Guidelines for Scientific Writing in OBE

What is scientific writing?

Scientific writing is a form of writing designed to communicate scientific information. There are multiple different kinds of writing that could be classified as scientific writing. Regardless of the genre, however, all scientific writing aims to present data or ideas with a level of detail that allows a reader to evaluate the validity of the results and conclusions based only on the facts presented. Clear writing is needed to reflect the precision of the research.

Examples of Science Writing:

1. Journal Article
2. National Science Foundation-style Research Grant Proposal
3. Scientific Poster
4. Magazine/Newspaper Article

1. Peer-reviewed Journal Article

The purpose of a peer-reviewed journal article is to share original research work with other scientists or for reviewing the research conducted by others (in the case of review articles). These papers are crucial to the advancement of modern science where the work of a scientist builds upon that of others. Scientific papers must aim to inform rather than impress. Thus, it is imperative that they are readable (clear, accurate, and concise). The scientific paper must contain the following elements: Title, Abstract, Introduction, Methods, Results, Discussion, and Literature Cited. Tables and figures should be placed at the end of the text.

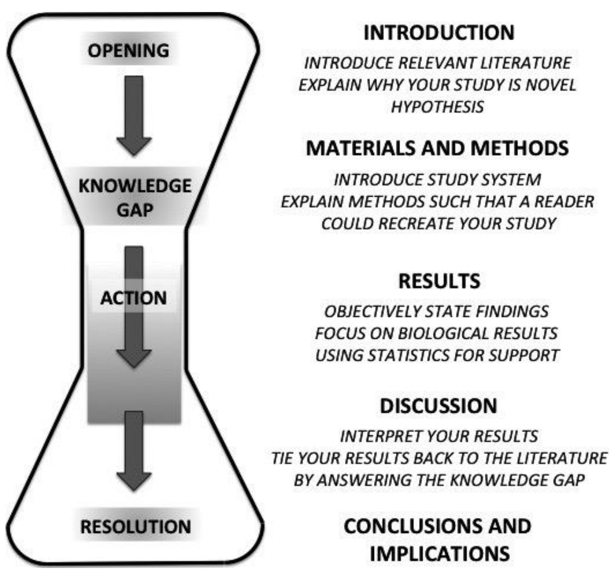

Fig. 1. Framing a scientific paper. The structure of a paper mirrors that of an hourglass, opening broadly and narrowing to the specific question, hypothesis, methods, and results of the study. Effective papers widen again in the discussion and conclusion, connecting the study back to the

existing literature and explaining how the current study filled a knowledge gap or experimental question.

Title

Include terms that highlight the major subject matter AND the organism(s) and/or ecosystem studied.

e.g. The effect of temperature on germination of corn

Abstract

The abstract is a one or two paragraph condensation (150-200 words) of the entire work described in the article. It should be a self-contained unit capable of being understood without the benefit of the text. In the abstract, be sure to summarize the intent of your research, your methods, your major findings, and the significance of your findings. *This section should be written last.*

<u>Common errors</u>

- Writing an incomplete abstract by not including summaries of all sections of the paper. Instead, be sure to give the <u>direction</u> and <u>magnitude</u> of the effect.
- Making statements that "treatments were significantly different;" the reader has no idea whether the treatment increased or decreased the parameter, e.g., "Watering increased photosynthetic rates by 47% compared to control plots."
- Statements such as "results will be discussed." Instead, state what the implications of the results actually are
- Including references (leave them out)

Introduction

The purpose of the introduction is to present the question being asked and place it in the context of what is already known about the topic. This section should contain:

1. A description of the problem under investigation and the current state of knowledge or understanding;
2. A statement of the purpose, scope, and general method of investigation in your study;
3. Hypothesis/hypotheses and predictions.

The introduction is meant to introduce the reader to *your* research, not summarize all past literature on the subject. Include only enough background information to allow your reader to understand why you are asking the questions you are and why our hypotheses are reasonable.

The *statement of purpose* expresses the central question you are asking and presents the variable you are investigating.

e.g. This study investigates the relationship between tree density and fruit size.

The *hypothesis* is the explanation you are proposing for certain observations. It is a tentative answer to the question you posed. It should be accompanied by a prediction of results expected under certain conditions if the hypothesis is correct.

e.g. If competition lowers reproductive output, then fruit size should be smaller when tree density increases.

Think of the introduction like a **funnel**; the first part of the Introduction, analogous to the wide portion of a funnel, is generally the broadest in focus and helps establish the theoretical understanding of the study. As the specific gaps in current knowledge are identified, the funnel becomes narrower. Lastly, as the objectives and hypotheses of the study are explained (addressing the identified knowledge gaps), the funnel becomes the narrowest.

Common errors

- Failing to review enough of the relevant literature so that the reader is unable to understand how your question furthers our knowledge
- Lack of explicit statement of your research question

Methods

This section should clearly address all the basic questions about the way the study was conducted (where, when, and how). The methods should be sufficiently detailed so that the reader could repeat the methodologies. State clearly what parameters you will measure and the size of your samples (e.g. *Table 1*). You do not need to explain widely known techniques; just give their names and cite a reference. If you are using new methods, describe them.

Table 1.

- Site characterization:
    - Study organism used, its origin, any pre-experiment handling or care
    - Description of field site or site where experiment was performed
- Experimental design:
    - Step-by-step procedures in paragraph form
    - Sample preparation
    - Experimental controls
    - Equipment used, including model numbers and year
    - Important equipment settings (e.g., temperature of incubation, speed of centrifuge)
    - Amount of reagents used
    - Specific measurements taken (e.g., wing length, weight of organism)
- Statistical analyses conducted (e.g., ANOVA, linear regression)

WHERE: In the case of field studies, give the exact location. Describe relevant features of the study site, such as vegetation, climate, topography, and human disturbance. Include figures of your study site(s) prepared in GIS (Geographic Information Systems). Explain why this was an appropriate site for the research.

WHEN: Give the time periods during which the work was done (year, month, day, time of day) whenever this is relevant to the type of data collected. Note the point within the seasonal (annual) cycle, or within other natural cycles (such as those of the tides), if appropriate. Describe special conditions of weather or other factors that prevailed during the study period.

HOW: Explain how hypotheses were tested by describing procedures and techniques for collecting data, and explain how your approach was replicated. Where procedures and techniques were employed in a standardized fashion, refer to published descriptions in the scientific literature. Be sure to describe your study design in enough detail that a reader can duplicate your approach, since repeatability is one of the basic requirements of scientific research. Including diagrams may also enhance explanations or descriptions. Indicate how samples were obtained in an honest, accurate, and unbiased fashion. State approaches used to make calculations, and look for patterns in the data. Finally, explain how hypotheses were evaluated by describing how statistical tests were performed and interpreted, and cite a published source for them. Also, be sure to state the P-value at which statistical tests were judged to be significant (generally, a P-value of 0.05 is used in scientific literature).

Results

The function of this section is to summarize general trends in the data without comment, bias, or interpretation. Statistical tests applied to your data are reported in this section although conclusions about your original hypotheses are saved for the Discussion section.

Data may be presented in figures and tables, but this may not substitute for a verbal summary of the findings. The text should be understandable by someone who has not seen your figures and tables.

Example:

Incorrect: The results are given in Figure 1.
Correct: Temperature was directly proportional to metabolic rate (Fig. 1).

1. All results should be presented, including those that do not support the hypothesis.
2. Statements made in the text must be supported by the results contained in figures and tables.
3. The results of statistical tests can be presented in parentheses following a verbal description.

Example: Fruit size was significantly greater in trees growing alone ($t = 3.65$, $df = 2$, $p < 0.05$).

<u>Figures & Tables</u>

- Each table and figure should be placed on a separate, full page and placed in numerical order(figures before tables) at the end of your paper.
- Each table and figure must have a descriptive caption that clearly describes the content, and identify the meaning of each symbol, heading, or abbreviation.

- Each table and figure should be capable of 'standing alone'—that is, the reader should be able to understand the content of each based on the information you provide in the caption.
- Make sure you reference each table and figure in the text, in every sentence where it is relevant to a point you are making (applies to Methods and Results—not as commonly in the Discussion).
- Pay attention to the number of significant figures ("SIG FIGS") you show when presenting data, since this communicates to readers your level of accuracy during data collection—generally, you should round data to either whole units (109 +2 trees/ha) or tenths (56.5+1.8mayflies/m2), since it's usually impossible to measure any more accurately than this.
- Use tables and figures to highlight patterns in the data(or lack thereof) as they pertain to your hypothesis(es). **Do not present raw data here**—these data should go in the Appendix.
- In general, it is preferable to use figures over tables in scientific papers to easily show patterns in the data, but tables are best when patterns are complex or when the author wishes to highlight multiple points.

Figures

- In general, use line graphs when the independent variable (X-axis) consists of continuous units (e.g., time or temperature), and bar graphs when the independent variable is categorical (e.g., different study sites or forest types).
- Use error bars whenever possible on graphs. If you have a measure of variation around a mean (and you almost always will), use an error bar of 1 SE (standard error--this is preferred over standard deviation). Some authors use 95% CL instead; be sure to state in the caption which you use.
- Most journals do not use titles on graphs. Be sure to use units in graphs and Tables. The correct heading of a Table column or graph axis might be "Gecko density (no./m^2)". Note that units are in ( ) for Ecology; (some journals use commas to separate units).

Common errors

- Confusing which ideas are in Results and which are in Discussion. Keep in mind that the results section presents the facts while the discussion section presents the analysis and significance of the facts.
- Restating data in prose form. Let the Tables and Figures give the details; in prose give the patterns.
- Failing to include prose at all; just putting Figures and Tables in the section
- Not bringing statistical results back to the biology of the situation. For example, "Prairie dogs with frequent human contact and prairie dogs with minimal human contact had different avoidance response distances (P=0.03)." Which group had a longer distance? By how much greater was its avoidance distance? Here is a good Results sentence that includes statistical results, says which treatment is greater, and tells the reader the magnitude of the difference: "Plants in watered plots photosynthesized 30% faster than plants in control plots in late season (P=0.01)… "

- Misusing “affect” and “effect.” In papers written for biology, “affect” will essentially always be a verb and “effect” a noun. E.g., “Heavy elk browsing affected aspen stands by increasing growth of mature stems (*P*=0.02, Table 1).” “Effects of elk browsing were severe on Rampart Range…”

Discussion

The function of this section is to analyze the data and relate them to other studies. To "analyze" means to evaluate the meaning of your results in terms of the original question or hypothesis and point out their biological significance.

1. The Discussion should contain at least:
   - the relationship between the results and the original hypothesis, i.e., whether they support the hypothesis, or cause it to be rejected or modified.
   - an integration of your results with those of previous studies in order to arrive at explanations for the observed phenomena.
   - possible explanations for unexpected results and observations, phrased as hypotheses that can be tested be realistic experimental procedures, which you should describe.
2. Trends that are not statistically significant can still be discussed if they are suggestive or interesting, but cannot be made the basis for conclusions as if they were significant.
3. Avoid redundancy between the Results and the Discussion section. Do not repeat detailed descriptions of the data and results in the Discussion. In some journals, Results and Discussions are joined in a single section, in order to permit a single integrated treatment with minimal repetition. This is more appropriate for short, simple articles than for longer, more complicated ones.
4. End the Discussion with a summary of the principal points you want the reader to remember. This is also the appropriate place to propose specific further study if that will serve some purpose, but do not end with the tired cliche' that "this problem needs more study." All problems in biology need more study. Do not close on what you wish you had done, rather finish stating your conclusions and contributions.

Conclusion

The conclusion, generally located in its own short section or the last paragraph of the Discussion, represents your final opportunity to state the significance of your research. Rather than merely restating your main findings, the conclusion should summarize the outcome of your study in a way that incorporates new insights or frames interesting questions that arose as a result of your research. Broaden your perspective again as you reach the bottom of the hourglass (Fig. 1). While it is important to acknowledge the shortcomings or caveats of the research project, generally include these near the beginning of the conclusion or earlier in the Discussion. You want your take-home sentences to focus on what you have accomplished and the broader implications of your study, rather than your study’s limitations or shortcomings. End on a strong note.

Acknowledgements
This brief section recognizes and thanks people and organizations that helped you complete your research.

Literature Cited
This is the last section of a scientific paper. References are listed by author, as indicated by the following sample list. Papers are not referred to by footnotes as in literature papers but are cited within the body of the text.

We will follow the format of the journal, Ecology. Other journals use variations on this theme. Ask your instructors for the specific format they want you to adopt for your work.

- *Journal*: Strong, D. R., Jr. 1980. Null hypothesis in ecology. Synthese 43: 271-285.
- *Book*: Eadie, W. R. 1954. Animal control in field farm and forest. MacMillan Co., New York, New York, USA.
- *Article in a book*: Werner, P.A. 1979. Competition and coexistence of similar species. Pages 287-310. *in* O.T. Sol- brig, S. Jain, G. B. Johnson and P. Raven, editors. Topics in plant population biology. Columbia University Press, New York, New York, USA.
- *Multiple authors*: Gross, K. L. and P. A. Werner. 1978. The biology of Canadian weeds. Canadian Journal of Plant Science 58:401-413.
- *Thesis*: Calvo, R. N. 1990. Pollinator limitation, cost of reproduction, and fitness in plants: a demographic approach. Dissertation. University of Miami, Coral Gables, Florida, USA.
- *Technical report*: Heinselman, M. L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. Pages 7-57 *in* H. Mooney, I. M. Bonnicksen, N. L. Christensen, J. E. Loten, and W. A. Reiners, editors. Fire regimes and ecosystem properties. USDA Forest Service General Technical Report WO-26.

All authors must be named in the Literature Cited; use "et *al."* only with the text. No reference is listed in this section unless it was cited somewhere in the text.

<u>Format for Citing References in the Text:</u>

You must cite another researcher whenever you refer to their results, conclusions, or methods in your paper. The reference in the text is made only to the author's name and date of publication.

1. Both the name and date can go inside parentheses if the name is not actually part of your sentence. Not all journals include the comma between author and year. For example:

    Enzymes are inhibited by cyanide (Grubb 1977).
    Because enzymes are inhibited by cyanide (Grubb 1977), I expect to find....

**Notice that the parenthesis is placed at the end of the sentence of clause containing the reference and that punctuation FOLLOWS the citation.

2. Another way to cite a study is to make the last name of the researcher the subject or object of the sentence or clause and follow it immediately with the date of the study in parentheses:

   Grubb (1977) found that cyanide inhibits enzymes. Because Grubb (1977) found that cyanide inhibits enzymes.... These data support the conclusions of Grubb (1977).

3. If you wish to emphasize the date of the cited study, you can omit the parentheses:

   As early as 1977, Grubb observed the inhibitory effect of cyanide on enzyme action.

   This strategy is often effective for presenting an historical perspective of the problem (i.e., useful in Introduction).

4. It is INCORRECT to separate the date of publication from the author's name:

   Incorrect: Grubb found that cyanide inhibits enzyme action (1977).

5. If you wish to cite more than one study per reference, i.e., if more than one author has reached the same conclusion or worked on the same problem independently, you may list them together in the same parentheses and separate their names by semicolons:

   Cyanide has been found to inhibit enzyme action (Grubb 1977; Smith 1980; Taylor 1983). By convention, these citations are listed in chronological order.

6. In the case of more than three authors, you may use et *al.* (from "et alii," Latin for "and others") after the first author's name:

   Cyanide has been found to inhibit enzyme action (Jones et *al.,* 1985).

In Comparative Animal Physiology, you will be asked to follow the citation format from the Journal of Experimental Biology. Follow these guidelines to properly cite your sources in JEB format:

References are listed in alphabetical order according to surname and initials of first author.

▪ Use the following style:
  - *Journal:* **Rivera, A. R. V., Wyneken, J. and Blob, R. W.** (2011). Forelimb kinematics and motor patterns of swimming loggerhead sea turtles (*Caretta caretta*): are motor

patterns conserved in the evolution of new locomotor strategies? *J. Exp. Biol.* **214**, 3314-3323.
- *Book:* **Hochachka, P. W. and Somero, G. N.** (2002). *Biochemical Adaptation: Mechanism and Process in Physiological Evolution.* Oxford, UK: Oxford University Press.
- *Book chapter:* **Feller, G.** (2008). Enzyme function at low temperatures in psychrophiles. In *Protein Adaptation in Extremophiles* (ed. K. S. Siddiqui and T. Thomas), pp. 35-69. New York: Nova Science Publishers, Inc.
- *Preprint server:* **Baillie-Johnson, P., van den Brink, S. C., Balayo, T., Turner, D. A. and Martinez Arias, A.** (2014). Generation of aggregates of mouse ES cells that show symmetry breaking, polarisation and emergent collective behaviour in vitro. *bioRxiv* doi:10.1101/005215.
- *PhD thesis:* **Jones, A. R.** (2016). Title of thesis. *PhD thesis*, University of Washington, Seattle, WA.
- *Dataset with persistent identifier:* **Zheng, L.-Y., Guo, X.-S., He, B., Sun, L.-J., Peng, Y. and Dong, S.-S.** (2011). Genome data from sweet and grain sorghum (Sorghum bicolor). *GigaScience Database*. http://dx.doi.org/10.5524/100012.
  Kingsolver, J. G., Hoekstra, H. E., Hoekstra, J. M., Berrigan, D., Vignieri, S. N., Hill, C. E., Hoang, A., Gibert, P. and Beerli, P. (2001). Data from: The strength of phenotypic selection in natural populations. *Dryad Digital Repository*. http://dx.doi.org/10.5061/dryad.166.

- If there are more than 10 authors, use 'et al.' after the 10th author.
- Within a group of papers with the same first author, list single author papers first, then papers with two authors, then et al. papers. If more than one reference exists for each type, arrange in date order. Use a and b for papers published in the same year.
- 'In press' citations must have been accepted for publication and the name of the journal or publisher included.

Miscellaneous Guidelines

- Data are plural—not singular! (“Our data support [not supports] the hypothesis that ...”)
- All sections of your paper, with few exceptions, should be written in past tense.
- All pages should be numbered.
- Significant digits—in general, it makes most sense to round up quantities to tenths (0.1) when in their final form (but do not round before you start calculations!). In ecology, we generally cannot justify an accuracy level to 0.01 or 0.001.
- Use the metric system and other international units throughout the paper.
- Write numbers as numerals whenever they are associated with measurements (e.g., 3 m) or are parts of dates or mathematical expressions. In all other cases, spell them out for numbers of ten or less (e.g., five rabbits), and always use numerals for numbers greater than ten.

2. Research Grant Proposal

The research grant proposal contains the following elements: Title, Abstract, Introduction, Methods, Possible Results and Significance, Literature Cited, Timeline

Consider your audience

Are you writing for scientific peers? Use fewer technical terms and assume less background if your audience is not scientific. Also, be sure to include the proper technical terms for the particular field of biology you are writing about. Above all else, make sure you read the request for proposals very carefully and propose a project that fits the goals of the funding organization.

Title

Make it interesting and not too dry, but on the other hand avoid titles that might come off as cute. Some effective examples:

- Analysis of pesticide transport pathways and degradation in natural wetlands
- The role of ecological interactions in diversification: phylogeny and population differences of goldenrod in two communities
- Reconciling molecular and fossil evidence on the age of angiosperms

Introduction

In this section you will give an overview of the proposed project and convince the reader that your research is interesting and will advance the current knowledge of your topic. However, proposals generally begin not with this description, but with some background on work done previously or with the rationale for why your research is important, e.g., it will help with plant conservation, or it will help us understand some basic botanical phenomenon, like how plants grow in stressful conditions.

You will need to show that you are familiar with and know other research that has been done on this topic. Your proposed research should build on this previous research and certainly not reinvent the wheel. Avoid the temptation to simply list references, e.g., "Edge effects have been studied by Smith (1999) and Reston and Avers (1998)." This tells the reader nothing; instead, state very briefly the most important findings of the previous research. End the Introduction with a clear statement of the question(s) and/or hypothesis(es) you want to test.

Methods

You must show in this section that you have chosen methods that will address your question. You must be detailed enough so that the evaluators know exactly what you will do (at least to start; once you start to collect data, your methods often need to be modified slightly). State clearly what parameters you will measure and the size of your samples. You do not need to explain widely known techniques; just give their names and cite a reference. If you are using new methods, describe them.

State the statistical tests you might use to analyze your data and briefly state how you will interpret various possible results (this section does not need to be completed before turning in your proposal in class).

If you are conducting research that involves a field component, describe your study site so the reader has enough information to know whether your question can be addressed there. This is sometimes done in a separate section entitled "Study Site" or “Study System”. Regardless of whether you have a field component you should include details about your study system, for example, describing the plant species you intend to use and why you decided to use that particular plant species.

Possible results and their significance

Describe possible outcomes of your study and what they would indicate for your specific question(s) and the larger botanical question(s) that you posed in the introduction. This is often the most difficult section to write, and it is critical because you explain to the reader the significance of possible outcomes of your proposed study.

Literature Cited

See Literature Cited guidelines in Journal Article section.

Timeline

Presenting a schedule helps you think through your time budget and shows the reader you have a realistic idea of what can be done. This section also gives an idea of when to expect data from your project.

General Proposal Writing Tips

- Try to use the active rather to the passive voice. For example, write "I/We will develop a cell line," not "A cell line will be developed."
- Keep related ideas and information together, e.g. put clauses and phrases as close as possible to - preferably right after, the words they modify.
- Simplify and breakup long, involved sentences and paragraphs. In general, use short simple sentences; they are much easier on the reader. **Your goal is communication, not literature**.
- Edit out redundant words and phrases. Edit and proofread thoroughly, and have another reader look over it as well. Don’t assume you can catch all the typos yourself. Look carefully for typographical and grammatical mistakes, omitted information, and errors in figures and tables. Sloppy work will definitely suffer in review. Reviewers feel that if the application is sloppy or disorganized, the applicant's research may be as well.

3. Scientific Poster

A well-written scientific poster must fulfill two objectives. First, it must clearly and concisely describe the theoretical context of the study, procedures that were followed, and primary results that were obtained. Second, it must place these results in perspective by relating them to the existing state of knowledge and by interpreting their significance in broader biological and ecological contexts. The format of posters closely follows the organization of scientific articles, which consists of the following primary sections: Introduction, Methods, Results, and Discussion. Each of these sections is discussed in more detail below. Title: Include terms that highlight both the major subject matter (e.g., competition, predation, human impacts, etc.) and the organism(s) and/or ecosystem studied.

Introduction

This section should provide background information necessary for the reader to understand the context of your research, and provide the basis for understanding the objectives of your study. An effective introduction should address the following questions:

- What conceptual and theoretical topics are relevant to your study, and what is the existing state of knowledge on these topics? You should incorporate such information from the recent primary literature in such a way that the reader can fully appreciate the backdrop of your study, and understand relevant ecological topics that bear on your scientific question and hypothesis. In addition, you should identify key "gaps" and inadequacies of current knowledge that are the basis of your study, and explain how and why addressing those gaps is important in the larger ecological context. You should cite at least five different sources of primary literature (scientific journals) here.
- What, specifically, is your study about and why is it significant or important? Here, you must indicate the specific objectives of your study, and explain how they are relevant to the gaps or inadequacies in current knowledge that you previously identified. You also need to include your research question and hypotheses here. These statements should be as succinct and specific as possible, and should be clearly capable of being either supported or refuted by the planned work.

The metaphor of a funnel is a helpful way of visualizing the organization of your Introduction. The first portion of your Introduction, analogous to the wide portion of a funnel, is generally broadest in focus and helps establish the theoretical understanding of your study. As one identifies the specific gaps or inadequacies in current knowledge, the funnel becomes narrower. Finally, as one explains the objectives and hypotheses of the study, which essentially should address the identified gaps or inadequacies in current knowledge, the funnel becomes most narrow.

Methods

This section must clearly address the fundamental question, "What was your experimental design for testing your hypothesis/es?" Very importantly, your Methods section should describe key components of your experimental design so that readers could replicate your study. In so doing, be sure to address:

- Where: In the case of field studies, give the exact location. Describe relevant features of the study site, such as vegetation, climate, topography, and human disturbance. Provide helpful figures and/or diagrams of your study site(s).
- When: Give the time periods during which the work was done (year, month, day, time of day) whenever this is relevant to the type of data collected. Describe special conditions of weather or other factors that prevailed during the study period.
- How: Describe the techniques of collecting data or of conducting experiments, and the equipment used. Where these procedures and equipment are standard, do this by reference to published descriptions. Otherwise, describe them in enough detail that a reader can duplicate them, since repeatability is one of the basic requirements of scientific research (use metric units only).Include diagrams to enhance explanations or descriptions of your sampling approach or how used equipment. Where statistical tests are utilized, describe their use and how they were performed, and cite a published source for them. Also, be sure to state the P-value at which statistical tests were judged to be significant (generally, a P-value of 0.05 is used in scientific literature).

Results

The text of this section should contain statements about data that address your hypotheses. You should prepare for writing this section by creating TABLES and FIGURES that express patterns in the data that support or refute your hypotheses. Tables and figures allow the reader to appreciate both the general patterns of these data and the degree of variability that they exhibit. DO NOT present raw data, which cannot effectively display patterns! The text of the results should concentrate on describing the general patterns, trends, and differences shown by data in tables and figures(clearly reference each one), and include references to statistical tests that clearly indicate the level of statistical significance (commonly shown in parentheses). For example, one might say, "The difference between means of the two sites, which were 110.2 +2.1 trees/ha and 50.6 +5.3 trees/ha, respectively, were statistically significant (paired t-test; t= 6.35, DF= 11, P< 0.01)." Another example: "We found that stoneflies were more abundant in riffle micro-habitats than in backwater micro-habitats in all sections of Trout Creek. For instance, in our upstream sample sites we found stoneflies had a mean density of 19.0+1.8 larvae/m2in riffles while in backwater the mean density was 10.5 +3.8 larvae/m2(paired t-test; t= -2.53, DF= 7, P= 0.04; Table 2)." Finally, the results section should be free of interpretation of the data, which is the function of the Discussion.

<u>Tips Regarding Tables/Figures</u>

- Tables and figures allow the reader to appreciate both the general patterns of these data and the degree of variability that they exhibit. Plan to show the most important patterns in your data that relate to your hypotheses in figures and tables—the reader should be able to look at these and note the most critical findings from your study. Do not present raw data here; tables and figures should reflect data that has been transformed to clearly show patterns (or lack thereof). Actual raw data should be placed in an Appendix.
- Posters are a visual medium, so the viewer will immediately be drawn to the tables/figures rather than the text. Even more than in a paper, the tables and figures need to be instantly

readable. Don’t try to cram too much into one table/figure, because it will take the viewer too long to understand it.

- Make sure each table and figure has a descriptive caption that clearly and fully describes the content of the table or figure, and that you explain the meaning of each symbol, heading, or abbreviation.
- Each table and figure must be capable of ‘standing alone’—that is, the reader should be able to understand the content of each based on the information you make available in the table headings and caption.
- Make sure each table and figure is referenced in the text, in each sentence where it is relevant to your point (applies to Methods and Results—not usually to the Discussion).
- Refer to tables and figures in papers in the primary literature as guides when you prepare your own.

4. Magazine/Newspaper Article (Public Communication)
Writing about science with a public audience in mind gives the author a lot more freedom than writing a peer-reviewed journal article. There is no set format to follow, but the goal is to successfully communicate your topic to any reader even if they don't have a background in science. That being said, here is the short list of some tips to help get your message across as you put your article together (from Cornelia Dean in her book *Am I Making Myself Clear?*):

- Use active verbs
- Avoid jargon, euphemisms, clichés, wordplays, and puns
- Use analogies and examples
- Only include critical details
- Create an outline
- Tell a story but stay true to the facts
- Spend a lot of time revising and rewriting
- Cite your sources
- Prepare to be edited

The following tips for science communication are from Carl Zimmer, a renowned New York Times columnist and author of 13 books about science. Zimmer teaches a class at Yale called "Writing about Science, Medicine, and the Environment." (Check out some of his publications for reference here).

The All-Important Introduction

Within a few paragraphs, a reader will decide whether to finish reading your story or to move on to something else. In this brief preliminary time, you should give readers a clear idea of where the story is heading, an idea compelling enough to keep them with you.

Journalists call the sentence or two where you sum up the gist of your story the **nut graf**. Your nut graf should be intriguing, perhaps even surprising. If it states something most readers already know, they won't feel the need to keep reading. If it is too obscure, readers won't know why they should care enough to invest more time with your story.

You should be able to underline your nut graf. Scattering it in bits and pieces around the first half of an article is not acceptable. Don't leave it up to your reader to gather those bits and pieces together and assemble your nut graf for you.

As you write the rest of your story, make sure that it really lives up to the nut graf. Otherwise, your readers will feel like they've been the victims of a bait-and-switch.

If you find yourself struggling to come up with a nut graf, that may tell you something important. You may not actually have a story yet. You may only have a topic.

Think of it this way: *Ebola* is not a story. *How health workers and scientists together stopped an Ebola outbreak* is a story.

Think about your reader's brain, part 1: no mind-reading required.

Once you have done the research for a story, all its pieces are accessible to you all at once. If you write some of it down on the page but leave things out, your expert mind will automatically fill in the gaps. It can be hard to realize how much you're filling in — it's a journalistic equivalent of an optical illusion.

Your readers don't have access to that knowledge. They have to rely for the most part on what you put on the page. If you leave a crucial piece of information out, or omit some crucial event in a sequence, you leave your reader to struggle. Be kind!

Think about your reader's brain, part 2: no ships in bottles.

Let's say you've taken part 1 of this guidance to heart as you work on a story about solar power. Determined to leave no gap in the story, you start explaining physics, from Archimedes to Newton to Bohr. By the time you're done with the ancient Greeks, you hit your word limit.

There's a paradox at the heart of science writing. On the one hand, you have to make sure that you include essential pieces of information in a story. But you cannot try to write *everything* about your story. In fact, a substantial amount of the work in giving a story structure is figuring out all the stuff you can throw out and still get away with a successful narrative. Rather than building a perfect miniature ship in a bottle, think of what you're making as a low-dimensional representation of reality: a well-made shadow.

Time is your friend.

Introductions distill your story's point at the outset, perhaps with a compelling scene or anecdote. Once you get past the introduction, give the overall story a structure that readers can follow intuitively. Stories take place in time, so use time as a tool.

Pick a point in time to begin telling your story. Let the reader know when that time is. Then move forward through time, in clearly marked steps. If you jump forward a year between paragraphs, let us know. Otherwise, we'll have to guess if you've jumped forward an hour or a decade. Again, be kind!

For the most part, narrative time should flow in one direction. Jumping back and forth in your chronology can be effective, but only if readers can keep up with your temporal acrobatics. Just as importantly, you need to make it clear why you're abandoning a strict timeline for flashbacks or flash-forwards. Otherwise, it may simply seem like bad organization. Remember that you alone can see your timeline clearly in your head. Readers have only what you put on the page.

Transitions

Why does one paragraph follow another? Why does one sentence follow another? Readers should be able to see for themselves the way that the parts of a story link snugly together. Otherwise, it's easy to get lost among disconnected passages.

When you follow a timeline, you can use chronological order to make these links clear. But if you are shifting from one aspect of a person's life to another, you can't rely on time. You need to find other ways to make the shift logical and compelling. If you are working your way through an explanation or an idea, you will have to show the conceptual links between the parts.

Magazine articles and books sometimes use line breaks and drop caps to divide stories into major sections. But these breaks are not an excuse to start up from some other, arbitrary place. To keep students focused on the importance of transitions, I don't allow section breaks in class assignments.

Scenes

Novels, short stories, and plays are all organized around scenes — focused moments in which people do and say things that advance the overall narrative. As reporters, we don't make up scenes. Instead, we reconstruct them from our reporting of real events.

In some cases, we can write about things we observed ourselves. While planning out your research, think about the opportunities you can have to observe parts of your story unfold. There may be an event already planned (a demonstration, a trial, a game). Or you can arrange a scene yourself, such as asking an ecologist you want to profile to take a hike together so you can observe how they make sense of the natural world.

Some scenes you'll write about took place long ago. You'll have to piece them together from whatever evidence remains — memories, videos lingering on YouTube, diaries in university archives.

Before you add a scene to a story, make sure it matters. What event or point is it illuminating? If you cut a scene out, does the story still hold together? If it doesn't, the scene is essential. If it does, then the scene is a digression. It may be funny, cool, amazing. But it has to go.

When you begin a scene, set it. Provide enough detail so that the reader knows where and when it's happening. To make it evocative, take advantage of the cinematic power of our brains. Give readers things to see, hear, touch, smell. But make sure these sensory details are relevant to the story and not random details.

Find ways to convey the humanity of people in your scenes. Use their words, appearances, and actions. A poorly developed scene will read like a procession of faceless ghosts drifting through a phantom world. Give your scenes life.

Paragraphs

Paragraphs are lovely, under-appreciated units of narrative — bigger than sentences but smaller than stories. Take full advantage of their power.

Each paragraph should be placed in the right logical place in a story. The internal structure of paragraphs matters, too. In the first sentence, we should understand why it flows from the last sentence of the previous paragraph, and each subsequent sentence should also flow logically from the previous one.

Each paragraph should have a unifying point. Don't start talking about one thing at the outset of a paragraph and then unwittingly slide into another topic midway through.

Endings

Give careful thought to where your story will stop, and how. Sometimes a quote from the main subject of your story will beautifully sum up the whole tale. Sometimes you build up to a climax, and then jump forward a few years to a brief scene that acts as a powerful postscript. An ending can be an opportunity to zoom out from the particulars of your story to the bigger picture (say, an archaeologist's work on an island and what it means for our understanding of the peopling of the world).

Resist the temptation of suddenly veering off onto a related topic at the last moment, leaving the reader hanging.

Style

***Stories are about people*.**

It's all too easy to forget that science doesn't happen by itself. To say, "A study found that salt is bad for you," is problematic. Studies don't *do* anything. *People* run studies. And people find out things.

Interview people to understand their experiences as human beings. Scientists are not robots chunking out new bits of knowledge. Doctors are not packages of software spitting out diagnoses. Asking a simple question such as, "How did you end up spending your life studying quantum computers?" or "What was the most important experience you've had as a hospice worker?" can uncork powerful human stories.

Writing about people also helps pull in readers who might not otherwise think that your subject is interesting. People like to read about people. To get readers to care about something — say, leeches — try to make them care about the people who care about leeches. (These people do exist, and they can be a lot of fun to hang out with.)

Active voice, not passive

The scientific community favors writing in the passive voice. They shouldn't, nor should you. The passive voice dissolves the power of narrative. It destroys the impact of action. It sows confusion about who did what. Sometimes the passive voice cannot be avoided. (See what I did there.) But for the most part you can find an active-voice alternative. This is not a meaningless grammatical game. By making an effort to create active prose, you will end up discovering more about the actions — and the people behind those actions — that give power to your story.

Quotes

People speak, write, sign, or otherwise communicate. No story can make sense without some sort of communication. Imagine a novel where characters don't say or think a single word. Imagine a movie without a line of dialogue. A reported story without any quotes can feel just as odd.

There are exceptions, of course — business analysis stories, for example, or short crime reports. But the long-form journalism we're working on in this class needs the spoken words of its characters. So quote people, quote them well, and quote them often.

It's important to start putting quotes into a story as early as possible. An opening scene, for example, is a natural opportunity to introduce voices to the narrative. As you introduce a main character into a story, you can find a good quote from them that sums up an important aspect of the story to come.

If you wait till halfway or more through a story to start quoting people, it will be a disconcerting surprise. By then, readers will have come to assume that you're telling a story without quotes. Why, after so many silent paragraphs, are you quoting people now?

Lots of quotes help a story, but they have to be good quotes. A good quote is pungent. It brings the speaker to life in the reader's mind. It doesn't meander. If you drop in a long paragraph of words from someone into your story, it's usually a good idea to see if you can cut most of it away, leaving behind the best part.

If you're narrating an event, set quotes off in their own paragraphs. It is confusing to read a paragraph in which a quote is wedged in the middle of exposition. It's even more confusing to have two or more quotes from a person sprinkled in a paragraph. And quoting two or more people within one paragraph is unreadable. Take a look at how fiction authors use dialogue in short stories and novels if you need a model.

With few exceptions, quotes should only be full sentences, not fragments dropped in the middle of a sentence. Readers need to shift clearly into the voice of a character for a time, and then back to the voice of the narrator. Fragments of quotes leave readers flipping back and forth in unnecessary confusion.

Here are some more rules for quotes:

— No brackets or ellipses. (Remember, these are not term papers.)

— You can trim out um's and ah's and other stammerings, but you can't leave out words or replace them with words you wish your subject had actually said.

— If a quote sounds like drab exposition, just use your own words to move that part of the narrative forward.

— Quotes should, whenever possible, have this format:

"Quod erat demonstrandum," said Irving Euclid, a geometer at the University of Athens.

They should not be set up backwards:

Irving Euclid, a geometer at the University of Athens, said "Quod erat demonstrandum."

or

Quod "erat demonstrandum," said Irving Euclid, a geometer at the University of Athens.

— Also, avoid needless alternatives to *said* or *asked*, such as *enthused, opined, ululated.* These words typically end up just sounding arch and arbitrary. It's the quote that matters, not the verb next to the quote.

— Avoid an "unquote." — i.e., *Euclid explained that quod erat demonstrandum*. It feels odd to have a narrator tell us what people said, rather than quoting them directly. It's as if the character is talking in another room. All we hear is muffled speech, with the narrator running in from time to time to let us know second-hand what they said.

— Introduce speakers clearly by name the first time you quote them. If you quote them again later, use their name if they haven't appeared in the story for a while. (Last name only for adults, first name for children and pets.)

Can you write in first person? If you're Joan Didion, definitely.

Students often want to write in the first person, especially when writing about scenes they witness during in-person reporting. I generally discourage this. Using the first person turns the writer into a character. Is the writer important enough to the story to warrant that special role? If not, the writer becomes an awkward guest.

There are, of course, exceptions to this rule. Sometimes first person is the right choice. A story focused on a writer's own experiences with a disease, for example, obviously requires the first person. For the most part, though, "I" am best left out of stories, even if that means making the extra effort to write around oneself.

Rhetorical questions

Try to avoid them. They are the empty calories of science writing. Replace rhetorical questions with declarative sentences that advance the story.

Jargon

Scientists invent words, which they use to talk to each other efficiently. But most people outside a scientist's subspecialty have no idea what many of these words mean — including other scientists. *Tritrophic, metamorphic, anisotropic* — these are not the words to tell stories with.

Everyday language has a wonderful power to express the gist of scientific research without forcing readers to hack through a thicket of jargon. But there's no algorithm you can use to determine what's jargon and what isn't. You need to develop your mind-reading abilities. Ask yourself if readers will know what you're talking about. If you need help, find a friend who is not an expert on your story's subject and conduct a little vocabulary quiz.

(I keep a running list of words I've encountered in assignments that are examples of unacceptable jargon. You can find it here.)

There may be times when you absolutely have to use jargon. These times are far rarer than you may think. If you choose to introduce a term, do not simply throw out it out in a sentence and then explain it later. Do the reverse. Until readers grasp the concept behind jargon, it acts as dead weight that pulls your story down into the murk of confusion.

Formality, jargon's dangerous cousin

Even if you don't use a single word of jargon, you can still use language in a way that's confusing and unwelcoming. Scientists, for example, will sometimes say that a drug works "in mouse." *In* is a familiar word. So is *mouse*. But "in mouse" only makes sense to certain scientists. The rest of your readers will have to struggle to figure out that you mean that the drug had promising results in experiments on lab mice. You want your readers flying forward, relishing your metaphors and dramatic turns. You don't want them puzzling over obscure phrases and trying to guess their meaning.

Formality is also dangerous because it drains the passion from prose. It is entirely possible to let readers experience wonder, sadness, fear, outrage, and joy when reading about science — without sacrificing accuracy.

Don't presume readers think just like you.

A lot of journalism has behind it a moral mission. Reporters want to tell stories that are important. Reading a story may improve people's lives. It may lead to changes in law, shifts in political priorities, or improvements in how people treat each other or the environment. Essays, op-eds, and other opinion-based pieces can also change how people think, using rhetoric, storytelling, and argument.

In order to change minds and move readers, you must recognize that many of your readers may not think the way you do. They may not rank their values in the same order as you. Things that you take for granted as being important may not seem that way to many of your readers. This doesn't make your readers monsters. In fact, if you dig down deep enough, you'll find a lot of common ground between you and many of your readers. But if you presume to think for them, you may alienate them.

Overlooking these facts can lead writers to mistakenly assume their readers share all their own values and have reached the same conclusions about the issues they're writing about. They end up preaching to the converted. If you're writing about someone trying to make a city more "sustainable," explain what you actually mean by that buzzword, and explain why it's important. Do not expect such words to light up a whole network of meaning and values in your reader's mind. They may not be familiar with the word, or they may not value it as you do.

Checking stories

It's dangerously easy to make factual mistakes in science writing, because we deal in so many facts — from the number of insects on the Earth (about 10 quintillion) to the year in which Henrietta Leavitt discovered a pattern in the brightness of stars that made it possible to measure the universe (1912).

Some publications will employ fact-checkers to check your work. Otherwise, check it yourself. If you check facts against published sources, go as far upstream as you can — to journal papers, government web sites, and other authoritative information. Don't rely on another reporter.

Do not simply send your drafts to sources to check. In doing so, you are giving away the responsibility for your work to someone else. It's fine to call a source and paraphrase information or quotes.

For more on checking, consult *The Chicago Guide to Fact-Checking*, by Brook Borel.

Formatting checklist

Before submitting a story (to a teacher or an editor), go through a final checklist. Even the most gorgeous piece of prose can be ruined by careless handling. Here are some crucial items to cross your list:

Is your file properly formatted? (File format, name, word count, etc.)

Is your in-person reporting on display?

Do you have a nut graf?

Are you close to the assigned word count?

Are your quotes properly formatted?

Is your fact-checking annotation in good shape?

Double-check your spelling and grammar. Kill that last dangling participle.

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