A Brief Guide to Figure Making in the Natural Sciences

Think back to the last time you came across an abstract for an exciting new scientific article. What component of the paper did you look at first? Most likely, you initially skipped over the text and headed straight for the figures. Good scientific figures should present data in a clear, effective, and efficient manner, condensing the "story" of the paper into a series of images. However, preparing such figures for publication is often a daunting task. Here we have compiled a brief overview of what to keep in mind when preparing figures for your manuscript.

1) **Tell a story with your data.** Before you start writing, consider **organizing the structure of your article around the figures**. This process can begin even before you have completed all of your experiments (and it may even inform further work!). Your data will define your results section, and because your figures are a representation of your data, this is an excellent way to begin outlining your article. During this stage of writing, you can assess whether or not your data tells a complete and compelling story. Keep in mind that you will be limited in the number of figures/tables that you can include in your article. For example, a typical Nature article can include up to 6 figures/tables. Before beginning to organize your figures, review articles in your target journal to understand the scope of the information expected. Data that does not contribute to the main story of your article, such as information on methods, additional controls, etc., can be assembled into supplemental figures (which may also have their own separate requirements).

2) **Each figure should correspond to a single take-home message**. Generally, each individual figure will consist of multiple pieces of data that support **one major point**. Each piece of data may comprise a separate part (a, b, c, etc.) of the figure.

3) **Figures should be self-explanatory.** Consider the take home messages from your experiments and what format will best allow you to display this data. Will you get your point across most effectively using images, tables, graphs, charts, or videos? Ensure that all components are adequately labeled such that the figures can stand alone without the reader having to refer to the text.

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4) ***Use concise figure legends.*** *Check your journal's character limit for figure legends, as some journals have length limits for the text. You may be required to include specific information about the figures, including the abbreviations used in the figure, scale bar lengths, the meaning of error bars, the number of data points displayed, etc. Some authors include a concise interpretation of the figure in the legend; others include this detail only in the title of the figure legend; while others will leave interpretation to the main text. Review articles for the convention used in your journal of choice.*

5) **Carefully review the chosen journal's figure guidelines**. Most journals have very specific requirements for figures, including the number of main and supplemental figures allowed, **image resolution, font type and size,** and **file format**. In general, digital figures should be at least **300 dpi** and often must be submitted in **TIFF format**. Ensure all text is legible by using a **clear font** (Arial and Helvetica are good choices) and a font size of at least **16 – 24**. Fit each figure to the dimensions specified by your journal – this could be one page in a one-column style journal or one column in a two-column style journal.

6) **Be consistent in style and formatting.** After you have chosen an appropriate font type and size, **consistently use that style** throughout your figures. The same goes for the color scheme of charts, graphs, and tables, the location and size of scale bars, etc.

7) **Create your figures.** A number of programs can be used to assemble figures, including **Adobe Illustrator, Adobe Photoshop,** and **Microsoft PowerPoint**. Note, however, that files output from PowerPoint may not be at high enough resolution for certain journals – refer to the submission guidelines of your particular journal. Graphical data can be produced using **GraphPad Prism** (available for free through the Yale software library), **Origin**, **Matlab**, **R**, or even **Microsoft Excel**. Free software is also available to produce representations of chemical structures (**Symyx Draw**), molecular biology data (**ApE** and **pDRAW32**), maps (**ArcGIS**), and 3D graphics (**Blender**). Adobe Illustrator and Photoshop are powerful tools for creating professional scientific figures, but they can be challenging to use. The Graduate Writing Lab, as well as the Yale Medical Library, occasionally offer **tutorials on figure making** with these software packages. A number of excellent tutorial videos can also be found online.

8) **Be careful and honest about image manipulation and alteration.** Many journals now use screening methods to identify incidences of nefarious image manipulation. Read your journal's guidelines for what constitute acceptable and unacceptable manipulations. For example, if you choose to display only part of a western blot, **be transparent** about where you have cut the blot using clear dividing lines. The Journal of Cell Biology offers thorough guidelines that may be applicable to many journals. In addition, some journals now encourage original data files to be uploaded to an online viewer for further transparency (for example, The Journal of Cell Biology).

9) A brief guide to the principles of figure design.

Aim for simplicity, legibility, and clarity in your figures – keep the reader in mind.

- Consider the **goal** of each diagram and image. Remove as much "visual clutter" and text as possible, while still clearly conveying your message.
- Use intuitive visual cues (such as diagram **shape**, **size**, **location**, **color***, and **orientation**, as well as arrows and text) to help make figures understandable upon first glance. For example, similar shapes can be used to represent related elements or to demonstrate a sequential process. You can use these same types of cues to **highlight information**
    - *Be aware that some journals require fees to print color images or do not publish hardcopies in color at all. In addition, color-blind individuals may have a hard time distinguishing between certain colors (see Bang Wong's article on color blindness for more details). If possible, try to make figures accessible in both color and black and white using different types of shading or line types (solid, dashed, etc.).

Examples

A) Use color, shape, and other visual elements with purpose. Figure 1(a) below includes several (unrelated) diagrams with confusing patterns and complex color schemes. These unnecessary details are distracting, which could hinder data interpretation. **Figure 1(b)** simplifies each of these diagrams to only their essential components. For example, the genomic loci AA and D are now clearly distinguishable from the surrounding loci.

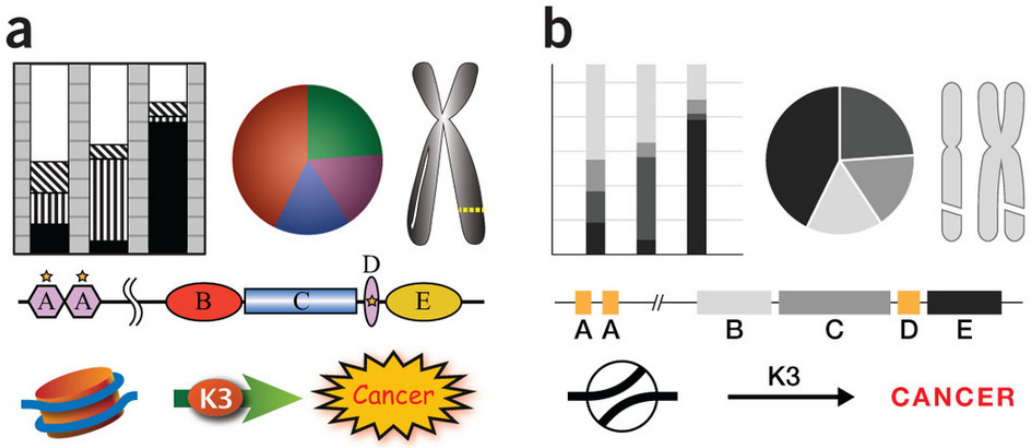

Figure 1.

Image from: Krzywinski, M. Points of View: Elements of visual style. 2013. *Nature Methods*. 10, 371.

B) Simplify for clarity. The two figures below **2(a** and **b)** illustrate the same chromosomal inversion and gene fusion event. However, while **figure 2(a)** displays several arrows and multiple steps, this information is conveyed with only two steps and one arrow in **figure 2(b)**. The subtle rotation of the center of the chromosome in **figure 2(b)** is an intuitive way of representing the inversion event.

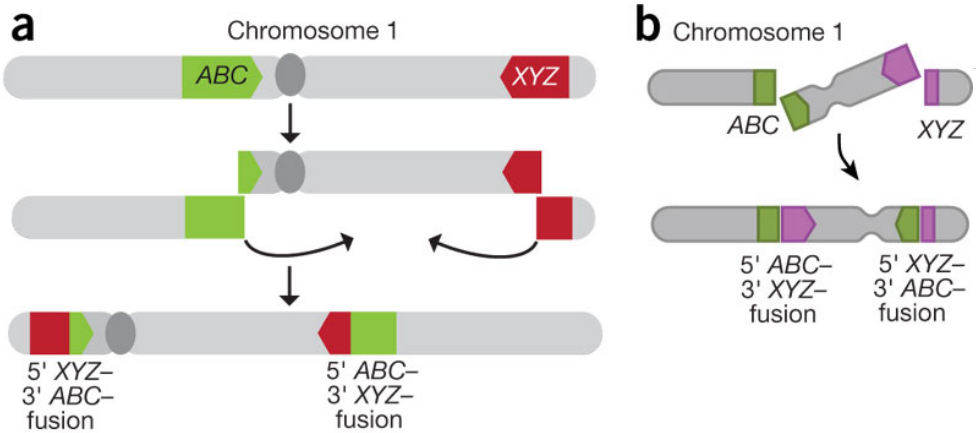

Figure 2.

Image from: Wong, B. Points of view: Simplify to clarify. 2011. *Nature Methods*. 8, 611.

C) Avoid visual clutter. Figures 3(a) and **(b)** below display the same seven series of data. While **figure 3(a)** attempts to display all of the data in a single panel by overlapping the traces, making data interpretation nearly impossible, **figure 3(b)** splits the data into seven separate plots. In the figure on the right, the use of color becomes unnecessary, even as more information (such as the use of a grey box behind each plot to represent the range of values) is displayed more clearly.

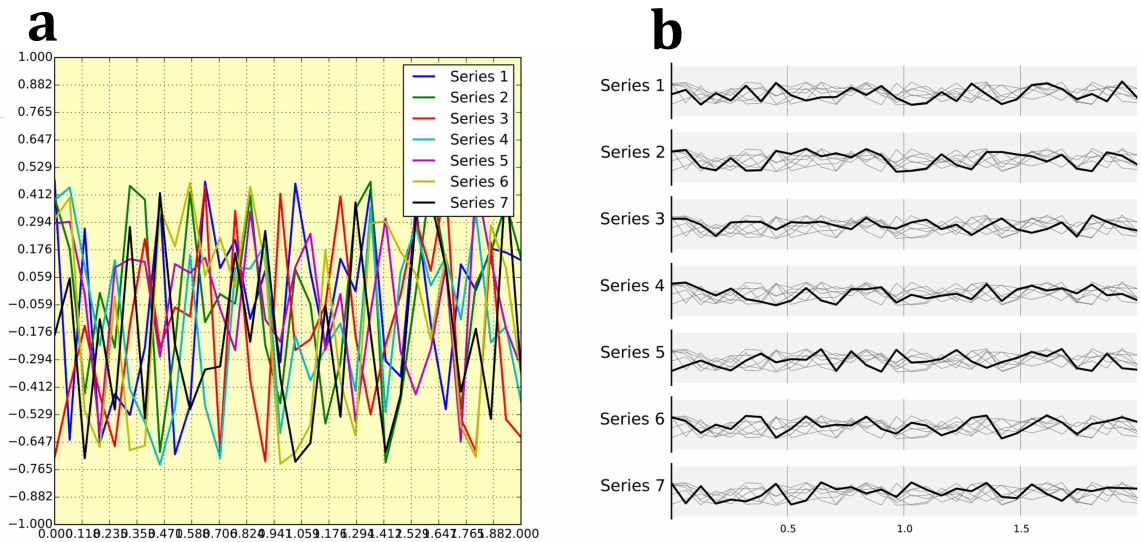

Figure 3.

Image from: Rougier, N. P., Droettboom, M., and Bourne, P. E. Ten Simple Rules for Better Figures. 2014. *PLoS Comput Biol.* 10(9).

Figure Design Checklist

Remember to check your journal's specific formatting requirements before creating your figures. Here is a brief guideline for making sure your figures are publication-ready.

- ○ Does each figure fit to your journal's size limits?*
- ○ Are your images at least 300 dpi?*
- ○ Have you adhered to the guidelines for figure manipulation for your journal?
- ○ Have you included scale bars on your images when appropriate?
- ○ Have you denoted the meaning of error bars and significance markers?
- ○ Are your images embedded (rather than linked) in your figure files?
- ○ Do the numerical axes on your graphs adhere to the rules of your particular journal (do they go to zero, can the axes be broken, etc.)?
- ○ Are your figure labels consistent?
    - Font type (Helvetica, Arial, etc.) and size (at least 16 – 24)
    - Nomenclature (gene names, chemical names, etc.)
    - Scale bar sizes and locations on images
- ○ Have you used the "symbols" font for Greek characters?*
- ○ Have you labeled each part of multi-part figures with a lower-case lettering system (a, b, etc.)?
- ○ Are your figures in the correct format (TIFF, EPS, etc.)?*
- ○ Are your figures clearly labeled with the figure number and the surname of the manuscript's first author?*
- ○ Are your color figures in RGB format?*
- ○ Have you reviewed the requirements for supplemental figures for your journal, if appropriate?
- ○ Are your figure files named appropriately?*

* Check your journal's instructions for these specific requirements.

References and Further Reading

- Hoogenboom, B. J. and Manske, R. C. How to Write a Scientific Article. 2012. *Int. J. Sports Phys. Ther*. 7(5), 512 – 517.
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- Liumbruno, G. M., Velati, C., Pasqualetti, P., and Franchini, M. How to write a scientific manuscript for publication. 2013. *Blood Transfus*. 11(2), 217 – 226.
- O'Connor, T. R. and Holmquist, G. P. Algorithm for writing a scientific manuscript. 2009. *Biochem. And Molec. Biol. Edu.* 37(6), 344 – 348.
- Rolandi, M., Cheng, K., and Pérez-Kriz, S. A brief guide to designing effective figures for the scientific paper. 2011. *Adv. Mater.* 23, 4343 – 4346.
- Rougier, N. P., Droettboom, M., and Bourne, P. E. Ten Simple Rules for Better Figures. 2014. *PLoS Comput Biol.* 10(9).
- Wong, B. Points of view: Color blindness. 2011. *Nature Methods*. 8, 441.
- Wong, B. Points of view: Simplify to clarify. 2011. *Nature Methods*. 8, 611.

See Bang Wong's "Points of View" from *Nature Methods* for a variety of essays on figure making in the natural sciences.