

## 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 filmmaking. 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

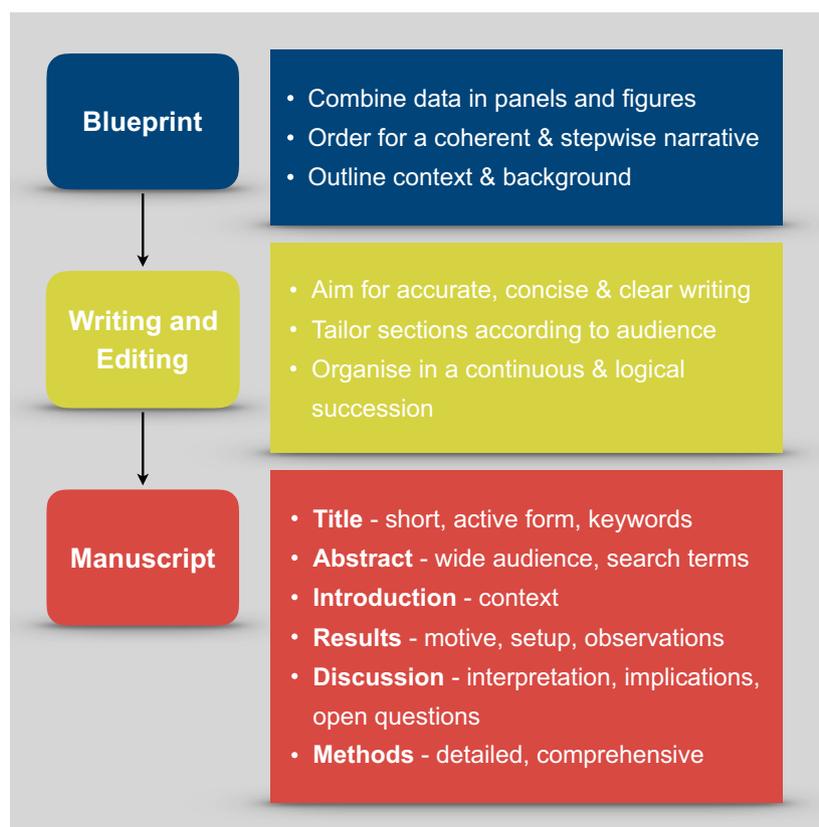
should have a key point and develop the central discovery in some significant way.

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 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.

### Reference

- 1 Letchford A, Moat HS & Preis T (2015) The advantage of short paper titles. *R Soc Open Sci* 2, 150266.