whether you want to become a PI, I think you ought to ask yourself the question whether you have this kind of passion for science inside you or if you are looking for job security—in the latter case, there are probably easier ways to find a permanent position.

Working on this book also reminded me of my childhood, when I used to play in my grandparents' attic and rummaged in old suitcases: every time I went back to the collected interviews to summarize another question, I was always excited to see what I pull out of this treasure trove next. I hope you got as much enjoyment out of reading this book as much I enjoyed writing it! If you have any comments or questions about what you read, please send a message to ThinklikePI@outlook.com.

Methods

10

Abstract

This chapter discusses how the material for this book was collected and contains some summary statistics on the interview subjects (gender and academic rank, how long they have been leading their own lab, their H-index, publications, citations, what countries and institutions they are from etc.*). It also explains what metrics were used for picking the "Top Publisher" PIs.*

Interview Subjects

One hundred and six tenured or tenure-track principal investigators and staff scientists (55 female and 51 male scientists) were interviewed from 44 research institutes in 11 countries in Europe (84 PIs), North America (16 PIs), and Australia (6 PIs).

The interviewed PIs work in the following countries: Australia, Belgium, Canada, France, Hungary, Portugal, Spain, Switzerland, The Netherlands, United Kingdom, and USA. Fifty five of the interviewed PIs are females and 51 are males. Most interview subjects have the rank of professor (Fig. 10.1). The number of children the interviewed PIs have is shown in Fig. 10.2, faceted by gender.

Table 10.1 summarizes the median, minimum-, and maximum values of how long the interviewed PIs have been leading their own lab, how long they spent as a postdoctoral researcher before, their H-index, number of their publications, citations, and in how many publications they have been cited. These statistics were derived from Scopus (https://www.scopus.com) around the time of the interviews.

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
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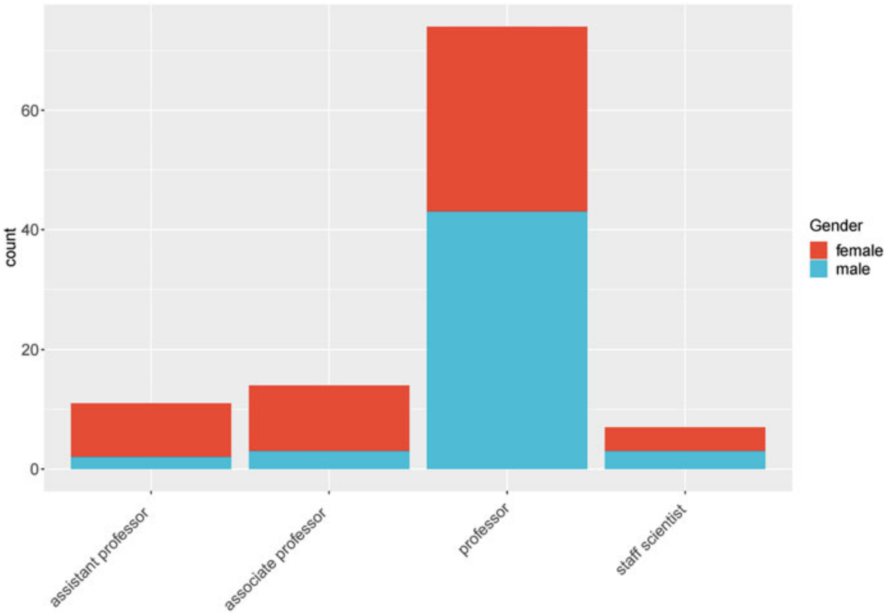

Fig. 10.1 Most interview subjects were in professor rank ($n = 106$)

Interviews

Most interviews were conducted in 2018 and 2019 (the two exceptions were obtained in 2010 and 2014). Typically, an interview would last for a little over an hour. They were conducted in person if it was possible, and if not, through video conferencing. There were a few PIs who preferred talking over the phone (without video connection) and two PI requested that I send them the interview questions and they answered in writing.

The interview questions came partly from my experience of working in various labs in biomedical science for thirty years, and partly from a "modelling interview" template used in a course by Bill Harris, the Founder of Centerpointe Research Institute (https://www.centerpointe.com/).

I did not record the interviews; I took notes which I later transcribed. Each interview was saved as an Excel (.xlsx) file and then incorporated in a database created in PowerBI (version: 2.93.981.0 64-bit at the time of writing this in May 2021). The publication and citation data were derived from Scopus and linked to this database.

As often as possible, I used direct quotes from my notes to convey the meaning of the interview subjects as close as I could (these are the text in italics between quote marks in the text). For full transparency, I would like to mention that although I interviewed 106 PIs, I did not get an answer to each question from each of them

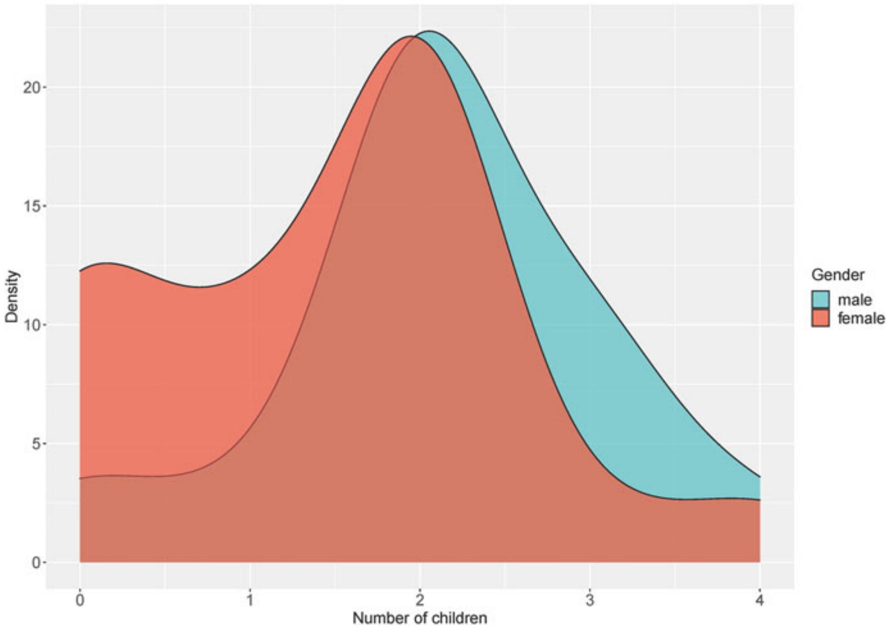

Fig. 10.2 Female PIs seem to have fewer children than male PIs. Although the median value was 2 for both genders, the distribution seems to be shifted towards fewer children for female PI. The average for female PIs was 1.45 ($n = 55$) and 2.13 for male PIs ($n = 47$)

Table 10.1 PI years, postdoc years, H-index, number of publications, citations, and citing documents of PIs

	Median	Min	Max
Years as PI	17	1	50
Years spent as postdoc	6	0	17
H-index	36.5	14	127
Documents published	117.5	22	869
Citations	6196.5	679	65,876
Citing documents	4778	552	48,587

(e.g. I had to skip the questions about the composition of the PI's lab many times because of time constraints).

Top Publishers

Because of the decisive role publications play in the life of a biomedical scientist, I grouped the interview answers of scientists who represented the top 10% of the group based on publication-related outputs to see whether the answers of those PIs differ from the answers of those who are not in that group. I used the following data from Scopus for each interview subject: H-index, number of published documents, and citations (without self-citations). I normalized each number by the number of

Table 10.2 The gender Distribution of the "Top Publisher" group

Gender	Top Publisher	Top Publisher (based on PI years)	Top Publisher (based on PI + Postdoc years combined)
Female	11	9	5
Male	14	8	11
Total	25	17	16

years the interview subject had been a PI to get a measure of their average performance over their career (and give junior PIs more of an equal footing).

Since many PIs spent several years as postdocs in somebody else's laboratory where they may have already been functioning as an independent investigator, I also normalized the H-index, published documents, citations (without self-citations) by the combined numbers of years the interview subject had been a postdoc and a PI.

The "Top Publisher" PIs are those who ranked tenth or higher in either of the six measures (H-index per years, documents per year, or citations per year, normalized either by their PI years or their postdoc and PI years combined). Since these rankings overlapped only partially, combining them yielded a list of 25 PIs (24% of PIs).

This ranking, however, gave some surprising results, e.g. the Nobel Prize winner in the sample was not among the Top Publishers, and, on a more personal note, some of the PIs that I found most inspiring and would have liked to work with also did not make it in the Top Publisher category—but, we live in a world where publications are everything and I tried to take that into account.

Table 10.2 summarizes the gender Distribution of the "Top Publisher" group.

For making Fig. 5.1, the total number of (unique) co-authors listed for a PI in Scopus was divided by the number of years the PI has been a PI or the sum of the number of years the PI has been a PI and a Postdoctoral researcher. For Fig. 5.2, the number of co-authors was divided by the number of documents a PI published.

Figures

Parts of the database mentioned above were re-exported into Excel files for analysis using R. The R scripts used for calculating summary statistics and making the figures as the word clouds are available upon request. The version of R used at the time of writing is 4.1.0, used with R-studio version 1.4.1106.

Recommended Reading

The following sources were mentioned by PIs during our conversation or I thought they might be useful for you:

1. Lab Dynamics: Management and Leadership Skills for Scientists by Carl M. Cohen and Suzanne L. Cohen.
2. The Black Swan: The Impact of the Highly Improbable by Nassim Nicholas Taleb.
3. The Formula: The Universal Laws of Success by Albert-László Barabási.
4. Loose Ends by Sydney Brenner (freely available at: https://current-biology-loose-ends.elsevierdigitaledition.com/main/index.html)—there are also several interviews available with him on YouTube.
5. Thinking, Fast and Slow by Daniel Kahneman.
6. A PhD Is Not Enough!: A Guide to Survival in Science by Peter J. Feibelman—first published in 1993 by Addison–Wesley.

B. Z. Schmidt, *Career Advice for Young Scientists in Biomedical Research*,
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