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Insights and advice for graduate students and post docs

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Words of Advice Collection

How to give a good talk

How to create a figure plan

How to write a paper

Writing fellowship applications

Making your next career move

Writing research papers

Avoiding common pitfalls of figure preparation

How to choose an important research question



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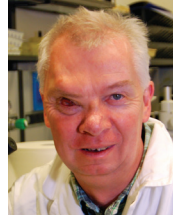
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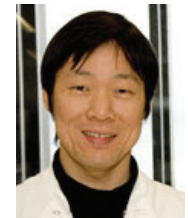
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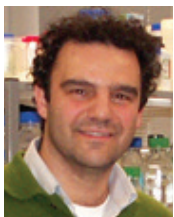
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Words of Advice at *The FEBS Journal*: learning from the triumphs and tribulations of others

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There is an old adage that someone who acts as his own attorney has a fool for a client. This is an astute observation, as it reminds us that it is usually the wiser option to seek professional advice when dealing with an important issue requiring experience and knowhow, than having a go oneself. Not that it's always a bad thing to learn by trial and error, but there are some things that are just too important to learn by simply having a bash. Like brain surgery, for example.

During the course of a career in science there are many and varied skills to master, some of which are mastered at the bench, but many of which are most definitely not. As a result, some of us (and I very much include myself in this) often attempt to do things that we are really not experienced enough to do well, and try to figure out how to do it through trial and error. This is all very well when learning how to perform a DNA ligation, or how to improve the purification yield of a recombinant protein, but some skills are more complex and are best acquired through taking advice from others and by tapping into accumulated wisdom. Indeed, some of the cleverest people I know ask the most questions (maybe this is why they are clever?) and seek out the opinions of others very frequently. As I was leaving a train station the other day I saw a sign that read: 'A mind is like a parachute, it only works when it's open'. So, it's good to be open-minded about how to go about doing something, especially when you are just attempting this for the first time. Certain things can take a long time to figure out by learning from one's mistakes and bitter experience. I'm thinking here of how to develop a research project that has the best possible chance of being published in a prestigious journal, or how to write an excellent fellowship application that could end up funding your work for the next 3 years, or how to plan your next move after completion of a PhD. Making the wrong decision, or learning from your own mistakes in some of these areas, can be difficult to rectify and can end up being very costly for your career.

It is against this backdrop that we introduced the Words of Advice series at *The FEBS Journal* in 2016 [1,2].

These articles are aimed at early career scientists and offer advice, insight and a good dollop of wisdom from more experienced scientists on issues that are frequently only learned through trial and error. It is not ideal for example to write your first paper as a PhD student when you have not yet mastered the skills of how best to present your shiny new observation to the scientific community. Of course, you can give it a bash and hope for the best, or you can seek the advice of others about how to do this to achieve the most optimal outcome. Similarly, there are common pitfalls of manuscript and figure preparation that are best avoided by finding these out well before you sit down to write up your paper. You would be surprised at how many papers are submitted to *The FEBS Journal* that contain large tracts of text directly cut and pasted from previously published work by others, crudely assembled in a patchwork quilt of obvious plagiarism. This practice is easily detected at the stroke of a key using plagiarism-checking software which we run all submitted manuscripts through. Of course, such papers are immediately sent winging their way back to the authors post haste, with a stern caution against doing this again. But it would be far better were such practices avoided through better guidance in the first place.

And then there is the tricky issue of how best to respond to referee comments. I still flush with embarrassment when I remember how, early in my career, I wrote a rebuttal letter to a referee's comments where I proceeded to rebut every single one of their arguments with highly charged and adversarial arguments to the effect that the referee really should read the literature more. Thankfully, my then post-doc advisor intervened before any damage was done.

Indeed, I still remember marveling at the smooth and diplomatic way in which my advisor made essentially the same points while politely thanking the referee for such clever insight and helpful suggestions. A lesson learned. However, it is still not that uncommon, in my role as an editor, to receive rebuttal comments to a referee's report to the effect that "the referee is an idiot" because they didn't recommend acceptance of the manuscript. Needless to say, these types of rebuttal letters generally don't elicit favorable responses from referees or editors. To quote another truism: 'you catch more bees with honey than with vinegar'.

Our Words of Advice articles cover a variety of topics, such as: 'how to write fellowship applications', 'how to avoid common pitfalls of manuscript and figure preparation', 'how to give a good talk', 'managing the transition from PhD student to postdoc', 'how to write a rebuttal letter', and many other topics. Thus far in this series we have published 4 articles covering 'How to write a scientific paper' [2], 'Avoiding common pitfalls of manuscript and figure preparation' [3] and 'Scientific career paths' [4, 5]. We hope you find these articles useful.

I know that I would certainly have appreciated reading about these topics when I was a PhD student and indeed, it is still very interesting for even seasoned pros to hear the opinions of other scientists on many of these issues. And of course, you don't have to agree with the opinions expressed in any of these articles. Like all advice, you can, to paraphrase Wilde, choose to follow it, or to quickly pass it along to someone else, due to it being of absolutely no use to yourself.

Finally, when it comes time to submit your own scientific masterpiece for publication, please keep *The FEBS Journal* in mind. We publish only 10 primary papers per issue, we offer free color figures to help showcase your work in the best possible light, we do not levy page or submission charges, your manuscript will be handled by our stellar international editorial board, and we place a high priority on fair and rapid review. What's not to like?

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How to write a scientific paper

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At its core, a scientific manuscript is held together by the science it reports. If a rigorous approach is maintained at every stage from the initial hypothesis to the design, execution and analysis of the experiments, the study will ultimately hold up against the scrutiny of even the toughest reviewers and the scientific community. But an incoherent manuscript can undermine even the most meticulous scientific study. If you think about it, writing a scientific paper is a lot like film-making. You need to consider how to frame your story, what to put in sharp focus and how to edit. And just like in films where inadequate framing or editing can ruin an otherwise good script, a substandard manuscript can undermine the communication of a good scientific study.

Drawing from our own experiences as scientists and editors, here we highlight the essentials of good manuscript writing and feature practical tips on how to make your paper stand out for editors, reviewers and the scientific community.

Begin with a blueprint

There are a lot of factors that dictate the timing of writing a manuscript. While developing your research project, have in mind your goal for publishing the work and the general scope of the data set, as this will influence the key decision of when to stop experimenting and start writing.

Indeed, if you create a blueprint of the figures early on in the study (a figure plan or storyboard), updating it as you go along, you'll know it's time to write up when the figure plan is complete. How do you create a blueprint when you don't yet have the data? Well, it's a bit like the preparation that a film director puts in before the actors are even on the set, or indeed before the sets are even built. The director generates a storyboard of how the sets will look, where the actors will stand and where the camera will shoot, and the movie is then shot using this storyboard as a guide. To create a storyboard or figure plan for your paper, it's best that you sit down very early in your study, when you have identified your key discovery (all papers should be built around a central observation or discovery) and imagine how you would best communicate this discovery to the scientific community. Each figure

should have a key point and develop the central discovery in some significant way.

This is a very good way of designing a paper as it lets you see, very early on, what type of experiments you will need to do and where they will fit into the big picture. At this stage, you will often find yourself thinking of controls that you should do and extensions of your discovery that were not obvious before you drafted your figure plan. It's useful to hand sketch rough approximations of the figures and then make this into a more professional figure template using standard figure generation software, with empty boxes in place of the actual figures. Adding some text inside these boxes will help remind you of what should be there (e.g. titration of X to demonstrate cell cycle arrest at high concentrations using FACS as a readout). This figure blueprint is then updated and modified as you go along. If you create a good figure plan, it should be obvious what data should go where within the figures. But don't worry if you can only see as far as Fig. 3 or Fig. 4; once you get these done, other ideas will occur to you as you go along.

Once you've decided to write up your work, start by drafting a blueprint of the manuscript that outlines how your central discovery will be framed. The chronology of the experiments doesn't matter. As noted above you will have combined your data in panels and figures in an order that conveys a coherent, stepwise narrative. It may sound painful, but be prepared to drop an experiment you've worked on for months for the sake of a manuscript that logically flows from one point to another. If an experiment doesn't add (even incrementally) to a conclusion, it's only a distraction. Sketch out the introduction with key background points and you're all set (Fig. 1).

Flow and order

The best order in which to write a paper is not necessarily the one in which it is laid out. Be flexible and follow your inspiration. Some people write in blocks, starting with the results or the introduction, and then moving to another section. Some toggle between all the sections. It may sound chaotic and inefficient but



Fig. 1. Planning, organising and writing a standout scientific manuscript.

as long as you keep the core message of your study in mind throughout, this can be an effective way to weave an interconnected manuscript that flows effortlessly to the reader. Remember, writing the methods is less frustrating than staring at a screen. So don't cut the writing flow – if you're not inspired to write the discussion, write the methods or work on the figures. Generate your inspiration, don't wait for it.

Although the bulk of the writing may be done once you have completed the figure plan, it's good to write certain sections of the paper very early on in the study. For example, as soon as you have made your new discovery or observation, even if you don't have any of the substantial proof for it yet (but you have a solid start), it's a good idea to come up with a few possible titles for the paper, as well as an abstract. This allows you to see how the claims you are making look on the page and it can be very motivational to already have the basic structure of the paper, even if you are many months from completing the study. Once you have the skeleton of the paper, you are already writing the manuscript and this can lower the threshold for doing the final writing when the figure plan is complete. It's also a good idea to write the results as you go along, as this really helps to guide

the study, and it's often when you are writing up the data that a nonobvious experiment, or critical control, suggests itself. Writing the results one paragraph at a time as you generate the data is also a fairly painless way to write up a manuscript.

Write first, edit later

Writing comes more naturally to some people than to others, but it's also a skill that can be honed with practice. The key is to start writing. Use the blueprint as a foundation from which to expand your draft (Fig. 1). Aim for accuracy over style. Apply the technical aptitude that you have acquired as a scientist to your manuscript writing. In a sense, good writing is one that mimics the scientific method: well defined, accurate and clear.

Once your draft is complete, it's time to edit. Continuity, in both substance and style, should be forefront in your mind during this process, and the initial blueprint will help ensure that the experiments and conclusions flow continuously in a logical succession. Your writing style is just that – yours – but keep your writing clear and concise by avoiding very long sentences, as well as fragmented ones. Combine the goal with the

action in the same sentence. Don't overuse phrases such as 'We showed that', 'In order to', or 'Next, we investigated' (and their kin). Separate large sections into paragraphs and pay close attention to transitions between subsections. Keep in mind that your paper has two audiences: a specialist and a generalist. Each will get something different out of your manuscript, so you need to tailor your writing accordingly – but we'll get into that later. Keep in mind, too, that format doesn't matter in the initial submission. Don't waste time reformatting your manuscript until prompted by the journal, usually at the acceptance stage.

Be unique

Most journals now use plagiarism-detecting software at some stage of the review process. Don't risk immediate rejection by copying sentences from another paper – or from Wikipedia! If necessary, there are a number of English language editing services that provide assistance for scientists.

Keep it running in the background

Dedicate a time for writing when you'll be the least distracted, and take active distraction-preventing measures such as not checking your email (at least not every 5 min). When you've done your writing for the day, don't put it away completely. Some of the best ideas come when you're not actively thinking about the task at hand. Be ready to jot down a title or an idea for a figure when you're not near your computer.

Now going into the specifics (See also Fig. 1).

Choosing the title

The title should be the key new observation that you have made. Don't underestimate the power of a single sentence. Write down a few titles and labour over them until you find the one that you think will have the most impact. Keep in mind that the best titles are short [1] (read more), in the active form, contain identifiable keywords and few or no acronyms. Try to avoid long, rambling titles: less is more. Avoid passive and descriptive titles that merely describe what you have done (e.g. 'Proteomic analyses of activated lymphocytes'). Keep refining your title until the very end of the writing process. It is not uncommon for an author to appreciate the most important point of their study only when they have completely finished writing the manuscript and now realise the best phrase to 'sell' their key observation or discovery.

Approaching the abstract

The first line of your abstract should introduce the reader to the broad sweep or context of the study and subsequent lines should get progressively more specific. However, writing the first line of the abstract can be daunting. If you're feeling uninspired, start by writing the last line, the keystone of your study and the strongest conclusion. Walk your way back to the main findings and experimental approach, the hypothesis or the goal of your study and the initial observations or background. This will help you stay focused on the core message. Think about the abstract as an invitation for readers, and write it in a way that will appeal to the widest possible audience. Make sure to include key words that will likely be used as search terms on Pubmed or Google Scholar.

Introducing the subject

Begin your introduction with a broad assessment of the state of your field. Then, introduce the specifics gradually until you reach your study, the point of the sharpest focus. Keep it short: think of the introduction as a more developed abstract. Cite a few relevant reviews when setting the broad framework but make sure to reference original papers for key discoveries, including papers that report conflicting results. This demonstrates thoroughness and transparency. In the final paragraph, focus only on the main conclusions of your study. Leave the details for the results section.

Describing the data

In the results section, report the motive for each experiment, its setup – with sufficient technical details – and your observations. Leave the interpretation for the discussion. Group the results into subheadings in a logical manner that allows each subsection to build on the preceding ones. Maximise the impact of your conclusions by using them as subheading titles.

Most journals now have a policy regarding supplementary information, so familiarise yourself with these guidelines ahead of submission. Remember that supplementary data are not integral to the study's main design and objectives, but rather support and strengthen the conclusions.

The interpretation

The discussion serves to interpret the results and to highlight the implications of your study and the advancement it brings to the field. It should be written with both a generalist and a specialist audience in mind. Make a clear distinction between the

conclusions that your data support and argumentation. Compare your study with what has been published in the field (e.g. similar observations in another model organism) and mention studies that report conflicting results and possible reasons for such conflict. Discuss unanswered questions or any limitations of your study, new questions that arose and make suggestions for future experiments. End on a high note by reiterating the main conclusions of your study.

The methods

This section should be written for the specialists. Use subheadings to allow your readers to find the relevant information quicker. Be accurate, comprehensive and give enough details to allow other researchers to reproduce the experiment if needed. Cite references for widely established protocols.

Figures, westerns and legends

Figures

When it comes to figures, all colours are the new black, except grey. *The FEBS Journal* does not charge for colour figures, so take advantage. Avoid using shades of the same colour to depict different data points, unless in a heat map. In that case, make sure that the extreme values are wide apart on the spectrum (e.g. white and dark blue). For the sake of colour-blind readers, choose colour combinations other than red and green. In line graphs, favour colours over symbols. Keep in mind that figures are usually reduced during page layout, so a font size 12 might look good for an axis title on your screen, but it is too small for print. As a rule of thumb, use font size 14 for axes numbering and 16 for titles. The same applies for HPLC spectra. In this case, it is good practice to manually add the spectral mass values on the profile. Avoid saturated signals in fluorescence images. Most adjustments should be made while acquiring the images. If at all possible, try to make the overall shape of each figure a neat square or rectangle, avoiding unnecessary whitespace between panels, and/or single panels sitting off to the side with nothing underneath. In general, figures laid out in portrait work much better than those in landscape.

Western blots

The quest for the optimal western blot image should be pursued at the bench, not on the computer. Optimise the western blot protocol to get the best signal-to-noise ratio. Make sure that the signal is within the

linear dynamic range if you are using the western blot for quantification and have molecular weight markers on every blot. The goal is to keep the need for image adjustment to a minimum. If you need to crop your blots, ensure that there is plenty of background around the bands – at least a space of five ‘bands’ above and below your band of interest.

Legends

Figures and their legends should be stand-alone items. A great way to introduce coherence and consistency in your manuscript is to use your results section subheadings as your figure titles (or vice versa). When describing individual figure panels, start with a conclusion, followed by the relevant and necessary technical information. Here, try to strike a balance between including enough technical details and rewriting the methods section. As a rule of thumb, prioritise what is present in the figure:

- For line graphs and charts: number of samples/data points, type of replicates (biological or technical), statistical test, type of error, *P* values.
- For microscopy images: Cell/tissue type, stains or fluorescent markers, scale bar and magnification. In some cases, it is also good to direct the reader's attention to key details in the images.
- Western blots: Type of samples (immunoprecipitation fractions, whole cell extracts), antigen, loading control.
- Heat maps: scale (logarithmic or linear) and normalisation.

And while we're on the subject, having the figure legend beneath each figure in your submitted manuscript will make your reviewers happy.

Enjoy the process or the end product

Whatever your approach may be, whether you enjoy the process of writing or the end result, it is good to celebrate the achievement. Labs often celebrate accepted papers. I advocate for celebrating submitted papers – after all it is a personal milestone each time. I recommend a drink at your favourite run down campus bar or a bowl of spaghetti – whatever is more memorable.

And remember, in the end it's all about the big picture.

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Avoiding common pitfalls of manuscript and figure preparation

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Progress towards understanding the natural world is in some ways like assembling a jigsaw puzzle. Individual pieces snap together, which then join to form larger and larger sections until a complete picture gradually emerges. Forcing a piece to fit where it does not belong can derail the entire puzzle. In the same way, scientific progress unfolds piece by piece, as scientists link small advances together into landmark discoveries. Therefore, writing up the results of a scientific study in an accurate and clear manner is essential for enabling other scientists to confirm and build upon the advance, together revealing the underlying puzzle.

However, the ‘publish or perish’ mentality within the research community can lead to papers being submitted and even published when they are not technically sound or rigorously developed, potentially undermining the foundation upon which scientific progress is based. In our first ‘Words of Advice’ article, we provided tips for developing a research plan and writing a strong, compelling manuscript [1]. In this instalment, we investigate the flip side of the coin – the tempting shortcuts to producing a substandard manuscript that can lead to your work being rejected, dismissed or even retracted, and tarnish an otherwise promising research career.

Writing: imitation is not the sincerest form of flattery

The strength of any piece of scientific writing comes from the ideas guiding the study, the experimental results obtained and the words put down on paper to describe it. Once you have explored the underlying ideas and have your data in hand, few things are more disheartening than confronting a blank Word document with a severe case of writers’ block. What is the harm in copying a few sentences from another related work – or even your own previous paper – just to get the creative juices flowing?

Do not risk it. Many journals, including *The FEBS Journal*, now use plagiarism detection tools such as [iThenticate](#) at some point during the review and publication process. These tools compare a submitted piece

of writing to large databases that include scientific papers, academic publications and archived webpages [2]. Figure 1 shows how the iThenticate report highlights plagiarised sections of an article. The software picks up each line of copied text, directing the user to the original source. It becomes a judgement call for the editor where to define the threshold for an appropriate similarity score. In some cases, authors are asked to reword their findings to minimise overlap with previously published material. In cases where extreme degrees of similarity are seen, automatic rejection of the manuscript and even contacting the host institution may be deemed necessary.

iThenticate detects outright plagiarism, and also uncovers instances of patch-writing. In this ‘failed attempt at paraphrasing’ [3], an author relies too heavily on an original piece of text, only making minimal changes to wording, tenses or sentence order to rephrase a point. Patch-writing can often be attributed to a lack of understanding of the original text, which makes it difficult to frame the point in an alternative way. To avoid this potential pitfall, take the time you need to read, reread and fully understand a previous study before using it to support your own research and writing (Box 1).

Writing a manuscript often means spending days deliberating over how best to present your research and formulating descriptions that suitably capture your findings. Once you have published a clear, lucid manuscript that has gone on to be embraced by the scientific community, it can be tempting to reuse this text in other pieces of work. However, it is important to start fresh with each study, to ensure that the results are appropriately contextualised and that recent advances are included in the introduction and discussion (Box 1). At *The FEBS Journal*, the one exception to this rule is within the Materials and Methods section. Protocols therein should be written exactly as performed, and can thus remain constant between several papers for clarity and reproducibility (we should note that other journals may take a different view on this practice). A ‘copy and paste’ approach for any other part of the manuscript, however, is not acceptable and can lead to editorial rejection.

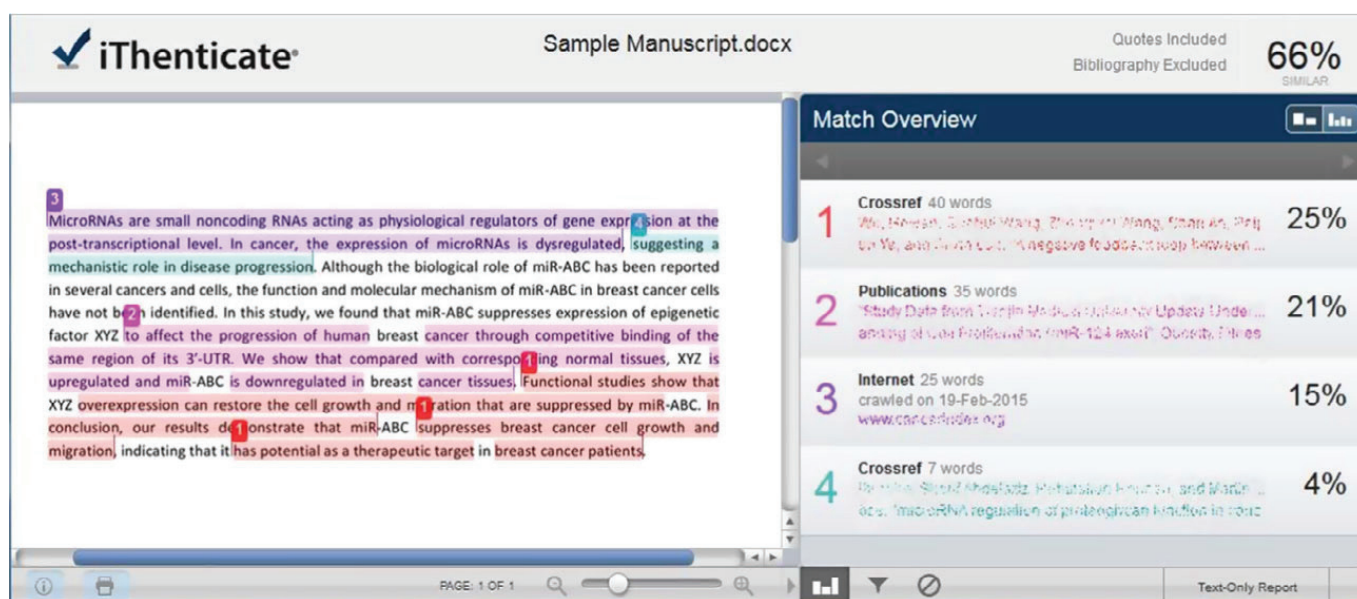


Fig. 1. Sample of an iThenticate report for a heavily plagiarised piece of text. The software compares the wording used in a submitted manuscript to large databases of published work, highlighting text that has been copied (left) and the original source (right). The amount of copied text used from each source is given as a percentage of the full text, and a cumulative similarity score is shown in the top right.

Do not let a hasty write up prevent your research from being seen. Take your time, use only your wording, and employ quotation marks when necessary (referencing original sources when doing so).

Experimental design and data presentation

Avoiding confirmation bias

Long before you begin the writing process, take time to design your experiments clearly and critically [1].

Box 1. Best practices in scientific writing

- Ensure that every source used in your writing is referenced. If sections of text are used, quotation marks should be included and the original source cited.
- Start adding provisional references at the very early writing stages.
- When referencing an article, take the time to fully read and understand it. The better you understand the finding, the better you will be able to paraphrase the study without duplicating the text.
- Do not assume authors on other papers have done as thorough a job on citing their references. Always check the original reference before citing.
- Non-native English speakers might wish to write the text in their native language then have it translated professionally.

Experiments should provide evidence for your central hypothesis, but data that disprove your hypothesis should not be discounted either. Rather, the hypothesis should be modified so that all observations – positive and negative – can be woven into the study. As scientists, we are impartial observers to the mysteries of the natural world; patient and persistent in collecting data rather than forcing data to fit a hypothesis. Thus, it is important not to succumb to confirmation bias – that is, searching for and including only evidence that supports your hypothesis and ignoring contradictory results (Box 2).

This should be reflected in your writing style, too. Take care to connect the results in your manuscript in a logical manner, but ensure the manuscript has not been written with an underlying tone of selection bias. Avoid phrasings that suggest that experiments were performed specifically to prove a point (e.g. ‘To prove that this mutation in protein X causes disease Y. . .’). Some results will necessarily generate open questions that can be tackled in a follow-up study: this is how the jigsaw puzzle expands, and science progresses. Another important point is to ensure that the raw data remain central to the study – this is especially critical for large, collaborative projects. As Professor John Hardy writes [4], ‘With regard to experimentation and data analysis the main lesson I have drawn is that if data is critical, make sure you see the raw data yourself.’ Let the data speak for themselves. Knowing your data set inside and out will allow you to draw appropriate conclusions from the findings.

Box 2. Show us the data

- Design your experiments meticulously, choosing adequate biological and technical replicates.
- Select suitable statistical tests before you pick up your pipette.
- Modify your central hypothesis to fit your data – not the other way around.
- Keep the raw data front and centre as you write up.

Designing the experiments

Statistical tests are used to check the (statistical) significance of scientific findings, i.e. to demonstrate that the observations are not due to a chance occurrence. The most suitable statistical test, which you will later use for analysing the results, should be selected at the design stage, before performing the experiment (Box 2). This will dictate the sample size (number of biological replicates) needed, which is especially important for large-scale and expensive ‘omics’ studies, as well as experiments involving animal models. Do not fall into the trap of thinking about the statistical analyses after the experiment has been performed, and end up repeating the experiment or tailoring the statistical test to get a ‘significant’ outcome. You should also perform an appropriate number of technical replicates, which serve to identify the variation associated with methodology (such as pipetting errors, measurement errors, etc.) rather than true biological variation. If you are unsure of which statistical test to use, get in contact with someone in your institute’s statistics department. There are also several online resources that are specifically targeted for biologists that explain the principles and concepts of correct experimental design and statistical analysis (see here).

Preparing blots, images and figures for publication: perfect data at the bench, not at the computer

When it comes to drafting the figures, ‘representative data’ do not mean cherry-picked data points that give the best-looking bar graph. Be transparent. Consider uploading your raw data to figshare or a similar data-sharing service (both for posterity and transparency), and familiarise yourself with the numerous types of graphs that can be used to represent variation between data sets [5]. Representative data should be used for microscopy images and western blots, when quantification is not needed. In this case, optimise and

standardise the protocols to minimise the need for extensive postacquisition image manipulation. On this note, when comparing digital images for quantitative purposes, ensure that you use identical pre- and postacquisition conditions (Box 3). This is especially true for distinguishing differences between controls and experimental repeats [6–8].

The continued advances in image-processing software allow even neophytes easy, user-friendly tools with which to modify digital images. However, in the words of Douglas Cromey, ‘Digital images are data: and should be treated as such’ [6]. We must, therefore, resist the temptation to excessively manipulate data for beautification purposes. Linear adjustments, whereby every pixel in the image is altered according to a linear function, are acceptable. Small changes to improve the brightness or contrast of figures, in polyacrylamide gels or fluorescent micrographs for example, are generally considered acceptable – so long as any modifications are made to the image as a whole, and not individual bands or areas of an image (Box 3).

Cropping of images is also common practice, but for blots it is important to leave a sufficient amount of background surrounding your bands. What may look like an artefact or background noise to you might represent valuable data to someone else or turn out to be a breakthrough. Indeed, the discovery of the aquaporin channel was made following the observation of

Box 3. Letting data speak for themselves

- Ensure that the data shown are truly representative, by optimising and standardising protocols to give clear and coherent results without postacquisition image manipulation.
- Consider depositing all raw data to a file-sharing service (figshare or similar).
- Take time to understand data acquisition tools and image-processing software, noting the manipulations that are deemed acceptable and those which are not.
- Standardise image acquisition procedures across related experiments to minimise the need for postacquisition image adjustment.
- Note modifications that you have made in preparing the figures, so that you can provide this information and the justification behind doing so if required.
- Always keep original raw files of your data.
- Carefully store your raw and modified data. Ensure all your data are well annotated (dates, conditions etc.) and easily retrievable to avoid accidents in mixing up data or in case project is passed onto someone else.

a 28 kDa protein that the authors initially thought was a degradation product of erythrocyte Rh polypeptides [9].

Though this is perhaps obvious to our erudite readership, it bears repeating that the selective use of brightness/contrast settings, cut and paste, or cloning/stamping tools that misrepresent the actual experimental findings are unacceptable and can lead to immediate rejection, or retraction if discovered after publication – even if the alternations do not materially affect the interpretation of the data. Figure 2 shows the most common kinds of acceptable and unacceptable image manipulation encountered in papers submitted to *The FEBS Journal*.

Editors and reviewers perform thorough checks on accepted manuscripts, poring over every figure prior

to publication. Furthermore, getting through the peer-review process does not mean that your paper is completely above scrutiny: it is still very much open to critique. The rise of postpublication commenting sites like PubPeer and PubMed Commons enables anyone with an Internet connection and image-processing software to detect, dissect and damn potential instances of image manipulation. Seeing your work picked apart by anonymous readers is a gut-wrenching experience, but by following the guidelines above you can be confident in the integrity of your data, knowing that even the most thorough of analyses will turn up nothing untoward. Defending the authenticity of your findings when a modified blot or gel is questioned can easily be achieved by providing original copies of your data files, which should always be kept to hand. It is

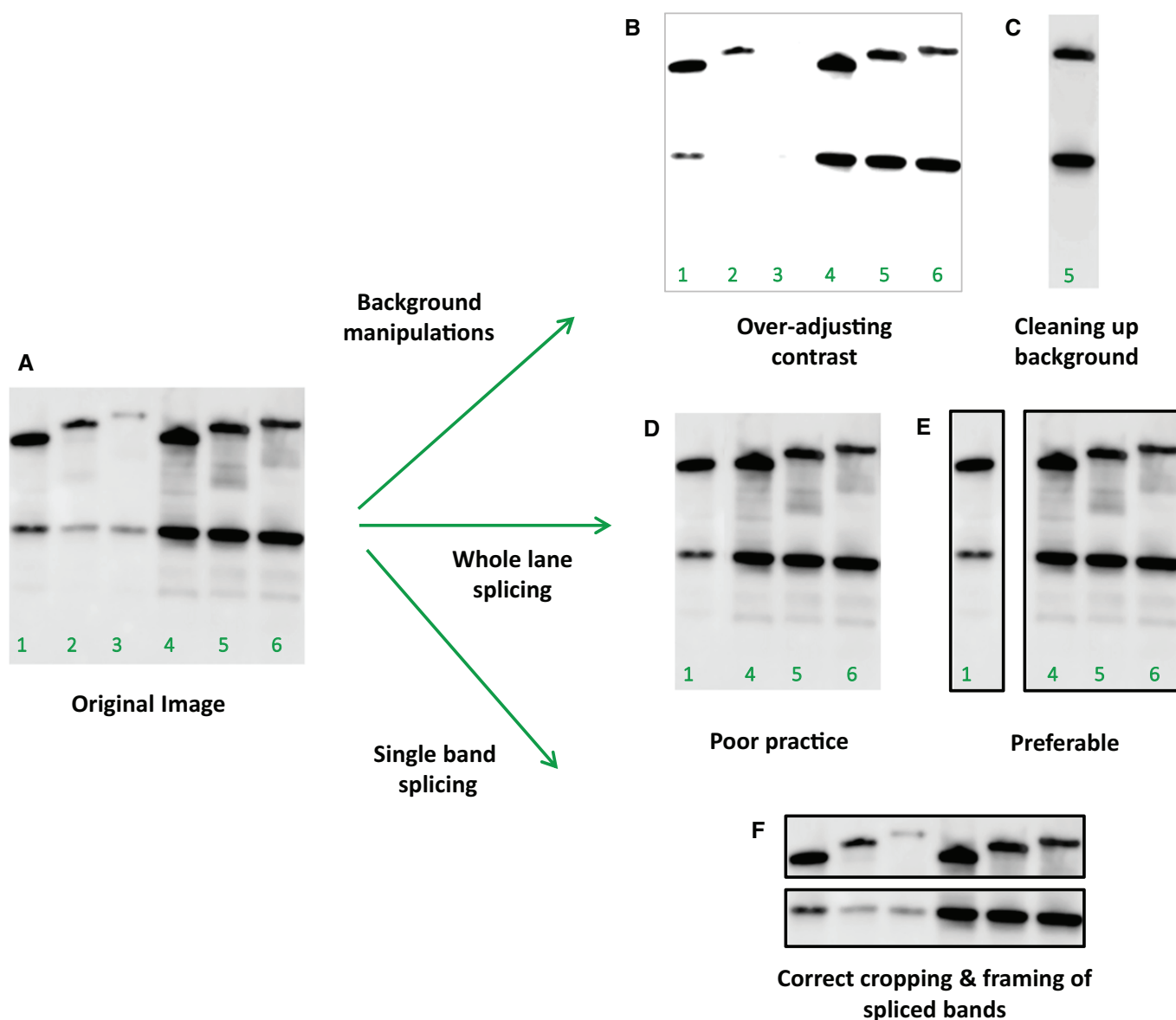


Fig. 2. Acceptable and unacceptable forms of image manipulation. (A) Original image, (B) Unacceptable over adjusting contrast, (C) Unacceptable cleaning up of background, (D) Poor practice in removal of lanes and (E, F) Correct representation of spliced lanes and bands.

Box 4. Drafting meticulous methodology

- When citing previous methods, ensure that you have provided details of any modifications germane to your study.
- When discussing antibodies, include the concentration used in each experimental condition (IP, western, IHC, etc), type (monoclonal or polyclonal), source and reference number. Consider submitting your data to antibodypedia or another community antibody validation resource.
- When listing biological material, include the source and reference number and indicate when cell lines were last authenticated. Misidentification of cell lines and mycoplasma infection is frustratingly common occurrences in biological research that can materially affect the conclusions of a study: the latest release of the ICLAC's Database of Cross-contaminated or Misidentified Cell Lines contains a staggering 488 entries.
- Names of other chemical reagents should be accompanied by the source and concentration.
- Commercial names (if available) and source or laboratory of origin (if not commercially available) of plasmids and siRNA should be given.
- Any specialist software should be accompanied by a reference or source and links.

also good practice to note all the modifications that have been used to prepare the finished figures (Box 3).

Writing the materials and methods section

When the bulk of your text has been written and the figures prepared, it is important to put as much care and effort into finishing your manuscript as you did in starting it. Too often the Materials and Methods section is added as a hasty afterthought, when in fact, precision here is essential for the reproducibility of your work (Box 4). Familiarise yourself with your chosen journal's guidelines regarding reagents and methods, and their expectations of availability of data and reagents after publication. In general, ensure that your methods section includes all necessary details that will allow other scientists to reproduce the experiments. Detailed step-by-step protocols can be deposited to

community resources such as Springer Nature's Protocol Exchange and protocols.io.

A solid foundation for future research

Original, reproducible work represents the foundation of science research. Observations made 50, 100, 150 years ago form the basis for the experiments you perform today. In this same vein, the research that enters the scientific canon today will inform our understanding of human physiology and pathophysiology for years and even decades to come. The reproducibility crisis in biological research is well documented. In an era of shrinking research budgets, it is important to make every dollar, euro, pound, yen, peso, renminbi etc. count by ensuring that published data accurately reflect the observations and that experimental protocols are described in sufficient detail to enable reproduction and confirmation. In this way, complex and mysterious biological systems are revealed, puzzle piece by puzzle piece.

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Scientific career paths – part I

Rita Gemayel

The FEBS Journal Editorial Office, Cambridge, UK

At each stage of your science career – whether you have just obtained a Master's degree, a PhD or are just about to wrap up a postdoc – you will face the same question: what next? For some, it may seem that there are not enough options and for others that there are too many options. Either way, having to take the next step along the career path can be daunting. But, you do not have to face the uncertainty alone. Your hopes and dreams are yours to fulfil; but others have successfully negotiated the postgraduate path and are willing to share their insight and advice.

In developing this two-part Words of Advice article, we have gathered opinion from PhD-level scientists, all of whom enjoy happy, fulfilling and successful careers in a wide range of disciplines. Each of them has given us an insider's view on their current roles, has outlined the steps they took to enter these professions and generously shared what they consider to be the main ingredients for a successful career. In part I, we bring you the perspectives of five of our experts: three of whom are at different stages of academic careers, and two who have chosen to pursue non-academic science careers. As diverse as their backgrounds may be, all of these experts have one thing in common: they are all science graduates and at some point, they too had to make important career decisions.

Transitioning from PhD graduate to postdoc – the postdoctoral training

The postdoctoral training is a pivotal transition step in a science career; it allows PhD graduates to sharpen their technical skills and acquire valuable new ones. If you are planning a career in basic/fundamental science research, choosing the right postdoctoral lab is critical for succeeding in the future, says Dr Sadeesh Ramakrishnan, a postdoctoral fellow at the University of Michigan. After earning his PhD in Biomedical Sciences from the University of Toledo, Dr Ramakrishnan joined Professor Yatrik Shah's lab at the University of Michigan in 2012 and has not looked back.

Dr Ramakrishnan advises prospective postdocs to look for a productive and successful lab that matches their research interests. Check the lab's funding history too, as this will indicate whether the Principle

Investigator (PI) has a good track record of grant writing. Look at the history of the lab's alumni – have previous postdocs successfully transitioned to independent group leaders? Dr Ramakrishnan also notes that the number of people in the lab is another factor to consider. A medium sized lab – typically between four and five postdocs or PhD students – will guarantee more interaction and knowledge sharing with the PI. Choose a lab that will support your career development, where you are likely to publish high quality papers, and allow you to gain the most relevant skills to becoming a PI: the ability to think creatively and critically, progression towards independence, paper and grant writing experience, mentoring of junior scientists, networking and collaborating with peers (Fig. 1).

Once you have landed your dream postdoc position, Dr Ramakrishnan says that actively pursuing these skills during your postdoctoral training, as well as seeking hands-on training in many different lab techniques, will help you correctly design experiments and troubleshoot problems. Collaborating on multiple projects and maintaining good working relationships within and outside your postdoctoral lab will also positively impact your publication record and strengthen your research profile. And importantly, write – manuscripts and grants – it is a skill that can only be acquired and perfected with practice [1]. A successful postdoctoral fellowship is based on discipline, hard work and willingness to help, and do not be afraid to take risks, adds Dr Ramakrishnan. And, the hallmarks of a successful postdoctoral training period are simple: excellent productivity and a finely honed work–life balance. Dr Ramakrishnan's parting advice is to maintain good relations with your PI and peers, and to learn and develop techniques that will make you unique, as this will help you stand out in a crowded job market. He adds, 'don't wait for a good time to apply for a faculty position. Whenever you see a position that may fit you, try to apply; but have a clear direction of what you want to do before applying for a faculty position'.

The postdoc is an important transition period, during which choosing the right lab is critical for succeeding in the future.
Sadeesh Ramakrishnan

Starting your own research group – the perspective of a junior PI

If you want to commit to a basic science career, start perfecting specific and relevant skills early, advises Dr Carole Linster, a PI at the University of Luxembourg. Dr Linster obtained her PhD in Biochemistry from the University of Louvain and, after a postdoc in Professor Steven Clarke's lab in UCLA, started her own group at the newly founded Luxembourg Centre for Systems Biomedicine in 2013. Like Dr Ramakrishnan, she notes the importance of becoming skilled in writing papers and grant applications as the foundation to a successful academic career (Fig. 1). 'Take every opportunity you can get to write grant proposals and to write up your regular papers and reviews independently in order to build up the self-confidence necessary for taking over this responsibility later on as a group leader'. Gradually take on more independence in your research projects by developing your own ideas and confirming scientific hypotheses that you have formulated, adds Dr Linster. Your aim is to obtain recognition and 'sincere expressions of trust from scientists that you respect'.

Once you have transitioned to independence, there are two crucial factors for successfully starting a research group according to Dr Linster: the right institute and the right people. You should aim to join an institute where your research topic will be appreciated, and where you will receive the necessary moral and

financial support. When recruiting new lab members, look for talent, motivation and a good level of social skills.

Starting a research group is challenging. Dr Linster advises that one of the most difficult aspects for a junior group leader is switching from focusing on a few to multiple projects, and taking on the managerial tasks of running a group. This necessitates a change in mindset: you need to think more broadly, for the long term and delegate whenever you can. In terms of what is needed on the personal level to succeed as a junior PI, Dr Linster lists seven significant attributes: 'the ability to say 'no'', being good at identifying priorities, the ability to focus despite multiple distractions, being a perfectionist – but only when necessary, being obsessive about reaching your goals, being able to make very high commitments to the job but without considering these as sacrifices and remaining curious and open-minded'. Dr Linster further highlights the importance of managing these attributes while maintaining 'authentically good relationships with your peers'. Her final advice to science graduates? 'Make sure you know exactly where you can make the difference, let this define your research line and don't let anybody interfere with this. Then surround yourself by excellent people that can work with you as a team to make the breakthroughs'.

The critical point is to have had mentors that were brilliant enough to impress you deeply for the rest of your career.
Carole Linster

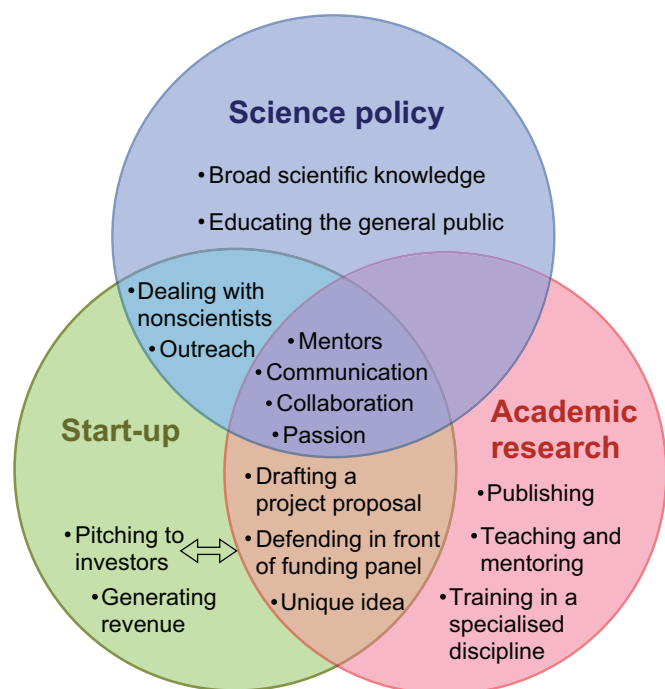


Fig. 1. The skills that PhD scientists acquire during their training are suitable for success across various disciplines.

Consolidating your academic career

When I asked Professor Andreas Villunger, a group leader at the University of Innsbruck, about the specific roles and responsibilities that most prepared him for becoming a PI, his response had striking commonalities with Dr Ramakrishnan and Dr Linster's answers (Fig. 1). Professor Villunger has been a PI at the Biocenter, Developmental Immunology Division for 14 years. He attributes his initial success in setting up his own lab to very supportive mentors, who allowed him to gain 'early independence in developing and driving research projects' and gave him the responsibilities of writing manuscripts and grants. Professor Villunger points out that running a lab is expensive, and therefore applying for multiple grants – especially when starting a research group – is essential. This reiterates the importance of a supportive mentor in your postdoctoral lab, where you will gain experience in grant writing and take the first steps towards independence. Equally important at this early phase is

a ‘good start-up project, ideally half done from your postdoc, so you can publish early in your independent phase; and sufficient start-up funds to hire at least two PhD students and a technician and still have the freedom to work in the lab yourself’, says Professor Villunger.

Maintaining a research group has its own sets of challenges. Keeping up with new technologies means constantly applying for funding – which can take valuable time and energy from a group leader. The key to avoiding becoming ‘a writer’, advises Professor Villunger, is ‘to make room for your creativity, for the science and the personal interaction with people in the lab’. Other, equally important attributes that can help a PI navigate these challenges is having the right people in the lab and the ability to motivate them (especially when research projects don’t go according to plan), establishing a network of peers and contacts in a community and ‘being as interactive and collaborative as possible’. On a personal level, Professor Villunger credits ‘endurance, tolerance against frustration, a love for science, a sharp mind and good people-management skills’ as important attributes for success. He also emphasises that a good PI is one who ‘can be a role model for others and stay human and in touch with junior researchers’. In other words, ‘don’t turn into the nerdy professor that no one wants to hang out with or have a beer with’ says Professor Villunger.

Establish contacts in the community – be as interactive and collaborative as possible. **Andreas Villunger**

Building a start-up

Start-ups are increasingly becoming a viable career option for science graduates and funding agencies and investors have started to recognise the potential impact of these companies. But attractive as they may seem, start-ups have high chances of failure, and success – true success – can take years and a fair amount of sacrifice, as I found out during my interview with Dr Lenny Teytelman, founder and CEO of protocols.io. Dr Teytelman obtained a PhD in Genetics and Computational Biology from the University of California, Berkeley followed by a postdoctoral training in Professor Alexander van Oudenaarden’s lab at MIT. The birth of Dr Teytelman’s start-up company came as a result of a phone call from a friend asking whether they could build a mobile app for scientists that ‘would make research easier’. It was a simple question that resonated with Dr Teytelman, who had spent a year and a half of his postdoc struggling with a protocol, only to discover in the end that a single step in

this published method was incorrect. Dr Teytelman soon drafted an app that would later become the nucleus of the protocols.io start-up: a central repository for scientists to deposit, share and update experimental protocols.

As Dr Teytelman points out, his company ‘happened by accident’ and this is not necessarily the approach that he recommends for science graduates. But he quickly adds that the skills scientists learn during their graduate training are perfectly suited for founding and running a start-up (Fig. 1): ‘drafting a project proposal and defending it in front of a funding panel, outreach, communication and soliciting feedback from other scientists’. Dr Teytelman also believes that the ingredients for start-up success are indistinguishable from those needed to succeed in academic research: ‘advisors and mentors who have experience, lots of luck, funding and passion for the idea you are pursuing’. And just like in basic research, ‘success for start-ups is a moving target’. When I asked Dr Teytelman what are the personal attributes needed to succeed in his job, his answer could easily describe most scientists: ‘tolerance for risk, optimism, ability to listen to advice and criticism’. And his advice to science graduates is perhaps the most revealing about this career path: ‘It’s not a job. It’s an experience. Kind of like having a child – exhilarating, stressful, rewarding, exhausting, unpredictable, consuming’.

Get advice from others. Seek the right mentors, advisors, supporters. **Lenny Teytelman**

Impacting society and education – working in science policy

In a quest to understand how biological research fits in the greater societal context and in hopes that this would make him a more effective biology instructor, Dr Marcelo Vinces applied for an American Association for the Advancement of Science (AAAS) Science & Technology Policy Fellowship after his postdoctoral training in Professor Kevin Verstrepen’s lab at Harvard University and the University of Leuven. This fellowship placed him at the US National Science Foundation (NSF), where he worked on various projects that supported research at undergraduate institutions, including outreach, and organising conferences and workshops. The AAAS fellowship’s goal is to place PhD graduates across US federal agencies and the US Congress in a bid to allow them to share their technical skills and analytical perspectives with policy makers. In return, PhD-level scientists get training in effective networking, science communication and learn

how government policy is formulated. This exchange of expertise happens in almost all agencies and institutions that are involved in policy-making worldwide. According to Dr Vinces, good communication skills and the ability to engage with nonexperts are critical for science policy work. He adds that working in science policy entails ‘embracing different ways of communicating and new forms of knowledge’. Perhaps the most significant attribute is ‘being comfortable with not being an expert anymore; leaving your hyper-specialised sub-discipline to do work that involves non-scientists in government’ (Fig. 1). Success in science policy has far-reaching implications: it can mean educating the public about a scientific breakthrough or providing scientific evidence that leads to the adoption of data-driven policies.

If science policy seems like a good fit for a career, Dr Vinces notes that fellowships are one way, but not the only way to get into this field. Head outside your lab and into the community to share your enthusiasm for science, and get involved in your local newspaper

or your scientific society and write about issues of concern involving science.

*Anyone with a science background can get involved in science policy in different ways. Scientists being involved in communications and education outside the lab is also part of science policy. **Marcelo Vinces***

We hope that our experts’ words of advice will help as you consider the myriad options now open to PhD-level scientists. And remember, as a scientist you are inherently bold and creative – so be bold and be creative in building your career too. In the second part of our Words of Advice article, we will draw upon several more experts in a variety of different science careers to share their secrets to success, so stay tuned!

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Scientific career paths – part II

Rita Gemayel

The FEBS Journal Editorial Office, Cambridge, UK

Introduction

In the first instalment of our Words of Advice on scientific career paths [1], we sought feedback from five scientists on how to build a happy, successful scientific career in academia, science policy or a start-up company. Their advice reflected their individual positions and career paths, but each expert also noted the importance of good mentors, clear communication and interpersonal skills, and passion for their field. These attributes are central to a successful, enjoyable career in many scientific professions, but the scientists that we interview in this second instalment on scientific career paths have something else to add: the importance of being open to opportunity.

Our experts this time hail from academia, where the words of two established professors will undoubtedly provide inspiration for their more junior colleagues; from a patent office, where claims of novelty are rigorously investigated; and from a publishing company, an industry that is facing rapid change. In addition, we are delighted to share the perspective of our former intern, who reflects on how taking a brief break from the bench affected her graduate studies. Whether you are just starting out, looking to make a change, or simply want to know what a different profession might be like, keep reading!

Taking time off bench work to explore different career options – Internships

As you work towards completion of your PhD or postdoctoral position, you might already have a clear idea of the career that you would like to have. However, if you have not yet settled on a career path, an internship can be an excellent way to get first-hand experience of the different roles that your science graduate degree allows you to pursue. In essence, an internship allows you to ‘look before you leap’ and get a taste of what working in a different environment is really like. In fact, some doctoral training programmes now require PhD candidates to complete an internship in a nonacademic setting. This is a low-risk investment that can pay dividends for your science career. Sùil Collins, a PhD student working on developing small molecule inhibitors of amyloidogenic aggregation using

microfluidics, at the University of Cambridge Department of Chemistry, used her 12-week internship at *The FEBS Journal* to get hands-on experience in science publishing. ‘When the time came to apply for this placement, I was still unsure about what I wanted to do after my post-graduate studies and thought it would be good to sample something completely new’, says Ms Collins. An interest in science communication was the motivator for her to apply for an internship at *The FEBS Journal*. The journal does not have a formal, advertised internship scheme, but that did not deter Ms Collins, who emailed the editorial office expressing her interest in working in science publishing as part of a BBSRC-funded internship. Ms Collins wrote a research highlight and attended an interview, after which she was offered a 12-week placement in *The FEBS Journal’s* editorial offices here in Cambridge, UK.

During her time in the editorial office, Ms Collins learned about the process of scientific publishing first-hand. She was tasked with ensuring that newly submitted manuscripts adhered to journal guidelines before formal assessment by the editors, developing reports for the journal and contributing to the journal’s Twitter feed. She also contributed to the Research Highlights section of the journal and wrote a Words of Advice article on best practices in manuscript preparation [2]. Importantly, her brief experience in science publishing helped her develop skills that transferred to her postgraduate studies when the time came to pick her pipette back up and rejoin her colleagues at the bench. Ms Collins credits her internship at *The FEBS Journal* for improving her writing skills and her ability to critically assess scientific publications, as well as expanding her scientific knowledge. These are extremely relevant skills for her PhD training and for a future career in research. Furthermore, as Ms Collins points out, an internship is just as much about learning on the job and about the job as it is about finding the type of working environment that you will thrive in. For Ms Collins, this was a previously ‘unrecognized factor’ that she will now take into consideration when deciding on her next career move.



I would definitely recommend other PhD students to try a similar internship if they are interested in a particular career, but want to try it out before taking the plunge!

S uil Collins

Is it novel or not? Ask a patent officer

During his postdoctoral training at the National Cancer Institute, Dr Zachary Miknis took some time off from his laboratory work to assess postdoctoral research grants at the National Institutes of Health (NIH). This experience convinced Dr Miknis that he would enjoy and succeed in an ‘office-based science job outside a lab’. As he also considered studying law after his PhD and was particularly interested in patent law, Dr Miknis seized the opportunity when he came across an ad for patent examiners at the United States Patent and Trademark Office (USPTO). As a patent officer at the USPTO, Dr Miknis analyses patent claims to determine whether they fulfil all the requirements of patentable inventions. This entails a fair amount of time searching various databases (e.g. patent, literature, sequence and structure databases) to verify whether the invention being claimed already exists as a standalone reference or as a combination of known elements, and thus whether the invention is patentable. Dr Miknis then makes his recommendations for or against a patent. While some cases are straightforward, others require the expertise of additional legal scholars.

‘The job of a patent examiner is like a postdoctoral fellowship, where the effort you put in determines what you get out of the job’, says Dr Miknis. It is also a job where you can transition towards independence. Since joining the USPTO, Dr Miknis has taken full advantage of the training and mentorship programmes available to drive his career towards full independence – where he could sign off on most of the cases he handles.

According to Dr Miknis, a successful examiner should be able to work independently on multiple cases at the same time. Flexibility and personal discipline are exactly the attributes a scientist would have acquired during a successful graduate or postdoctoral training programme [1]. ‘If you enjoy spending time searching online resources for very specific information and if you enjoy writing, then this is a job for you’, Dr Miknis advises. But be ready for a constant stream of different cases that ‘will have some sort of clock running on them’. Like any industry, there are goals and expectations to be met. And in passing on

previous advice that he found helpful, Dr Miknis says, ‘take your time to write up the reasoning behind each decision, even if this entails more work’.

In some ways, the job of an examiner is like a post-doctoral fellowship, where the effort you put in determines what you get out of the job.

Zachary Miknis

As Ms Collins and Dr Miknis point out, knowing what sparks your interest (and equally as important, what does not) can help guide your decision-making process and point you towards a rewarding career. Once you have identified a profession that aligns with your interests and capabilities, you can then gradually build up your knowledge about a particular career by getting first-hand experience (through an internship, for example) or by reaching out to someone working in that field. Taking time outside the laboratory to pursue other science-related roles will help you decide whether a certain role is a suitable career option for you or not. Although a several-month break from the laboratory will undoubtedly set your research goals back, the additional maturity and expertise gained from these experiences are well worth the price of admission – not to mention that future employers will be delighted to see a relevant position on your CV.

Entering the changing landscape of science publishing

A sure-fire way to land a position you love is to actively learn about the ins and outs of a certain role and to build a skill set geared towards a long-term objective. However, while you are working your way towards that tenured faculty position, stay open to all possibilities. ‘The biggest decisions in life are often the ones we take most instinctively, rather than analytically, because we can’t possibly predict how things are going to work out when we step into something new’, advises Dr Matthew Day, Head of Open and Data Publishing at Cambridge University Press. Dr Day was poised to move to a postdoctoral position after writing up his PhD dissertation, but an inspiring interview with a hiring editor convinced him to get into science publishing, and he has not looked back. Dr Day began his career at an imprint of Taylor and Francis before moving into positions at BioMed Central and Nature Research. In his current role, he acts as a liaison between various departments within the company and outside collaborators as he ‘redefine[s] Cambridge University Press’s policies and practices around Open Access (OA) and data publishing’.

Dr Day attributes his skills and willingness to help others with their writing as his initial motivator to apply for jobs in science publishing. And while the basic editorial and publishing processes have remained unchanged over the past 10–20 years, Dr Day says the publishing industry is still developing as it adapts to the advent of digital publishing and Open Access. In fact, it was a two-year spell at the technology company Wolfram Research that shaped Dr Day's understanding of how technology can impact academic publishing and helped him land his current job – another example of how taking a brief detour from your planned career path can yield dividends. As Dr Day explains, 'there are a lot more technology start-ups serving the scholarly communications world, and we are seeing real growth in new approaches in all aspects of publishing, from authoring tools, preprint servers and postpublication peer-review, to new ways of measuring impact and usage'. And for these reasons, Dr Day thinks the best attributes for success are 'being comfortable with change and spending time to figure out the right strategic thing to do next'. But equally relevant for a service industry like publishing, is a genuine 'interest in people, what they do and what they want to achieve', Dr Day adds.

His advice to science graduates applying for a job is to understand the key aspects of the job ad and job description and to 'show why the job interests you'. And echoing Dr Miknis's thoughts, Dr Day also touches on the importance of hard work and 'putting in the hours of work to best effect'.



I think that the biggest decisions in life are often the ones we take most instinctively, rather than analytically, because we can't possibly predict how things are going to work out when we step into something new.

Matthew Day

Words of wisdom from two passionate academics

As we found in the first part of this series [1], inspiring mentors can have a long-lasting effect on one's career. For Professor Alexander Wlodawer, the Chief of the Macromolecular Crystallography Laboratory and Senior Investigator at the National Cancer Institute, the motivation to pursue an academic science career was to follow in his mother's footsteps. His mother, Professor Paulina Wlodawer, worked in the Nencki Institute of Experimental Biology of the Polish Academy of Sciences in Warsaw, and later at the Karolinska Institute in Stockholm. Prof Wlodawer notes that

'having a good role model and being exposed to science and scientists at an early age prepared me to become a PI'. Once he decided on his career path, Prof Wlodawer geared his plans towards that goal: after completing his PhD at the University of California, Los Angeles, he chose to pursue his postdoctoral training in Prof Keith Hodgson's laboratory at Stanford. His experiences there provided opportunities to gain independence and collaborate on interdisciplinary projects; a decision that he says was 'crucial to my future career'. It is intriguing to note that Prof Wlodawer views interdisciplinary collaborations as fundamentally positive experiences, supporting the view that one does not need to leave the laboratory entirely to gain a different, enriching perspective.

Professor Sophie Zinn-Justin, a PI at the French Atomic Energy Commission (CEA), also credits being in the right laboratory and working on collaborative projects during her PhD and postdoctoral training as key factors that allowed her to pursue an academic career in science. Prof Zinn-Justin earned her PhD at the Protein Engineering Department of CEA, and was hired there to contribute to the setup of a Structural Biology Laboratory. To first establish a research group and then go on to have a long, successful science career, Professors Wlodawer and Zinn-Justin both cite the importance of having extensive knowledge of and unique expertise in the proposed field of research, as well as possessing the self-assurance to motivate people even while dealing with setbacks. Both professors also agree that, on a personal level, a successful PI must have excellent interpersonal skills, be patient and passionate.

Professor Wlodawer adds that running and maintaining a successful research group means accomplishing two 'contradictory roles': on one hand 'pushing for the most challenging projects without any assurances of success'; and on the other hand, 'supporting the careers of students and postdocs by allowing them to have a significant number of good publications'. The best solution, according to Prof Wlodawer, is hiring the right people—'very bright associates who can help in making the best decision themselves'. Professors Wlodawer and Zinn-Justin also have very similar advice to anyone who wants a career in academic research. 'Have very clear ideas of what you want to accomplish' says Prof Wlodawer and choose an area of research, although potentially risky and not very glamorous, where 'you should put all your energy for many years', according to Prof Zinn-Justin and in which 'you could become the best in the world', according to Prof Wlodawer. Although, as Dr Day asserts, it is impossible to forecast future professional

success or happiness, choosing a research project that challenges and excites you is an important first step in achieving a fulfilling academic career.



Take time to read a lot, discuss with people, choose a topic for which you will stay enthusiastic for several years; don't hesitate to collaborate with people who inspire you.

Sophie Zinn-Justin



Become an academic scientist only if you have clear ideas of what you would want to accomplish.

Alexander Wlodawer

In these two pieces, we have interviewed 10 experts who enjoy thriving professional lives in several different arenas – what key points can we take away from their advice (Fig. 1)? Being passionate about something is highly advisable and is far more likely to lead to success. As the saying goes: ‘choose a job you love and you will never have to work another day in your life’. Putting in hard work and effort are clearly very important and this is undoubtedly much easier to do when you are working at something you enjoy. Supportive mentors are also key ingredients for a successful career, perhaps more so in academia than in other nonacademic scientific careers. However, the importance of good mentorship is not restricted to early

career scientists – a constructive relationship with a senior figure in your chosen profession can only help, no matter your career stage. Likewise, clear communication skills are a must for any science professional. By the time you have that PhD in hand, you should have already acquired solid communication skills from writing your PhD thesis and papers, and presenting talks and posters. But as you move up or out of the laboratory, keep sharing your work, as it is only through practice that you will develop better ways to communicate your science and inspire the next generation of scientists. It is also important to take advantage of opportunities that might lead you away from your core interests, be it an internship, a fortuitous job interview or research break that leads to a successful long-term career in a different area, or a thriving collaborative project.

Finally, recognize what it is about science that excites you and will keep you coming back through the laboratory or office door: a long-term career, like any long-term relationship, will have its ups and downs. After all, no job is 100% perfect 100% of the time. Navigating these hard stretches requires patience, determination and compromise – much easier to muster when you fundamentally enjoy what you do.

We thank the experts for their candid thoughts and their inspiring words. We hope that this two-part Words of Advice provides you with satisfying answers to questions about careers in science. Please do reach out to us by email or on Twitter if you would like to share your experiences!

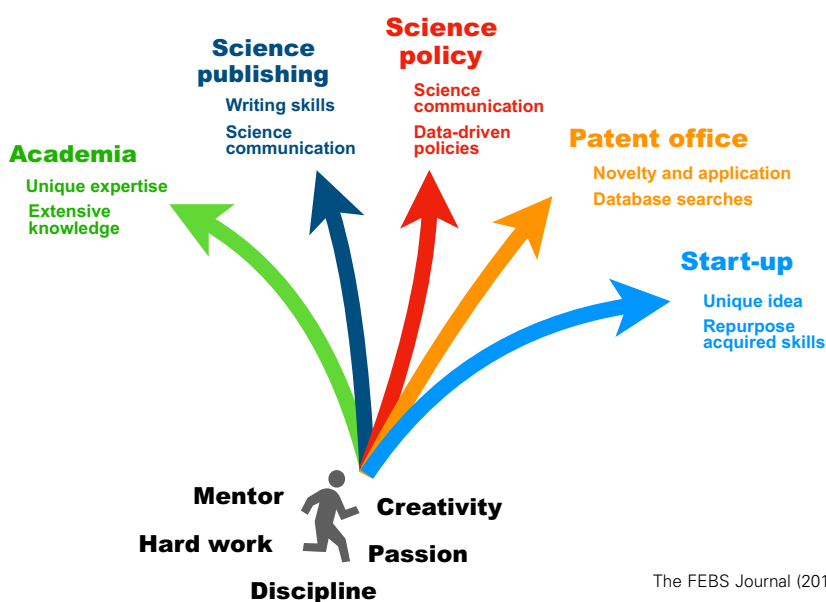


Fig. 1. Your skills as a science graduate allow you to take multiple paths towards an enjoyable and rewarding long-term career in a scientific profession. Any path you take starts with a supportive mentor, hard work, creativity and passion.

Disclaimer

The opinions described in this article by Dr Zachary Miknis are personal views and do not reflect the official views of the USPTO or the Department of Commerce.

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