Table of Contents

What is Scientific Writing?

Function of Scientific Documents

- Record keeping and documentation.
    - Accurate documentation and organization of data is a fundamental component of making scientific progress. Written documentation is a reference for future scientists and researchers.
- Formal and vetted conversation/dialogue
    - There are many avenues through which scientists can discuss results and the interpretation of results, including: conferences and presentations, published abstracts, casual conversation, and through publication in peer reviewed journals.

Types of Scientific Documents

There are many types of professional writing in the sciences.

- Lab notebooks and protocols
    - Written for the individual, laboratory or group of labs that use specific experimental designs or methodologies. While these documents are not published, they are formal documents and follow standardized "science" rhetoric.
- Published abstracts
    - Abstracts must be submitted prior to presenting at a conference. These abstracts are then published and available through online resources. They represent formal progress updates and are often of work that has not yet been published through the peer review process.
    - Here, abstracts do not need to include results/data. This is because at the time of submission it is possible you do not know what data you will include and what your story is.
- Original research articles
    - Published through the peer review process and a part of the formal dialogue.
- Review of research articles

    - Published through the peer review process and a part of the formal dialogue.
- Response to published review articles
    - Published through the peer review process and a part of the formal dialogue.
    - Editors, researchers, or reviewers may choose to respond themselves or suggest another scientist write a response to a recently published article. This is often done when the published article has significant flaws or when it represents an important potential shift in paradigm thinking.
- Grant Writing
    - In order to have funding to conduct research, one needs to apply for funding (typically from the government) using a research proposal.
    - Research proposals are often organized similarly to published research, with the 'results' section replaced by a 'expected results' section.

The Peer Review Process

- The mechanism of formal quality control.

Reviewers

- Upon submission to a journal, 2-3 (usually anonymous) reviewers read and evaluate the submission
- Evaluation criteria:
    - Methodologies and Statistical Analyses: Are they standard and were they conducted well for the given experiment?
    - Scientific Argument: Are the given conclusions/interpretations appropriate based on the experimental design and the stated results?
    - Literature Cited: Are the references cited appropriate? Do they provide the evidence the authors are using them for? Should the authors be citing other work as well?
    - Finally, reviewers are asked if the submitted manuscript is appropriate for the journal. Will it have the "impact" on the field that is expected of publication in this journal?

- Journals provide criteria for reviewers. Below is the criteria given online from *Science* (taken from: http://www.sciencemag.org/site/feature/contribinfo/review.xhtml)

  "**Peer Review at Science**

  As a peer reviewer for Science magazine, you are part of a valued community. Scientific progress depends on the communication of information that can be trusted, and the peer review process is a vital part of that system.

  Only some of the submitted papers are reviewed in depth. For in-depth review, at least two outside referees are consulted. Reviewers are contacted before being sent a paper and are asked to return comments within 1 to 2 weeks for most papers. Reviewers may be selected to evaluate separate components of a manuscript. We greatly appreciate the time spent in preparing a review, and will consult you on a revision of a manuscript only if we believe the paper has been significantly improved but still requires input. The final responsibility for decisions of acceptance or rejection of a submitted manuscript lies with the editor.

  Ethical Guidelines for Reviewers

  - Reviews should be objective evaluations of the research. If you cannot judge a paper impartially, you should not accept it for review or you should notify the editor as soon as you appreciate the situation. If you have any professional or financial affiliations that may be perceived as a conflict of interest in reviewing the manuscript, or a history of personal differences with the author(s), you should describe them in your confidential comments.
  - If, as a reviewer, you believe that you are not qualified to evaluate a component of the research, you should inform the editor in your review.
  - Reviews should be constructive and courteous and the reviewer should respect the intellectual independence of the author. The reviewer should

avoid personal comments; Science reserves the right to edit out comments that will hinder constructive discussion of manuscripts.

- Just as you wish prompt evaluations of your own research, please return your reviews within the time period specified when you were asked to review the paper. If events will prevent a timely review, it is your responsibility to inform the editor at the time of the request.
- The review process is conducted anonymously; Science never reveals the identity of reviewers to authors. The privacy and anonymity provisions of this process extend to the reviewer, who should not reveal his or her identity to outsiders or members of the press. The review itself will be shared only with the author, and possibly with other reviewers and our Board.

  The submitted manuscript is a privileged communication and must be treated as a confidential document. Please destroy all copies of the manuscript after review. Please do not share the manuscript with any colleagues without the explicit permission of the editor. Reviewers should not make personal or professional use of the data or interpretations before publication without the authors' specific permission (unless you are writing an editorial or commentary to accompany the article)."

Editors

- An editor is assigned to each submitted manuscript. In addition to reading and evaluating the manuscript themselves, they oversee the review process. They can decide if more reviewers should be consulted, if a manuscript is rejected, needs to be revised for a second round of review, or is accepted. Typically, the same editor oversees all progress for a manuscript."

<u>Examples of Formal Publications (Scientific Journals)</u>

- *American Naturalist*
- *Biological Reviews*
- *Journal of Cell Biology*

- *PLOS Biology*
- *Nature*
- *PLOS ONE*
- *Proceedings of the National Academy of Sciences*
- *Proceedings of the Royal Society*
- *Science*
- *Journal of the American Chemical Society*
- *Chemical Reviews*
- *Chemistry Letters*
- *Advances in Physics*
- *American Journal of Physics*
- *Journal of Physics*
- *Nature Physics*

Impact Factor and Rating Publications

- Not all journals are considered equal. Published research is often valued based on the quality of the publication it is in.
- Typically, impact factors are assigned to publications and represent the average number of citations/ article over the course of 2 years .
- However, it is important to remember that journals from different disciplines have different ranges of impact factors. For example, in the field of medicine articles are often cited more regularly. Therefore the impact factors of journals in medicine are higher than those in animal behavior.
- Journals can by ranked by different categories (http://www.scimagojr.com/journalrank.php)
    - *The Journal of Experimental Medicine* is rated 5th in its category and had an impact factor of 13.2 in 2012.
    - *Behavioral Ecology* is rated 5th in its category and had an impact factor of 3.2 in 2012.

Organization of Research Papers

Abstract

- *GOAL:* A stand alone summary of the whole research paper
- Typical format of an abstract
    - Why was the study conducted?
        - ~ 1-3 sentence summary of the introduction
    - What was the hypothesis or research question?
        - Usually the last part of the introduction
    - How was the study conducted?
        - What data was collected?
        - How was the data analyzed?
        - ~ 1-3 sentence summary of the methods
    - What conclusions were reached?
        - ~ 1-3 sentence summary of the most important results
    - What is the significance of the findings?
        - ~ 1-3 sentence summary of the discussion (usually the first paragraph) or the conclusion.

Introduction

- *GOAL:* The introduction provides background/justification for the study.
    - Tell the reader what important work contributed to the field prior and influenced the formation of research goals.
    - Identify what is currently unknown in the field.
    - Indicate what type of information would fill these gaps in the knowledge.
- Start more general and become more specific.
- The introduction should end with a description of your study (~ a paragraph) that clearly states your hypothesis or research goal.
- Include many in-text citations for each of the above goals.

Methods

- *GOAL:* Provide an overview of what was done so that anyone could replicate your study from reading your methods section.
    - In practice, scientists are rarely able to replicate a complete set of methodologies from a methods section. Typically the authors would need to be contacted and the scientists would discuss. Therefore, it is valuable to remember that the methods section is an outline rather than a comprehensive overview of everything that happened while an experiment was conducted.
- Important details to include in the methods section.
    - What study species or system was used?
    - What was the timeline of the experiment?
    - What treatment groups were used?
    - What is the experimental design?
    - What laboratory methods were used?
    - What statistical analyses were used?
        - What computer programs were used for analyses?
        - How and where were graphs made?
    - Provide a justification that your methods are valid. Referencing previous work or at times providing a graph that validates your methods is appropriate.
- Formatting the methods section:
    1. *General overview or timeline*. This includes an introduction to terms.
    2. *Specific description of experiment design.* If there is more than one experiment, each experiment can be explained separately.
    3. *More specific details.* Description of laboratory methodologies.
    4. *Summary of analyses or statistics conducted.*

Results

- *GOAL:* Describe all the results in words and with statistics, tables and/or figures from the analyses that you proposed in the methods section.
- The results section is not meant to include any interpretation of the statistics.
    - However, it should be more than a list.
    - As much as possible let numbers and significance be indicated in tables and figures and use the text to provide a narrative. This means some interpretation and guiding can happen in the results section.
    - "Reporting Statistics" (see Page 25)

<u>Discussion</u>

- *GOAL:* Provide an interpretation for your results and situate them within the research already conducted for a given field.
- Questions addressed in the discussion section:
    - What are the most important results from your study?
    - Do your results agree with the results and/or ideas presented in previous research?
    - What are the limitations of your study design?
    - What is the significance of your results?
        - How do your findings change the field's approach to similar investigations?
        - What are the practical applications of your results?
        - Who should be interested in your results?
        - Do your results suggest a direction for future experimentation?
- Discussion sections are highly variable. Some general patterns include:
    - The first paragraph often clearly states the most important results and briefly addresses their significance.
    - If you are going to suggest a new direction for future experimentation, this typically happens at the end of the section.
    - If no specific conclusion section is required by the journal the final paragraph of the discussion section has the same function as the conclusion section.

Conclusion (if required)

- *GOAL:* In a paragraph summarize the most important findings and their significance.

Acknowledgments

- *GOAL:* Identify people who are not authors that have contributed to the work.
- Specifically include:
    - Funding sources
    - Lab or field technicians
    - Other labs contributions of technology or resources
    - Researchers that contributed ideas
        - Helped with statistics
        - Trouble shooting
        - Development of figures
    - Anyone (including the peer reviewers) who looked at or commented on drafts of the manuscripts

What Makes Science Writing Unique?

<u>Audience</u>

- Science writing is discipline-specific. The target audience for a scientific manuscript is a specific sub-field.
- Science writing is designed to be precise and focused. Scientific articles are not easily understood by all scientists or the general public. They function as part of a broader professional conversation on their given topic. (*Note:* communicating science to broader audiences is a critical skill ~ see page 38).

<u>Goal of writing in the sciences</u>

Here is a good example of how others define the goal of science writing

- From University of North Carolina (http://writingcenter.unc.edu/handouts/sciences/)

> "To present data and/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. The reader should be able to easily follow both the methods used to generate the data (if it's a primary research paper) and the chain of logic used to draw conclusions from the data. Several key elements allow scientific writers to achieve these goals:
>
> - Precision: ambiguities in writing cause confusion and may prevent a reader from grasping crucial aspects of the methodology and synthesis
> - Clarity: concepts and methods in the sciences can often be complex; writing that is difficult to follow greatly amplifies any confusion on the part of the reader
> - Objectivity: any claims that you make need to be based on facts, not intuition or emotion"

Rhetoric

While science writing is discipline specific, there are several general rhetorical differences between science writing and "other" discipline.

- Sentence structure
    - "Clear and Concise" writing is often employed across many disciplines and is, for example, advocated as a general goal for all writers by Strunk and White *Elements of Style.* However, practically what this means varies considerably across disciplines. Here are a couple reasons for using clear and concise language in the sciences
        - The reader should be able to distinguish between "facts" and "ideas": "facts" being statements on observations made from a study which would be difficult to dispute, and "ideas" being statements regarding the interpretation of data which are based on assumptions. Concise and direct language facilitates readers' ability to correctly understand whether a statement is fact of idea.
        - Multiple interpretations of a sentence are problematic. In the sciences, discussions are contextualized within data. Therefore, misinterpreting an author's statement can be akin to misinterpreting a conclusion from the data.
    - Simpler syntax and shorter sentences are preferred in the sciences, compared to humanities and the arts.
    - The content of science makes passive voice rather than active voice more typical (see page 17).
    - Tense Usage:
        - Past tense is used to discuss research or ideas that have been conducted.
            - Methods and Results sections are discussed in past tense.
            - Past perfect and past progressive can be used to describe processes.
        - Present tense can be used when you are drawing new conclusions.

            - This is typically done in the Discussion section and occasionally for summary sentences in the Results
        - Future tense is used when you are suggesting or proposing future studies
            - If you are suggesting a follow-up study, this can happen in the Discussion section
            - This is often done in research proposals and grant writing
- <u>Citations</u> (See page 21)
    - There are many different ways to cite both in-text and in the bibliography
    - In-text citations do several things:
        - They provide accountability for statements made.
            - Any idea that is not considered "general knowledge" or is not your own "completely novel" idea should be cited (see page 21). In practice, what can be considered common knowledge and what can be represented as a novel innovation are judgment calls and depend somewhat on context. For example, a technique that might be common knowledge in a specialty field might need to be cited to aid readers in a different area of science.
        - The readability of sentences is improved when the accountability is done in a parenthetical outside of the actual sentence.
        - Citations also facilitate others' understanding (and perhaps their own research) by providing key background sources.
    - Quoting
        - Unlike in the humanities, quotes are less valuable in the sciences.
        - The language a writer uses is often less important than the facts or data they report.
        - If a previous writer made a particularly elegant argument, then you could quote them directly. In this instance you would cite them the same as you would if you had not quoted them directly.

How to Write Clearly and Concisely

Word Choice

- Longer words are not always better
- One way to write more clearly is to reduce the number of words.
  - In the sciences, **the focus should always be on the facts so choose your qualifiers and introduce new clauses with care!**
  - In creative writing, it is often beneficial to provide many descriptive words; in the sciences choose one (even if they are all true)
    - Example 1: Zebra finches are highly social, gregarious, and live in large groups.
      - In this instance those three qualifiers have the same meaning.
    - Example 2: Zebra finches are a small, highly social passerine native to the unpredictable dry desserts of Australia.
      - Here Zebra finches and their habitat both have 3 qualifiers. Not all of the qualifiers mean the same exact thing; however they are also probably not all necessary. Consider which qualifiers are the most important and include only those.
  - Choose the one word alternative in place of a longer phrase:
    - Here is a list of examples from The University of Sydney's Intermediate Skills Manual in the Biological Sciences:

(sydney.edu.au/**science**/**biology**/learning/generic.../**Scientific_Writing**.pdf)

Wordy	**Concise**
... if conditions are such that	... if
... in order to	... to
... there can be little doubt that this is	... this probably is
... plants exhibited good growth	... plants grew well
... bright green in colour	... bright green
... by means of	... by/with
... created the possibility	... made possible

... due to the fact that	... because
... fewer in number	... fewer
... for the reason that	... because, since
... in all cases	... always
... in view of the fact that	... since, because
... it is often the case that	... often
... it is possible that the cause is	... the cause may be
... it would appear that	... apparently

Scientific Jargon

- Scientific jargon is specialized vocabulary that describes aspects of science.
- There is an argument that one way simplify language in scientific writing is through avoiding scientific jargon.
    - The assumption here is that all words in science can be substituted for a colloquial counterpart. This is usually not true.
        - Example [1]:

          "Specialized terms capture the complexity and specificity of scientific concepts. Consider astronomy, in which both 'photometry' and 'spectroscopy' denote techniques that could be described in a jargon-free way as 'methods of studying light'.

          Yet photometry is the measurement of light's intensity and spectroscopy is the study of its relationship to its source. Both are complex, important and highly specific techniques. No other words in the English language encapsulate their meaning quite as well, and if they are dismissed as jargon, then that meaning is lost."
- While jargon adds specificity, it is important to consider if the level of detail is appropriate for the audience. Often the answer is yes.

[1] Quirk, T. 2012. Writers should not fear jargon. *Nature* **487,** 407 doi:10.1038/487407a

Abbreviations

- Most complex jargon such as chemical names, methodologies, neuroanatomical regions, hormones, and theories can be abbreviated.
    - In the abstract use the full name with no abbreviation.
    - The first time the name appears, write it out in full and put the abbreviation in parenthesis. After the first use, always use the abbreviation.
        - Example: Dehydroepiandrosterone (DHEA) is a precursor to Testosterone (T).

Headers

- Headers are used in certain journals (more common in certain sub-disciplines) to make the transitions between ideas or paragraphs clearer. In these instances, transition sentences may be less important.

Use graphs and visuals

- Some complex ideas and data patterns could take pages to explain thoroughly. In many instances the same information can be portrayed more clearly in a visual (see page 27).

Passive vs Active Voice

Passive vs. Active Voice

- Sentences can be divided into either Active or Passive Voice
  - Active voice highlights the subject.
    - EXAMPLE: I put the tubes in the centrifuge. *(7 words)*
  - Passive voice highlights the object.
    - EXAMPLE: The tubes were put in the centrifuge. *(7 words)*
    - OR The tubes were centrifuged. *(4 words)*

Historical use of passive voice and the avoidance of personal pronouns

- Historically, there has been an increase in the use of passive voice, an increase in the use of complex noun phrases, and a decrease in the use of personal pronouns (I, we) in scientific writing since 1700 and especially since 1900. Use of passive voice is particularly common in the methods section of articles.
- Why avoid I and we?
  - It is not clear. **In part** scientists may want to appear as objective, dispassionate and disinterested researchers by adopting a more impersonal and technical style.
    - Researchers displaying an opinion, emotional interest/investment, or passion might be dismissed as being biased. It is important to note this is not just among scientists but among the public as well.
    - However, the idea that a scientist has dedicated sleepless nights and a minimum of 8 years of schooling to something that they have no interests or opinions in is clearly, fundamentally false!
    - Research has suggested that personal pronoun use often appears to indicate specific choices, stipulations or assumptions of the research (e.g., "we assumed a 10% increase in population per decade").

A place for the passionate scientist

- Most scientists are passionate, emotional and fiercely dedicated to their work! Think of the eccentric scientist ☺ This makes it more important to use language that highlights where passion and bias may have influenced work. **Thus, the use of personal pronouns and active voice can be critical tools!**
- There is some evidence that use of personal pronouns is becoming more frequent in the sciences. Currently, very few journals avoid personal pronouns in scientific articles. Perhaps as an extension of this, there is now a backlash against passive voice and certain instructors may discourage the use of passive voice all together.

Why avoid passive voice

- Whether to use passive or active voice is a heated debate not just in the sciences, but also amongst all writers! Generally active voice has been considered to be "better" because:
    - The agent (actor) is missing.
        - Example: The lentils were added after the water was brought to a boil.
            - We do not know who was cooking.
        - This could be evidence that the writer does not know who the agent is
    - Passive voice is considered wordy and too long (though as noted earlier it is not necessarily so).

Why use passive voice

- There are many instances outside of science when it is valuable to use passive voice.
    - The actor is unknown
        - Example: The cave paintings of Lascaux were made in the Upper Old Stone Age. [2]
    - The actor is not important
        - You may want to be vague about who the actor was.
        - There may be many actors and that is not important.
        - This is often the case when describing a process.
        - Example: The lentils were added after the water was brought to a boil.

        - If you are giving someone instructions about how something was cooked, it does not matter who the cook was.
    - The statement is considered a general truth
        - Example: Vaccines <u>are considered most effective</u> if administered young.
            - This would be true for anyone.
    - The object acted upon is the most important theme of the sentence
        - Example: Insulin <u>was first discovered</u> in 1921 by researchers at the University of Toronto. It is still the only treatment available for diabetes.[2]

<u>Arguments for Active Voice in the sciences</u>

- Sentences in the active voice are often shorter.
    - However, this is not always the case.
- Makes the subject known
    - This is often critical for accountability in the sciences. However, this is often redundant with citations. Oftentimes the subject is ambiguous, not known, or may be very complicated (a list of many different people/labs etc).
        - Active voice: Many labs including XXX, XXX, and XXX, <u>have done</u> research to discredit this theory.
            - *The theoretical point has been buried behind an awkward list of the many actors (subjects).*
        - Passive voice without citations: Research <u>has been done</u> to discredit this theory.
            - *Clearly this leaves the subject unaccounted for and discourages accountability amongst scientists. However, the accountability in science writing is in the in-text citations.*
            - Passive voice WITH citations: Research <u>has been done</u> to discredit this theory (XXXX, XXXX, XXXX).

[2] Sentences from http://www.writing.utoronto.ca/advice/style-and-editing/passive-voice

        - *Here there is no question about who has done the research. Also note that the sentence is arguably clearer and more straightforward without leading with the list of actors.*

Arguments for the Passive Voice in the sciences

- The focus of the sentence is often on the result found or the process (methodologies) being described. This results in often putting the object (not the subject) first.
    - EXAMPLE:
        - Active Voice: I (The researcher) spun the tubes at 10,000Xg in the centrifuge for 10 min. Next, I removed the supernatant.
            - *Here the subject or actor is fronted in the sentence ~ however the actor is really not important here. Also note the length (17 words for the two sentences)*
        - Passive Voice: The tubes were spun at 10,000xg in the centrifuge for 10 min. Next, the supernatant was removed.
            - *Here the action conducted to the samples is fronted. Note the length (17 words)*
    - This is often the case in the methods section when processes are being the described.
- Accountability is often addressed through citations (above example). This allows the objected to be fronted for emphasis in a sentence.
- Many statements in the sciences are considered truths (above example).

Citations in Science

Who should be cited?

- Previous research (both old and new) should be cited if it is relevant to your work.

What if there are too many manuscripts to cite?

- It is usually the case now that there is too much relevant research to cite all of it.
- How much is too much?
    - There is a lot of personal opinion here.
    - Typically 3-5 references for one point are enough. More than that can be daunting.
    - For an original research paper there is a huge range in the total number of references. ~30-50 would be considered average range.
    - Many more references are required in a comprehensive review of the literature (>100).
    - There are fewer references in journals with shorter page limits (*Science* and *Nature).*
- How do I pick what is relevant?
    - The introduction will have older references (relatively older considering the field of interest). Often the original citation should be presented in the introduction along with a couple more recent citations.
    - If there is a lot of research on one topic (Example: reproduction in birds), you will have the freedom to choose citations (and a sentence) that address a more narrow topic that is relevant to your work (Example: Female reproduction in zebra finches).
    - You can reduce the number of citations by using the same reference many times. This is also a good strategy because it suggests that this reference is more applicable to your work.

How to cite yourself?

- When you should cite yourself:
    - If you have an original idea or data that is published in a previous paper, it is considered practically and ethically problematic if you do not cite yourself in the current manuscript.
    - If you are showing a figure of data that is previously published and you have modified it, it is still considered plagiarism if you do not cite yourself.
    - In short, if someone else should cite you, then you need to cite yourself.
- When you should not cite yourself:
    - Because the number of times a researcher is cited is evidence of their importance in the field, it is common for people to "self-cite" to improve their perceived contribution.
    - Self-citing to self-cite is frowned upon.
        - However, it is difficult to know when someone is doing this because everyone needs to cite their own work.
        - Self-citing just to self-cite is akin to a researcher that likes to only talk about themselves. It suggests that they may not be "good listeners".

Examples of Citation Styles

- Every journal has a "house" style. It is important to look at the guide for authors before submitting a paper (available on a journal's website).
    - This is true for both in-text citations and bibliographies.
- Be sure to use a consistent style. (Do not mix and match citation styles.)
- In-Text citations
    - Unlike in the humanities, the page number is less important because it is unusual to quote someone directly. However, the date of the publication is very important because gives information about the timeline of research in this field.
    - Variation with in-text citations.
        - Typically in-text citations are either the author's last name and the date of the publication or just a numbered reference.

        - From *Hormones and Behavior* Guide to Authors[3]
            - 1. *Single author:* the author's name (without initials, unless there is ambiguity) and the year of publication;
            - 2. *Two authors:* both authors' names and the year of publication;
            - 3. *Three or more authors:* first author's name followed by 'et al.' and the year of publication.
            - Citations may be made directly within a sentence (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.
        - From *Science* Guide to Authors[4]
            - Place citation numbers for references and notes within parentheses, italicized: (18, 19) (18-20) (18, 20-22). Do not use superscript numbers. Citations are numbered sequentially, first in the text, then through the references and notes, then through the figure and table captions, and finally through the supporting online material. The acknowledgments follow as an unnumbered note.
- Bibliographies
    - There is more variation across House Styles (within a journal) in the bibliography
        - The references may be organized by author's last name (alphabetically) or by the order they appeared in the text (by number).
        - The use of abbreviations varies as well.
    - From *Hormones and Behavior* Guide to Authors[5]

---

[3] http://www.elsevier.com/journals/hormones-and-behavior/0018-506X/guide-for-authors#68000
[4] http://www.sciencemag.org/site/feature/contribinfo/prep/res/refs.xhtml
[5] http://www.elsevier.com/journals/hormones-and-behavior/0018-506X/guide-for-authors#68000

    - References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.
    - *Examples:*
    - Reference to a journal publication: Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2010. The art of writing a scientific article. J. Sci. Commun. 163, 51–59.
    - Reference to a book: Strunk Jr., W., White, E.B., 2000. The Elements of Style, fourth ed. Longman, New York.
    - Reference to a chapter in an edited book: Mettam, G.R., Adams, L.B., 2009. How to prepare an electronic version of your article, in: Jones, B.S., Smith , R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281–304.
  - From *Science* Guide to Authors[6]
    - **Journals**
    - 1. N. Tang, On the equilibrium partial pressures of nitric acid and ammonia in the atmosphere. Atmos. Environ.**14**, 819-834 (1980). [one author]
    - 2. William R. Harvey, Signe Nedergaard, Sodium-independent active transport of potassium in the isolated midgut of the Cecropia silkworm. Proc. Natl. Acad. Sci. U.S.A.**51**, 731-735 (1964). [two or more authors]
    - 3. F. H. Chaffee, Jr., The discovery of a gravitational lens. Sci. Am. **243**, 60-68 (November 1980). [journal paginated by issue]

[6] http://www.sciencemag.org/site/feature/contribinfo/prep/res/refs.xhtml

Reporting Statistics

Common Types of Statistics

- The "Statistic" (e.g. T or F value), Degrees of Freedom, and the P value should all be reported for each analysis in either the results section or in the table (cited in the results section).
- If descriptive statistics are used, indicate what the numbers are.
- There are many more types of statistical analyses than can be covered. Three examples will be given here.
- Variation in reporting statistics (all are equally appropriate, however respect any house preferences that exist).
    - The format of P
        - Capitalized or not
        - Italicized or not
        - # decimal places
        - Exact p value or rounding (> 0.05) etc.
    - The format of T or F statistic
        - Italicized or not
        - # decimal places
    - The format of the Degrees of Freedom
        - In parenthesis
        - As a subscript
- Examples:
    - Chi Squared Test
        - (χ^2 (2) = 14.14, P <.01)
    - T Test
        - (T (32) = 2.10, P = .034)
    - ANOVA
        - ($F_{1, 132}$= 2.24, P > .05)

Reporting statistics in a table[7]

Table 1

Effects of season, stress and brain region on corticosterone and DHEA in the brain

Variable	Three-way mixed-design ANOVA					
	Corticosterone			DHEA		
	d.f.	*F*-ratio	*P*-value	d.f.	*F*-ratio	*P*-value
Season	2,271	1.39	0.25	2,271	1.22	0.30
Stress	1,271	115.41	< 0.0001	1,271	0.15	0.70
Season × stress	2,271	2.85	0.06	2,271	0.78	0.46
Region	5,271	6.67	< 0.0001	5,271	4.18	0.0012
Season × region	10,271	1.93	0.04	10,271	1.08	0.38
Stress × region	5,271	4.68	0.0005	5,271	0.28	0.92
Season × stress × region	10,271	2.21	0.02	10,271	1.09	0.37

Where should your statistics be reported?

- Depending on the amount of statistics you have to report, the actual statistics can appear in either results section text or in the table (which is referenced in the text).
- For some journals it is common to report statistics in the figure legends for the corresponding results.
    - This can be either instead of or in addition to reporting statistics in the text or tables.
- The significance should be indicated on figures/graphs.
    - Most commonly using asterisks.
- If data is presented in a table, significance should be indicated with bolded text and or asterisks.

[7] Newman, A.E., and Soma, K.K. (2009) Corticosterone and dehydroepiandrosterone in songbird plasma and brain: effects of season and acute stress. *Eur J Neurosci*. May; 29(9): 1905–1914.

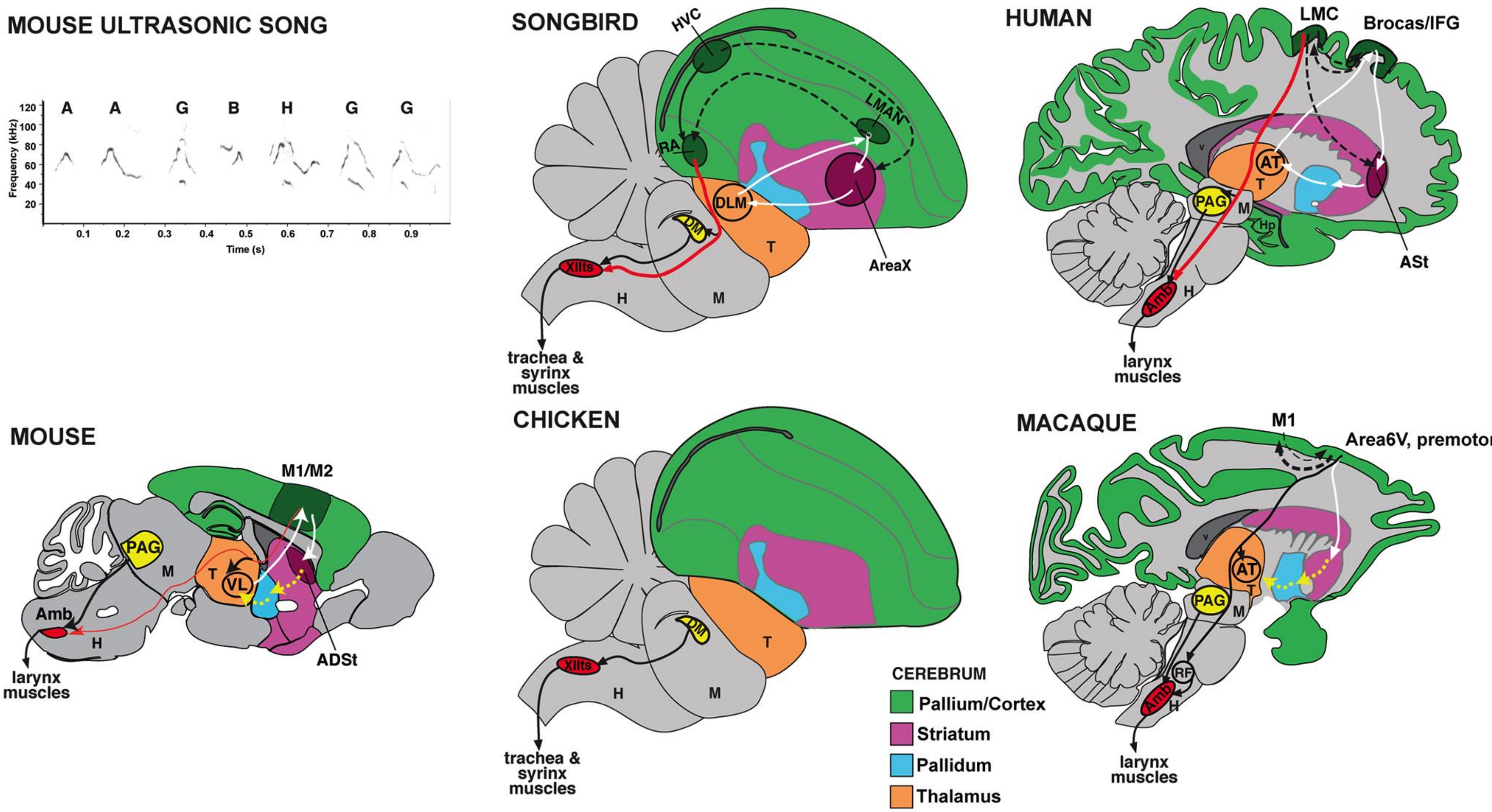
The Use of Visuals in Science Writing

Goal of Visuals

- Some information/ ideas or data can be conveyed more quickly and efficiently through visuals than text.
- Examples:
    - The timeline for a study
    - Spatial information
        - Physiological diagram
        - Heat maps of spatial distributions

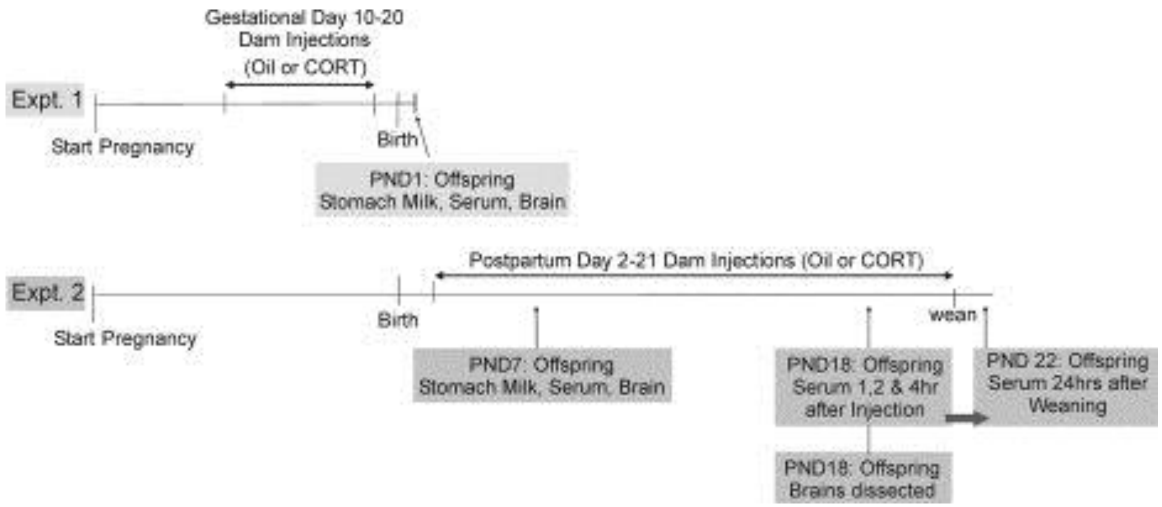
How to develop good figures

- Figures can be:
    - graphs
    - diagrams
    - photos
    - drawings
    - maps
- Try several options as you think critically about what type of visual will best show your story.
    - Get a lot of feedback
- Plan figures or visuals that are as simple as possible.
- Make your figures big enough that they can be seen easily.
- Pay attention to what the most prominent parts are of your visual. These will be seen first and therefore it is more effective if the prominent parts are the most important parts.
- Include detailed figure legends that correspond with labeled parts of the figure.


MOUSE ULTRASONIC SONG
A A G B H G G
Frequency (kHz)
120
100
80
60
40
20
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Time (s)
SONGBIRD
HVC
LMAN
RA
DLM
DM
XIIts
T
AreaX
H
M
trachea & syrinx muscles
HUMAN
LMC
Brocas/IFG
v
AT
T
PAG
M
Hp
ASt
Amb
H
larynx muscles
MOUSE
M1/M2
PAG
M
T
VL
Amb
H
ADSt
larynx muscles
CHICKEN
DM
XIIts
T
H
M
trachea & syrinx muscles
CEREBRUM
Pallium/Cortex
Striatum
Pallidum
Thalamus
MACAQUE
M1
Area6V, premotor
v
AT
T
PAG
M
RF
Amb
H
larynx muscles

From: Arriaga, G. et al. (2012) Of Mice, Birds, and Men: The Mouse Ultrasonic Song System Has Some Features Similar to Humans and Song-Learning Birds. *PLoS one*, DOI: 10.1371/journal.pone.0046610

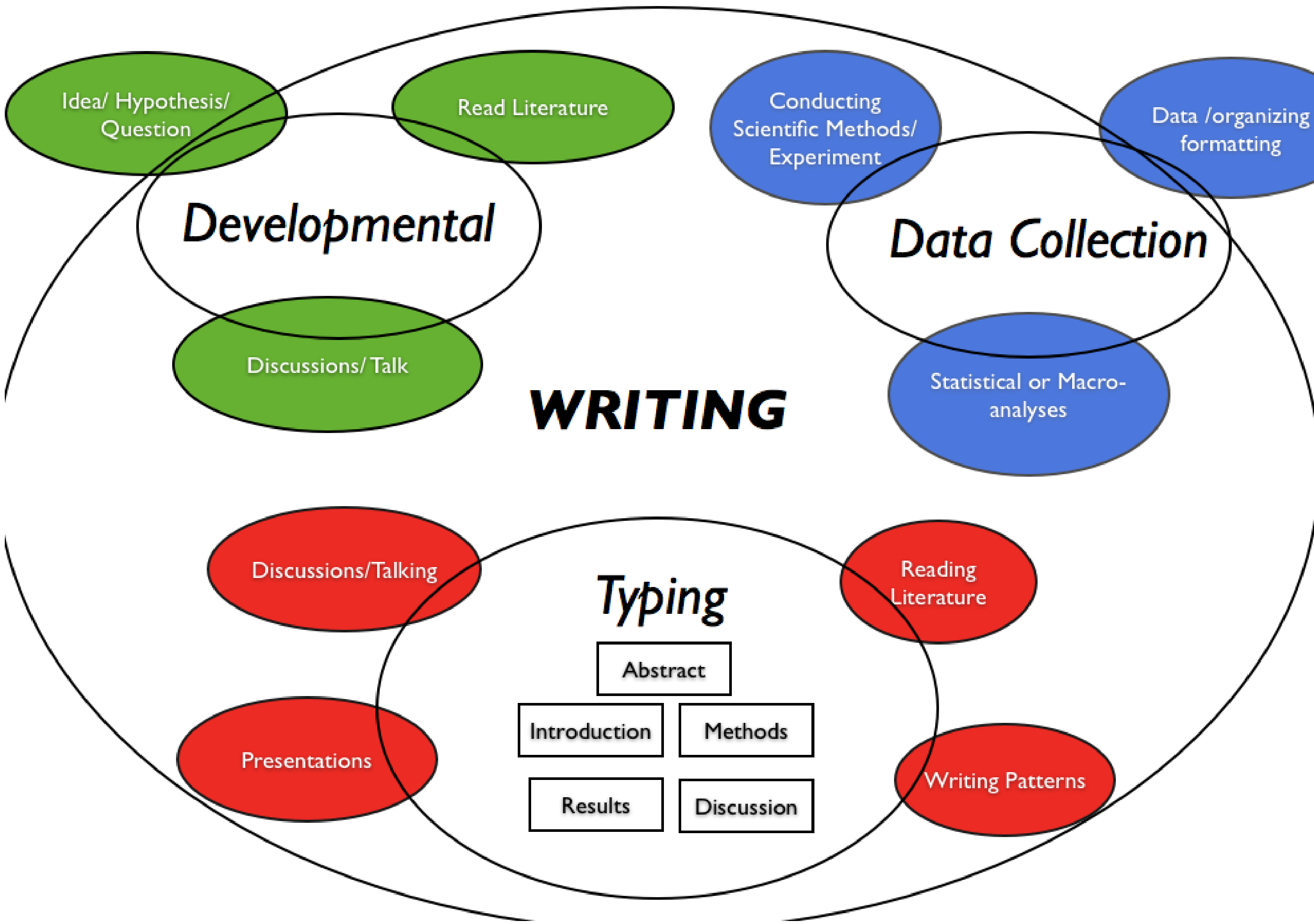
Figure 1. Brain systems for vocalization in birds and mammals.
A, Typical ultrasonic song segment (sonogram) of a male B6D2F1/J (BxD) mouse produced in response to presentation of female urine. Multiple distinct syllables (letters) are produced in long sequences (sometimes over 30 sec), but only 1 second is shown so that the frequency contours and nonlinearities of individual units can be resolved. The sonogram was generated from Audio S1. **B–C**, Summary diagrams of vocal learning systems in songbirds and proposed pathway in humans [6]. Red arrows, the direct forebrain projection to vocal motor neurons in the brainstem (RA to XIIts in song learning birds; Laryngeal motor cortex [LMC] to Amb in humans) [6], [9], [13], [18]. White lines, anterior forebrain premotor circuits, including cortico-striatal-thalamic loops. Dashed lines, connections between the anterior forebrain and posterior vocal motor circuits. **D–E**, The direct cortico-bulbar projection is said to be absent in vocal non-learners such as chickens and monkeys. Monkeys possess an indirect cortical pathway to Amb [22], but this circuit does not appear to influence programming of vocalizations [9]. **F**, Summary diagram of mouse song system connectivity discovered in this study. Two pathways converge on Amb: one originating from the periaqueductal grey (PAG) and one from M1 (red arrow) similar to humans (C). Yellow lines indicate proposed connections for cortico-striatal-thalamic loop that need to be tested. Auditory input is not shown. All diagrams show the sagittal view. Abbreviations: ADSt, anterior dorsal striatum; Amb, nucleus ambiguous; Area 6V, ventral part of Area 6 premotor cortex; Area X, a song nucleus of the striatum; ASt, anterior striatum; AT, anterior thalamus; DLM, dorsalateral nucleus of the mesencephalon; DM, dorsal medial nucleus of the midbrain; H, hindbrain; Hp, hippocampus; HVC – letter based name; IFG, inferior frontal gyrus; LMAN, lateral magnocellular nucleus of the anterior nidopallium; LMC, laryngeal motor cortex; M, midbrain; M1, primary motor cortex; M2, secondary motor cortex; nXIIts, 12th tracheosynringeal motor neurons; PAG, periaqueductal grey; RA, robust nucleus of the arcopallium; RF, reticular formation; T, thalamus; VL, ventral lateral nucleus of the thalamus.



From Brummelte, et. al. (2010), Elevated corticosterone levels in stomach milk, serum, and brain of male and female offspring after maternal corticosterone treatment in the rat. *Devel Neurobio*, 70: 714–725. doi: 10.1002/dneu.20805

Figure 1. Timeline of the two experiments. Dams in Experiment 1 (Exp. 1) received daily corticosterone (CORT) or vehicle (oil) injections from Days 10 to 20 of gestation, whereas dams in Experiment 2 (Exp. 2) received CORT or oil injections from Days 2 to 21 postpartum. Offspring were sacrificed on postnatal day 1 (PND1) for Experiment 1. For Experiment 2, stomach milk, brain, and serum were collected on PND7. Brain samples were collected on PND18. Serum samples were collected from the remaining offspring on PND18 and PND22 (The bolded gray arrow indicates that the same animals were used for both collection time points).

The Writing Process and Strategies for Organizing a Scientific Argument



When does the writing process start?

- Perhaps more than any other discipline, the writing process in the sciences starts long before any text is necessarily written.
- The writing process includes
    - Project development
        - Brainstorming conversations
        - Reading previous literature
            - Focusing on experimental designs and methodologies
        - Drafts of protocols
        - Learning the methodologies or laboratory techniques
    - Project execution
        - Data collection (often a several month process)
        - Lab notes on data collection
        - Adjustments may be made to the methodologies
    - Initial analyses
        - Discussions about statistical analyses
        - Often multiple analyses are conducted prior to "finalized results"
        - Development of preliminary graphs
        - Presentation of preliminary results at Lab meetings, coffee shops, or professional meetings
        - Brainstorming conversations
        - Reading and referring to the literature
            - Focusing on the results and interpretations
        - More data and/or experimentation may be required
    - Finalized results and write up
        - Conduct new statistics
        - Incorporate new data
        - Revision of text
        - Revision of visuals
        - Referring to the literature

        - Presentation of results
    - Peer review process
        - Incorporate new data
        - Revise text
    - While the write up of studies is very linear, typically the writing process/ data collection is not linear. Frequently these above steps can be co-occurring and/or reorganized depending on the data and study.

<u>When is your scientific argument developed?</u>

- One's argument is developed over a long period time and throughout the entire writing process.
- It is normal for your argument to be "fine-tuned" up until the day it is published.
    - Typically, an argument is largely developed prior to the "write up" stage of the process. However, the act of writing clarifies and helps researchers articulate their argument.
    - Furthermore, even after publishing you may have insights into the importance of your findings and rearticulate your argument for future discussions.
- For non-research (data) based articles, the same writing process exists.
    - Data collection is the act of summarizing and compiling previous results and conclusions rather than through novel experimentation.

<u>Guidelines for developing a strong argument</u>

- First and foremost, document and be conscious of your writing process.
    - This starts with good record keeping of your ideas as you read the literature
    - Always write out your protocols (or data collection plans)
    - Document changes to your argument
        - As new information appears, record the impact it has on the development of your argument
        - Record a timeline documenting changes to your argument

- Keep detailed/organized notes
    - It is important that you can easily reference any:
        - information regarding the execution of your study
        - piece of your data
        - piece of your analyses
        - changes in your ideas around your arguments or the goals of your research
            - These usually influence what you did, and are often the justification behind your data collection and analysis
        - ideas based in other literature
            - it is critical to know the difference between your ideas and others' ideas.
            - It is easy to forget if something was originally your idea or someone else's.
- Talk to people
    - Arguments need to be tested and you have to practice making them.
- Keep track of your ideas vs. other peoples' ideas.
    - One technique is to use mind mapping
        - Your ideas are the connections (lines) you see between points.
        - Other peoples' ideas are the points (bubbles) that you have written down.
    - Another technique is to use outlines
        - In your outline, clearly cite as many references as you have read.
        - The idea is not all of these will end up being in your final paper, but you have a record of how they have impacted the development of your paper.
- Break down your argument
    - Every statement in science needs to be backed up.
        - Try this exercise:
            - Write down your argument.

- Then write down the things that need to be true in order for your argument to be convincing.
- Then do this again for the new things you have written down.
- This process allows you to identify the pieces of evidence that need to be brought together in order for your argument to be a strong one.

Variation in science writing

Writing in the sciences is primarily a contextualized and collaborative process. This means no matter your experience level, you always need to be aware of the many styles! There is not only one way to write!

Stylistic differences

- People have personal preferences about everything
    - How to write
        - the writing process,
        - how to collaboratively write
            - what are the roles of multiple authors
            - who should write
        - what an early draft should look like
        - when results are discussed (months before writing, at the time of the first draft… etc.)
        - how long it should take to write
        - how many drafts should be written
    - What to write
        - which results are included
        - how to decide what to exclude
        - how much interpretation to put in the result section
        - how much interpretation to put in the discussion section
        - how long should each section be
        - what information needs to be in figure legends
        - what data should be presented in tables vs. figures vs. text
    - Rhetoric
        - active vs. passive voice
        - the length of sentences

        - specific word preferences
            - what can be abbreviated
            - which abbreviations should be used
    - Citations
        - who should be cited
        - what facts require citations (what counts as basic knowledge)
        - how many references should be cited
- These stylistic differences can been seen at every level
    - Personal
    - Laboratory
    - Micro-field (interdisciplinary is the new norm: most researchers work across multiple disciplines).
    - Journal

<u>Conclusion: Be aware of your writing process. It will not only make you a stronger writer, it will make you a better collaborator and a more flexible and fluid scientist.</u>

Communicating with Scientists and Writing About Science

<u>What is Pop Science?</u>

- **The audience is no longer just scientists: it is broader and may include everyone, or a specific subgroup.**
- **Pop science is not part of the professional scientific discourse (although it could be). Pop science more broadly a part of the public discourse**
- Many people with science backgrounds (including scientists) write pop science
    - Science blogging
    - Science podcasts
    - Science news
    - Science books

<u>Discourse of Pop Science</u>

- It should be easily accessible to a broad audience.
    - Unlike primary literature, this may be the most important part of a pop science article.
- The primary focus **is not** on the data or methodologies.
- The primary focus **is on** the significance of the findings.
- The primary focus **is on** the human relevance **rather than** basic science.

<u>The challenges of pop science writing</u>

- Primary literature in the sciences is necessarily full of jargon and complex.
    - It is not easy to simplify the ideas and results from primary literature without losing important pieces of this complexity.
    - Complexity has to be lost. How do you choose what is necessary and what is extra information?
- Science does not prove things…. Ever!
    - Science would be more easily accessible if we can say we something was proven. This is dangerous because stating something is "known" without a doubt or "proven" is actually beyond what any study can show. Thus it is

important that pop science writing avoid reinforcing misconceptions about science and the nature/process of science.