Scientific Writing: A guide from data to draft

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SCIENTIFIC WRITING

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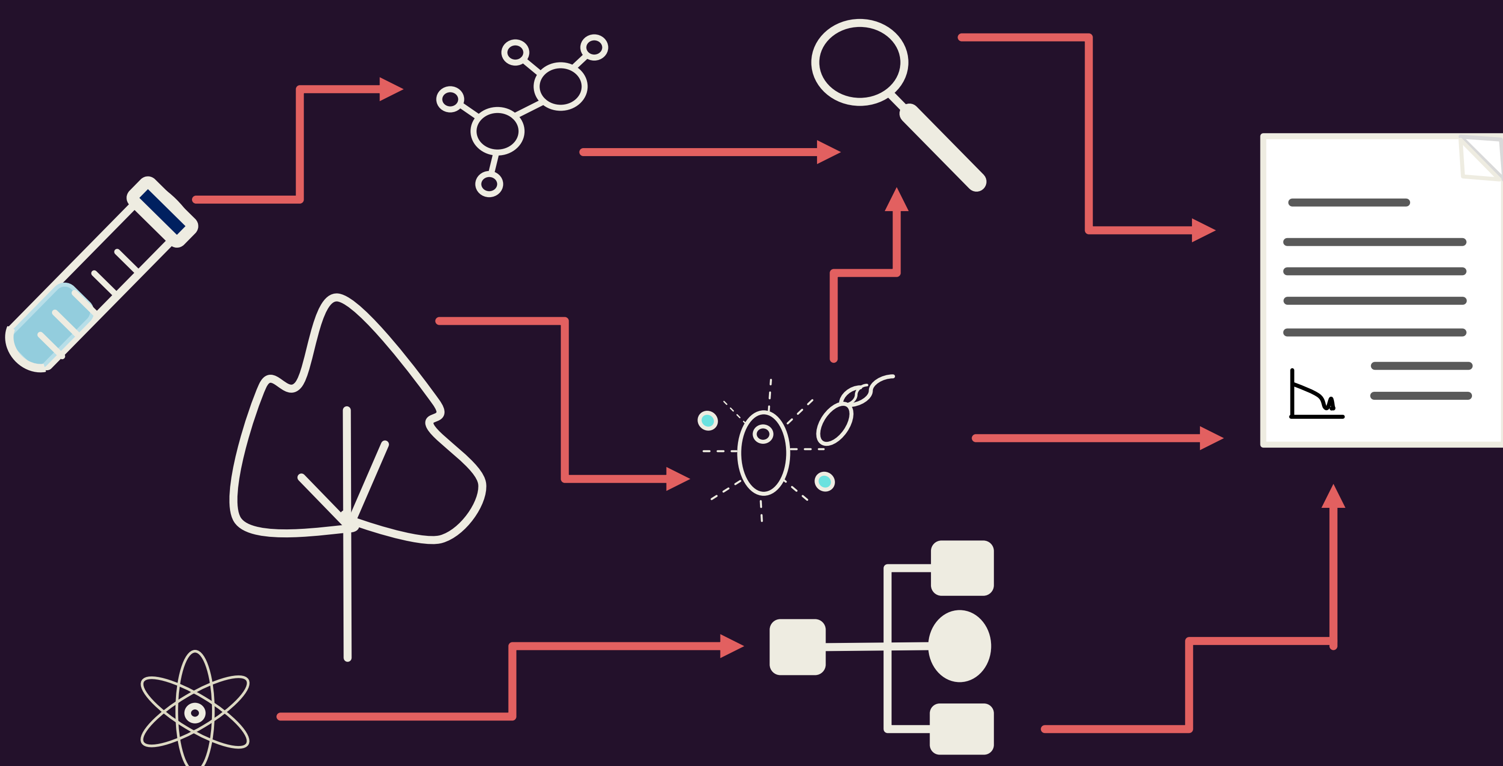


Table of Contents

Forward

Welcome! This textbook contains conventions and tips for writing about scientific research.

Audience: Undergraduate researchers can use this textbook to draft and refine their scientific writing. This textbook complements the material and activities in ENGL302W (Scientific Writing). ENGL302W is a writing-enriched course at Duquesne University, required for several science undergraduate majors. In this course, we explore and practice scientific writing across genres as a semester-long process. This textbook does not include all of our course activities or cover all of our content. Instead, it contains examples and tips related to some course material. Use this book to support foundational skills during the course, or review material years after the course ends.

Textbook overview: This textbook builds the fundamental skills needed for scientific writing, focusing on generic conventions that can be used in any scientific discipline. Scientific writing textbooks routinely cover content and style. These are real challenges, but not the first barriers on a writing journey. In fact, my research has shown that almost half of early writers use their sources incorrectly. Before you can write in the sciences, you need to find and understand the correct information for a task. For that reason, this textbook emphasizes the scientific process and scientific information literacy as essential parts of the writing process.

Instructions: I recommend reading chapters 1 and 2 first, as they cover the fundamentals of how science and writing work together, as well as common types of writing. Chapter 2 also introduces signaling language, which appears throughout the book. After that, use the table of contents to learn or view examples of the material you need. Each chapter contains examples to demonstrate basic structure or conventions. Use these examples as a model for your own work. At the end of each chapter, there are tips for best practices to get you started with a writing project or revise your work.

A final note: Most of my science students don’t choose their major because they like to write. Like many of my students, I’m a trained scientist – not a grammarian or writer by profession. However, writing is still an essential part of being a scientist and communicating research. There’s something special about seeing years of your hard work published in a research article (or a decade of teaching in a textbook!). Put a few words on a page and trust the writing process. This textbook is my gift to you to help you get started.

All my best,

Kristin Klucevsek

(Or as my students know me, Dr. K)

Chapter 1. Writing and science as iterative processes

Chapter 1 overview and objectives:

Chapter 1 explores the related processes of performing scientific research and writing about research. Much like good science, "good" writing does not happen quickly. Both writing and research require an iterative process of planning, reflection, feedback, and revision.

In addition, scientific writing *models* the scientific process. Scientific writing assumes that both the reader and the writer understand how science works.

In this chapter, you will learn:

- The difference between scientific writing and science writing
- The process of performing scientific research as an iterative process
- Basic rules for scientific writing
- The importance of writing as an iterative process
- Tips for writing and time management

1.1 The audience of scientific vs. science writing

Identifying your audience is the first rule of good writing. Science communication includes both scientific writing and science writing. However, each type of writing has a different audience. This textbook covers *scientific writing.*

- **Scientific writing** targets a scientific, health, or professional audience. This audience expects concise, specific writing, full of data, citations, and terminology. Examples of scientific writing include journal articles, posters, and grants.
- **Science writing** targets a public audience. A public audience expects a simplified explanation of concepts and data, made relevant to their needs or interests. Examples of science writing include news articles, organizational websites or reports, and nonfiction books.

1.2 A scientific audience knows the scientific process

The scientific process is an important part of performing research *and* writing about research.

Scientific writing is formulaic, not creative. Scientific journal articles have conventional expectations, detailed in later chapters. Readers expect to see specific content in each section of a paper. This content usually aligns with the steps of the scientific process.

Most children learn the scientific method as a set of steps or a simple cycle of these steps:

- Observe
- Conduct background research
- Form a hypothesis
- Design and conduct an experiment
- Analyze data
- Conclude
- Share results

In practice, the scientific method is a recursive and iterative process, not a simple cycle or a set of steps (**Figure 1.1**). Scientists often start with a question based on an observation. As scientists develop an objective or hypothesis, they read relevant background research in the field. This helps scientists situate their objective in existing research and determine the best methods to answer their questions. However, this background search also ensures that the topic is novel. Most journals and grants prioritize novel research. Therefore, most new research fills a gap in existing knowledge or examines a need in the field. This is the *justification* for the research.

As scientists design an experiment and analyze data, they continuously return to previous steps. For example, experiments sometimes fail, requiring new approaches or methods. New research is also published all the time, which may lead to improved methods or controls, or even an answer to the same questions the scientists were already asking. These normal events become feedback loops, helping scientists reflect on their original objectives as they examine data. In addition, scientists share their results throughout their research process through lab meetings, presentations, preprints and peer-reviewed publications. This consistent stream of communication provides regular opportunities for feedback and revision.

While the scientific process is not linear in practice, most scientists write about their research by organizing their work into the basic steps of the scientific method that children learn first.

Why?

Because, science can be complicated enough! A simple organization decreases the cognitive effort required for readers and writers. If the reader knows what information to expect and where to expect it, the reader can focus on the science rather than being distracted by the organization.

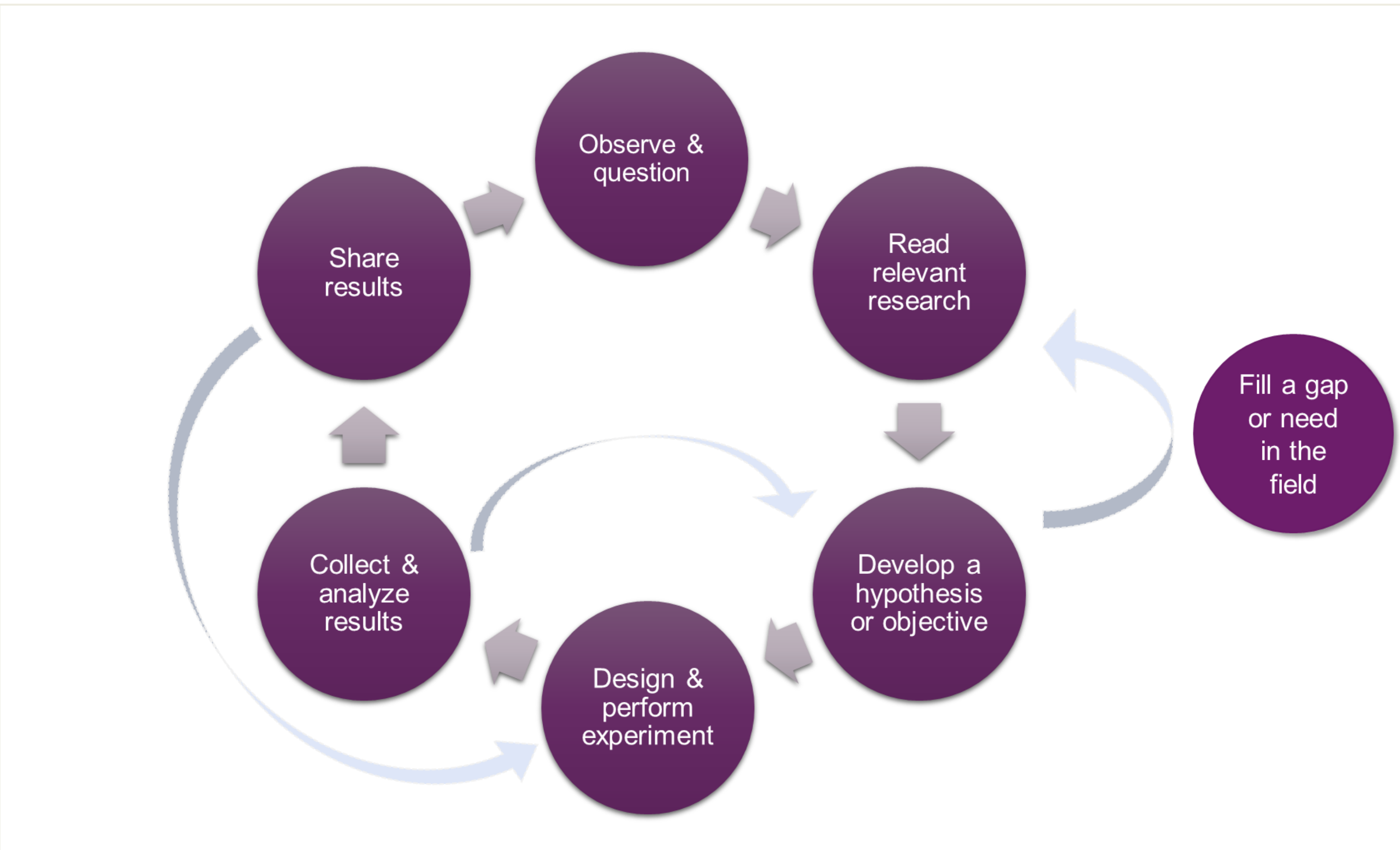


Figure 1.1 The scientific process. The scientific process involves an iterative, non-linear set of moves as scientists reflect on their research and how it fits a gap in the field. Scientists will revise and repeat their methods as they collect, analyze, and share results.

1.3 Preparing to write

The second rule of writing is to know the formatting and content requirements for the task. Each genre of scientific writing has specific content expectations, discussed in later chapters of this book. However, no formatting requirements apply to all scientific or health disciplines. For example, each scientific journal can have its own formatting requirements for items like word length, figures, headings, and citations.

Basic writing rules

1. Know your audience
2. Read guidelines and examples
3. Draft as an iterative process

Let's pretend a scientist is ready to write up their first primary research article and submit it to a journal. Early in this process, the scientist should choose a target journal and read the journal's scope and aims to make sure the journal and the research align. Then, the scientist should read their formatting requirements and examine published examples. This preparation allows the writer to outline the article according to requirements, while also adding bullet points as placeholders for genre expectations. An outline makes the drafting process easier, and helps a scientist get words on the page.

1.4 Writing as process

The third rule of writing is to make it an iterative process, just like the scientific research process described earlier in this chapter.

In an iterative writing process, the writer recursively works on a paper rather than writing it from start to finish (**Figure 1.2).** The writer reflects on content independently and with feedback, continuously revising the work. In the sciences, feedback can come through informal peer review (lab mates, professors, and colleagues) or formal peer review after submission to a journal. Feedback makes the writing stronger and clearer for the audience.

There are several similarities between the scientific process and the writing process. For example, writers and scientists should read relevant research over time, rather than all at once at the beginning of a new writing or research project. It can be tempting to gather all sources at the beginning of a project and never do it again. However, the writing topic can shift, analysis can prompt new questions, and new research is consistently published. Therefore, reading research should be done consistently.

In addition, writing happens at all stages of the research process. This forces consistent revision and reflection. A scientist writes about the research in grants, drafts abstracts and visuals for a poster or lab talk, and recycles some of this content later for an oral presentation. Later, the scientist will adapt this content for a publication.

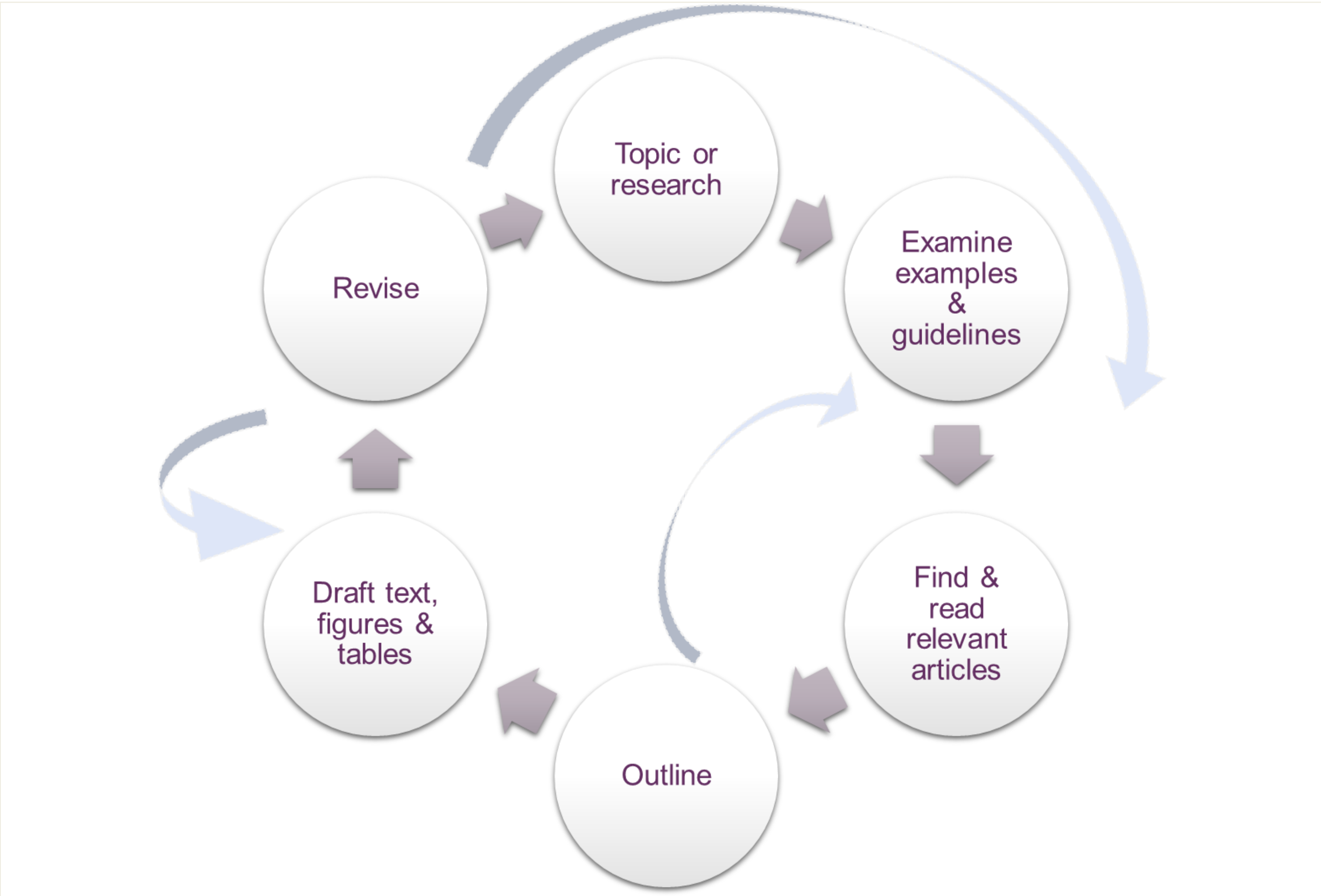


Figure 1.2 The writing process. The writing process involves an iterative, non-linear set of tasks. Writers should continuously revisit these tasks as they draft and revise.

1.5 End of chapter tips: Time management for the writing process

Like research, writing takes dedication and planning. Time management can help. Here are some tips to help you organize your writing process:

- **Outline and format early in the process.**

  This saves you time in the long run and decreases writing anxiety because you know what to do.

- **Break down the writing task into smaller goals that you can complete in 1-3 hours.**

  For example, set a goal of finding 10 articles on your topic in one morning. A future goal could be reading 2-3 of these articles and taking notes.

- **Set aside time to write as you would to study.**

  Find times that work best for your energy and schedule.

- **Plan to work on tasks over time.**

  While you may aim to finish a section by a specific date, plan to revisit the section later. This ensures continuous revision.

- **Start writing early in the research process.**

  You may not start writing a draft until the project is near completion. However, you can start creating content earlier. For example, you can create figures and tables for presentations, and modify those visuals for a manuscript. You can also collect articles to begin an introduction to your paper while your research is in progress.

- **Plan backwards to map out your writing process.**

  Set a final, personal due date for yourself to budget time. The personal due date you set should be earlier than the actual due date. This gives you extra buffer time if you need it. Plan backwards by setting mini-goals for each task to help you reach this personal due date, and pair each mini-goal with its own due date.

To map out your writing process, you can use a simple checklist or calendar, or you can modify **Table 1.1**. **Table 1.1** also correlates to relevant chapters in this book. Keep in mind that tasks do not need to be completed in a specific order, or all on one date. Schedule time to draft, read research, and revise recursively.

Table 1.1. Example organization for identifying goals and target due dates.

Task	Date range	Goals for drafting and revision	Example Goals	Chapters
Prepare to write			○ Find genre examples ○ Format according to the outlet's guidelines ○ Outline	1-2
Find relevant articles			○ Use a variety of databases ○ Collect primary and secondary sources ○ Organize sources	3-5
Read research			○ Actively read and annotate articles ○ Paraphrase and cite into a document to take notes ○ Source-mine	3, 6

Draft the main article			○ Draft each part, such as:
			  ○ Introduction
			  ○ Methods
			  ○ Results
			  ○ Main text
			  ○ Discussion
			  ○ Conclusion
				2, 4-5

Create figures and tables			○ Follow guidelines ○ Place in the order of the story	8
Draft abstract			○ Draft near the end ○ Follow guidelines	9
Revise and reflect			○ Seek feedback ○ Revise style	7

Chapter 1 summary:

Research and writing are iterative, overlapping processes. Scientists will write throughout the research process. However, when scientists are ready to write a large document, like a primary research article, it can still feel like a daunting task. Fortunately, if a writer knows the steps in the scientific process, they can use this knowledge to organize and plan their writing. Importantly, writers must dedicate time to revise and reflect on writing over time.

Future chapters will describe how scientists signal the scientific process in their writing with specific language (Chapter 2) and organize the scientific process into the sections of a primary research article (Chapter 4) or poster (Chapter 9).

Chapter 2. Journal articles and signaling language

Chapter 2 overview and objectives:

Chapter 2 overviews academic journal articles. Journal articles are a prime example of scientific writing that all scientists read and write. A writer must know the difference between the types of journal articles. There are several characteristics of journal articles that can help you distinguish them. These characteristics include the use of signaling language to signal the scientific process described in Chapter 1. Once you learn to recognize signaling language in scientific writing, you can use it help you identify and read articles efficiently and write effectively.

In this chapter, you will learn:

- Different types of scientific writing and journal articles
- Signaling language that can be used in scientific writing
- Characteristics of primary and secondary scientific writing
- Methods of identifying article type using signals and characteristics

2.1 Types of scientific writing

The most iconic example of scientific writing is the journal article. Sometimes, students will use different words to refer to journal articles, such as research articles, medical articles, or scientific articles. Therefore, we will use the following language from this point forward:

- A **scientific journal** will often focus on one or more areas of science, including science, math, computer, engineering, health, or medicine.
- A **journal article** is any article published in a peer-reviewed, scientific journal. There are several types of journal articles.
- **Primary Research Articles** are a type of journal article written by the scientists who conducted the research. These scientists are publishing their findings for the first time. These are primary sources (Chapter 4).
- **Review Articles** are a type of journal article written by scientists who synthesize the most recent and relevant research on a given topic. These are often secondary sources, but there are exceptions (Chapter 5).

> **Research in the sciences:**
>
> In the sciences, the term research denotes a scientific process performed by scientists that results in new knowledge. Primary research includes empirical, observational, theoretical, and computational research.
>
> Research is **not** the process of *finding or reading* sources to learn information. Most literature reviews would not be considered research articles.

Most primary research articles and review articles will be peer reviewed. Scientific journals publish additional articles, such as opinion pieces, editorials, corrections, and news articles for other scientists. These articles will often comment on one or two recent primary research articles or a field, but they will not cover the field extensively like a review.

There are also other types of scientific writing, including posters, reports, and grants. However, if you understand the structure of the most common types of journal articles, you can apply that content knowledge to other genres as well.

2.2 Signaling language

Scientists use **signaling language** to alert the reader to specific *moves* that the writing is supposed to make. These moves usually reflect steps in the scientific process (Chapter 1).

Signaling language is an important tool in the scientific writing toolbox. Writers can use signaling language to outline an article. Readers can use signaling language to navigate an article. As you learn how to read and write in later chapters, you can return to **Table 2.1** to help you outline and draft your article.

Signaling language can also be used to help distinguish a primary research article from a review. For example, a primary research article will signal that the authors performed a scientific experiment, using specific verbs and language such as “In this study, we examined....” Or, “Here, we used this method to identify this result”. A review will not use signals that indicate they performed original research. Instead, a review article will use broader language and often include the word “review” or “overview”, such as “This review will discuss...” or “Here, we overview...”

Table 2.1 Examples of signaling language for scientific moves.

Move	Signaling Language
Gap in the field or justification	• However,... • It is unknown/unclear • The challenge/question remains... • The problem... • While... X is lacking
Objective of the primary research	• In this study, we... • Here, we examine... • To answer/address this question, we...
Overview of a review’s purpose	• This review will explore... • Here, we review...
Connecting the objective, method, and result of an experiment	• To [objective of an experiment], we used [method of an experiment]. We found [result of an experiment] • For [objective], we collected [method]. We found...[result]
Connect a figure or table to the text	• [Result]... (Figure 1). • As Figure 1 shows... • ... as shown in Table 1.
Summarize conclusions and results	• Overall, we find • In conclusion, our study... • Here, we find...
Note limitation or unexpected result	• However,... • It is unclear... • It should be noted... • The question remains...
Analyze the implications of the research	• [result]. This implies/suggests... • Together, this research supports...
Future directions	• In the future, research should explore... • Future research should examine...

2.3 End of chapter tips: Identify article types before use

In scientific writing, journal articles are the most common genre to write and cite. In Chapter 6, we will learn that writers use primary research articles and reviews differently. Therefore, you must be able to identify the type of journal article you are reading before you use it

You cannot rely on formatting to help you identify journal article types because all journals use different formatting. For example, while most primary research articles have a methods section, some reviews do, too. However, you can use signals (**Table 2.1**) and other characteristics to aid identification. **Table 2.2** compares some of these characteristics and how they can differ between types.

Keep in mind that there are exceptions to these characteristics. Use these characteristics as clues to help your assessment of articles, but always assess the article as a whole. *Ask yourself: does this article have any signals or characteristics of original research, conducted by the authors?*

Table 2.2 Characteristics to help distinguish primary research articles from reviews.

Characteristics	Primary Research Articles	Reviews
Purpose	First-hand account of original research	Synthesize current research in a field
Author	Scientist performing the research	Scientist in the field
Audience	Specific research area	Broader scientific audience
Title	Reflects the result or the objective of the experiment (often a longer title)	Overviews topic using broad language
Abstract	Contains specific method and results of an experiment and uses active verbs to represent the scientific method (We observed... we calculated...)	Overviews a topic, but does not include the specific detail of an experiment
Figures and Tables	Original, uncited data in figures and tables	Figures and tables cite other articles or overview concepts
Signals	At the end of an introduction, a sentence will signal the objective the study.	At the end of an introduction, a sentence will signal an overview of the paper.

Chapter 2 Summary

The most iconic example of scientific writing is the primary research article. The primary research article is a type of journal article, but journals also publish reviews, news, editorials, and opinions. Primary research articles are primary because they contain original results from the authors' experiments, published for the first time. It is important that you can distinguish primary research articles from other sources because these articles are written and used differently (Chapter 6). Later chapters will cover the structure and content in primary research articles (Chapter 4) and reviews (Chapter 5), as well as best practices for finding these sources (Chapter 3).

Further, signaling language (**Table 2.1**) can be used to efficiently read a journal article (Chapter 4) and effectively write them (Chapters 5 and 6).

Chapter 3. Finding and organizing sources

Chapter 3 Overview and objectives:

Chapter 3 explores finding and organizing journal articles for research and writing.

Reading relevant research helps you situate your ideas in the field, understand the current knowledge, and ask new questions with the appropriate methods.

Scientists need to know how to use keywords, effective search strategies, and appropriate databases for their task. However, this chapter does not explore resources or search strategies in detail. For resources specific to Duquesne University Gumberg Library, and ENGL302W, see **Appendix A**.

In this chapter, you will learn:

- Types of sources in scientific writing
- Techniques for finding related research, including source-mining and AI-mapping tools
- Benefits of organizing sources with citation managers

3.1 Types of sources for scientific writing

Some writing outlets will limit the types of sources an author can cite in scientific writing. Scientific writing expects scientific, professional sources. This means that most science writing, such as websites and news articles, will not be appropriate sources for a professional audience.

Instead, journal articles are the most accepted type of sources for scientific writing. Most journal articles have been peer-reviewed and contain in-text citations, making them established sources in the field. In addition, scientific writing requires authors to situate their research in the field, and journal articles are one of the best ways to do that.

However, there are other professional sources that make sense as sources in scientific writing. For example, scientists can cite primary data from organizations or government bodies that provide reports, such as the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC).

Scientists can also cite preprints in most writing. **Preprints** are scientific articles that have been uploaded to preprint servers by scientists prior to submitting them to a peer-reviewed journal. Although preprints are not peer reviewed in the traditional sense, other scientists can openly comment on this research through social media, PubPeer (an online community journal club), and some preprint servers. Preprint servers cross-list with some databases, but they can also be accessed independently. Examples include arXiv (physics), bioRxiv (biology), medRxiv (health sciences), techXriv (engineering), ChemXriv (chemistry), and psyArXiv (psychology). An author will publish a preprint article to get the research out faster in a way that is accessible and citable. However, if the author has since published their peer-reviewed version, a writer should cite that instead.

When possible, find newer sources for a topic. Older research is valid and citable. However, a topic *without* current research signals a deeper problem - it is not an active area of research. If the research is no longer needed in the field, it is more difficult to ask new questions, obtain funding, or write about it. Finding a recent review can help lead scientists to newer research areas.

3.2 Finding sources

General database recommendations

University libraries are the best resource when finding sources for a research question or topic. Librarians can also teach the best search methods for a task, such as ways to use Boolean operators to improve results. Resources and databases vary by institution. For resources specific to Duquesne, see **Appendix A.**

Scientists *can* find scientific articles in broad databases and search engines, such as Google Scholar or Academic Search Elite. However, science-specific databases index more content related to science topics, as well as better limits to narrow scientific fields. Science-specific databases are by far a better choice for a scientific topic.

Each database has a different focus, too. For example, PubMed is a government-funded database that focuses on health, while ScienceDirect includes more research related to environmental, physical, and forensic sciences. Therefore, effective search techniques include using more than one database for each project to improve the likelihood of finding relevant information.

Source-mining

Source-mining allows a novice searcher to see what experts are citing. It is the easiest way to find more research on a topic. Start with an initial article related to the topic.

- To **reverse source-mine**, scan the titles cited at the end of the initial article. This identifies older articles related to this topic. Practice identifying article types by title (Chapter 2). Look up articles of interest.

- To **forward source-mine**, find more recent articles that have cited this initial article. Some databases, such as ScienceDirect, display this information in a location that says "Cited by" in a sidebar. Alternatively, put the title of the initial article into Google Scholar and click "Cited by" under the article.

Tools for mapping concepts and sources

There are several Artificial Intelligence (AI) AI-driven tools that can provide citation maps on a given topic. These programs use networks to connect articles beyond what a database or source-mining can do. In addition, these programs help visualize scholarship in a field. These tools can be used to find additional papers or shift a topic idea to an active area.

Some of these programs are free-to-use, some require an account, and some only offer paid services. These platforms are rapidly evolving to offer more options, but most begin with the same premise. Start with a topic idea or set of articles on the topic, and use this to as a starting point for creating a network. **Figure 3.1.** shows an example of a map derived from seed papers using Inciteful_XYZ.

Examples of AI mapping tools include:

- Open Knowledge Maps
- Research Rabbit
- Litmaps
- scite
- Connected papers
- Consensus
- Elicit
- Inciteful_XYZ

There is a genuine and valid concern about the use of AI in writing and analysis. However, the use of mapping tools is simply another method of finding articles on a topic, similar to databases.

Many of these AI-tools are not generative, and do not create text. Therefore, there are limited ethical plagiarism concerns for using these tools to explore topics. As always, refer to instructions in your course or writing outlet to confirm appropriate use and attribution of AI for a task.

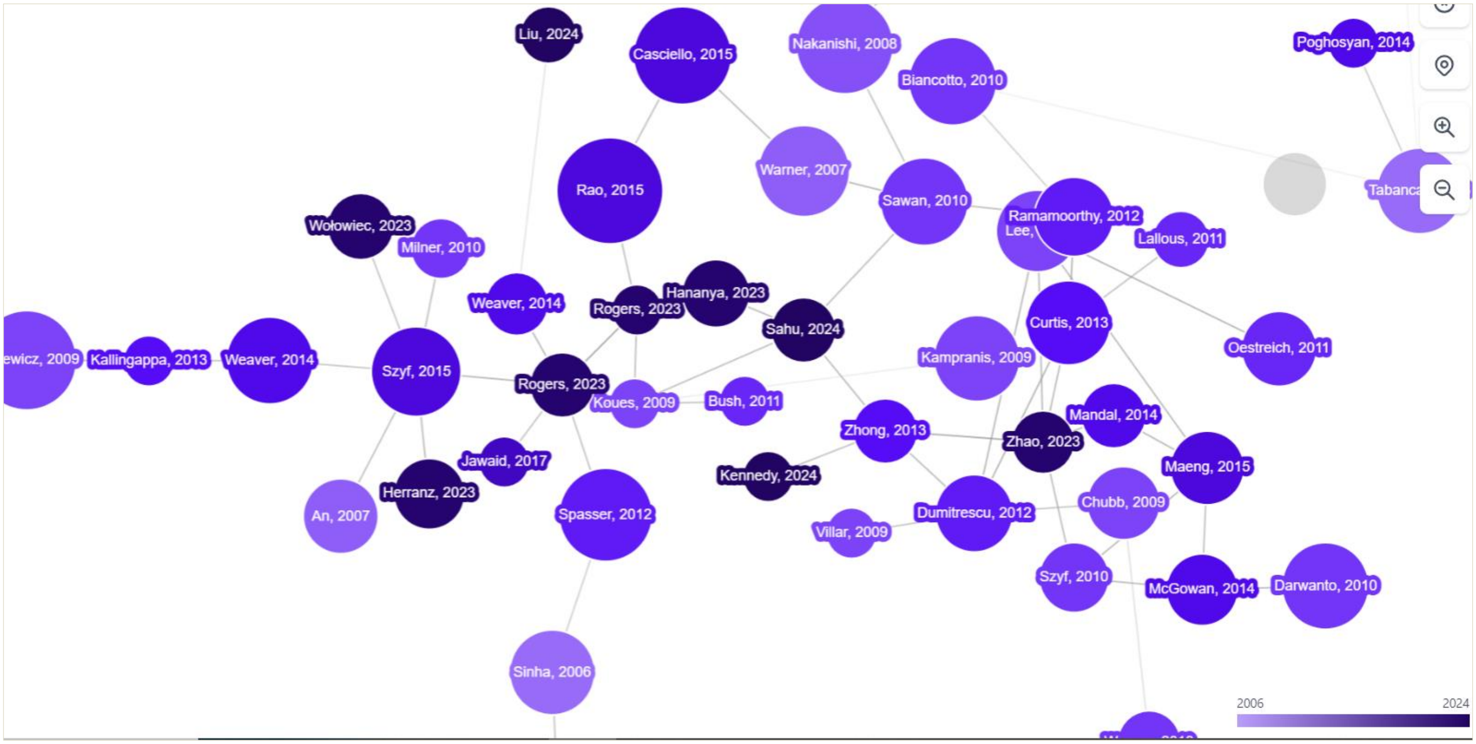


Figure 3.1. Example of a source-map generated by Inciteful_XYZ. Mapping programs connect papers of interest with other papers in the field. They visualize strong connections or groups, as well as outliers. Clicking on a paper links to the text, and some programs can export citations. These maps use different methods of creating networks, which vary based on the number of citations, age of a paper, or connection to a field. This map was generated using 5 papers related to H2B ubiquitylation via Inciteful_XYZ.

3.3 Organizing sources

Ideally, scientists should save full-text articles as they find them, so that they can be read multiple times. Save sources in a convenient, easy to find location as PDFs. Do not "save" articles in browser tabs or as links in a document – this organization method makes it easy to misplace your sources and more difficult to read off-line.

Instead, consider using a **citation program** to help organize and save articles for later use. Citation programs organize and save sources, but they also keep track of citations during the writing process. Many citation programs keep both citation information and PDFs in one place.

Citation programs can also create citations in any style through a selection on a drop-down menu, saving a scientist valuable time. This is more efficient, and often more accurate, than using a citation website or creating citations by hand. Popular citation programs include EndNote, Zotero, and SciWheel. These citation programs integrate into a word processor, allowing scientists to insert citations as they write. The programs also place the citations in alphabetical or numerical order (as needed).

3.4 End of chapter tips: Consider your need

As you find sources for a project, consider:

- What sources are you allowed to use for this project? *See Chapter 1 for preparing to write.*
- Are your sources primary research articles, reviews, or other types? *See Chapter 2 for identifying source type.*
- Do you have sources for background information? *See Chapters 5 and 6 for using reviews.*
- Do you have sources for evidence? *See Chapters 4 and 6 for using primary research.*
- Do you have sources that support the relevance of the topic?
- Are your sources recent?
- Have you visited your local librarian to find the best databases and practices at your institution?

Chapter 3 summary

Scientific writing requires scientific sources. This chapter discussed common sources in scientific writing and methods of finding them.

Effective searching takes time. It should include multiple databases and techniques, including source-mining and mapping tools to navigate scholarship. Search strategies should also include consistent reflection on what you have and what you need. It is normal to discard sources during research and writing when they no longer apply to your work. In addition, it is essential to search for papers continuously to keep up to date with a changing field.

A citation program can help you efficiently organize sources, giving you more time to focus on reading, writing and critical thinking (Chapter 6).

Chapter 4. Structure and content in a Primary Research Article

Chapter 4 overview and objectives:

Chapter 4 explores the structure and content of primary research articles.

By definition, a primary research article in the sciences is a first-hand account of new, previously unpublished research as a result of the scientists' experiments (Chapter 2).

The structure of primary research articles appears throughout scientific writing because it models the scientific method (Chapter 1). For example, students often write lab reports that follow the structure of a primary research article, and posters follow the same basic order of information.

As a writer, you can use the structure of primary research articles to outline and draft, using signaling language (Chapter 2) and the content described in this chapter. Understanding the structure of a primary research article also prepares you for reading these articles efficiently and effectively in Chapter 6.

In this chapter, you will learn:

- The audience of primary research articles
- The IMRD structure of primary research articles, including moves that match the scientific method
- How signaling language accomplishes specific moves in each section
- The content in each section of a primary research article, with examples

4.1 Types of primary research articles

Chapter 1 defined a primary research article as an article that details original research from the authors. There are different types of primary research articles, depending on the way scientists design and perform their research. Research can also be quantitative or qualitative.

- **Empirical research** uses experimental observation. Scientists design experiments to collect data, fulfilling an objective or testing a hypothesis. This type of research can come in several forms, including clinical trials, case studies, observational studies, interviews, surveys, longitudinal studies, statistical analyses, and lab experiments.

- **Theoretical research** uses existing knowledge, frameworks, or assumptions to develop new theories or ideas. It can develop new models using equations or computations, but it does not test them empirically. This type of research is common in physical and mathematical sciences.

Due to this variety in research design, it's not surprising that primary research articles can have different structures depending on the journal.

4.2 The structure and audience of primary research articles

Primary research articles often use IMRD structure (Introduction-Methods-Results-Discussion). However, the order of these sections, as well as the headings, is decided by the journal. In addition, some primary articles lack these sections entirely. Still, most primary research articles have this IMRD content somewhere, even if is organized in a different way. For simplicity, this chapter will use the IMRD structure to describe content in each section. Notice that the content in these sections aligns with the scientific process described in Chapter 2.

Figure 4.1 diagrams the content conventions in IMRD sections for primary research articles. The article is diagrammed as an hourglass because the middle of the article (the methods and results) is the most specific and technical. Early researchers often find that the methods and results sections are the most difficult sections to read because they have the highest audience level. In contrast, introductions and discussions are easier to navigate for early researchers.

Primary articles also include abstracts (Chapter 9).

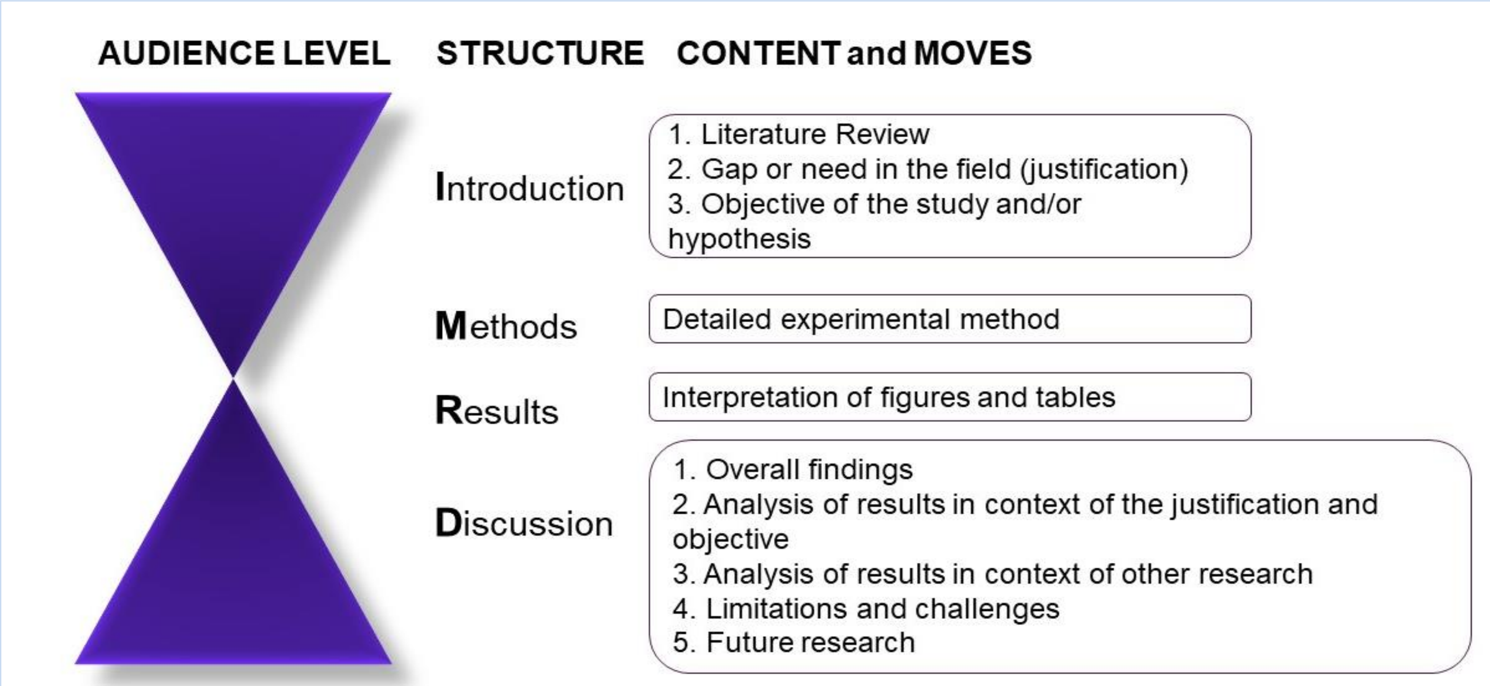


Figure 4.1. The structure and content in a primary research article. Primary research articles often use IMRD structure to organize the scientific process. In each of these IMRD sections, writers include specific content and perform specific moves (numbered). These moves can be recursive. Though primary research articles target a niche scientific audience of experts, the most complicated material is in the methods and results section.

4.3 Content, moves, and signaling in primary research articles

Title.

Titles reflect the overall result of the research or the objective and method of the research.

Titles tend to be longer and more specific than other journal article titles. They contain technical language, which targets an expert audience.

Examples:

- Single-cell eQTL mapping in yeast reveals a tradeoff between growth and reproduction
- A Complementary Remote-Sensing Method to Find Persons Missing in Water: Two Case Studies
- Resolving molecular frontier orbitals in molecular junctions with kHz resolution

In these examples, the first title represents the major result in the research, while the second two titles represent the objective and method of the research experiments.

Introduction.

Content:

The introduction contains a literature review of the relevant research in the field and narrows into the reason for the present study. It often starts with a statistic or basic definition for relevance. **Figure 4.2** contains an example introduction, matching the required moves from **Figure 4.1** and the signaling language from **Table 2.1**.

In the last 1-2 paragraphs of the introduction, the writer should signal the gap or need in the field through a justification sentence, followed by sentences that describe the present study's objective. The objective of the study is to address the gap in the field, connecting previous knowledge and unknowns. Sometimes, scientists also include hypotheses and brief methods with this objective.

Characteristics:

The length of an introduction depends on the article and journal. There are typically several citations per paragraph. Introductions can have anywhere from a few sources to over 30.

The most common citations for an introduction are other journal articles. Reviews serve as sources for background concepts that are well-known, while primary research articles should be cited for specific data. Scientists can also find statistics and background information from organizational and governmental reports, such as the CDC and WHO.

Scientists use a range of verb tenses in the introduction (Chapter 7), but the present tense should be used predominantly to cite facts about the topic.

Example Introduction (Excerpt)

Hospital-associated infections (HAIs) are a common cause of morbidity and mortality [1], in particular among vulnerable patients [2]. Many HAIs caused by common bacterial pathogens are no longer treatable with affordable first-line antibiotics, such as penicillins and cephalosporins [3,4]. For example, β-lactam resistance in bacteria has been documented over the past 2 decades [5,6]...

Prevalence surveys (PPS) have been used to infer incidence rates of HAIs in Europe and the United States [9-12] and could help set priorities for surveillance of HAIs. However, the inference of global trends in HAIs from PPS is challenging for several reasons. Firstly, an estimate of 4.95 million deaths are associated with bacterial AMR [13]. While this represents the first comprehensive overview of the global burden of AMR, it does not distinguish between hospital and community-associated settings and uses an intractable approach that is difficult to verify [13]. In this study, we used resistance prevalence extracted from 474 hospital-based PPS and published between 2010 and 2020 along with country-level estimates of hospitalization rates and durations. We combined this with statistical extrapolation based on common economic indicators to estimate the number of HARIs per year by country and by country income group.

Move: Literature Review

- Define important concepts or terms
- Cite relevant statistics and data
- Narrow into the present study

Move: Justification

Move: Objective of the present study

Figure 4.2. Example of moves and signals in the introduction of a primary research article. The introduction must accomplish three moves, often aided by the use of signals (yellow highlight; Table 2.1). This text has been adapted and used under CC-BY 4.0 (Balasubramanian et al., 2023).

Methods.

Content:

The methods section must contain all information necessary for another scientist in the field to understand the experiments and repeat the methods. Details include information such as time, sample characteristics or demographics, amount, temperature, equipment, lot numbers, companies for materials, statistical analysis, and software.

Characteristics:

The methods section is the most detailed and specific section of a primary research article. It is written for an audience of other scientists who are familiar with this work.

This section typically contains multiple paragraphs, which can be broken up into smaller sections for each type of experiment. This section can also include tables, flow charts, diagrams, or photos to support this information. Scientists can cite other papers in the methods section as needed.

The methods section sometimes goes at the end of the article or go by a different heading (e.g., experimental procedures, methodology), depending on the journal's format.

Historically, scientists have used past passive voice in this section, though first-person past tense is becoming more common in this section because it enhances clarity (Chapter 7).

Example Method (Excerpt)

A commercially available scanning tunnelling microscopy (STM) apparatus was used with a signal access module III (Bruker, Multimode STM), in which the current amplifier and piezo driver were replaced by an SR570 (Stanford Research System) and E-663 (Physik Instrumente), respectively. The feedback loop for the STM operation was controlled using a custom-made program based on an FPGA (National Instrument, PCIe 7852R), which has an analogue-to-digital conversion sampling rate of750 kHz. Meanwhile, the I–V measurement rate was 5 kHz (for further details, see ESI Sections 1 and 5†). The sampling rate determines the frequency at which data points were collected, while the measurement rate refers to the frequency at which I–V curves were repeatedly recorded. The SMJs were formed using the BJ method based on STM (45).

Content:

- Detailed description of experiments (e.g., equipment, equations, materials, conditions)
- Often uses passive past voice
- Written for an expert audience familiar with the experiments

Figure 4.3. Example of content in the results section of a primary research article. The methods section contains enough detail for expert readers to understand or repeat the experiments. This text has been adapted and used under CC-BY NC 3.0 (Isshiki et al., 2024).

Results.

Content:

The results section writes about each experiment in the paper, calling out each figure and table in order of apperance. Most figures and tables contain several data points. However, scientists only write about the most important results here. **Figure 4.4.** contains an example, which connects content to popular signaling language (**Table 2.1**).

Scientists differ in the amount of interpretation and analysis they include in this section. *All* scientists briefly interpret each figure and table. Some scientists also note limitations or unexpected findings here, building on previous studies. This more detailed interpretation allows scientists to tell a story by connecting figures and tables, but these moves are still required for the discussion section, too. For that reason, some journals combine the results and discussion section, so that all analysis happens in one location. Scientists should choose the amount of analysis they include in the results section based on their preferences, the discipline, and journal conventions.

Characteristics:

A figure or table can be called out more than once in the article (Chapter 8).

Scientists describe their research in past tense in this section.

Example Results (Excerpt)

To explore how Chk1 signaling contributes to the maintenance of DDC-dependent cell cycle arrest, we depleted DDC factors Ddc2-AID, Rad9-AID, or Rad24-AID in chk1Δ cells 4 h after the induction of DSBs. Depletion of these upstream factors in the absence of CHK1 led to a more rapid release from the cell cycle arrest (Figure 3D-F) compared to the depletion of DDC factors alone (Figure 2A-C). Collectively, these findings demonstrate that Chk1 plays a key role in maintaining cell cycle arrest in response to DNA damage.

Content:

- Describe the objective and method of each figure and table in order of apperance
- Interpret a figure or table
- Analyze the overarching result (optional)

Previous studies have shown that, in addition to Mec1, Tel1 can also target Chk1 for phosphorylation (Limbo et al. 2011 ; Sanchez et al. 1999). Additionally, when the initial 5' to 3' end resection of DSB ends is impaired, Tel1 alone can activate the DDC (Usui and Petrini 2007). To study how Tel1 contributes to the maintenance of the permanent cell cycle arrest, we deleted TEL1 in 2-DSB strain. Unlike chk1Δ with 2 DSBs, a TEL1 deletion did not affect either the establishment of the DDC nor the maintenance of checkpoint arrest up to 24 h (Figure S4), agreeing with previously published results (Dubrana et al. 2007). .

Content:

- Cite relevant research to justify or compare the experimental design (optional)
- Interpret a figure or table
- Interpret the result in context of relevant research (optional)

Figure 4.4. Example of content and signals in the results section of a primary research article. The results section must overview the objective, method, and brief result of each figure and table in order of apperance. Some result sections also connect experiments to other literature or describe unexpected results and limitations. This section continues to use signaling language for flow (yellow highlight; Table 2.1). This text has been adapted and used under CC-BY 4.0 (Zhou et al., 2024)

Discussions and conclusions.

Content:

Most articles end with a discussion section. The goal of the discussion is to position the new research within the rest of the field.

The discussion begins with the overall findings from the present research. It describes how this new research fills the need or unknown in the field, connecting the discussion back to the justification noted in the introduction. The discussion also connects the new research to existing research through citations. Scientists describe the limitations of the current research and suggest future research to address these limitations and remaining unknowns. These moves widen the scope of the paper to acknowledge that research is always ongoing.

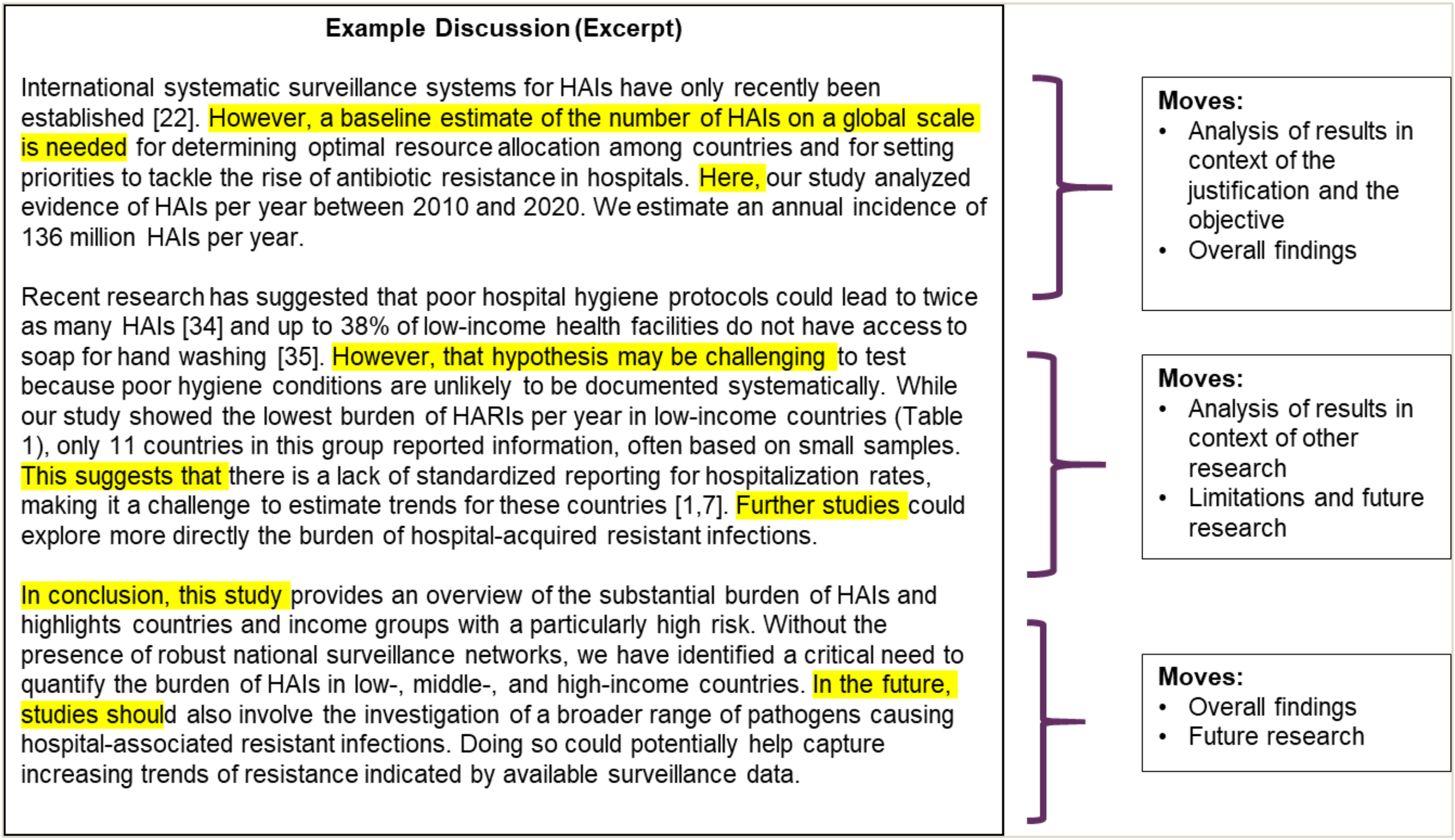
Figure 4.5 contains example discussion language, matching the required moves from **Figure 4.1** with the signaling language from **Table 2.1**.

Characteristics:

Discussions should be longer than the introduction. Discussions use some of the citations from earlier parts of the article, as well as new citations relevant to the findings.

Some articles also include a **conclusion** after the discussion. If present, a conclusion should be a brief 1-paragraph summary, noting the largest findings and future need. There is an example conclusion in Chapter 5 with the structure of a review.

Discussions use a range of present, past, and future tense as needed.


Example Discussion (Excerpt)

International systematic surveillance systems for HAIs have only recently been established [22]. However, a baseline estimate of the number of HAIs on a global scale is needed for determining optimal resource allocation among countries and for setting priorities to tackle the rise of antibiotic resistance in hospitals. Here, our study analyzed evidence of HAIs per year between 2010 and 2020. We estimate an annual incidence of 136 million HAIs per year.

Recent research has suggested that poor hospital hygiene protocols could lead to twice as many HAIs [34] and up to 38% of low-income health facilities do not have access to soap for hand washing [35]. However, that hypothesis may be challenging to test because poor hygiene conditions are unlikely to be documented systematically. While our study showed the lowest burden of HARIs per year in low-income countries (Table 1), only 11 countries in this group reported information, often based on small samples. This suggests that there is a lack of standardized reporting for hospitalization rates, making it a challenge to estimate trends for these countries [1,7]. Further studies could explore more directly the burden of hospital-acquired resistant infections.

In conclusion, this study provides an overview of the substantial burden of HAIs and highlights countries and income groups with a particularly high risk. Without the presence of robust national surveillance networks, we have identified a critical need to quantify the burden of HAIs in low-, middle-, and high-income countries. In the future, studies should also involve the investigation of a broader range of pathogens causing hospital-associated resistant infections. Doing so could potentially help capture increasing trends of resistance indicated by available surveillance data.

Figure 4.5. Example of moves and signals in the discussion of a primary research article. Primary research articles must accomplish several moves in the discussion, often aided by the use of signals (yellow highlight; Table 2.1). This text has been adapted and used under CC-BY 4.0 (Balasubramanian et al., 2023).

4.4 End of chapter tips: Outlining primary research articles

Primary research articles usually follow a specific format with expected content and moves. Therefore, you can use information and examples from this chapter to help you outline a primary research article or lab report. As we learned in Chapter 1, writing should be a process. Breaking down this process into manageable steps helps us get started. For example:

- Outline the paper using the heading, font, and citation requirements of the target journal.
- Create figures and tables before writing the results. Decide on the order of these visuals first. They do not need to be in chronological order. Instead, they should be in the order that best builds towards the largest or more detailed result.
- Use **Figure 4.1**. to outline the required moves of the paper.
- Use **Table 2.1** to begin writing these moves with signaling language.
- Do not worry about style or sentence structure during the initial drafting process. Getting words on a page is important. At the revision stage, use style tips from Chapter 7.
- Keep it iterative. Remember to consistently search for relevant research, seek feedback, and revise your work (Chapters 1 and 3).

Chapter 4 summary

Chapter 4 described the basic IMRD structure of most primary research articles. Not all primary research articles use IMRD structure, and some reviews also use IMRD structure. However, all primary research articles have IMRD content, even if the order of information or headlines are different. Understanding the structure of primary research articles will help you read articles efficiently and cite them correctly (Chapter 6).

Writers can use signaling language to signal moves in each section of a primary research article (Chapter 2). Primary research articles also include figures and tables (Chapter 8) and abstracts (Chapter 9).

Chapter 4 references

Balasubramanian, R., Van Boeckel, T. P., Carmeli, Y., Cosgrove, S., & Laxminarayan, R. (2023). Global incidence in hospital-associated infections resistant to antibiotics: An analysis of point prevalence surveys from 99 countries. *PLoS Medicine*, *20*(6), e1004178.

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Chapter 5. Structure and content in a review article

Chapter 5 overview and objectives:

Chapter 5 explores the structure and content of reviews.

In Chapter 2, we learned about different types of journal articles, including reviews. Reviews are more accessible to broader scientific audiences because they concisely synthesize recent research, providing current trends and updates on the field. Some parts of a review overlap with the parts of a primary research articles. For example, both journal articles contain introductions that overview background information. However, basic reviews do not contain original, primary research.

This chapter will provide examples of the basic literature review structure, as well as how to use signaling language to accomplish the expected moves (Chapter 2). This chapter also includes tips for organizing information within a review, such as the binning method. The binning method can be used in other applications for organizing information, including the introduction of a primary research article (Chapter 4) and paragraphs within a section (Chapter 7).

In this chapter, you will learn:

- Types of review articles
- The audience of review articles
- The structure of review articles, including moves that match each section's purpose
- The content in each section of a review with examples
- How signaling language accomplishes specific moves in each section
- Methods of organizing research in review sections and paragraphs

5.1 Types of review articles

Reviews synthesize recent research in a field. They often analyze the current state of the field, pointing out discrepancies, challenges, unknowns, limitations, and opportunities for new research.

There are several types of reviews. Popular types include:

- **Literature Review:** An overview of a topic; articles chosen by the author
- **Scoping Review:** A broad overview of a topic to identify gaps or map a field
- **Systematic Review:** A review that asks a specific question and answers the question using research found from a reproducible and unbiased search strategy
- **Systematic Review + Meta-analysis:** A systematic review that also collectively and statistically analyzes the data from all of these studies

Literature, scoping, and systematic reviews are usually secondary sources of information because they do not produce new data as a result of empirical or theoretical research (Chapter 2). However, a meta-analysis also contains primary research because new data is produced from the authors' statistical analysis.

5.2 The structure and audience of review articles

Most literature reviews will not have the IMRD structure of primary research articles. However, it is common for other types of reviews to use IMRD. For example, a systematic review must describe the search methodology, including the keywords, databases, and limits used by the author. Therefore, systematic reviews have a methods section to describe these steps with enough detail for a reader to repeat the same search and find the same papers. If you are writing a review article with IMRD structure, follow the basic structure and moves described in Chapter 4 rather than the structure and moves in this chapter.

For a literature review, follow the structure of **Figure 5.1**. Similar to a primary research article, this is diagramed as an hourglass because the middle of the article is the most specific. Reviews target an audience of other scientists, but they are more approachable for a broader scope of scientists than a primary research article.

Review articles also include abstracts (Chapter 9).

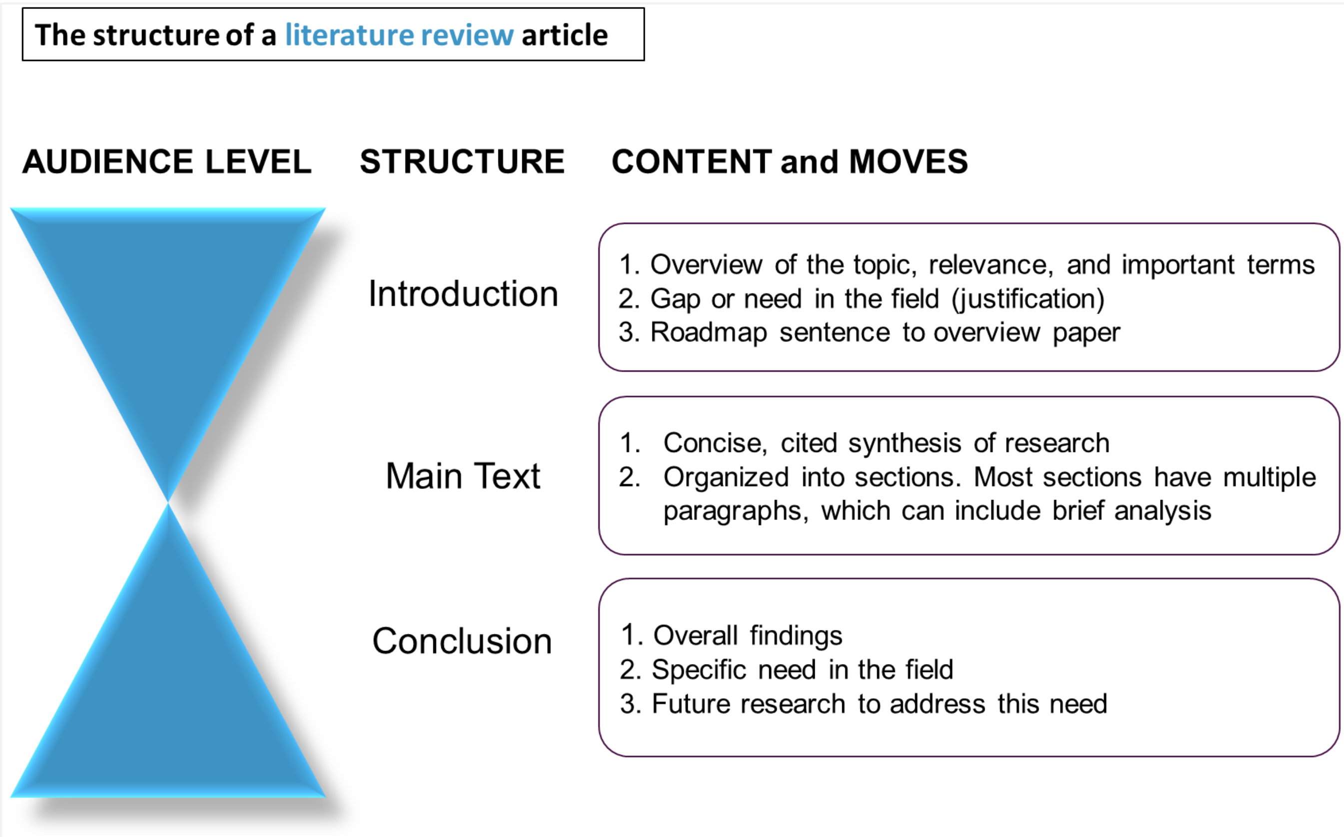

Figure 5.1. The structure and content in a literature review article. Though review articles target a broader scientific audience, the most detailed information is in the main text. This main text (or middle) is broken up into small sections of similar information. In each of these sections, writers must address specific content (numbered).

5.3 Content, moves, and signaling in review articles

Title.

Titles tend to be shorter and broader than primary research article titles. They can use language that signals the type of review article and/or broad language to demonstrate an overview of the field. If the title is longer, it usually contains a colon to break up content.

Examples:

- Smart membranes for separation and sensing
- Conceptualizing Cybercrime: Definitions, Typologies and Taxonomies
- Human migration on a heating planet: a scoping review
- Comparative efficacy and safety of pharmacological interventions for the treatment of COVID-19: A systematic review and network meta-analysis

Introduction.

Content:

The introduction of a review defines important terms and acronyms for the reader. It often starts with a statistic or basic definition for relevance. **Figure 5.2.** contains an example introduction, matching the required moves from **Figure 5.1** with signaling language from **Table 2.1.**

In the last 1-2 paragraphs of the introduction, signal the gap or need in the field through a justification sentence, followed by 1-2 sentences that overview the purpose of the review. This overview sentence is different than an objective sentence in primary writing (Chapter 4). It does not indicate the author performed an experiment. Instead, this overview sentence lists the content or sections in the review.

Characteristics:

The length of an introduction depends on the article and journal. A literature review introduction is usually shorter than a primary research article introduction because more research is cited later. Scientists cite other reviews for background concepts and well-known information and primary research articles or reports for specific data and statistics (Chapter 6).

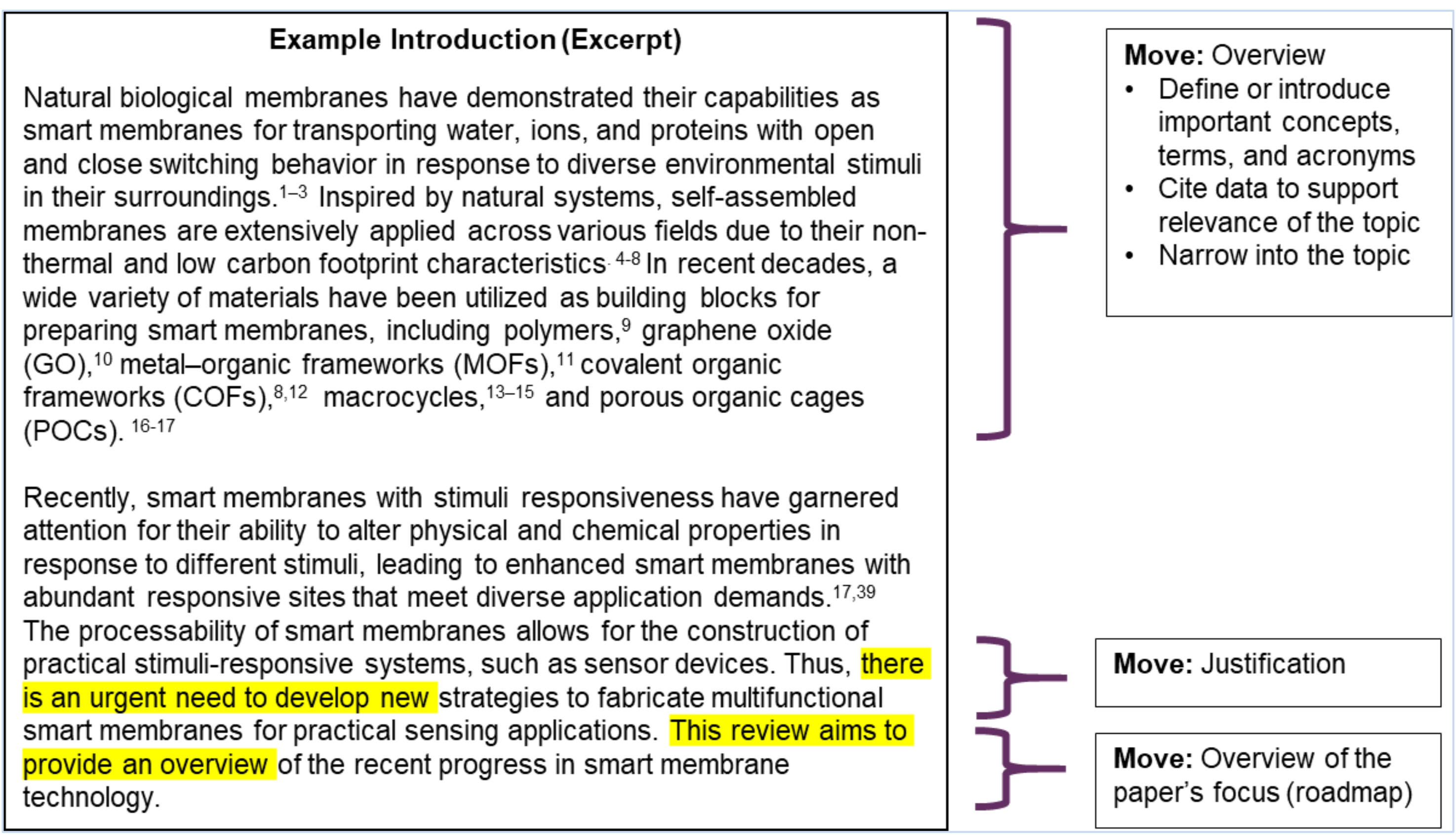

Figure 5.2. Example of moves and signals in the introduction of a review article. The introduction must accomplish three moves, often aided by the use of signals (yellow highlight; Table 2.1.) This example has been adapted and used under CC-BY NC 3.0 (Liu et al., 2024)

Main Text (middle).

Content:

The main text organizes research into headings, making it easier for a reader to find the information they need. Reviews can be organized methodologically, thematically, or chronologically (**Table 5.1**). A later section in this chapter provides methods for deciding on this organization using the binning method.

Characteristics:

Sections can be further broken down into subsections. The middle of the review should be the longest part with the most citations. In most cases, sections contain more than one paragraph, and most paragraphs cite several sources concisely.

The main text can use broad visuals to demonstrate concepts (Chapter 8). Reviews often use tables to compare quantitative and qualitative data from multiple, cited studies. This allows the scientist to analyze the field collectively and visually.

Table 5.1. Common methods of organizing review

Type	Organization	Example sections for a review on fentanyl detection
Methodological	Compare two or more methods for the same objective, focusing less on results	Compare detection methods: • Fentanyl Test Strips, • Raman Spectrometer • Fourier-Transform Infrared Spectrometer
Thematic	Compare or discuss common topics in the field	Compare tissues used in testing: • Urine • Oral Fluid • Hair
Chronological	Detail steps in a process, the natural order of events, or changes over time	Detail infant exposure to fentanyl: • Symptoms of fentanyl exposure in newborns • Detection of fentanyl • Treating exposure

Conclusions or discussions.

Content:

Most reviews end with a conclusion, though some end with a discussion *and* a conclusion. Similar to the discussion of a primary research article, a review discussion analyzes the field, its limitations, and future research. However, reviews do not have new research to analyze in the discussion. Therefore, a conclusion does the same moves more concisely and can substitute a discussion altogether. **Figure 5.3.** contains an example conclusion, matching the required moves from **Figure 5.1** with the signaling language from **Table 2.1.**

Characteristics:

A conclusion should be 1-2 brief paragraphs. The conclusion may not need citations if it only summarizes the paper, justification, and future directions. Conclusions should avoid new information that isn't included in the paper.

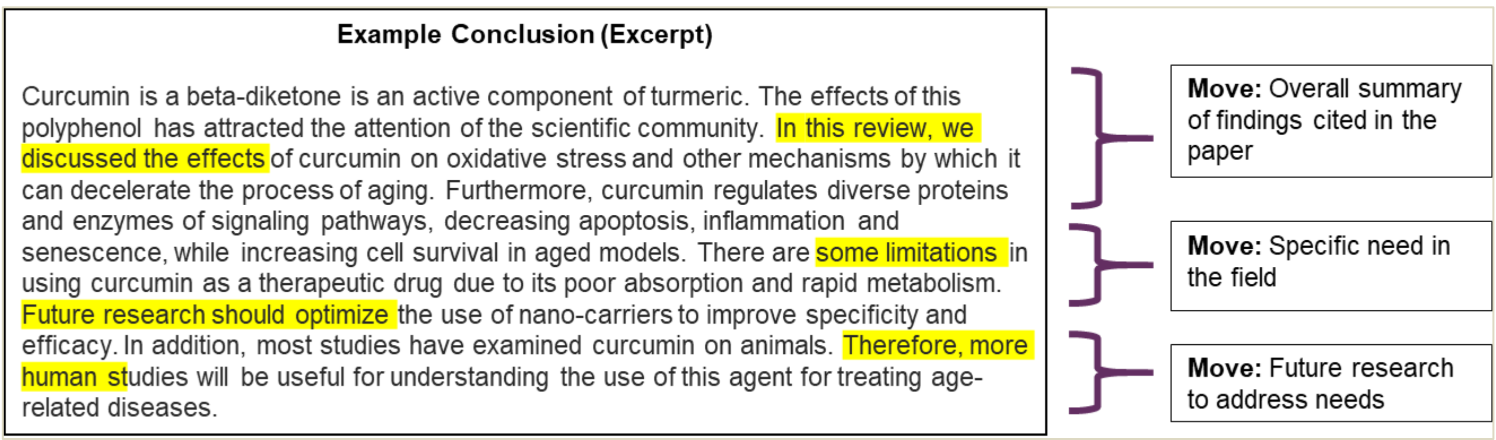

Figure 5.3. Example of moves and signals in the conclusion of a review article. The conclusion must accomplish three moves, often aided by the use of signals (yellow highlight; Table 2.1.) Example has been adapted and used under CC-BY 4.0 (He et al., 2025).

5.4 Methods of organizing sources and information

The binning method organizes sources to identify potential sections

Before deciding on section headings in a review, find at least 10-20 sources on the topic to preview the field. Use these sources with the **binning method**. The binning method helps scientists identify naturally occurring *bins* of information. It is a method of sorting this information, similar to sorting a load of laundry. Then, scientists can use section headings that represent these bins. There is an example of the binning method in **Figure 5.4.**

The binning method can also be used to sort information into paragraphs within any section of a paper.

To perform binning:

1. Consider the overarching question or topic to be explored.
2. Find recent sources on this topic and list them in a document.
3. Using the titles and/or abstract of each source, identify common language, findings, methods, or themes in each source. Write these common terms next to the titles. This common language should be 1-2 words that can serve as potential "bins". Bins are groups that could become sections.
4. Use color-coding or another method of labeling to "bin" all the sources from the list.
5. Notice which organizational strategies from **Table 5.1.** fit the bins: Methodological, Thematic, Chronological
6. Decide on the most logical order of these sections (below)

Potential sources (title)	Potential bins	Bin organization
Microplastic pollution on island beaches, Oahu, Hawai`I	Global levels	
Microplastics in Mediterranean Sea: A protocol to robustly assess contamination characteristics	Global levels	Global levels of microplastics In the ocean
Microplastics prevalence in water: two economically important species of fish in an urban riverine system in Ghana	May not fit	
Microplastics in Lake Mead National Recreation Area, USA: Occurrence and biological uptake	Global levels	
Bioaccumulation and biomagnification of microplastics in marine organisms: A review and meta-analysis of current data	Levels in shellfish	Microplastic levels in shellfish
Abundance and distribution of microplastics within surface sediments of a key shellfish growing region of Canada	Levels in shellfish	
Use of sediment dwelling bivalves to biomonitor plastic particle pollution in intertidal regions; A review and study	Levels in shellfish	Potential effects of microplastic in shellfish
Starch digestion in blue mussel Mytilus galloprovincialis exposed to microplastic particles under varied food conditions	Effects on shellfish	

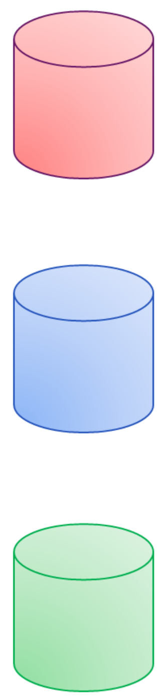

Figure 5.4. An example of the binning method. Binning allows authors to organize sources, identify sources that do not fit, and mark potential sections. To bin sources, identify common language or themes in the titles and abstracts of each source. Use color-coding or labeling to group these sources into 2 or more bins. Here, the titles have been binned into three possible sections: *Global levels of microplastics*, *Microplastic levels in shellfish*, and *Potential effects of microplastics in shellfish*. This is a thematic organization. A section on *global levels* should come before *levels in shellfish* because this orders information from broad to more specific. A section on *levels in shellfish* should come before a section on the *potential effects of microplastics in shellfish* because this orders the information from cause to effect. Titles in this figure have been used or adapted under CC-BY 4.0 (Baldwin et al., 2020; Bendell et al., 2020; Blankson et al., 2022; Kazmiruk et al., 2018; Kedzierski et al., 2019; Miller et al., 2020; O'Brien et al., 2021; Rey et al., 2021).

When binning, consider:

- You can use sources in more than one bin, or in more than one part of a paper.
- If you have more than 4-5 bins, your topic may be too broad.
- If you do not have at least 2-3 bins, your topic may be too narrow.
- If you have one bin with only a few sources, you can use this potential bin to help you find more (Chapter 3).
- If you have a bin that uses mostly secondary sources, it may not be an active area of research.
- Some sources may not fit into any bins, and therefore may not be useful to your article.

Logical methods of organizing sections and paragraphs

Once potential bins emerge, decide on a logical order for these bins using **Table 5.1** or the box on the right.

There are several logical ways to order sections and paragraphs.

For example, bins that describe "problems" should go before bins that propose potential "solutions" for the problem. Bins describing a "cause" should go before bins that describe an "effect" (**Figure 5.4**). A paper should start with older, well-known research and end with the newest research that has the most potential, yet the most unknowns.

Logical methods for ordering information:

- Problem to solution
- Older to newer
- Broader to more detailed
- Known to unknown/unclear
- Cause to effect
- Normal to abnormal
- Wildtype to mutant
- Steps in a mechanism
- Objective to method to result

5.5 End of Chapter tips: Outlining reviews

Literature reviews survey recent research for a broader audience. A well-organized review helps a reader understand the current state of this research and the next steps to address research gaps and challenges. When writing a review, use the writing process described in Chapter 1.

- Before writing, outline the paper using the heading, font, and citation requirements of the target journal.
- Use **Figure 5.1.** to outline the required moves of the paper.
- Use **Table 2.1** to begin writing these moves with signaling language.
- Find recent research in the field before deciding on content, and be open to shifting the focus of the review to reflect the research that exists.
- Use the binning and organization methods in this chapter to create section headings and paragraphs in the main text.
- Create figures and tables to compare research or conceptualize the field (Chapter 8)
- When drafting, do not worry about too style or sentence structure. Getting words on a page is important. At the revision stage, use style tips from Chapter 7.
- Keep it iterative. Remember to consistently search for relevant research, seek feedback, and revise the work (Chapters 1 and 3).

Chapter 5 Summary

Reviews are a common type of journal article that target a broader scientific audience. There are several types of reviews, but this chapter focused on the structure of a narrative literature review. Most literature reviews have an introduction, main text, and conclusion. Literature reviews comprehensively cover a topic, but they do not need to methodically survey databases like systematic and meta-analysis reviews.

The main text of a literature review should reflect a logical organization, synthesizing current research in the field. Use the methods described in this chapter to help organize sections before drafting.

Importantly, most reviews also analyze the research field to point out gaps in the research and future research needs.

Reviews also include figures and tables (Chapter 8) and abstracts (Chapter 9).

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Chapter 6. Using sources: Reading, analyzing, paraphrasing, and citing

Chapter 6 overview and objectives:

Chapter 6 explores how to read and use sources correctly.

All scientific writing contains citations, but the citation style depends on the outlet. Regardless of the citation style, the citation *conventions* are the same. This chapter uses a variety of citation styles to demonstrate citation conventions.

Scientists do not quote sources. Instead, they paraphrase and cite information concisely. Scientists cite sources to synthesize background, provide evidence, suggest additional reading, compare or critique research, and identify gaps in the field. These moves demonstrate that scientists understand the research and allow scientists to connect research through writing.

To teach you how to use sources correctly, this chapter will overview common mistakes and how to avoid them. Importantly, this chapter teaches reading *and* writing strategies because active reading is an essential part of paraphrasing and citing sources.

Before reading this chapter, you should have a strong ability to distinguish source types (Chapter 2) and navigate the structure and signals of primary and secondary articles (Chapters 4 and 5).

In this chapter, you will learn:

- How to use primary and secondary sources
- Where and when to use a citation in a sentence
- Common source-writing errors
- Methods of pre-reading (skimming) and deep-reading (analyzing)
- Methods to avoid source-writing errors (summarizing research and Figure Facts)

6.1 Choosing the right source

The most common types of sources in scientific writing are *other* types of scientific writing, such as primary research articles, preprints, reviews, or organizational reports. Sources like news articles or general websites should be avoided. Chapter 3 has information on finding sources.

Importantly, use sources differently depending on the type:

- **Cite primary research for the scientists' experiment**, such as their objective, method, result, or overall conclusion. Citing a primary article or report provides specific evidence for the reader.

- **Cite reviews or secondary sources for background,** such as well-known concepts or broad conclusions. Citing a review connects the reader to more sources on the topic.

6.2 Citing conventions

Scientists cite a lot. It is common to have several citations per paragraph, or even several citations in a sentence, especially in the introduction and discussion. In these sections, the scientists connect and summarize current research and identify remaining gaps. Citations help the scientists provide this evidence.

What needs a citation?

- Specific methods and data from other sources
- Broad conclusions, concepts, or analyses from other sources
- Background information

What doesn't need a citation?

- The objective, methods, and results of your unpublished, primary research
- Your analysis
- Topic or transition sentences that introduce cited or original data for good flow
- Common knowledge*

* Common knowledge is well-known information in the discipline that is difficult to cite.

Be careful with the term "common knowledge", because your knowledge isn't necessarily common knowledge. It's true that common knowledge doesn't need to be cited, but common knowledge may not be needed in a paper at all. For example, a scientist does not need to cite the structure of DNA because this is well-established knowledge *across disciplines*. In addition, there is no scientific writing source that would work for this task because general websites and textbooks are not appropriate sources. However, a scientist doesn't *need* to explain the structure of DNA to a scientific audience. This knowledge is so common that children learn it in middle school.

In contrast, a scientist should cite background knowledge on a specific gene and its relationship to a disease, even if this is well-established in a *field*. If it is an area of active research, it should be cited. A recent secondary source is usually appropriate for these well-known concepts. When scientists cite a secondary source for background, they are telling the reader that this information represents years of research. The citation provides the reader with another source for detailed information on these concepts. If you are in doubt about whether or not something needs a citation, you should cite it.

Citation styles

Scientific Writing uses a variety of numerical (e.g., AMA or ACS) or author-based alphabetical styles (e.g., APA).

Outlet-specific:

- Citation style

Citing conventions:

- Where to place citations
- Which sources to cite
- Why cite a source
- When to cite sources

Numerical styles are listed in the order of appearance. Numerical styles offer the advantage of cleaner sentences, focusing readers' attention on the data, not the authors. This is especially helpful when some disciplines commonly have over 5 authors on one paper.

Author-based styles list authors in alphabetical order. Author-based styles offer the advantage of connecting a scientist to a sentence by name, helping a reader learn scientists in the field.

In most styles, the citation comes before punctuation. However, some numerical styles place the citation after the punctuation. Numerical styles can use brackets [1], parentheses (1), superscripts [1], and/or hyperlinks.

Journals develop their own styles, which has led to hundreds of options. In addition, some journals tweak an existing style to make it different. For example, two journals can ask for Vancouver, but the numbers are formatted differently. This is why it is important to consult a set of formatting guidelines for a journal or outlet. This is also why a citation program makes citing easier in the sciences (Chapter 3).

Fortunately, citation *conventions* cross genres, disciplines, and outlets. So, while the style can change, citation placement remains consistent.

Citation placement

Table 6.1. demonstrates examples of citation placement.

Any sentence that uses a source should contain a citation, even if that means citing the same source twice in a row.

The most common location for a citation is the end of a sentence. However, authors can split citations in a sentence to separate information from different sources, or their work from someone else's work.

In the sciences, writers do not need to use integral-naming citations. Integral-naming citations use the authors' names at the beginning of the sentence to describe their work. There are several reasons to avoid using integral-naming citations. First, most papers list several authors. Second, the focus of science is on the data, not the ideas of the people who did the work. Third, it is difficult to achieve strong paragraph flow with authors' names at the front of a sentence (Chapter 7). However, if a writer chooses to use integral-naming citations, the citation should directly follow the name.

Table 6.1. Citation placement examples.

Sentence example (Sentences adapted and used under CC-BY 4.0 (Issa et al., 2023))	**Citation convention**
In contrast, an ecological study using migration and environmental data from 1960–2000 found that higher temperatures were significantly associated with higher emigration rates in middle-income countries [48]. In addition, higher temperatures correlated to reduced migration rates from rural to urban areas, possibly due to poverty [48].	Citations are typically placed at the end of a sentence and with the first use of a source. Citations are used twice in a row if the source is used twice in a row.
This is in certain well-established migratory corridors, such as border crossings from Mexico to the USA [8, 53, 59].	Multiple citations are placed at the end of a sentence if they contribute equally to the sentence.
For those in temporary settlements, such as camps, heat can cause direct (HRI) and indirect threats (wildfire, drought, air pollution) [78], which can be worsened by a lack of access to alleviating mechanisms such as water and shade	Citations are split to separate cited research from the authors' new research or analysis.
Indexes used to measure heat include Universal Thermal Climate Index (UTCI) [54], Neighbourhood Heat Index [61], WetBulb Globe Temperature (WBGT) [54, 64], and the Moisture Index [39, 42].	Citations are split if they contribute to specific items in a list or separate parts of the sentence.
In Australia, Baker et. al [26] found a statistically significant association between long-term exposure to extreme temperatures and out population flows in the Darling Basin.	A citation directly follows an integral-naming citation, if present.

6.3 Common mistakes when using sources

Writers commonly make mistakes when writing with sources. These mistakes include misplacing or forgetting a citation, mixing up a citation, or using a source incorrectly.

This section provides examples of using sources incorrectly. Future sections in this chapter explain how to avoid these mistakes.

There are common source-use errors that writers make:

- **Plagiarism** occurs when a writer uses the same language as the source, with or without a citation.
- **Incorrect attribution** occurs when a writer cites the wrong information from a source, attributing credit to the wrong scientists. The writer cites a primary source for information that the scientists did not find in their experiments (such as something cited to another source), OR the writer cites a secondary source for specific, cite data, rather than summarizing concepts from the secondary source.
- **Patchwriting** occurs when a writer does not paraphrase a source, and the sentence structure closely mirrors the source.
- **Sentence-mining** often occurs with incorrect attribution and/or patchwriting. In sentence-mining, a writer attempts to rewrite a sentence from the original source rather than summarizing information. This makes the sentences similar.

Did you know?

Writing mistakes can be reading mistakes!

Writers commonly make these mistakes because they cite information from the first page of an article, indicating an overall poor habit of only reading the beginning of an article rather than engaging with the research.

You can avoid most source-use errors by improving your reading skills. For that reason, later sections in this chapter will promote active reading strategies.

Table 6.2. demonstrates these mistakes, as well as an example of good paraphrasing. The table uses a modified passage from the results section of a primary research article and four sentences that cite this information.

Table 6.2. Examples of source use: common errors and solutions

Original excerpt adapted under CC-BY 4.0 (Hubbard & Dunbar, 2017):
There was a major shift in the relative importance placed on different aspects of papers, whereby undergraduate students ranked the abstract and discussion as being the most important sections, but senior researchers saw these as relatively unimportant for understanding the paper. In contrast, experienced researchers saw the Figures and Tables and Results as being the most important sections, but these were relatively undervalued by undergraduates (Fig 2B). Making sense of the results can be cognitively challenging, particularly for readers who may be unfamiliar with the terminology of the field in the Results [21].

Example writing citing source (Hubbard & Dunbar, 2017)	Correct or incorrect	Explanation
There was a major shift in the relative importance placed on different aspects of papers, whereby undergraduate students ranked the abstract and discussion as being the most important sections, but senior researchers saw these as relatively unimportant for understanding the paper (Hubbard & Dunbar, 2017).	**Incorrect**: Plagiarism	*This sentence is identical to the first sentence. This is plagiarism, even with a citation. Quotations are not allowed.*
Students may find the Results section cognitively difficult because they are unfamiliar with the technical language (Hubbard & Dunbar, 2017).	**Incorrect:** Incorrect attribution	*In the original text, this content contains the citation [21]. This means the authors of this paper did not find this information themselves. When citing primary research, only paraphrase the methods and results of the authors' experiments, not other work cited in the paper.*
Experienced researchers saw the Results as being the most important sections, but these were relatively underappreciated by undergraduates (Hubbard & Dunbar, 2017).	**Incorrect:** Sentence-mining and patchwriting	*This sentence closely mirrors one sentence in the original with only a few changes. The reader has not paraphrased this information.*
Undergraduates value the figures and tables less than academics, and value the abstract and discussion more (Hubbard & Dunbar, 2017).	**Correct:** Summary of results	*This sentence is a summary of the authors' results in the excerpt. It uses the same terminology as the original, but represents an understanding of the entire passage rather than one sentence. This is the correct use of the source.*

6.4 Reading to paraphrase

Reading for purpose

To paraphrase effectively and cite sources correctly, a scientist needs to understand the article. This requires active reading strategies.

This section focuses on techniques for reading primary research articles. Reading primary research articles is a challenge, but it becomes easier with practice. In addition, you can use the same techniques from this section to read any scientific writing. Primary research articles are the only sources of specific data and evidence, so all writers must use them.

Technically, the only “wrong” way to read a primary research article is not to read it at all. Most scientists do not read an *entire* article top to bottom. Instead, experienced readers use what they know about the structure of primary research articles (Chapter 4) to help them navigate it.

Read for what you need. For example, to learn about a method for your research, read the methods section. Reading the introduction or discussion is optional in this scenario. However, if you are a non-expert on the topic, the methods section may not make sense to you without more background reading. To find more sources on a topic, read the introduction or discussion. If you already know a lot about the topic, you might skip the introduction and focus on the figures and tables.

This is the beautiful thing about formulaic structures for scientific articles. Knowing what to expect in each section allows readers to skip around!

Reading techniques for pre-reading and analyzing research

While a reader can skip around a primary research article to meet their need, writers must analyze results if they plan to paraphrase and cite the research. The following technique breaks down the reading process into pre-reading and analysis steps.

- **Pre-reading steps** familiarize the reader with an article. It is an intentional and directed “skim”. Pre-reading also helps verify the type of article and whether or not the article fits the need.
- **Deep reading steps** promote analysis. It is a method of breaking down complicated data with active reading strategies.

To learn more about the types of analysis scientists include in writing, see Chapter 7.

Steps to reading a primary research article:

1. Pre-read.
   - Read the title and abstract.
   - Skim the article structure for essential moves, using signals as a guide (**Table 2.1**). Highlight or underline these moves (**Figure 4.1**):
     - The justification or gap in the field (End of introduction)
     - Aim, objective, or hypothesis of the current study (End of introduction)
     - Overall findings (Beginning of discussion)
   - As needed, read background information in the introduction or from other sources.
2. Deep read to analyze the results, figures, and tables.
   - Analyze each figure and table (See Figure Facts method, later in this chapter).
   - Compare the figures and tables to the text in the results.
   - Read the results and methods actively: Write in the margins. Examine controls and methods. Draw visuals to connect ideas, results, and mechanisms.
   - Read the discussion. Ask big picture questions, such as:
     - How does the new data connect to previous data?
     - Does the title accurately reflect the objective or findings?
     - Did the scientists accomplish their objective or meet their hypothesis?
     - Did the scientist use the best methods to address their questions?
     - Do the results match the overall claims and conclusions?
     - What are the limitations of the methods?
     - What future research is needed?

Watch a Video Tutorial (YouTube- 9 minutes)

Pre-reading and deep reading a primary research article: Steps and demo

6.5 Paraphrasing techniques

Overview of paraphrasing

Paraphrasing does *not* mean rewording individual sentences.

Once scientists read an article, they need to decide which information in a text is most relevant to the task. As writers, scientists use a source concisely for 1-2 sentences of information (or less). In some cases, a scientist will summarize the overall results of a research paper. In other cases, a scientist will want to use a specific data point from the text, figure, or table.

To avoid source-use mistakes (**Table 6.2**), spend time reading and analyzing an article first. This section describes two methods of writing with sources to avoid source-use mistakes: summarizing text and analyzing figures and tables with figure facts.

Both methods can be used interchangeably. Together, they focus on having the writer read and understand content before writing.

Why is paraphrasing important?

Paraphrasing shows that the scientist understands the research and which information is relevant to the task.

If a scientist sentence-mines, quotes, or uses artificial Intelligence to write, they rely on another person's or program's interpretation of the research. This can be incorrect or miss crucial connections.

Paraphrasing demonstrates critical thinking and analysis, which every scientist needs to be able to do.

Summarizing text

Summarizing is performed by reading and digesting a chunk of information, then condensing it into relevant key points. Importantly, a summary does not reword existing sentences, or use synonyms to replace essential terminology. A summary does not re-write an entire paragraph.

Instead, a true summary demonstrates that a scientist has read the article, understands the content, knows which information matches their need, and can communicate this content concisely in 1-2 sentences or less. A summary should always be less text than the original. **Table 6.2** includes an example of a paraphrased summary.

Summarizing can help avoid common errors like sentence-mining and patch-writing.
To avoid incorrect attribution with a primary research article. summarize only the Results section or Methods. Do not summarize the abstract or introduction, which rely heavily on other sources. If summarizing a review, summarize concepts or background in one section.

When summarizing...

- Actively read the original chunk of information to understand it.
- Write a summary without looking at the original.
- Summarize the most important information in 1-2 sentences (or less).
- Use important terminology or data points for evidence and specificity.

Analyzing and writing from data using Figure Facts

Figure Facts is a method of analyzing the figures or tables in a paper (Round & Campbell, 2013). In this method, the reader focuses on interpreting each figure or table rather than relying on the scientists' written interpretation in the text. This method was originally developed to help novice readers understand research. However, it can also be used to write. Using Figure Facts, it is impossible to make any of the citation errors in **Table 6.2.**

Figure Facts is an active, deep-reading strategy.

To perform Figure Facts:

1. Pre-read the article and background as needed.
2. Focus on each figure and table in the Results section without reading the results. For each figure or table, write down:
    a. What did scientists already **know** about this research?
    b. What is the **objective** of this experiment?
    c. What **method** did the scientists use?
    d. What are the **results**?
3. Compare your analysis to the written results.
4. After interpreting all the figures and tables, decide which results best fit your task. Turn these notes into cited sentences in your paper.

> Watch a Video Tutorial (YouTube – 9 minutes)
>
> Reading to paraphrase: Learn common source-use errors and methods to avoid them, including Figure Facts

Figure 6.3. demonstrates an example of Figure Facts analysis. The benefits of paraphrasing with Figure Facts include:

- The sentences are original because you describe what you see and understand, not what you read.
- The sentences avoid too much technical terminology. However, you can expand, replace, or add terms and data points after drafting a sentence.
- By analyzing a figure before reading the scientists' interpretation, you practice analyzing independently, without being influenced by the text. Scientists occasionally make incorrect statements, or point out different results than what interests you.

Figure Facts is not always the best method for analysis and writing. If you are unfamiliar with the methods, Figure Facts is more challenging. In addition, the figures and tables must be good enough that they can stand alone (Chapter 8). Poorly made visuals are more difficult to interpret without the text. In these cases, use the results section to help you understand the visuals simultaneously, or read background on these methods using other sources.

A.

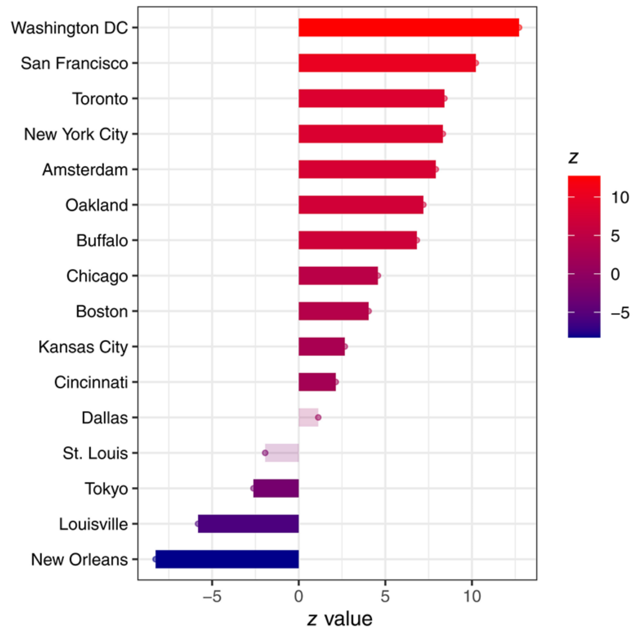

Fig. 1. Trends in rat sightings across 16 cities.
Mann-Kendall trend test statistic, estimating changes in rat numbers for 16 cities that have long-term data on public rat complaints and municipal inspections. The *z* value does not represent the raw numbers of rats observed but rather the change in these numbers over time. All cities had a significant trend (increase or decrease) except for Dallas, Texas, and St. Louis, Missouri, USA.

B.

Example Figure Facts Analysis:

Known: Rat populations are changing in cities globally.

Experimental Question: Are rat sightings increasing or decreasing over time?

Experimental Method: Statistical analysis to calculate trends over time.

Results: Washington DC and San Francisco report the highest increase in rat sightings, while New Orleans reports a decreasing trend in rat sightings based on public complaints and inspections. Dallas and St. Louis show no significant trend in rat sightings.

Example sentence(s): Over an average of 12.2 years across 16 cities, Washington DC reported the highest positive trend in rat sightings (citation).

Figure 6.3. Example of Figure Facts analysis for reading, analyzing, and paraphrasing research. **A.** Example figure and caption have been adapted and used under [CC-BY 4.0](CC-BY 4.0) (Richardson et al., 2025) **B.** Figure Facts is a method of reading and analyzing figures or tables in a paper. Before analyzing these visuals, pre-read the paper. Next, analyze one visual at a time using Figure Facts (Round & Campbell, 2013). Write down something that is known about the subject, the experimental question and method in the figure or table, and a result that you see. There may be more than one result, but note the results you find most interesting. Compare your analysis to the original text. These results can be turned into sentences that you cite in your paper. To expand these sentences, you can add more specific details and methods from the text. The example sentence was expanded with a detail about length in years.

6.6 End of chapter tips: Best practices for using sources

Before writing with sources, understand when to use sources, what to cite, and where to place citations. After learning these conventions, focus on your active reading strategies. These strategies promote better summarizing and paraphrasing.

Keep these tips in mind when using sources:

Do not…

- ⃠ Paraphrase sentence by sentence -this leads to sentence-mining. Instead, summarize large chunks of information.
- ⃠ Write while looking at the text – this leads to patchwriting or plagiarism.
- ⃠ Paraphrase by replacing language with synonyms or deleting words– this can also lead to patchwriting.
- ⃠ Do not cite information that is attributed to other studies – this leads to incorrect attribution.

Do…

- ✓ Understand the research before paraphrasing it.
- ✓ Practice active reading strategies: take notes while you are reading, analyze figures and tables, or talk out loud.
- ✓ Use Figure Facts to write what you analyze and understand, not what you read.
- ✓ Decide which information best suits your task.
- ✓ Use technical language and specific data from the source. This is evidence.
- ✓ Watch citation placement.
- ✓ Cite concisely.
- ✓ If using a primary research article, summarize the methods or results. Avoid citing information from the introduction or abstract.
- ✓ If using a review article, summarize concepts and background information.

Chapter 6 summary

Scientists cite research to demonstrate their knowledge of a topic, make connections for the reader, provide evidence, credit other scientists, and analyze the field. While citation styles depend on the outlet, scientists cite their paraphrased research using a set of conventions for when to cite, what to cite, and where to place the citations.

There are common mistakes that writers make when paraphrasing and citing sources, such as incorrect attribution and patchwriting. To avoid these mistakes, use the strategies in this chapter.

Good writing requires strong reading skills. Therefore, practice reading and analyzing articles to improve your paraphrasing. In addition, consider writing the data that you see in figures and tables rather than trying to re-word text. This improves your analysis skills while also ensuring that you put data into your own words.

To learn more about where to put analysis in writing, see paragraph structure in Chapter 7.

Chapter 6 references

Hubbard, K. E., & Dunbar, S. D. (2017). Perceptions of scientific research literature and strategies for reading papers depend on academic career stage. *PLoS One*, *12*(12).

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Chapter 7. Style conventions

Chapter 7 overview and objectives:

Chapter 7 explores style conventions and revision techniques for scientific writing.

Scientists prefer concise, specific, and formal writing. There is no need to "hook" a reader with creativity in scientific writing. The purpose of scientific writing is to inform an audience, not entertain them.

In many ways, scientific writing is formulaic. Earlier chapters described the content and structure conventions of primary and secondary writing. Similarly, style has a set of conventions.

Style conventions can be overwhelming at first, especially if you are transitioning from another writing style. Therefore, *don't* worry about style when you begin writing. When your text starts to come together, use this chapter to help you revise your style through a drafting process.

This chapter includes common style conventions, examples of common problems and solutions, and techniques for editing sentences and paragraphs.

In this chapter, you will learn:

- When to use active voice and first person
- When to use past or present tense
- How to edit for clear, concise sentences
- How to write specifically with data and key terms
- Methods for making content flow within a paragraph using key terms
- A common paragraph structure to synthesize and analyze evidence
- Types of analysis in scientific writing

7.1 Verbs

Active voice and first-person

Most students have heard that they *have* to write in passive voice and that they are *not allowed* to use first person on a lab report. There is some truth to this. If someone tells a scientist that they have to use passive voice, then they *have* to use passive voice. As we learned in Chapter 1, following guidelines is an important part of writing!

Historically, scientists used passive voice to remain impartial and objective in their writing. However, times have changed. Most modern scientific journals and writing textbooks encourage scientists to use more active voice to improve clarity. Scientific writing also allows first-person for emphasis, though not for personal beliefs.

Voice and person conventions:

- Use active voice and first-person to demonstrate something you did or found in your experiment. Use this for emphasis.
- Use active voice and first-person to provide an overview or an objective of a paper.
- Use active voice to improve clarity and simplify sentence structure.
- Use past passive voice to describe methods in the method section.
- Use passive voice when it helps flow.

Common Problems and solutions:

⃠ Qualitative and rapid ethnographic methods to explore mental health in the context of the 2019 wildfire season in Anchorage and the Kenai Peninsula in Alaska <u>were used</u> (Fig 1).

This sentence is difficult to read because the verb is in passive voice at the end of the sentence.

✓ <u>This study used</u> qualitative and rapid ethnographic methods to explore mental health in the context of the 2019 wildfire season in Anchorage and the Kenai Peninsula in Alaska (Fig 1).

✓ <u>We used</u> qualitative and rapid ethnographic methods to explore mental health in the context of the 2019 wildfire season in Anchorage and the Kenai Peninsula in Alaska (Fig 1).

✓ <u>Our study used</u> qualitative and rapid ethnographic methods to explore mental health in the context of the 2019 wildfire season in Anchorage and the Kenai Peninsula in Alaska (Fig 1).

These solutions move the verb to the front of the sentence and use active voice. Two solutions use first person.

Verb tense

Verb tense depends on the content and location.

Tense conventions in primary research: Use past tense to describe your methods and results (Chapter 4).

Past tense examples (primary):

- ✓ We observed a sharp increase under pressure for UP1dm, confirming the loss of stability from the inter-RRM salt bridges
- ✓ The pressure of UP1dm sharply increased under pressure, confirming the loss of stability from the inter-RRM salt bridges.
- ✓ A sharp increase in Rg was observed under pressure for UP1dm, confirming the loss of stability from the inter-RRM salt bridges.

All three examples use past tense to demonstrate the scientists' result in a primary research article. The first two examples demonstrate active voice. The third example demonstrates passive voice. All sentences keep one simple verb in the front half of the sentence.

These sentences were modified under CC-BY 4.0 (Levengood et al., 2024).

Tense convention when citing research: Choose present or past tense when citing other studies. The tense tells the reader how you perceive the information.

- **Past tense** indicates that the cited result is conditional or happened at one specific point in time. Past tense is an appropriate choice when citing a case study, a small study, or a study that depends on time and location. Past tense allows you to comment on the experimental conditions of that study, such as sample size. In past tense, the scientist can cite the objective, method, and/or result. To use past tense, set context with language such as "A study..." or "It has been found...".

Past tense examples (citing sources):

- ✓ Soil moisture has been shown to drive optimal sites for vector reproduction [18].
- ✓ One study found that soil moisture drove optimal sites for vector reproduction [18].
- ✓ In one case, soil was examined for nutrient and moisture levels over a two-year period [18]. Unlike nutrient level, soil moisture drove optimal sites for vector reproduction [18]. However, it is unclear if this would be true in other conditions.

The first two examples cite the result in past tense. The second example also demonstrates active voice. In the third example, multiple sentences use past tense to describe the objective, method, and result of the study. The last, uncited sentence critiques the methods.

- **Present tense** indicates that the cited result is a fact. In present tense, cite results and/or limited method, but do not cite the objective of the study. Present tense is more concise than past tense, which improves flow when creating paragraphs. Present tense also allows a more specific key term as the subject, rather than a generic word like "study".

Present tense example (citing sources):

- ✓ Soil moisture drives optimal sites for vector reproduction [18].

A sentence with present tense cites results as facts. Because it is more concise, it is easier to link together facts about soil moisture in a paragraph (see later sections flow).

Verb choice

Hedging convention: Hedge results from correlation studies. Correlation studies demonstrate a link between variables. Correlation studies are valid sources of information, but their results cannot be stated as cause and effect because they are not causation studies. Instead, use conditional language to hedge results from correlation studies. Hedging language includes words like may, could, suggest, imply, correlate, link, and risk.

Common Problem:

- ⃠ Agriculture and urbanization cause malaria [50, 51].

Solutions:

- ✓ Agriculture and urbanization correlate with cases of malaria in those regions, likely due to deforestation [50, 51].

The solution sentence hedges the result from a correlation study, more accurately describing a potential relationship between two conditions that cannot be proven through cause and effect.

Direct verb conventions: Choose single, direct verbs that demonstrate the action. Avoid using redundant or unnecessary verbs in one sentence, especially in passive voice. Often, extra verbs include or appear near verbs such as shown, found, proven, found and be/been. In addition, avoid nominalization when possible. Nominalization is the act of turning a verb into a noun.

Common Problems:

- ⃠ A study examined the evolution of antibiotic resistance and found that it occurs more readily in an immunocompromised host (32).
- ⃠ A study has been performed to show the evolution of antibiotic resistance and it found that the resistance occurs more readily in an immunocompromised host (32).
- ⃠ A study performed an analysis of the evolution of antibiotic resistance and found that the resistance occurs more readily in an immunocompromised host (32).

The problem sentences use extra verbs that are not necessary for the sentence to function (studied and shown; has been done and found). The last sentence also nominalizes the verb "analyze".

Solutions:

- ✓ It has recently been shown that the evolution of antibiotic resistance occurs more readily in an immunocompromised host (32).
- ✓ One study found that the evolution of antibiotic resistance occurs more readily in immunocompromised mice (32).
- ✓ The evolution of antibiotic resistance occurs more readily in an immunocompromised host (32).
- ✓ A study analyzed the evolution of antibiotic resistance, finding that the resistance occurred more readily in an immunocompromised host (32).

The solution sentences remove extra verbs to simplify the sentence structure, but they also demonstrate the choice of past or present tense when citing a source. The first two examples describe a result in past tense (conditional). The second sentence also includes the experimental method by mentioning the model system (mice). The third sentence describes the result in present tense (as a fact). The fourth sentence reverses the nominalization to turn "analysis" into the active verb "analyze".

7.2 Sentence structure

Scientific writing prefers simple sentence structure (**Figure 7.1A**).

Sentence structure conventions include:

- Avoiding long sentences (> 18 words)
- Avoiding semicolons to link sentences
- Avoiding embedded clauses in the middle of a sentences
- Avoiding nonspecific language or emphasizing language beyond what is necessary
- Avoiding redundancy
- Using direct and active verbs when possible
- Keeping more familiar, specific key terms at the beginning of a sentence
- Putting more difficult language, new information, or lists at the end of a sentence
- Keeping lists parallel

Concise, specific writing is clearer to the reader. Concise doesn't necessarily mean short. Concise means keeping specific language that is essential, but avoiding extra language that is not. Concise writing allows the reader to focus on the science.

Specific writing provides evidence to the reader. Evidence can come in the form of numerical data, as well as key terms. **A key term** is a specific word that is important to the topic. For example, in a sentence about deforestation in the Amazon, numerical evidence could be the rate of deforestation over time or the number of acres cleared in one region. Key terms could be a list of the most vulnerable tree species in this region.

In contrast, nonspecific language clutters scientific writing, making it less concise. Nonspecific language relates to any topic. Examples include nouns such as study, experiment, scientist, research, result, and finding, as well as adverbs or adjectives such as big, very, and extremely. Avoid an overuse of nonspecific language or emphasizing phrases like "it is important to note".

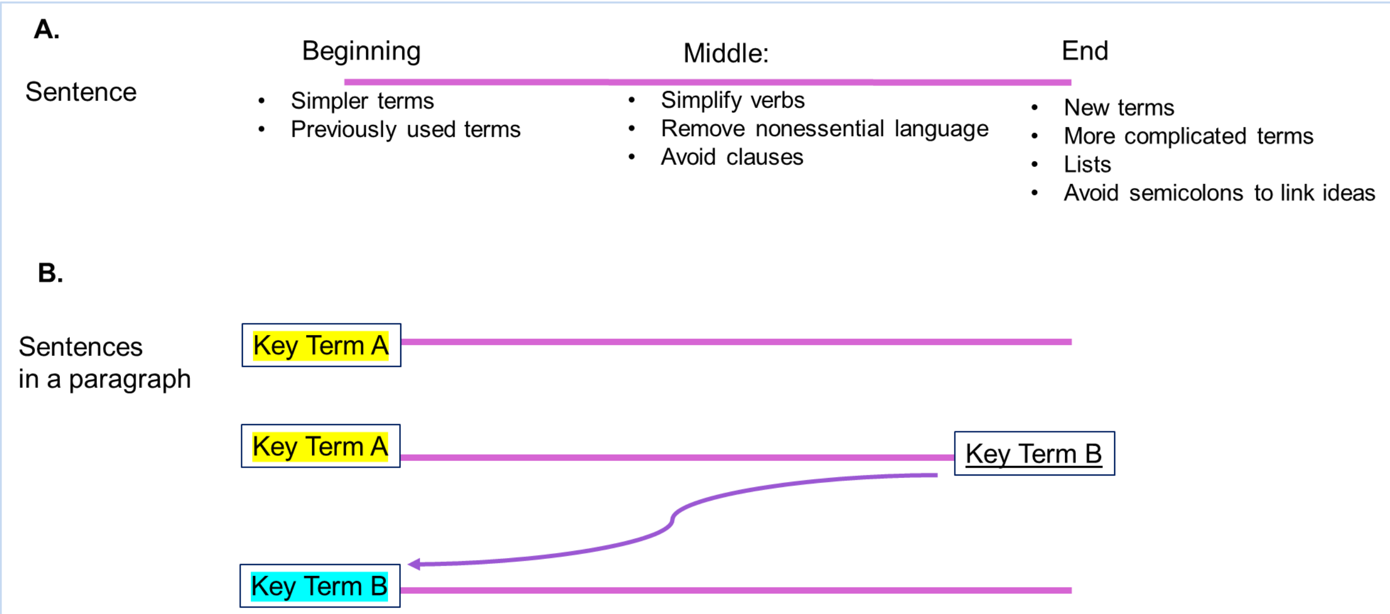

Figure 7.1. Schematic of simple sentence and paragraph structure. A. The purple line indicates a basic sentence and tips for simpler sentence structures. **B.** Multiple purple lines indicate sentences in a paragraph. Start sentences with key terms, which are specific words important to the topic and paragraph. When editing paragraphs, position a familiar key term (Key Term A in yellow) at the front of several sentences in a row. Introduce a new term (Key Term B, underlined) after and in context of Key Term A. Future sentences can use this newly familiar key term (Key Term B in blue). This improves flow and helps teach new language to a reader.

Common Problem: Nonspecific information

⃠ A projection from the *Journal of Microbiology* found that the economic impact of antibiotic resistance will cost the health care system a lot of money in the future (30).

This sentence contains excess and nonspecific information. It lacks evidence. The place of publication does not affect the result, and "a lot of money in the future" is not specific in amount of money or time.

Solutions:

- ✓ The economic impact of antibiotic resistance is estimated to surpass US$1 trillion in health care costs by 2050 (30).
- ✓ Projections predict that the economic impact of antibiotic resistance will surpass US$1 trillion in health care costs by 2050 (30).

The solutions avoid nonspecific information and add evidence through specific, cited data. The first solution uses passive voice, and the second solution uses active voice. In this case, choose the solution that promotes flow within the paragraph.

Common Problems: Long, unclear sentences with complicated structure

⃠ In the late bell stage, hard dental tissues form through the processes of amelogenesis for the enamel, dentinogenesis for the dentine, and cementogenesis for the cementum, which, in essence, consists of the deposition of cell layers and their posterior mineralization [5].

Solutions:

✓ In the late bell stage, hard dental tissues form through the deposition of cell layers and their posterior mineralization [5]. The processes that form these tissues include amelogenesis for the enamel, dentinogenesis for the dentine, and cementogenesis for the cementum [5].

The solution addresses several conventions:

1. *Avoiding long sentences (> 18 words)*
2. *Avoiding embedded clauses in the middle of a sentence*
3. *Putting lists at the end of a sentence*

Common Problems: Unparallel lists

⃠ A single swab method was used whereby a small aliquot of sterile water was deposited on one side of the swab, then rubbed against the stain, and finally the dry side of the swab was used.

Solutions:

▶ A single swab method was used whereby a small aliquot of sterile water was deposited on one side of the swab, rubbed against the stain, and rotated to use the dry side of the swab.

The solution keeps the items in the list parallel and at the end of the sentence. Parallel items start with the same type of grammar, such as a list of nouns or a list of verbs.

Common Problems: Using unfamiliar or nonspecific information at the beginning of a sentence.

⃠ As Zaitchik et al., [38] mentioned, the probability that mosquitoes will be found in a potential breeding site decreases with high temperatures. This is because too-warm conditions would bring disruption to some important life cycle phases of vector development. For example, Pathak et al. [39], showed that increasing temperatures (>28˚C) were detrimental to Plasmodium falciparum declines as well, due to the decrease in the mean proportion of mosquitoes infected with oocysts, and infectious with sporozoites.

Solution:

✓ The probability that mosquitoes will be found in a potential breeding site decreases with high temperatures [38]. High temperatures would bring disruption to some important life cycle phases of vector development. In one study, for example, higher temperatures (>28˚C) correlated with a decline in Plasmodium falciparum [39]. This was likely due to the decrease in the mean proportion of mosquitoes infected with oocysts and infectious with sporozoites [39].

The solution addresses several conventions:

1. Keeping more familiar, specific key terms at the beginning of a sentence *(high temperatures)*
2. *Avoiding integral-naming citations when possible because they disrupt flow (Chapter 6)*
3. *Avoiding long sentences (> 18 words)*

7.3 Paragraph structure and flow

Paragraph content and flow

Scientists gather data from several places and weave it together concisely in a paragraph. How do scientists edit for paragraphs that flow?

Paragraph flow improves with several conditions, including simple sentence structure (this chapter), transition phrases, and signaling (Chapter 2). However, to intentionally connect information in a paragraph, the content has to have something in common to begin with. The easiest way to achieve flow is with a common key term or concept that ties the information together.

Figure 7.1B contains a schematic of flow in a paragraph. In short, familiar key terms should be at the front of the sentence. Remember that a key term is a specific term (Chapter 7.2). These terms could be the subject, the object of a preposition, in a dependent clause, or referred to by a pronoun or alternative name. A key term should be repeated in several sentences before switching to a new key term. To use a new key term, position it *after* the familiar key term. This connects two terms, teaching that connection to the reader.

Common Problems: Lack of flow

- ⃠ The heterogeneous nuclear ribonucleoprotein A1 (hnRNP A1) is a ubiquitous RNA binding protein that regulates RNA metabolism under normal and pathological cellular conditions. Transcripts are synthesized, processed to maturity, exported from the nucleus and translated into protein products, all while engaging with hRNPA1. There are multiple structures of the UP1 domain, which suggests different functions of the hnRAP A1 protein in RNA and DNA recognition. Scientists believe the protein may bind to various targets via idiosyncratic mechanisms.

This problem paragraph does not flow. Each sentence starts with a different key term (highlighted in a different color).

Solution:

- ✓ The heterogeneous nuclear ribonucleoprotein A1 (hnRNP A1) is a ubiquitous RNA binding protein that regulates RNA metabolism under normal and pathological cellular conditions. As a general regulator of RNA, hnRNP A1 engages with transcripts from the moment they are synthesized, processed to maturity, exported from the nucleus, and translated into protein products. Efforts to understand the functions of hnRNP A1 have led to multiple **structures** of its UP1 domain, each showing different mechanisms of RNA or DNA recognition. These structures suggest that the protein binds its various targets via idiosyncratic mechanisms.

The solution paragraph has more flow (Figure 7.1B). While the information is the same in both paragraphs, the first few sentences in the solution begin with the same key term (hnRNP A1), which links facts about this protein. Towards the end of the paragraph, a sentence introduces a *new key term (structure) in the context of hnRNP A1. The new key term (structure) begins the subject of the next sentence. This connects the key terms hnRNP A1 and structures for flow.*

These sentences were modified under [CC-BY 4.0](CC-BY 4.0) (Levengood et al., 2024).

Paragraph structure

Using key terms, scientists can connect data from their own work or different sources to craft strong paragraphs that flow. Paragraph structure also helps strengthen this connection.

Before reading this section, you should have a solid understanding of the moves and signals in scientific writing (Chapters 2, 5, and 5). Chapter 5 also discussed techniques for logically ordering information in a section, which is useful for ordering information in a paragraph as well (see right-side box).

From Chapter 5:

Logical methods for ordering information:

- Problem to solution
- Older to newer
- Broader to more detailed
- Known to unknown/unclear
- Cause to effect
- Normal to abnormal
- Wildtype to mutant
- Steps in a mechanism
- Objective to method to result

Figure 7.2 provides a basic, default paragraph structure in the sciences. This type of default paragraph structure can be used in the introduction, main text, discussion, or conclusion of an article.

In the default paragraph structure, a topic sentence introduces the key term that will bring content together in the paragraph. This topic sentence can be cited or uncited.

The middle of the paragraph is the most detailed. These sentences connect evidence (primary data or cited data) related to the key term.

If the scientists analyze the research, they place this brief, uncited analysis after the evidence, often at the end of the paragraph. This broadens the scope of the research.

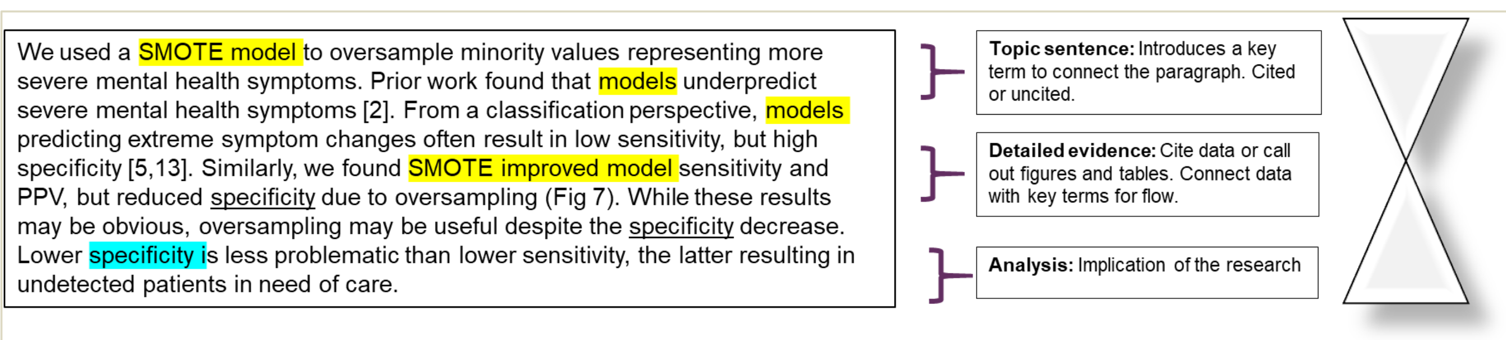

Figure 7.2. Example of paragraph structure with evidence. A common paragraph structure follows an hourglass. It begins with a topic sentence with a key term (highlighted yellow- SMOTE/models). This sentence may be uncited or cited information. The paragraph continues with detailed evidence (cited or uncited primary data). These middle sentences continue to use the key term (SMOTE) before introducing a new key term (underlined and in blue- specificity) (Figure 7.1.B). Analysis follows evidence as an uncited sentence. Example text has been adapted and used under CC-BY 4.0 (Adler et al., 2022)

Adding analysis to paragraphs

Many paragraphs end with analysis in a clause or sentence after the evidence. Analysis is not the same as a summary. A summary sentence simply restates or concludes information in the paragraph. This should be avoided in scientific writing because it is redundant. In contrast, analysis sentences demonstrate that the scientist has critically assessed their data, other sources, or the field.

This level of analysis depends on the section of a paper (**Table 7.2.)**. While analysis should be present throughout a paper, analysis is not required in every paragraph. Original analysis should be intentional, uncited, and concise (1-2 sentences).

Examples of analysis include:

- Interpretation of data
- Comparison of methods and results between studies or experiments
- A limitation in the method or overall experimental design
- An unknown or challenge in the field
- Future research need
- Conflicting data
- Unexpected results
- Potential mechanisms
- Potential applications
- Recommendations for professionals
- Implications or broader impacts of the findings

Table 7.2. Analysis in scientific writing varies by location

Types of analysis	Examples of locations
Interpretation of a figure, table, or calculation	Results section of a primary research article
Analysis of the field	Introduction, Discussion, Conclusion of any article
Analysis of a cited study	Any section of any article
Analysis of the authors' primary data in the context of cited data	Results and Discussion sections of a primary research article

7.4 End of chapter tips: A style revision checklist

Revision should happen recursively throughout the writing process. Consider tracking changes, leaving comments, and saving new versions of the paper. This helps you see your editing process and return to earlier drafts when necessary.

When revising for style, pick a few goals to work on at a time. You can use this summary as a checklist from Chapter 7 to help you revise. Practice self-identifying items from the checklist that you'd like to work on:

- ✓ Verbs:
  - Choose active verbs and first person when possible
  - Avoid nominalization
  - Simplify verb choice
- ✓ Simplify sentence structure
  - Avoid long sentences over 18 words
  - Avoid semicolons to link sentences
  - Avoid complex sentences with embedded clauses
  - Keep lists parallel, and at the end of a sentence
  - Keep complex information or new terms at the end of the sentence
  - Keep the subject and verb close together
- ✓ Write concisely, yet specifically
  - Avoid nonspecific language
  - Avoid emphasizing language
  - Include specific key terms and data points
- ✓ Paragraph structure
  - Connect sentences with common key terms
  - Position familiar key terms at the beginning of the sentence choice
  - Position analysis after cited or original evidence

Chapter 7 summary

In the sciences, style isn't a matter of what *sounds* right. Style is about following conventions.

The style conventions in scientific writing help authors write clearly, specifically, and concisely. These conventions also help scientists form evidence-based paragraphs. To connect information in a paragraph, reuse key terms from related studies or evidence.

Each writer has a unique style, and therefore a unique set of style goals to improve their writing. Practice identifying your individual style goals as you revise. Peer review can also be helpful in this process to obtain feedback on clarity and audience level.

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Chapter 8. Figures and Tables

Chapter 8 overview and objectives:

Chapter 8 explores figures and tables in scientific writing.

Figures and tables are as essential to scientific writing as the writing itself. These visuals provide evidence, clarify concepts, and demonstrate relationships. There are several types of visuals that scientists use to support their writing.

In this chapter, you will learn:

- How to choose the best figure or table for the need
- How to call out a figure or table in the text
- Conventions for formatting figures
- Conventions for formatting tables
- Tools for creating visuals

8.1 Choosing the best visual for the task

Visuals serve different needs in a scientific paper. **Table 8.1.** lists examples of figures and tables in scientific writing, as well as their purpose.

Sometimes, a visual displays information or data in its original format, such as a photograph of a crime scene or a western blot image. However, scientists often choose the type of visual based on what they want the data to show.

Consider the scenario where you have numerical data from several trials or conditions. You have a choice in how you visualize that data.

- **Choose a table** to compare data numerically. Tables allow the reader to see specific numbers, statistics, and variables.
- **Choose a graph** to demonstrate a trend or relationship across data sets. Most graphs do not allow the reader to extract specific numbers.

Follow formatting requirements

This chapter describes conventions for figures and tables, not rules. Design visuals according to the formatting requirements of your target outlet or assignment.

If using a graph to demonstrate trends, consider the type of graph that most accurately shows this trend. For example, a bar graph demonstrates overall trends, which works well if all the data points cluster together. In contrast, a scatterplot reveals the scope of individual data points, which can visualize outliers or different populations within a data set. To see which graph accurately and clearly displays the data, put the data into a spreadsheet and explore graph types before making a final choice.

Regardless of type, **all figures and tables must be able to stand alone**. This means that the visual needs enough information in the title, caption, and/or labels for the reader to analyze them without reading the text (Chapter 6-Figure Facts). Important information could include:

- Objective of the experiment
- Detailed method and conditions
- Labels or keys
- Acronyms
- Statistical information
- Citations (if necessary)

Table 8.1. The purpose of figures and tables in scientific writing

Type of visual	Purpose
Diagram	Visualize equipment or location.
Reaction	Demonstrate process.
Timeline or pedigree	Demonstrate connections and relationships over time.
Flowchart or concept map	Visualize steps in a process, cause and effect, or a relationship.
Map	Visualize location, method, or relationship.
Graph or chart	Demonstrate relationships or trends across variables.
Model	Display examples or hypotheses.
Photograph	Display raw data, methods, location, or equipment.
Spectrum or structure	Display data.
Table	Compare quantitative or qualitative data or terms.

8.2 Integrating figures and tables

All figures and tables must be called out in order of appearance at least once in the text. They can be called out as part of the sentence, or in parentheses at the end of the sentence.

For example:

- As shown in Fig. 3A, our silicon photonic DP-MZM has four carrier-depletion–based EO phase modulators (in yellow) along with several TO phase shifters (in green).
- As Fig. 3B shows, our SSB modulator is packaged both optically and electrically, with a fiber V-groove array.
- The doped regions of silicon in the carrier-depletion–based EO phase modulators are 1.55 mm in length (Fig. 4).

These sentences have been adapted and used from a primary research article under CC-BY-NC 4.0 (Kodigala et al., 2024).

Calling out a figure or table provides evidence in a sentence, but it also refers the reader back to the visual for more data. These sentences connect the figure or table with a brief interpretation of the experiment.

A sentence that calls out a figure or table must also include some of the information from the visual, such as the method, result, or terms. Choose key points or data to include in that sentence, but do not list *all* the data from a visual in the text.

8.3 Figure Conventions

Figures visualize concepts or methods (**Figure 8.1**.) or present data and relationships as evidence (**Figure 8.2**). Journals and rubrics have specific formatting requirements for figures. However, generic conventions for designing figures can be used across disciplines.

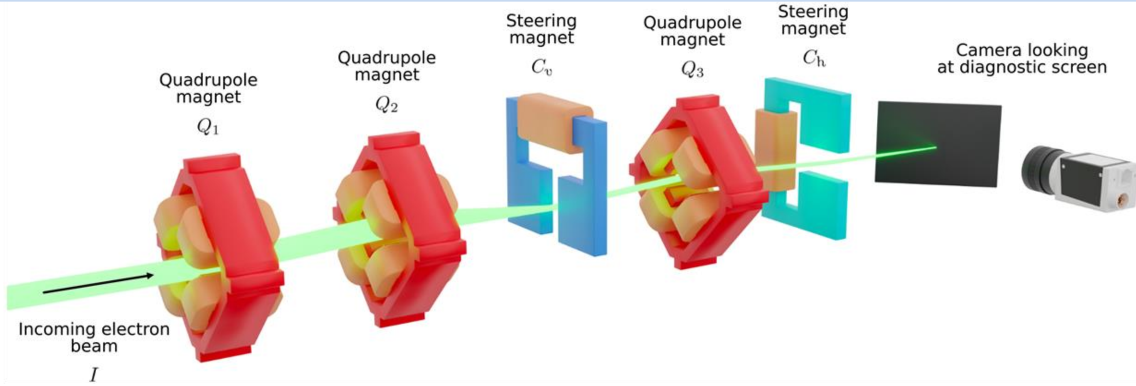
Figure conventions include these parts:

- A **title** is an incomplete sentence that states the objective and method of an experiment or an overall result (**Figure 8.2**). Titles usually appear below figures.
- A **caption (or legend)** is a brief description of the figure that comes after the title. A caption should use complete sentences. For data-containing figures, the caption should include enough method to understand the experiment without reading the text (**Figure 8.2**). The caption does not need to interpret the result of the figure. For concept-based figures, the caption should overview the information with key terms (**Figure 8.1**).
- **Keys, labels, and/or statistics** can be part of the figure or in the caption (**Figure 8.2**).
- **Citations** are necessary if the figure contains data or concepts from another source, or if the figure itself comes from another source. Place citations in the caption.
- **Panels** separate one figure into 2 or more smaller figures (**Figure 8.2**). Each panel is labeled with a letter that corresponds to the caption. Use panels when several individual experiments connect to a larger experimental objective.
- **Graph design (if applicable)** should include the dependent variable on the Y axis and the independent variable on the X axis.

These conventions apply to figures in written communication, such as journal articles or dissertations. However, scientists can use the *same* figure in other types of scientific communication with slight adjustments.

For example, a poster is a type of written and oral communication (Chapter 10). A scientist can use the same figure in an article and on a poster. In an article, this figure will have the title and caption below it. In contrast, posters are more visual. On a poster, titles can go above or below the figure, and the caption is generally shorter. This promotes visual appeal with less text because the scientist can explain details orally.

In an oral presentation, a scientist can use the same figure again, but the title appears on the top of the slide so the audience can see it easily. Because the scientist will explain each slide, the figure can contain keys, statistics, or labels, but no caption.



Title (below) is an incomplete sentence describing the image..

Caption or legend (below) connects specific terms, identifies terms, and includes citations (as needed).

Fig. 4. Schematic of the experimental area section of the ARES linear particle accelerator. Quadrupole magnets are shown in red; the vertical and horizontal dipole are shown in blue and turquoise, respectively. The electron beam is shown as a green envelop passing through the magnets and onto the screen at the end of the experimental area.

Figure 8.1. An example figure visualizing method. Authors can use diagrams, schematics, flowcharts, and models to visualize complicated concepts, methods, or equipment. At a minimum, the figure should include a title and caption below the image. If citations are needed, place them in the caption. Example has been adapted and used under CC-BY 4.0 (Kaiser et al., 2025).

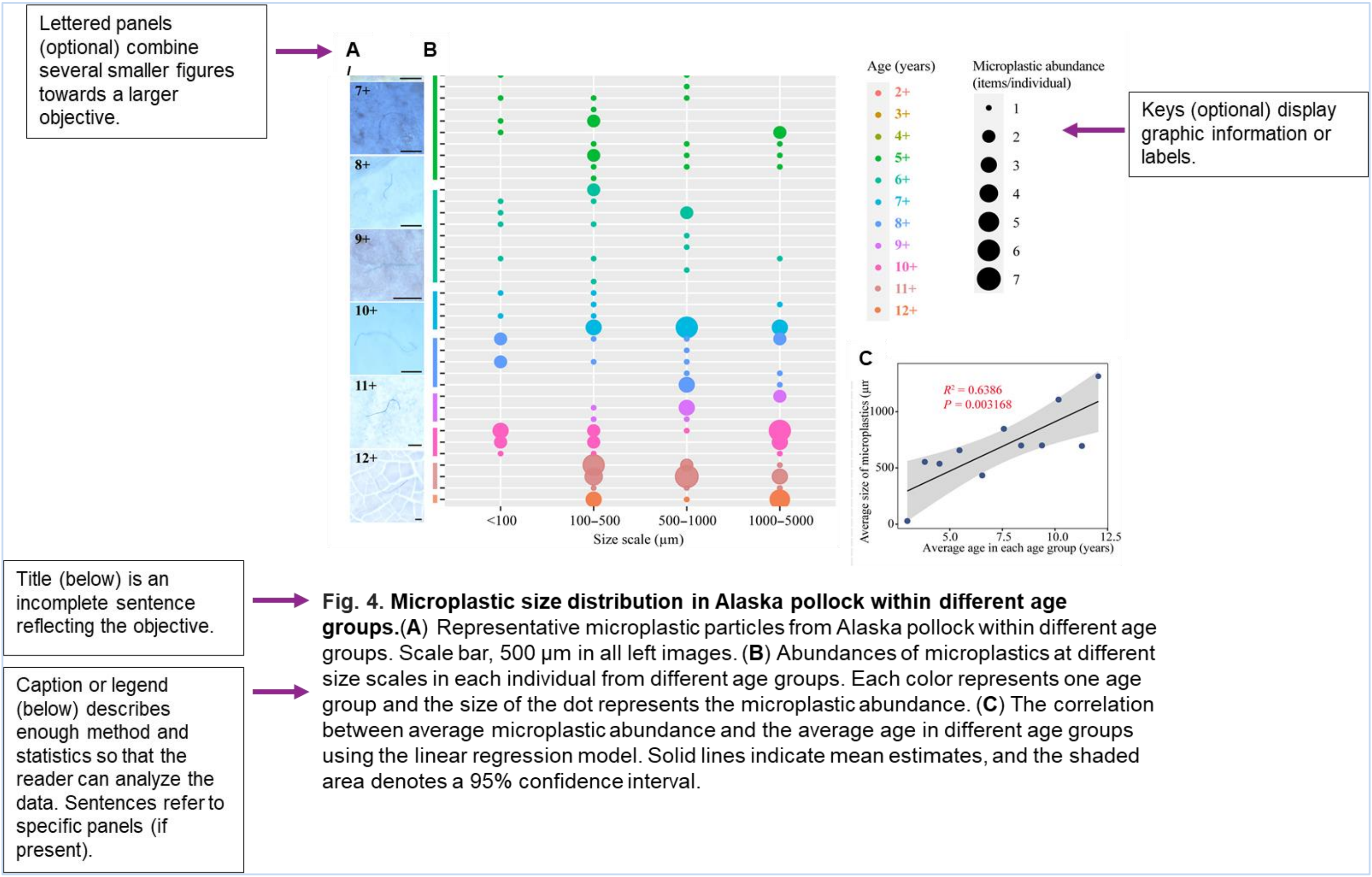


Figure 8.2. An example figure containing data. Primary research articles usually have several figures to display data. Graphs are an appropriate choice when the author wants to display trends, not specific numerical values. At a minimum, figures should include a title, a caption describing the method, and appropriate labels. Some figures include panels and keys, as shown here. This figure has been adapted from a primary research article under [CC-BY-NC 4.0] (Ding et al., 2023).

8.4 Table Conventions

Tables compare information quantitatively and/or qualitatively, making them a versatile and popular visual in reviews (**Figure 8.3**) and primary research articles (**Figure 8.4**). The following list provides a generic set of conventions for designing tables that can be used across disciplines.

Table conventions include:

- A **title** is an incomplete sentence that describes the objective or method for data-containing visuals (**Figure 8.4**). Titles usually appear above tables.
- **Keys or Statistics** can be included under the table in incomplete sentences or a smaller font (**Figure 8.4**), if necessary. Tables should not have captions like figures. Instead, as much information as possible should be present in the headings and title.
- **Citations** are necessary if the table contains data from another source. The most common place to put citations is in a column where each row corresponds to a source (**Figure 8.3.**).
- **Table design (if applicable)** includes columns in the order of the scientific method: objective, method, result. If there is an independent variable, it usually goes in the first column.

Title (above) is an incomplete sentence reflecting the objective.

Column cites references compared in the table

Columns place information in the order of objective, method, and result/implication (if present).

Table 2 Heat wave mitigation potential of various green infrastructure and blue infrastructure strategies

Location	Strategy	Scale	Mitigation potential	References
Melbourne, Australia	Doubling the city's vegetation coverage	City	Reduction in the heat-related mortality rate ranging from 5 to 28%	[116]
Phoenix, US	Urban vegetation increased by 5, 10, 15, and 20%, respectively	City	Reduction of 17, 35, 53, and 70% in emergency calls related to heat respectively	[84]
Sydney, Australia	Planting of an additional 2 million trees	City	Reduction in peak daily temperature by as much as 1 °C, Reduction in excess heat-related morbidity from 3.7 hospital admissions per day to approximately 2.6 per day per 100,000 inhabitants.	[117]
293 Cities from Alps, British Isles, Eastern Europe, France, Iberian Peninsula, Mediterranean, Scandinavia, Turkey	Urban trees	City	2–4 times cooling potential than tree-less urban green spaces	[114]
Washington DC, US	Additional vegetation	City	Reduction in surface air temperature within urban street canyons by 4.1 K. Reduction in road-surface temperatures by 15.4 K, and building-wall temperatures by 8.9 K during heat wave days.	[111]
Chicago, US	Green roofs	Metropolitan area	Reductions in cooling energy consumption by 14.0%	[118]
Trondheim, Norway	Urban greening	Building	28.5% decrease in cooling energy demand compared to no greenery scenario.	[119]
Karachi, Pakistan	Water bodies on an isolated street	Urban Area	Reduction in ambient air temperature by 0.9 °C and surface temperature by 3.5 °C, improved wind velocity.	[112]

Figure 8.3. An example table from a review. Reviews often include tables to compare methods and/or results across studies cited in the paper. Tables can contain numerical information and/or qualitative information. At a minimum, these tables must have a title, as well as a column to cite references used in each row. Example has been adapted and used under CC-BY 4.0 (Joshi et al., 2024)

Title (above) is an incomplete sentence reflecting the objective.

Specific headings label the columns and rows.

Table 7 IRR of consuming each sugary drink type (for perceived healthiness) and any sugary drink (for social norms) in the past 7 days

		Australia[a]		**Canada**		**Mexico**		**UK**	
		IRR(99%CI)	***p***	**IRR(99%CI)**	***p***	**IRR(99%CI)**	***p***	**IRR(99%CI)**	***p***
Perceived healthiness[b](ref = not unhealthy)	Regular soft drinks (*n* = 70 367)	0.55 (0.46;0.65)	< 0.001	0.55 (0.46;0.65)	< 0.001	0.77 (0.73;0.82)	< 0.001	0.58 (0.49;0.69)	< 0.001
	100% juice (*n* = 8577)	0.58 (0.43;0.78)	< 0.001	0.44 (0.34;0.57)	< 0.001	0.72 (0.60;0.86)	< 0.001	0.52 (0.39;0.68)	< 0.001
	Diet soft drinks (*n* = 8704)	0.39 (0.23;0.67)	< 0.001	0.36 (0.21;0.61)	< 0.001	0.43 (0.28;0.68)	< 0.001	0.41 (0.28;0.60)	< 0.001
	Energy drinks (*n* = 8406)	0.67 (0.19;2.41)	0.423	0.33 (0.07;1.66)	0.077	0.59 (0.29;1.21)	0.058	1.10 (0.26;4.65)	0.862
	Sports drinks (*n* = 8009)	0.27 (0.13;0.54)	< 0.001	0.38 (0.18;0.80)	0.001	0.46 (0.34;0.64)	< 0.001	0.64 (0.29;1.40)	0.144
	Chocolate milk (*n* = 8048)	0.71 (0.39;1.29)	0.143	0.79 (0.48;1.30)	0.219	0.57 (0.39;0.83)	< 0.001	1.36 (0.70;2.64)	0.234
	Iced tea (*n* = 8094)	0.33 (0.17;0.62)	< 0.001	0.67 (0.38;1.20)	0.079	1.03 (0.75;1.42)	0.796	0.96 (0.47;1.95)	0.871
Social norm[c] (ref = not agree)	Descriptive norm (*n* = 54 438)	0.73 (0.67;0.80)	< 0.001	0.77 (0.71;0.84)	< 0.001	0.91 (0.87;0.96)	< 0.001	0.81 (0.74;0.89)	< 0.001
	Injunctive norm (*n* = 54 438)	0.84 (0.77;0.92)	< 0.001	0.95 (0.88;1.04)	0.142	0.95 (0.90;1.00)	0.007	0.90 (0.82;0.99)	0.005

Abbreviations: *UK* United Kingdom, *US* United States, *IRR* Incident risk ratio, *CI* Confidence interval

[a] Each model was adjusted for year and sociodemographic variables including age, ethnicity, sex, perceived income adequacy, education, and the presence of a child under 18 at home

[b] These models examined the association between perceived healthiness toward each drink category and the intake of each drink category in the past 7 days

[c] These models examined the association between social norms and the intake of any sugary drink in the past 7 days

A key define acronyms, statistics, or conditions if needed. Tables do not require captions.

Figure 8.4. An example table from a primary research article. Tables can compare quantitative or qualitative information from methods or results. Tables are the best choice for comparing results with specific numbers, opposed to graphs that display trends. Tables must include enough information so that the reader can analyze the data without reading the text. At a minimum, this means tables include a title and specific headings. Some tables will also include keys at the bottom with additional information, though these are not always required. Most tables do not have detailed captions. Example has been adapted and used under CC-BY 4.0 (Drolet-Labelle et al., 2025)

8.5 Creating original figures and tables

There are a variety of programs that can be used to create visuals depending on experience and availability. Some programs are commonly installed in computers or available for free, but software can be purchased for more complicated tasks. For example, scientists can:

- Create tables with Word or Google Docs
- Create images, diagrams, or flowcharts with programs such as PowerPoint, Canva, Adobe, and BioRender
- Create chemical structures with programs such as SciFinder's Chemdraw
- Create graphs with programs such as Excel, GoogleSheets, Tableau, OriginaLab, GraphPad, R, and Python

Scientists often create original figures and tables for their work, rather than using a figure or table that already exists. However, there are times when a scientist wants to reuse a previously published figure or table. Before doing that, check the copyright license of the original source and gain permission if needed. The original article should be attributed in the caption and the reference list. Scientists can also use an open-source image (such as a map) and overlay data on top of this image. In this case, the scientist can usually name the necessary programs or image source in their caption (not the reference list).

8.6 End of chapter tips: Using visuals to tell the research story

Scientists make figures and tables throughout their research projects. These visuals are used in several communication genres, including presentations, grant proposals, and manuscripts. While the titles, formatting, or captions may need to be re-formatted for each communication, the basic schematic, graph, or table can be used across genres.

By creating figures and tables as you perform research, you can think about your research visually before writing a primary research article.

Figures and tables do not need to appear in the same order in which the experiments were done (Chapter 4). Instead, order the figures and tables to tell a research story. It is easier to write the results section of a paper *after* creating visuals and deciding on the best order. The earliest visuals usually describe background knowledge or data, such as controls, demographics, and methods. As the paper continues, the figures and tables provide more insight with detailed results or potential mechanisms.

You can use the following tips to help you create figures and tables during the scope of your research project:

- Look at example visuals in the papers you are reading. This can help you generate ideas for your own work.
- Choose the best visual for your task (**Table 8.1**). Consider: what do you want the reader to see?
- Make figures and tables as you design experiments and collect data.
- Ask others to give feedback on your visuals without reading your text. This lets you know if the visuals they can stand alone.
- Use programs to design figures and tables.
- After finishing figures and tables, decide on the order that will best support your hypothesis or objective. This may not be the same order in which you did the experiments. Write results that calls out your figures and tables in this order.
- Format final figures and tables to match your outlet's requirements.

Chapter 8 summary

Figures and tables are essential components of all scientific writing and communication. Scientists demonstrate concepts and methods using infographics, flowcharts, or models. Scientists also present original or cited data in graphs, tables, and images.

Visuals often follow scientific conventions for content, though formatting rules can be outlet-specific. Creating visuals early in the research process can help you reflect on your data and write about data continuously (Chapters 1 and 4).

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Chapter 9. Abstracts

Chapter 9 overview and objectives:

Chapter 9 explores abstracts in scientific writing.

An abstract concisely overviews the information in a manuscript, poster, conference presentation, or grant. Abstracts serve an important purpose in scientific writing. A good abstract makes a good first impression so that potential audiences want to learn more.

Most journal articles have abstracts, and most readers skim abstracts before deciding whether or not to read the full article. In addition, scientists often submit abstracts to conferences if they want to give an oral or poster presentation, making the abstract a gateway to that conference.

In this chapter, you will learn:

- General rules and tips for writing abstracts
- Content in primary research abstracts
- Content in literature review abstracts
- Content in structured abstracts (popular for articles such as systematic reviews and clinical trials)

9.1 General rules for abstracts:

Most abstracts follow strict requirements for word count and content, set by the outlet or conference. To stay concise, follow these general rules:

- Adhere to the word count limits and formatting requirements of the outlet
- Follow the general structure of the paper
- Focus on major findings
- Avoid abbreviations and definitions beyond the first sentence, unless essential
- Avoid citations, unless allowed

Abstracts generally follow moves for primary research (Chapter 4) or review articles (Chapter 5), and can use the same signals (Chapter 2). An abstract is a miniature version of the work itself (**Table 9.1**). For that reason, scientists should draft an abstract towards the end of a research or writing process.

Table 9.1. Basic content in an abstract

Primary Research Abstract	**Secondary (literature review) abstract**
Background and relevance	Background and relevance
Justification (gap or need in the field)	Justification (gap or need in the field)
Objective of the research	Overview of the paper and major findings in the field
Method	Future implications
Specific results	
Future implications	

9.2 Primary abstracts

A primary research abstract is appropriate for a primary research article, poster, or oral presentation that presents original work.

This chapter focuses on a generic, descriptive structure that can be used for any purpose. Some scientists choose a narrow abstract structure that only details the methods and results of the research, with little emphasis on the background, justification, or implications. A narrow abstract is only appropriate for niche audiences. In contrast, the descriptive structure described in this chapter is more appropriate and accessible for general scientific audiences and conferences.

When drafting a primary abstract, start with a sentence to represent each of the required moves in **Table 9.1.** Use signaling language (**Table 2.1.)** to draft these moves. Once these moves are in place, fill in any remaining space with more specific methods, terms, and data points from the experiments. This information should take up the majority of the space within the middle of an abstract.

Figure 9.1. contains an example of the moves from **Table 9.1.**

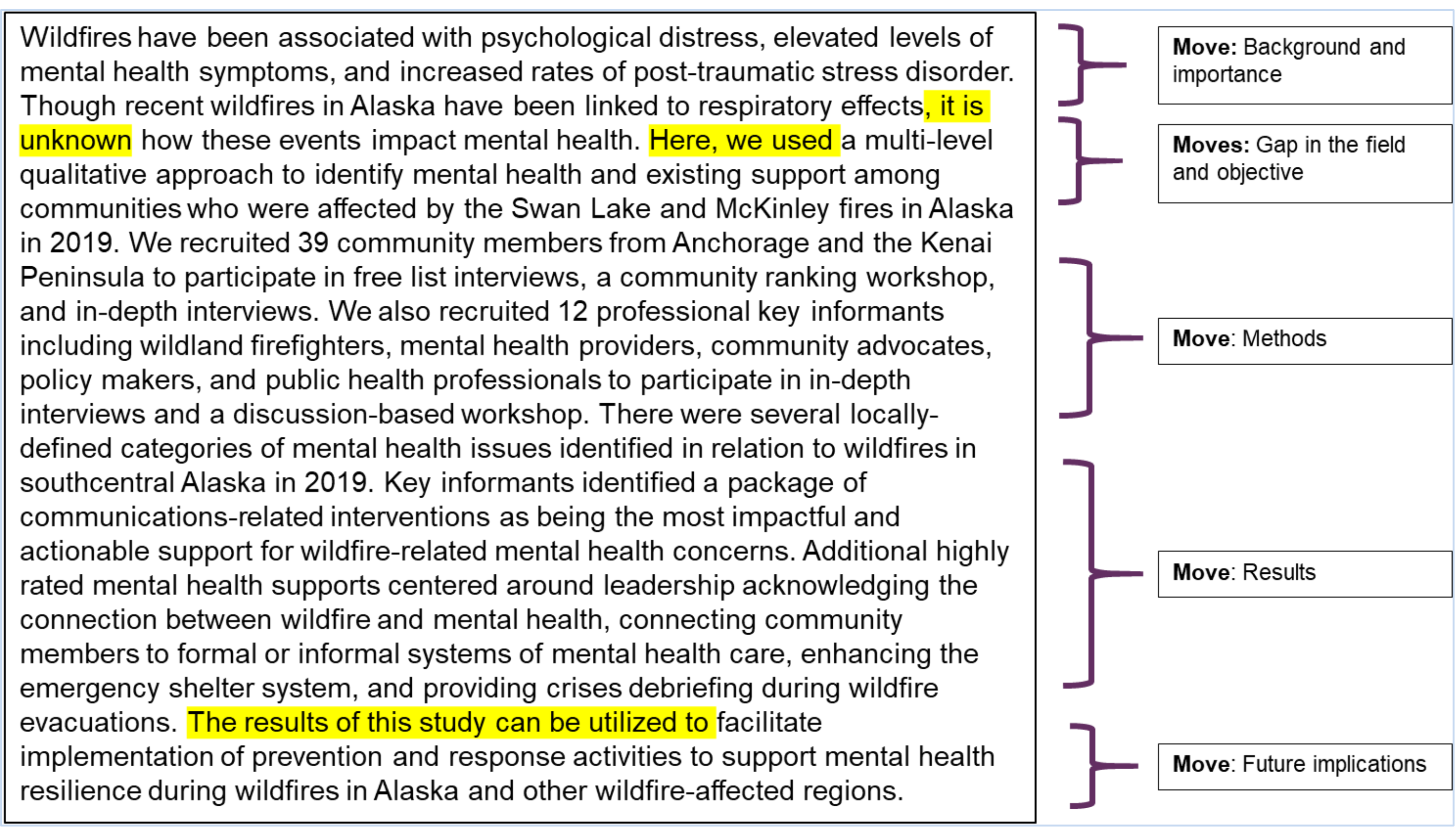

Figure 9.1. Example of a descriptive abstract from a primary research article. This abstract uses the moves from **Table 9.1.** and signaling language from **Table 2.1.** (yellow highlighting). Notice that the abstract contains specific numbers and terms to represent the methods and results of the study. Example has been adapted and used under CC-BY 4.0 (Hahn et al., 2023).

9.3 Narrative review abstracts

Literature reviews use a basic narrative structure for their abstract (**Table 9.1**). This structure mirrors the overall structure of the reviews described in Chapter 5. **Figure 9.2.** contains an example of these moves with common signaling language.

Because abstracts typically do not have citations, authors should avoid specific data points in literature review abstracts. Instead, summarize the main findings in the field using specific terminology from the paper.

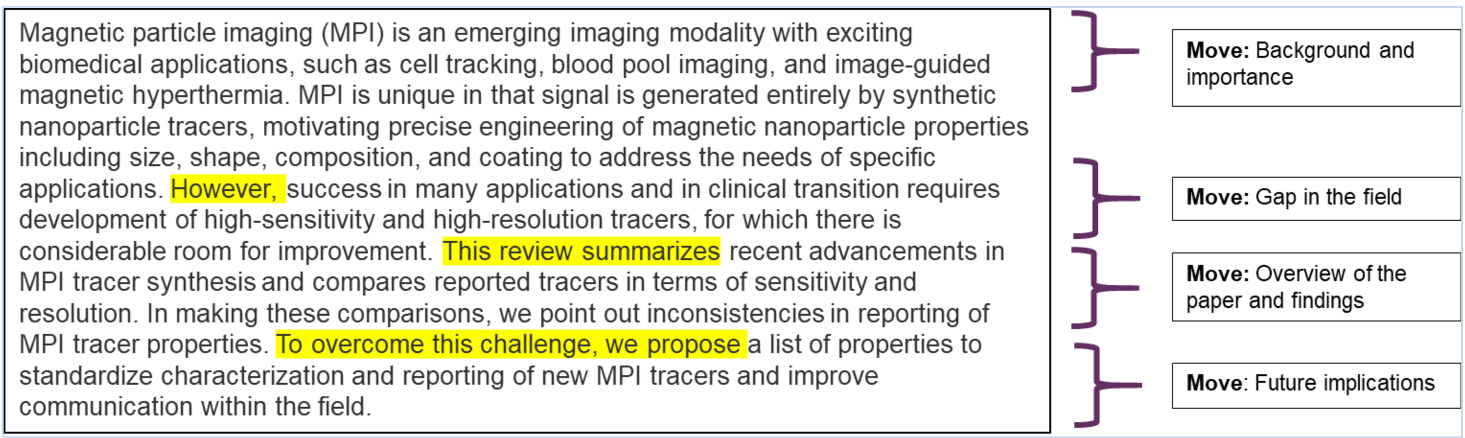

Figure 9.2. Example of a narrative abstract from a literature review abstract. This abstract uses the moves from Table 9.1. for review abstracts with signaling language from Table 2.1. (yellow highlighting). Notice that the abstract contains specific terms to summarize research overviewed in the paper. It does not contain specific data points because it is not primary research. Example has been adapted and used under CC-BY 4.0 (Velazquez-Albino et al., 2025).

9.4 Structured abstracts

Some journals require structured abstracts (**Figure 9.3**). The structured abstract is sectioned into parts with headings similar to IMRD sections (Chapter 4). These abstracts allow the reader to easily identify the moves, rather than watching for signaling language. A structured structure is common for clinical trials or medical studies, as well as systematic reviews and meta-analyses. A structured abstract is not appropriate for a literature review.

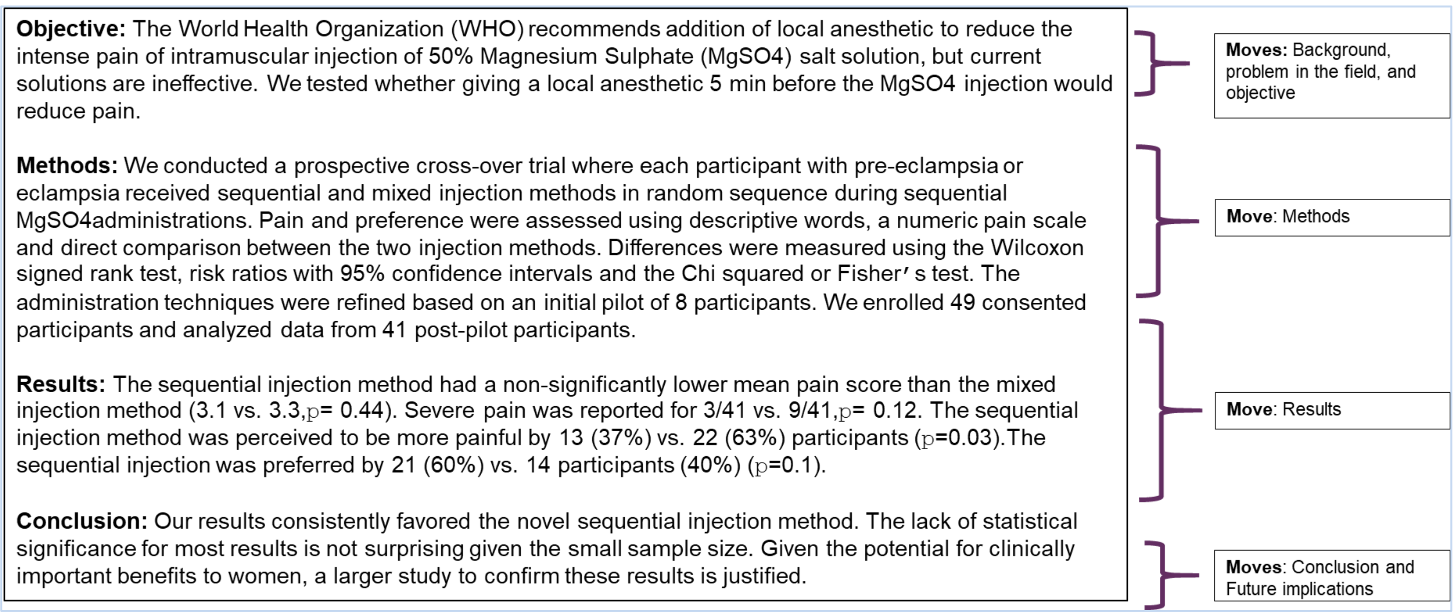

Figure 9.3. Example of a structured abstract from a clinical trial. A structured abstract divides the required moves into sections, making it easier for the reader to navigate and skim the content. This type of abstract is required by some journals. Example has been adapted and used under CC-BY 4.0 (Jamieson et al., 2024).

9.5 End of chapter tips: Drafting and reviewing an abstract

When possible, draft abstracts towards the end of a writing or research process. Abstracts require authors to note specific methods and findings that aren't usually known early in a project.

Abstracts often have word count requirements. The easiest way to draft an abstract is to take the following steps:

1. Write one sentence per move as described in **Table 9.1**. Use signaling language to help flow.
2. Perform a word count and check the outlet's requirements.
3. If it is a primary abstract, fill in the remaining space with specific results and methods. If it is a secondary abstract, fill in the remaining space with specific terminology or lists from the middle of the paper. In both cases, this helps the reader know what to expect.
4. An abstract is your chance to make a strong first impression! Edit for concise, specific, and simple sentences as described in Chapter 7.

Chapter 9 summary

Most genres of scientific writing include abstracts because they concisely preview information for an audience. Additionally, abstracts can serve as a gateway to communicating research to a broader audience. Readers skim abstracts to help them decide if they will read the article, and audience members skim abstracts to help them decide if they will go to a talk or a poster.

A well-written abstract will use the same structure and content of the genre, using signals (Chapter 2) and specific, concise writing (Chapter 7). For example, a primary research article abstract will have IMRD information (Chapter 4), similar to the article itself. Therefore, it is easiest to draft an abstract after completing some of the initial research and writing.

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Chapter 10. Posters

Chapter 10 overview and objectives:

Chapter 10 explores posters as a genre of scientific writing.

A poster is a common method of communication for scientists at conferences. A researcher can design a poster at any project stage, even if the project has just begun or if the scientist is still troubleshooting the method. This makes a poster an accessible mode of communication for undergraduate scientists to postdoctoral fellows.

Posters are a piece of scientific writing because they contain text and figures, just like an article. However, posters are also a type of oral communication because scientists prepare brief presentations to explain their poster and answer questions. Often, scientists receive feedback on their research during this presentation and exchange ideas with other scientists.

Most posters follow the same IMRD format of primary research (Chapter 2). Secondary poster designs exist, but they are not a focus of this chapter.

In this chapter, you will learn:

- The basic structure of primary research posters
- Heading and organization choices for posters
- The connection between posters, primary research articles, and the scientific method
- Design considerations

10.1 Basic poster structure

This chapter will describe a typical poster design that mirrors the IMRD moves of primary research articles, described in Chapter 4. This design emphasizes the scientific process as described in Chapter 2.

When designing a poster, first identify the requirements of the conference. Conferences often have specific size or content requirements.

In addition, some conferences have broad scientific audiences (like an undergraduate symposium), while other conferences have a specific expert audience (like a symposium on transcription). The background on a poster should reflect the knowledge base of that audience.

There are free templates available online for creating a poster, but a template is not required to make one. Scientists uses programs such as PowerPoint, Canva, Google Slides or Adobe to design the poster, save it as a PDF, and send it off to print full-size.

In a typical poster design, there is:

- A title that reflects the objective or result of the research
- A list of authors and affiliation
- Three columns that contain headings for different sections
- Acknowledgements (other scientists or funding)
- A few references

There are several options for headings and sections on a poster. Usually, posters have more sections on a poster than a primary research article. This enhances visual appeal and makes it easier to navigate. For example, a primary research article has an introduction with three moves: Background, Justification/Problem, and Objective (Chapter 4). A poster will have the same introduction moves, but these moves can be individually labeled, sectioned, or marked with italics and bold lettering.

Example headings include:

- Background
- Problem or Need
- Hypothesis, Objective, or Aims
- Methods
- Results
- Discussion, conclusion, or summary
- Limitations
- Future directions
- Acknowledgements
- References

Similarly, the discussion can be broken into smaller sections.

Posters do not require abstracts because the abstracts usually appear in a conference program. This frees up space for more visuals on the poster.

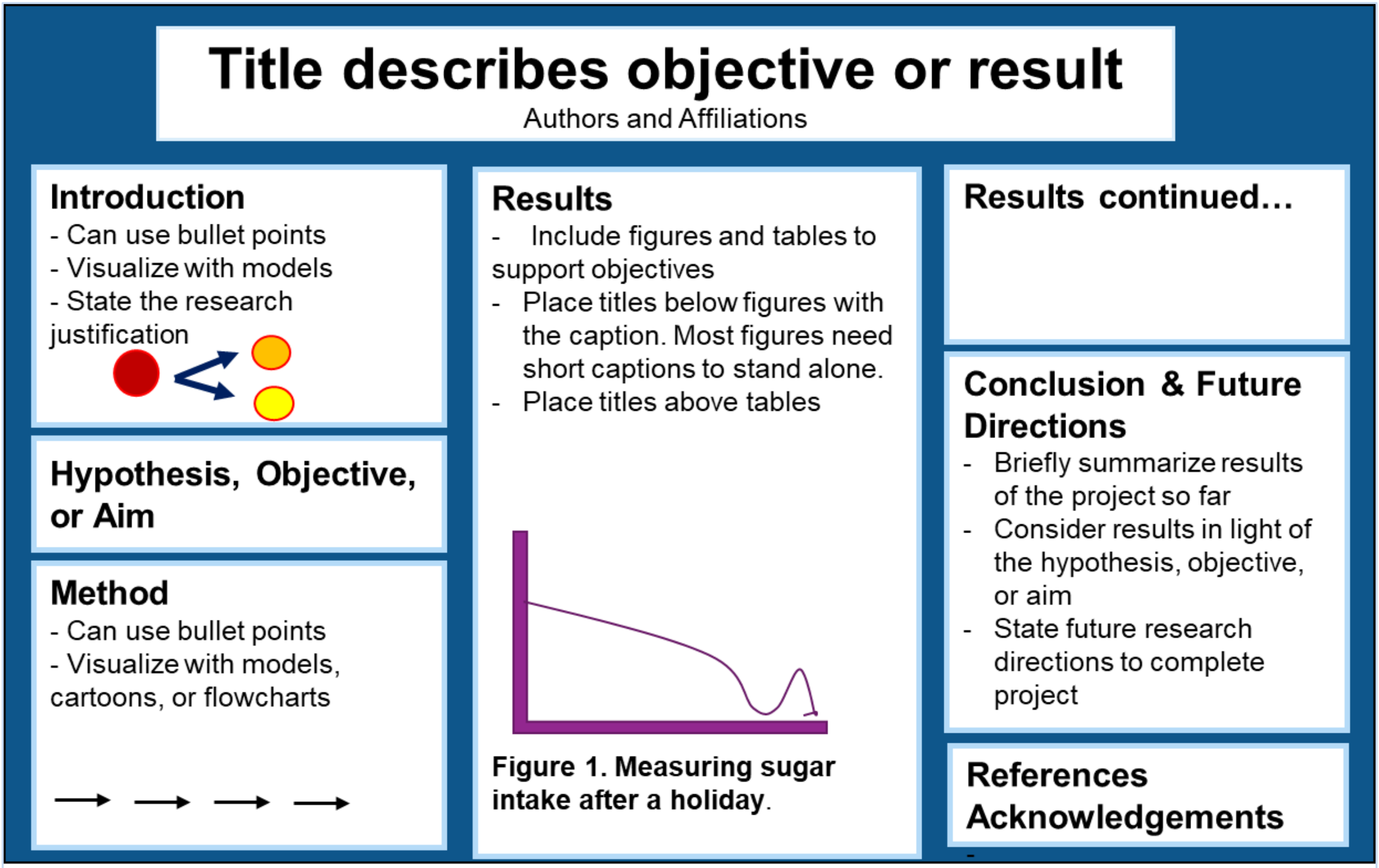

Figure 10.1. Example design of a scientific poster. Most scientific posters use a three-column design with headings that represent steps in the scientific method (Chapter 1) or IMRD articles (Chapter 4). Posters should use color, visuals, and space to promote contrast and increase text size.

10.2 Designing a poster

The trick to a good poster is to design something that supports both written and oral communication. Written communication needs enough content to stand alone without a presenter, but oral communication needs more visual content with less text.

A poster should be visually pleasing and easy to follow. However, do not miss this unique opportunity to design something original. While primary research articles must be formal and methodical, posters can use color and visuals to attract attention. In fact, an appealing poster design attracts a bigger audience.

When designing a poster, consider:

- Contrast
- Color
- Font size and font choice
- Blank space
- Images
- Amount of text

Color choice is a popular poster debate. Most audience members will agree that fluorescent colors are visually offensive on posters, but beyond that, the audience rarely agrees on color schemes. For that reason, color choice is personal preference. The most important part of color choice is that the color palette does not diminish readability. The color palette must have light and dark contrast, especially for text and data. For example, black text is easiest to read on a white background. However, a scientist could use their favorite color for a border or accent without affecting the readability.

Poster space should be divided into 40% visuals, 40% blank space, and 20% text. To accomplish this, limit the amount of text, using visuals to replace text when possible. Posters do not need heavy paragraphs and complete sentences in most sections. In fact, a conference audience will not stop to read this much text, especially if a presenter is there to explain it. Instead, use bullet points, flowcharts, and models to visualize background, methods, and summaries.

Pick a font and font size that is accessible and easy to read from *at least* 1 m away. The title should be the largest font size (at least 80 points), while the titles for figures and tables should still be above 20 points when possible. **Bold** lettering and *italics* can help draw attention to important terms or concepts, but use this sparingly.

10.3 End of chapter tips: Drafting and revising a poster

Creating a poster is an exciting opportunity to communicate your work to an audience. It can be an example of both scientific writing and oral communication, but a good scientific poster must be able to stand alone.

Don't miss this opportunity to merge your personality with your science – as long as the science is still clear. Before drafting your poster, look at examples for inspiration. There are plenty of examples of posters online or in a science hallway. This can help you decide on a color palette or template that suits your project and preferences. Check the conference guidelines for rules on poster dimensions.

After drafting your poster, consider:

- Using online templates to help with sizes and spacing
- Get feedback from your peers on readability
- Print out a mini-version of your poster to proofread and check color and contrast

Chapter 10 Summary

Posters are a common method of presenting research at a conference. As an example of oral communication and writing, posters should be visually pleasing with good contrast and use of space.

Most posters follow an IMRD structure similar to primary research articles (Chapter 4), but they can contain more section headings to indicate moves in the scientific method (Chapter 1). Posters are visual representations of this process, indicating research that has been done on a project up until that point. They should contain figures and tables to support the background, method, and results (Chapter 8).

Conclusion and Acknowledgements

After a decade of teaching scientific writing, I never found a textbook (let alone an open resource textbook) that emphasized the reading, paraphrasing, and citing challenges I see students face.

With the support of an Open Education Resource Fellowship through the Gumberg Library and Duquesne University, I am thrilled to put so much of this information in one place.

I want to thank Arthur Harper for his consistent support throughout the year-long process of writing this textbook. Arthur's examples, tools, and timeline were an essential part of helping me achieve my goals. My peer OER fellows, The Writing Center, and The Center for Teaching Excellence also provided me with valuable feedback and company over the last year.

Every semester, I embark on a new journey with approximately 70 science students. While the content I teach may largely be the same, the students are not. Each semester is an opportunity to learn about the research that my students love through their writing. It's also an opportunity for me to reflect on ways to help students write. I want to thank my students for all that they share with me every time they write a draft.

A special shout-out goes to the students of Fall 2024 who helped me decide what belongs in the first edition of this textbook. Because, let's face it. There may very well be another edition or updates to this online textbook. After all, writing *is* a process.

Appendix A: Chapter 3 Resources

Gumberg Library at Duquesne University has several resources to help you find scientific writing sources.

Scientific Writing Guide: A specific guide for resources covered in ENGL302W

Science databases by subject: Databases covered in ENGL302W matched with relevant majors

Gumberg databases: A comprehensive list of databases from Gumberg Library. Filter by subject.

EndNote Library Guide: A guide for downloading, installing, and using EndNote

Find full text with LibKey: A browser-extension for finding full-text PDFs while browsing any database

Heath sciences video playlist: A collection of YouTube videos from Gumberg library that demonstrate how to use controlled vocabularies (Embase, PubMed, and CINHAL databases)

Keywords for effective database searches: A YouTube video to demonstrate effective search questions and Boolean operators

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