Principles of Scientific Communication

PRINCIPLES OF SCIENTIFIC COMMUNICATION

CHEM 803 at Queen's University

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"Science isn't finished until it's communicated."
– Sir Mark Walport

Science will accomplish nothing if scientists cannot communicate their research and findings. We would not have known Darwin's name if he did not, two decades after collecting and analyzing his data, finally publish his manuscript *On The Origin of Species*.[1]

Why is writing important in science? It's not enough to simply have an idea, or discover something. Credit for the finding will go to the person who first published the work. This is what motivated Darwin; more than 20 years after his data collection voyage he received a letter from another naturalist, Alfred Wallace, who had made similar discoveries and was developing a theory of natural selection. Darwin went into a writing frenzy and finished a quarter of a million words within one year.

Scientific writing is different than creative writing, although both can be improved by storytelling. Writing for science requires clarity since the goal is to explain new discoveries or concepts.

"Writing is an art. But when it is writing to inform, it comes close to being a science as well."
– Robert Gunning,The Technique of Clear Writing

Types of Scientific Communication

You will encounter many types of scientific communication during your graduate degree in the Department of Chemistry at Queen's University. Each has its own purpose, format, and style guide. Most importantly, each has its own audience and **knowing your audience** is the key to effective communication.

1. A. Desmond, *Encyclopædia Britannica*, https://www.britannica.com/biography/Charles-Darwin, Accessed August 5, 2020

Less officially, you often need to communicate your work with people outside the Chemistry Department, Queen's, and to non-scientists. Do you struggle to explain what you do to your family over the holidays? Communication of science to the general public is a challenge, but also one of the most important forms of scientific communication.

Modes of scientific communication

- Essays
- Scholarship Applications
- Research Reports
- Group Meeting Presentations
- Teaching
- Abstracts
- Poster Presentations
- Oral Presentations
- Scientific Papers
- Research Seminars
- M. Sc. and/or Ph.D. Thesis
- Cover Letters and Resumes
- Research Proposals

Resources

There are countless resources to help students and academics communicate their science. Check the Resource page for both general and Queen's specific resources.

MODULE I

MODULE 1: WRITING

1.

ACADEMIC INTEGRITY

Read time: 2 minutes

Academic integrity is the foundation of science

At Queen's University, the Center for Academic Integrity (CAI) defines academic integrity as ...

> "A commitment, *even in the face of adversity*, to five fundamental values: **honesty**, **trust**, **fairness**, **respect**, and **responsibility**. From these values flow principles of behavior that enable academic communities to translate ideals into action."

Plagiarism is a departure from academic integrity by presenting someone else's work as your own. In science, ideas matter, so theft of ideas is a serious form of fraud.

To avoid plagiarism, make sure that sources of ideas and work in your written work and presentations are properly cited. Write in your own words or quote and cite.

- Citing sources gives credit to the intellectual work of others. It recognizes the work that others have done
- Citing sources helps other scientists find your source information
- Others can then read the source information and see how your ideas fit with others in discussing the subject

INTEGRITY IN ACTION

The following is an excerpt from the Queen's School of Graduate Studies Academic Integrity Policy.

"Within a graduate program, it is essential that an environment exists in which faculty and students have the utmost regard for the principles of academic integrity. Honesty and mutual trust constitute the very basis of all scientific and scholarly exchange. It is the responsibility of the entire University community to contribute to creating a community based on the principles of academic integrity.

Graduate students must:

- pursue their research activities in a manner that is consistent with the highest standards of ethical and scientific practice;
- adhere to Queen's University's ethics boards, the General Research Ethics Board (GREB) and the Health Sciences Research Ethics Board
- carry out research in honest search for knowledge, base findings upon a critical appraisal and interpretation according to scientific, scholarly and/or creative principles appropriate to the particular discipline."

Self-Plagiarism

In academia, there is a growing problem of self-plagiarism. The Editors of the journal *ACS Nano* described the effect on the scientific community:[1]

> "Recycling old data as new material (the accomplishment or quality), when it is not so, is tantamount to attempting to deceive one's audience."[2]

Why is it plagiarism if it's your own ideas or data? The point is that it is fraud, a deliberate deception of the reader. It creates a distrust and poor reputation, and also contributes to overloading the peer review process. The *ACS Nano* article details several examples of self-plagiarism, summarized below:

1. *ACS Nano* **2012** Vol. 6, No. 1, pp. 1-4
2. Hexham, I. Academic Plagiarism. http://people.ucalgary.ca/~hexham/content/articles/plague-of-plagiarism.html

1. Copying several paragraphs verbatim or slightly rewritten from an earlier manuscript.
2. Using identical schematics or figures as those use in earlier papers.
3. Data augmentation and/or repackaging to look like a new set of results.
4. Submitting related and overlapping content to several journals at once.

2.

WRITING BASICS

Read time: 11 minutes

Overview

This chapter will review the basic writing structures of sentences and paragraphs.

There are different levels of structure in writing. The overall structure of the proposal, article, or thesis (see individual chapters for examples) and structures within the sections *e.g.,* an article introduction has a common structure of broad to narrow. This chapter will discuss sentence and paragraph structure.

Sections in this chapter

- Sentence structure
- Paragraph structure
- Paragraph coherence

Sentence Structure

Sentence Basics

Sentences are arrangements of subjects and objects (nouns), verbs, and adjectives. Sentences in a scientific paper are on average 25 words, and in a Times Magazine article the average is 17 words.

- Basic: one subject, one verb
- Complex: basic sentences joined with dependent clauses
- Compound: Two or more sentences joined by a conjunction.

There are no set rules around sentence length, but it's good to keep an eye out for long sentences and vary the length.

Active vs. Passive Voice

In this section, we'll look at how sentences are structured in active voice and passive voice.

Active voice: A **stirring bar** **mixed** **the chemicals**.

Passive voice: **The chemicals** **were mixed** **with** a **stirring bar**.

- Subject = **stirring bar**
- Object = **the chemicals**
- Verb = **mixed**
- Auxiliary verb = **were**
- Preposition = **with**

In the example above, we see an example of a common chemistry method described using active and passive voice. **Passive voice** may seem more familiar, it is extremely common in methods sections of scientific articles. But why?

One reason is that methods are often written in the past tense, and people tend towards passive voice when writing past tense. Passive voice is useful when you need to be vague, or if the actor is unknown or irrelevant.

Another reason is personal liability. To say "The reagents were mixed but no products were obtained." lies the blame on some unseen passive force; We know that the authors did the reaction, but in this sentence it's not stated explicitly. In active voice, "We obtained no products", adds some personal liability to the authors.

Lastly, academics often use passive voice because it seems more professional. This has been questioned for years and is finally starting to change.

Active voice is more clear and requires fewer words. In the example above you see that the active voice does not need an auxiliary verb or preposition. Since science is about generating ideas and taking ownership of actions, we should try to take responsibility for actions by using active voice. Passive sentences like "Studies have been conducted..." confuse the reader: Who did the studies, you or someone else? Should there be a citation?

Grammar and Spelling

While many like to argue, grammar is not set in stone, and there are specific rules for grammar in science. Still, using acceptable grammar is important when writing scholarship applications and journal articles; you don't want to annoy your reviewers!

The newer versions of Microsoft Word (Office 365 Suite) provide grammar corrections along with classic spell check. There are also many resources online, including the free version of the Grammarly tool. This tool

allows you to upload text and scans it for grammar, spelling, clarity, and wordiness. With Grammarly you can tune your feedback by setting your audience (general, knowledgeable, expert), formality, context (email, academic, business), and even tone.

Punctuation

(.) period – terminates a sentence; abbreviations
(?) question mark – terminates a question
(!) exclamation point – terminates an exclamatory statement
(,) comma – pauses the flow of a sentence to prevent ambiguity
(-) hyphen – clarifies compound modifiers
(–) dash – sets off phrase with emphasis; don't overuse
(:) colon – initiates series
(;) semicolon – initiates independent clause
( ) parenthesis – encloses nonessential words and phrases

Commas: use after an introductory phrase *"Therefore, we..."*, to separate clauses (after *and, but, or*...), and to enclose phrases *"The catalyst, which we make in our lab, works at low concentrations"*.

Hyphens: Use for compound adjectives like *"high-spatial-frequency components"*. Do not use a hyphen as a negative sign symbol!

Capitalization: Capitalize titles of journals, books, reports (*Journal of the American Chemical Society*), and references to figures (*Chapter 2, Figure 8, Appendix C).* Do not capitalize medical terms, laws, principles, theories, or constants, unless they are eponyms.

- infectious mononucleosis; third law of thermodynamics; synthesis
- Alzheimer's disease; Boyle's law; Avagadro's number

Unless at the beginning of a sentence or title, the name of an element (iron) is not capitalized but the short form (Fe) is always capitalized.

Italics: use for Latin words (*et al.*, *e.g.*, *cis*, *trans*) and for emphasis.

Bold: use for headings, compound numbers (compound **34** was...), and for emphasis.

Abbreviations:

- M.Sc.
- Ph.D.
- *et al.* (and others)
- *i.e.* (that is)
- *e.g.* (for example)
- Fig. (figure), Eq. (equation)
- **Acronyms**: NMR, ESI-MS, HTML

Table 2.1. Unit abbreviations

K	Kelvin
s	second
m	meter
kg	kilogram
mol	mole
L	liter
J	joule
Hz	Hertz

Numbers: You can either use Arabic numerals (1,2,3) or write out numbers as words (one, two, three). At the start of a sentence, write out the number. In other situations, do what is best for the flow of the paper. If two numbers appear together in a sentence (see example below), spell out one of them. Express units of measure and percents in Arabic numerals.

> The solutions of **12%** methanol were prepared in **seven 25 mL** volumetric flasks. **Thirty-two** additions of base were required for the titration, as shown in Figure **7.3** (page **37**).

Common spelling mistakes

The molecule is a dimmer with a low molecular wait and tongues ten is the central element.

A traditional spell checker finds no mistakes in the above sentence! The new proofing features in Microsoft Word (Office 365) are very good but are unfamiliar with terms used in scientific writing. One solution is to download and use a customizable Chemistry Spell-Check Dictionary for Word Processors.

It's and Its

It's is a contraction of the words "it is". *Its* is a possessive form of *it*. People confuse these because apostrophes are often used in other possessive forms of words.

> It's always a good idea to dry your reagent and check its purity.

Your and You're

You're is a contraction of "you are" and *your* is a possessive form of *you*.

> When you're using the instrument you should have your goggles on!

Lose and Loose

Loose can be an adjective or verb and means the opposite of tight or contained. But lose is always a verb:

> If the flask is loose and falls then I could lose my entire reaction mixture.

Compliment and Complement

Complement is used for something that matches or completes a set. A *compliment* is something nice you say to someone.

> I want to compliment you on your style: your lab coat complements your goggles nicely.

Principal and Principle

In science you probably mean to say *principle.* A *principal* is the head of a school.

> Queen's has a principal instead of a president, who upholds our universities principles.

Except and Accept

Accept means to include, but *except* means to exclude.

> I can't accept that result, except if you are sure you ran the procedure properly.

Affect and Effect

Effect is a noun, something that happens. Affect is a verb.

> Increasing the temperature in my reaction had a dramatic effect on the yield, this affected my plans for the next stage of the study.

Paragraph Structure

This section is adapted from Communication at Work by Jordan Smith which is licensed under a Creative Commons Attribution 4.0 International License.

Like sentences, paragraphs should vary in length depending on audience needs and abilities, as well as the topics being covered. An audience with advanced literacy skills can handle longer paragraphs that would lose an audience reading at a more basic level, which takes us back to our earlier points about adjusting the message to the audience profile. Some topics need more development sentences than others and don't easily divide in the middle, though a paragraph of ten sentences or more is really pushing it. "Wall-of-text" paragraphs longer than a page are out of the question in professional writing. No matter what the size, however, all paragraphs should follow the standard structure explained below so that readers at any level can easily find what they're looking for.

A well-organized paragraph has three parts :

1. Topic sentence
2. Body or development sentences

3. Transitional or concluding sentence

The **topic sentence** states the main point or thesis of the paragraph and thus summarizes the small collection of sentences following it, so the reader can take in the whole before examining the parts. In the following **body sentences**, readers should be able to see how every sentence in any well-organized paragraph expands on something said in the topic sentence. The sentences that follow the topic sentence (including this one) illustrate how that system works with examples. The final **concluding sentence** wraps up the topic as broached in the first sentence while bridging to the next topic sentence, which in this case is about how to come up with a topic sentence.

1. TOPIC SENTENCE

For many writers, drafting a topic sentence is typically a search for one while writing the rest of the paragraph first and then discovering it as a concluding summary exercise. When you are just putting ideas down in the drafting stage of the writing process, you may not know yet what your point is at the outset of writing a paragraph. You likely have a general sense of your topic and some points to cover, probably based on information you collected in your research earlier. As you connect that evidence and build sentences around those information points, you begin to see where you're going with the topic and it suddenly comes into focus near the end. If you then say "In conclusion, ..., " summarize what you were getting at in a nutshell, and leave it there, however, you will do your reader a disservice by leaving your topic sentence buried under the pile of evidence that should be supporting it. In this case, delete "In conclusion," highlight the final sentence, cut and paste it at the top of the paragraph so it does what a topic paragraph should do: preview what follows with an at-a-glance summary.

2. BODY OR DEVELOPMENT SENTENCES

The development sentences expand on every part of the topic sentence in a sequence of complete thoughts. The sentences that comprise this sequence explore the topic by following an organizing principle through detailed explanations, supporting evidence, illustrative examples, rhetorical counterpoints, and so on. As parts of a logical sequence of sentences, each sentence connects to those around it with pronouns that use effective repetition (referring to nearby points without repeating them word for word) and transitional expressions (see Table 2.2) to drive the topic exploration forward. In this paragraph, for instance, the pronoun "this" in the first development sentence (the second sentence in the paragraph) represents the topic (development sentences). In the sentence above this one, the transitional phrase "for instance" signals an illustrative example offered as supporting evidence of the topic sentence thesis on the sentences' path towards the transitional or concluding sentence.

3. TRANSITIONAL OR CONCLUDING SENTENCE

The final sentence of a well-organized sentence wraps up the topic exploration by completing the main point stated in the topic sentence, as well as establishing a thematic bridge to the topic sentence of the next paragraph if indeed there is one. As a bridge, the final sentence looks forward to the following topic sentence by previewing some of its terminology, just as the paragraph preceding this one does. As a wrap-up, the final sentence should do more than merely paraphrase the topic sentence. Rather, the final sentence completes the expansion of topic-sentence points carried by the development sentences, leaving no loose ends to confuse the reader.

Paragraph Coherence

Coherence is achieved by paragraphs **sticking to the topic summarized in the opening sentence**, as well as using pronouns and transitional expressions to link sentences together while developing that topic. Generally, a paragraph sticks to just one topic while the one following it covers a related but distinct topic.

Like the organizational principles we explored above, we have a repertoire of recognizable pronouns, transitional expressions, and particular words or phrases that connect ideas in our writing so readers can easily follow our trains of thought. **Pronouns** such as *'this', 'it', 'they', 'he', 'she'* allow us to represent nouns, phrases, and even whole sentences that came before (called antecedents) without repeating them word for word—as long as the antecedents are clear (Pronouns, 2016; Darling, 2014).

Transitional expressions drive a topic forward by establishing the relationships between the content of sentences. Table 2.2 below collects many such adverbs and conjunctive adverbs, prepositions and prepositional phrases, coordinating and subordinating conjunctions, infinitive phrases, interjections, and so on.

Table 2.2. Transitional expressions. Source: Transitional Expressions (2003) – use with caution!

Transition Type	Examples		
1. Sequence	First, ... Second, ... Third, ... Initially, ... From the start,	...Next, ..., then ... Later,	...Ultimately, ... Finally, ...
2. Addition, repetition	Additionally, ... Again, ... Also ... Not only ..., but also ... Furthermore, ...	... and ... ... or ... ..., as well as ... Besides, ... Equally important ...	Further ... Alternatively, ... In addition, ... Another ... Moreover, ...
3. Time	When ... / Whenever ... Before ... Earlier, ... Recently, ... Meanwhile, ...	While ... Now ... Currently, ... During ... Immediately ...	Simultaneously, Subsequently, After ... Afterwards, ... At last, ...
4. Place, position	Above ... Below ... Near ... To the left/right of ...	Opposite ... Close to ... Adjacent to ... Farther on ...	Beyond ... In front of ... Behind ... Throughout ...
5. Logic, cause & effect	Therefore, ... Thus, ... For this reason, ... Consequently, ...	Hence ... If ..., then ... Clearly then, ... It follows that ...	Accordingly, ... As a result, ... Because ... Since ...
6. Similarity, comparison	In the same way, ... Just as ..., so too ...	Likewise, ... Similarly, ...	... also ...
7. Example	For example, ... For instance, ...	..., specifically ... ... in particular ...	To illustrate, ... In this way, ...
8. Opposition, exception, contrast	However, ..., however, ... notwithstanding, ... On the one/other hand, ... On the contrary, ...	..., but ... ..., although ... Nevertheless, ... Nonetheless, ... instead ...	Still, ..., yet ... Despite ... In contrast, ...
9. Emphasis	Indeed, ... In fact, ...	Even ... Of course, ...	
10. Paraphrase, summary	In other words, ...—that is, ...—that is to say, ... To paraphrase, ...	To summarize, ... In conclusion, ... In sum, ... in a nutshell, ...	In a word, ... In brief, ... Ultimately, ... in the end, ...

3.

STYLE TIPS

Read time: 4 minutes

Overview

This chapter will discuss tips for improving the style and readability of your scientific writing. **Style** is the way your research is described, whereas **format** it the way your paper is arranged.

Sections in this chapter

- Balancing honesty and efficiency
- Precision
- Clarity
- Familiarity
- Fluidity
- Forthrightness
- Conciseness
- Imagery

Balancing honesty and efficiency

Scientific writing is a craft rather than a science, and is subject to two constraints: Honesty and Efficiency

Honesty – you must include all research results, including the data points, even those which don't fit the curve. You must give fair treatment to opposing theories and experiments.

Efficiency – you must inform your audience as efficiently as possible, however not with the paper with the shortest length, but with the paper that takes the readers the shortest time to understand.

What makes for good science writing?

- Have something to say
- Be logical and clear

- Brevity
- Apply simple rules of style
- Read other's writing
- Try talking (out loud) before writing
- Know and respect your audience
- Revise and proofread
- Learn to cut out words
- Get help from peers

Precision

Choose and use the right words in your scientific writing. For example, know if you need to use "weight" or "mass". Don't hesitate to repeat a word if the word is the right word. Ideally a scientific term should only have one meaning, but there are many words that have different common meanings than scientific meanings. For instance, a "theory" in common language is like a hunch or guess, whereas in science theories are built from large bodies of evidence. Be aware of multiple meanings or negative connotations in your writing (e.g., "adequate" can have a negative connotation).

Clarity

Keep your sentences as simple as possible in scientific writing. Follow the guidelines in the Writing Basics chapter to make your sentences short and clear.

Using jargon or pretentious words and phrases will reduce the clarity if your writing. You may be encouraged to use these words by your supervisor or peers, and you will see them everywhere — they look smart, right? — but they are part of what makes science so difficult to read. Table 3.1. shows a list of words and phrases you should stop using along with simple replacements. See the next section on Familiarity to learn more about jargon.

Table 3.1. Pretentious words and phrases to avoid

Pretentious words and phrases	**Simple replacements**
approximately	about
affords / furnishes	gives
novel	new
implement	carry out
utilize	use
activate	start
facilitate	make
subsequently	then
"...clearly demonstrates..."	"...demonstrates..."
"As is well known, amines..."	"Amines..."
"Obviously, the reaction..."	"The reaction..."

Familiarity

Find and use language that is familiar to your audience (this requires knowing the audience for your writing!). If you need to use an unfamiliar word, define it using words in which are familiar. You can also use use examples or analogies to help the reader.

It can be hard to avoid jargon, especially phrases that developed in your own laboratory and that you use with your peers. Some examples of common jargon phrases are:

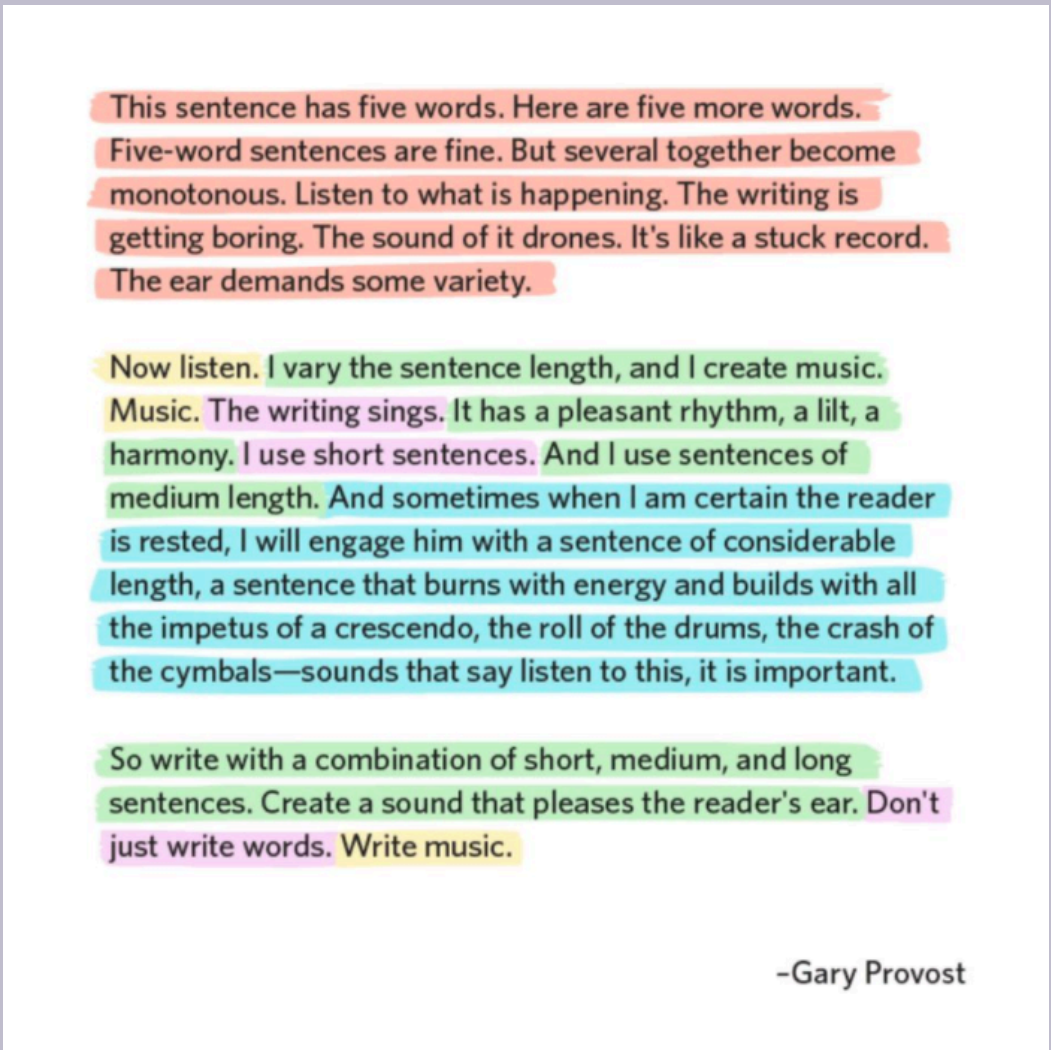
- "the solvent was rotovapped"
- "the compound crashed out of solution"
- "the NMR showed"

Fluidity

Fluid writing is difficult to accomplish in the first draft, and we'll come back to it when we discuss Editing your work. One factor to fluidity is variability (see "Write music" below); vary your sentence or paragraph length and structure. The second factor is to use strong connective words, or conjunctions, to keep your thoughts flowing from one to the next.

Write music

This tip comes from "100 ways to improve your writing " by Gary Provost.



This sentence has five words. Here are five more words. Five-word sentences are fine. But several together become monotonous. Listen to what is happening. The writing is getting boring. The sound of it drones. It's like a stuck record. The ear demands some variety.

Now listen. I vary the sentence length, and I create music. Music. The writing sings. It has a pleasant rhythm, a lilt, a harmony. I use short sentences. And I use sentences of medium length. And sometimes when I am certain the reader is rested, I will engage him with a sentence of considerable length, a sentence that burns with energy and builds with all the impetus of a crescendo, the roll of the drums, the crash of the cymbals—sounds that say listen to this, it is important.

So write with a combination of short, medium, and long sentences. Create a sound that pleases the reader's ear. Don't just write words. Write music.

–Gary Provost

Forthrightness

Use active-voice whenever possible to avoid vagueness that often comes with passive-voice. Use strong nouns that require few adjectives, and use strong active verbs and don't overly hedge your statements (Table 3.2).

Table 3.2. Weak and passive vs. strong and active phrases

weak verb phrase: strong verb:	"made the measurement of" "measured"
needlessly passive: active:	"is used to detect" "detects"
needlessly passive: active:	"is capable of" "can"

Conciseness

Being concise means eliminating redundancies. This is difficult to do while writing, but can be easier during the revision stage. Below are some examples of common phrases, with the redundant word in [square brackets]. If you imagine a sentence for each one with and without the redundant word, the meaning should remain the same.

Redundant words

- [already] existing
- [completely] eliminate
- [basic] fundamentals
- [currently] underway
- [continue to] remain
- mix [together]
- never [before]
- [still] persists

Replace these phrases with single words:

- "in the light of the fact" = **because**
- "in the vicinity of" = **near**
- "at this point in time" = **now**
- "has the ability to" = **can**

Examples of redundant wording

Example 1

WORDY: US Government blackout order during World War II:

> "Such preparations shall be made as will completely obscure all Federal buildings and non-Federal buildings occupied by the Federal government during an air raid for any period of time from visibility by reason of internal or external illumination."

CONCISE: President Roosevelt's response:

> "Tell them that in the buildings where they have to keep the work going to put something across the windows."

Example 2

WORDY: Our website **has made available** **many of the things you can use** **for making a decision on** the best solvent. (20 words)

CONCISE: Our website **presents** **criteria** **for choosing** the best solvent. (9 words)

Imagery

Often in writing, we are trying to supply a mental image of our science and research. Chemists work at the molecular scale, on processes not visible even under most microscopes, and imagistic words can help convey this molecular world, for example...

> "the host molecule encapsulates the guest"

Using a description that evokes the five senses can also help a scientist trying to reproduce a method, e.g.,

> "a red syrupy oil" or "bright yellow needle-like crystals".

When words are not enough, we can use schemes, figures, and other illustrations to convey our meaning in science: you'll see more on that in Module 2.

4.

PROPOSALS

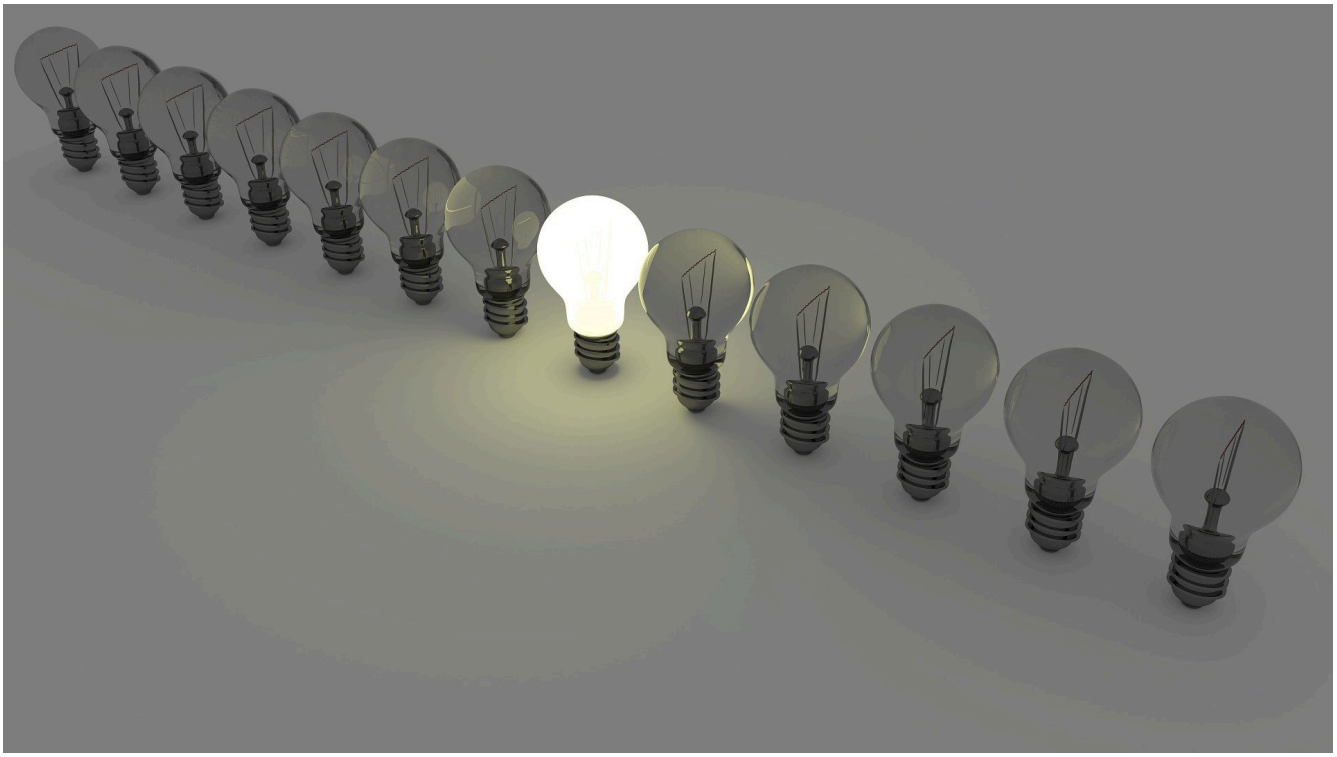
Read time: 3 minutes

Overview

In science, research efforts are often paid for by federal, provincial, or private funding bodies. To get funding, scientists must submit exciting and concise research proposals that are reviewed by committees of other scientists. If you learn to write about your research in a simple and engaging way, your proposal will stand out from the crowd. In this chapter, you will learn about the specific structure and goals of research proposals, and find many resources to help you write your own.

Sections in this chapter

- Audience and style
- Structure of a proposal
- Resources



Audience and Style

A research proposal has a unique style that combines new ideas with clearly laid out goals and plans, where the author must demonstrate expertise without making the writing too complex. Proposals are often short, especially for scholarship applications (1-2 pages) or NSERC Discovery Grants (5 pages). In this small venue, the writer must convey research motivations, intended methods, goals, and the possible significance of the proposed work. The writing should be as concise and forthright as possible, even if the proposal is being reviewed by other scientists in the same field. Most of all, the main goal of the research should be written in a way that a layperson (non-scientist) could grasp. Before writing your research proposal think about the intended audience; if you aren't sure, ask your colleagues or supervisor how the review process works.

Related to the audience is how your proposal is being graded. Check the funding body's website for a detailed rubric (NSERC CGS rubric).

Proposals are often graded on the following criteria:

1) the quality of the research being proposed,

2) the ability and potential of the researcher, and

3) the potential significance and impact of the work.

Structure of a Proposal

The exact format of a research proposal will depend on where it is being submitted. Typical graduate scholarships require a 1-page proposal with strict guidelines for margins, spacing, and text size. Overall, a strong research proposal usually follows the format in Table 7.1. Ask your colleagues, friends, and research supervisor if they can share successful research proposals with you.

Table 7.1. A general format for a strong research proposal

1	**Background and motivation**	Provide a general introduction to the topic and include the most relevant background literature. Write in a way that outlines the motivation for the work, and write a more general audience.
2	**Current status and gaps**	Provide more detail on recent progress (yours or others) and point out specific gaps that motivate your proposed work.
3	**Specific aims and hypotheses**	Explicitly and concisely state the aims of the proposed work. When describing a specific project or experiment, state the hypothesis.
4	**Detailed plan and methods**	Be as detailed as possible about your plan and proposed methods, but avoid using complex language or jargon (this is a tough balancing act!). It is especially important for early career researchers to show that they know which methods are appropriate.
5	**Significance and Impact**	Restate the aims (goals) of the work in a way that frames their potential impact on the field. Then, think big and discuss the broader implications that your work would have, including how it will benefit the general public.

Resources

Use the information in Module 1 to guide you in writing a concise and engaging research proposal. Usually, research proposals include at least one Figure, and you can find guidance on that in Module 2.

List of scholarships, awards, and available funding for graduate students.

Ontario Graduate Scholarship (OGS) Proposal (Plan of Study) Guide

Natural Sciences and Engineering Research Council (NSERC) PhD Scholarship Guidelines

Natural Sciences and Engineering Research Council (NSERC) MSc Scholarship Guidelines

5.

JOURNAL ARTICLES

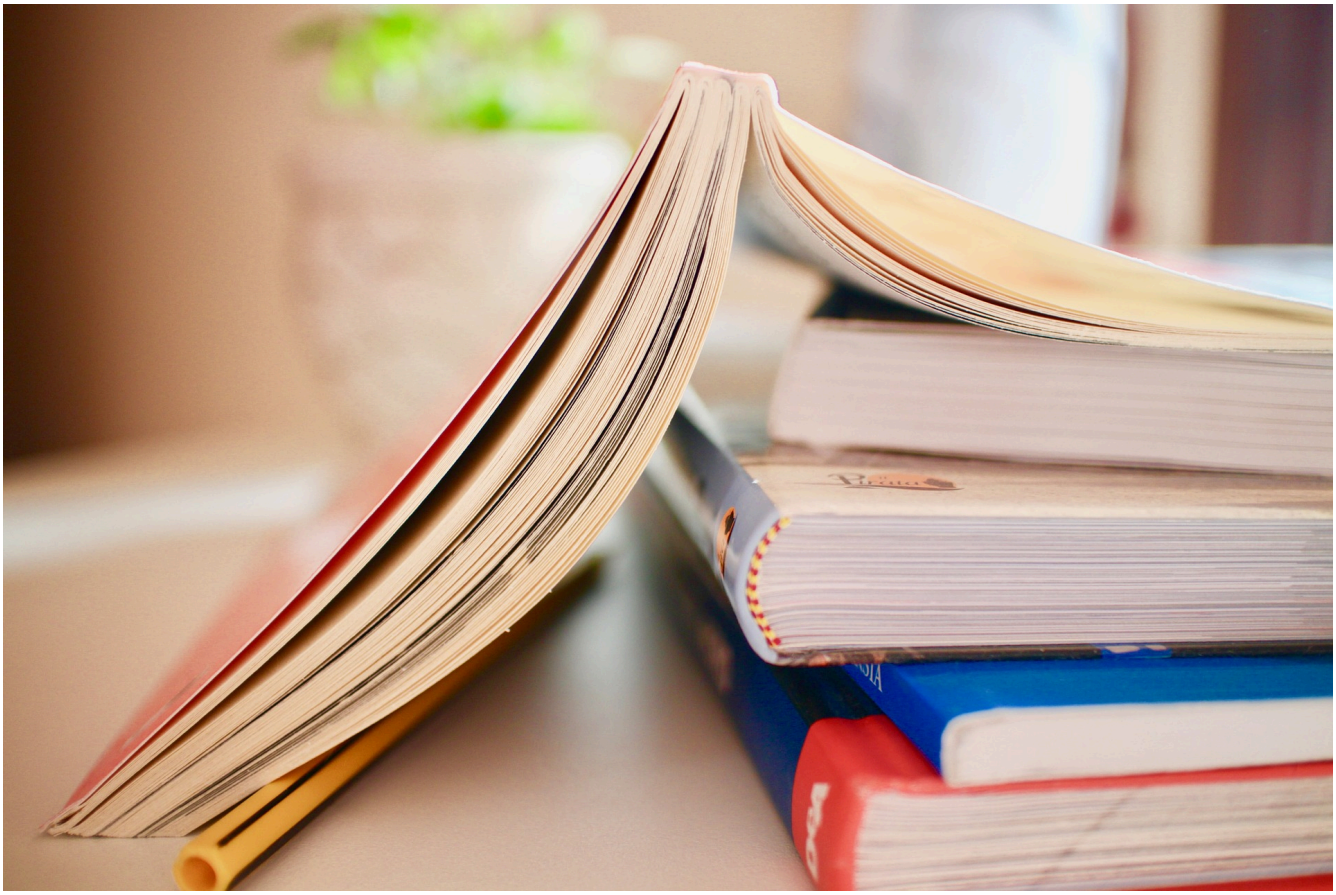
Read time: 12 minutes

Overview

This chapter will outline writing structures, styles, and tips related specifically to journal articles.

Sections in this chapter

- Choosing where to publish
- Peer review
- Manuscript Types
- Structure of an article
- Form and Tense
- Tips for each section
- Reviews



Choosing where to publish

Choosing which journal to publish your research in relates back to the audience of your research. Big discoveries that will have influence across science are published in broad readership journals like *Nature* or *Science*. Research that will have wide-ranging influence in chemistry, and a broad readership across chemistry's subdisciplines, are published in journals like the *Journal of the American Chemical Society*. More specialized journals are the right fit for research that has an audience of other experts in the sub-discipline (i.e. organic chemistry, inorganic chemistry, materials, etc.).

Once you choose where to publish, many journals (or the publishers) provide guides and document templates (Click here for the Author Guide to *JACS*). These guides will provide you with specific formats and structures of articles in that journal. Templates can be useful, but if you are a perfectionist it is best to leave them until you have a final draft! Otherwise, you will focus too much on positioning figures and fixing text styles too early in the process. Some researchers ignore the templates altogether and submit their work as a single column, double spaced, common Word document that is easier to read and review; once the paper is accepted, the editorial office can help put the article into the correct template.

Beware of Predatory Journals

Predatory journals charge a fee to publish but lack credibility. It can be difficult to spot a predatory journal because they have names that look credible (*e.g., Journal of Chemistry and Biochemistry*), but upon closer inspection, you will see the following indicators:

- Not linked to a credible scholarly society
- Send unsolicited spam emails and invites with no "unsubscribe" button
- Brag about high quality of the journal using fake journal metrics
- Editor-in-chief also edits other journals in a variety of disciplines
- Promise fast publications
- Make it difficult to find information about the journal

Check the website PredatoryJournals.com for an updated list.

Peer review

Scientific works must undergo peer review to be published in a journal. This is a process where other scientists evaluate the work, usually anonymously, for its merit, originality, rigour, and scope. Peer review provides researchers with another perspective on their work.

Where is peer review used?

- Scientific publication
- Grant review
- Tenure and promotion

Editors and Reviewers have to examine manuscripts for evidence of scientific misconduct in the forms of (Hengl and Gould, 2002):

- Gift Authorship – authors who did not contribute to the paper
- Self-plagiarism – publishing essentially the same work in multiple journals
- Plagiarism – using other's words or ideas without proper credit
- Fabrication – using data not obtained by actual experiments

- Falsification – manipulating data to obtain false conclusions
- Conflict of Interest – obtaining biased results

Reviewers usually have several choices for recommendations on publishing a manuscript (Hengl and Gould, 2002):

- accept for publication as written
- accept after minor revisions
- reconsider after major revisions
- reject
- recommend for submission to another journal

Common reasons for rejection include (Hengl and Gould, 2002):

- The topic is too specific or irrelevant to the journal
- The paper does not offer anything significantly new
- The objectives and conclusions are not clear or connected
- The methods and/or results are unclear, weak, or misleading
- The writing style is unclear, unfocused, or incoherent
- The data is of poor quality due to the study design, sampling, or method

Manuscript types

The structure and length of the writing depend on the manuscript type. Manuscripts can have several formats:

- **Communications**: Short (2-page) articles of recent discoveries that need to be published quickly. Must be very concise! [template]
- **Articles**: Longer and detailed description of a finished project, describing detailed methods and scope. May expand on findings from a Communication if providing new insights and breakthroughs.
- **Reviews**: Comprehensive and critical review of a specific topic or subfield that compiles literature and reflects on the past and future. Typically long (10-50 pages). These articles do not contain original research but serve the community as a historical record and time-saver for new researchers.
- **Perspectives**: Are personal reviews of a field or topic that are not meant to be comprehensive.

Structure of an article

Scientific research articles follow the "IMRAD" format: Introduction, Methods, Results, and Discussion. See Table 8.1 below for the structure and parts of a typical scientific paper. Tables and Figures (with captions) are included without the Body and Supplementary Materials.

Table 8.1 Parts of a scientific paper

Title List of authors and addresses Abstract (text and graphics) Keywords	**Front Matter**
Introduction Methods and Materials (Experimental) Results Discussion	**Body**
Conclusions Acknowledgements References and Notes Supplementary Materials	**End Matter**

Consider the reader's view

It's rare that someone will sit down and read through your whole article. Typically, readers will skim for important information and only read into the details if necessary.

So what does a typical reader read, and in what order?

1. Title and author list
2. Abstract (and keywords)

3. Figures and their captions
4. Skims text and section headings
5. Conclusions
6. Equations
7. Portions of the main text in more detail

Devote extra time to crafting the title, abstract, figures, and headings!

Form and Tense

Knowing whether to write in the present or past tense can be tricky and depends on the context and section of the article (See Table 8.2). The most important thing is to be consistent. In your editing and final proof of your article, do a read-through to check that you are consistently writing in the same tense, at least within each article section.

Table 8.2. Typical writing tense in different sections of an article, with examples.[1]

Abstract	
Past tense (when referring to your own work)Present tense (when describing context)	"This resolution **was** accomplished using a Brønsted acid catalyst" "Azomethine imines **are** valuable substrates in asymmetric catalysis"
Introduction Past or present tense	"These versatile compounds **are** well known as substrates in 1,3-dipolar cycloadditions and nucleophilic additions" "Since this report, there **have been** many examples of catalytic stereoselective reactions with N,N'-cyclic azomethine imines"
Materials and Methods Past tense (your own procedures)	"The ee value **was** determined by HPLC using a Diacel ChiralPak AD-H column."
Results and Discussion Past or present tense	"Bulky alkyl- and naphthyl-substituted azomethine imines **were** less reactive" "The binding mode of these catalysts **is** unique"
Conclusion Past or present tense	"In summary, we **developed** a kinetic resolution ..." "This protocol **demonstrates** the first example of stereoselective reduction of azomethine imines"

Tips for Articles by Section

Title

Review the chapter on Style and write your title to be clear and descriptive, without being too wordy or too vague. Omit the starting "The" and avoid abbreviations and jargon. Avoid using these redundant phrases:

- On the
- A study of
- Research on
- Use of
- Report on

1. Bongers, A., Moon, P. J., Beauchemin, A. M. *ACIE* **2012** *54* 15516-15519

Also, be on the lookout for misplaced modifiers! In the following title, does the detection use azine dyes or do the sponges contain the dyes?

"Detection of Natural Products from Sponges with Azine Dyes"

Authors

Authors are listed who contributed significant work, data, and writing to the research article. In Chemistry, the first author is usually a graduate student or postdoctoral fellow to did the bulk of the work. The last author is usually the research supervisor (Professor) who also serves as the corresponding author (*). Other authors are listed by contribution or alphabetically. *Be aware that you will see different formats or author orders based on the field or personal preference of the corresponding author.*

A.B. Smith, R.J. WIlson, P.E. Adams, C.D. Jones*

* cdjones@university.ca

Abstract

The abstract for your article needs to be a concise summary that also draws in your audience to read the rest of the article. It should stand alone and highlight only the most important aspects of the article. The "10% in 10 minutes" activity is a great way to shorten an abstract that is too long-winded. It is best to write the abstract at the very end, one the rest of the paper is finished.

Follow this sentence-by-sentence manual from Julia Eckhoff, Associate Editor at Springer Nature, to writing an abstract.

Most journals also have graphical abstracts that are included with the text. These range from simple schemes to elaborate works of art, and from low to high quality. For examples of interesting or funny abstracts, and some examples of *what not to do*, check out the TOCROFL blog.

Two excellent examples of abstracts and graphical abstracts from Queen's Chemistry

Hai-Jun Li, Soren K. Mellerup, Xiang Wang, and Suning Wang* *Org. Lett.* **2019**, 21, 8, 2838–2842.

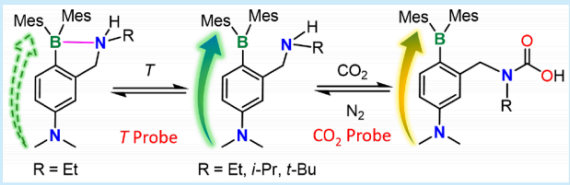
D–π–A Triarylboranes as Reversible Fluorescent Probes for CO_2 and Temperature

Hai-Jun Li, Soren K. Mellerup, Xiang Wang, and Suning Wang*

Department of Chemistry, Queen's University, Kingston, Ontario K7L 3N6, Canada

Supporting Information

ABSTRACT: Alkylamino-functionalized donor–π–acceptor (D–π–A) triarylboranes have been found to be able to capture CO_2, forming the carbamic acid derivative. Due to the close proximity of the amine substituent to the boron center, CO_2 binding greatly influences the intramolecular charge transfer fluorescence, causing distinct and reversible emission spectral/color change, with a rapid response time, and a detection limit as low as 100 ppm in methanol. In addition, this system is also effective as fluorescence "turn-on" temperature probes due to the dynamic B ← N bond dissociation/association.



Yin Gao†, Yizhe Dai, and Gang Wu*, *Phys. Chem. B* 2017, 121, 30, 7311–7317.

Solid-State ^{15}N and ^{17}O NMR Studies of *S*-Nitrosothiols

Yin Gao,[†,‡] Yizhe Dai,[‡] and Gang Wu*[,‡]

[†]The College of Life Sciences, Jilin University, 2699 Qianjin Street, Changchun 130012, China

[‡]Department of Chemistry, Queen's University, 90 Bader Lane, Kingston, Ontario K7L 3N6, Canada

ABSTRACT: We report a solid-state ^{15}N and ^{17}O NMR study of two representative *S*-nitrosothiols (RSNO): *S*-nitroso *N*-acetylpenicillamine (SNAP) and *S*-nitrosoglutathione (GSNO). The ^{15}N and ^{17}O NMR tensors are experimentally determined for the first time for this important class of nitric-oxide (NO)-related compounds. The observed NMR characteristics for RSNO include large ^{15}N and ^{17}O chemical shift anisotropies and large ^{17}O quadrupole coupling constants. Quantum chemical calculations are also performed for the ^{15}N and ^{17}O NMR tensors in two simple RSNO models: *t*-BuSNO and MeSNO. On the basis of computational results, we have identified the molecular orbitals that are responsible for the observed large chemical shift anisotropies in RSNO compounds.

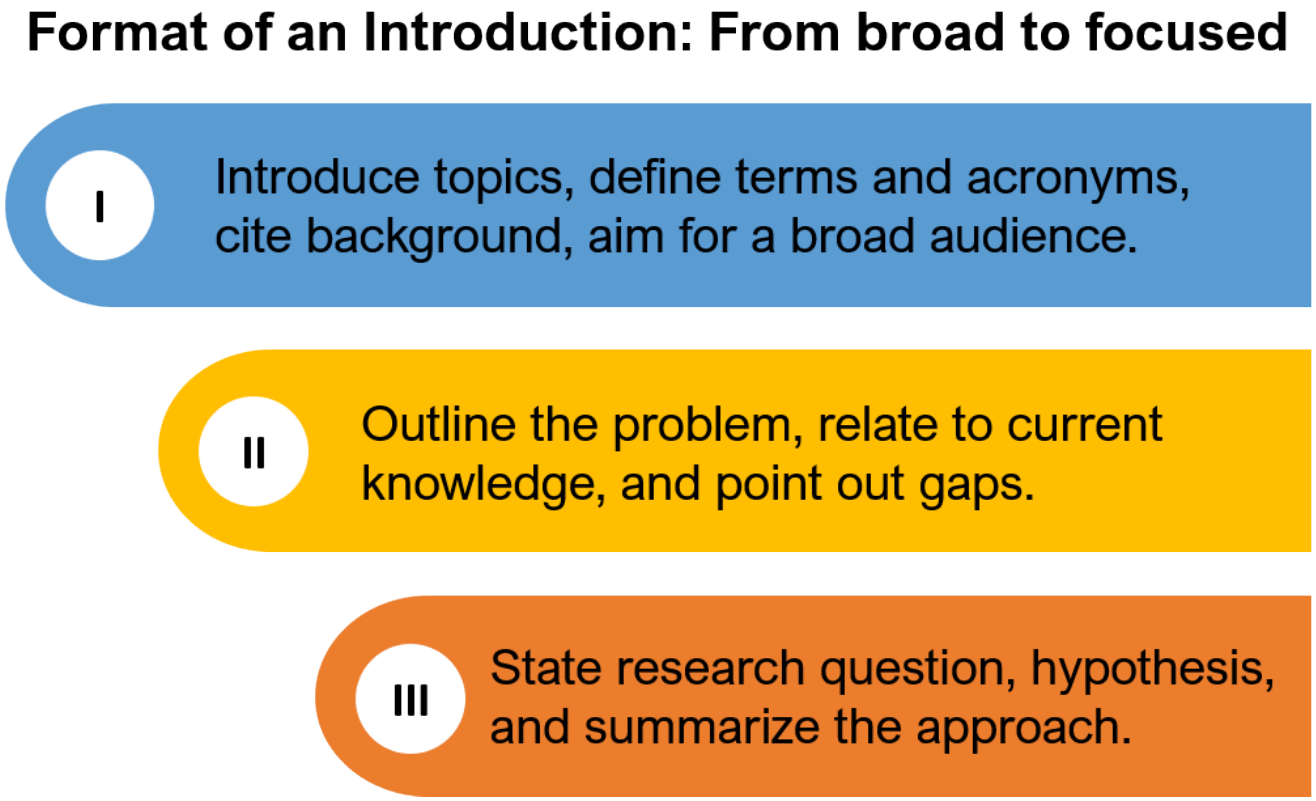
Keywords

Some journals require a list of 5-10 keywords or phrases for each article. Choose these carefully by thinking of how you want your article indexed by the search feature and to be aligned with your title and abstract. See this tutorial from Springer for more tips and examples.

Introduction

The introduction of an article introduces the topic, situates the work within current knowledge, and indicates

a gap that the research addresses. This section thus starts broadly and then focuses in on specific research questions and objectives, which should be stated clearly at the end of the introduction.



Your introduction will need a brief but thorough description of prior research in the area, and it is imperative to cite the important and relevant background articles. If your introduction is getting too long due to an extensive literature review, consider if you can cite fewer articles or cite a review that helps readers find more information. If you can't remove any references, create a separate 'Literature Review' subsection.

Example of a short concise introduction following the above format

Introduction: Excerpt from Yin Gao, Yizhe Dai, and Gang Wu*, *Phys. Chem. B* 2017, 121, 30, 7311–7317.

I

S-Nitrosothiols (R—S—N═O or RSNO) are a class of organic molecules that play important roles in nitric oxide (NO) chemistry, potential therapeutic applications, and protein post-translational modification.(1-10) Recently, the reactivity of RSNOs toward H_2S under physiological conditions has attracted considerable attention(11-15) and also generated controversies.(16-21) This new reaction pathway adds further complication for possible "cross talks" between the two major gaseous signaling molecules, NO and H_2S.

II

Because RSNOs are generally unstable, only a limited number of X-ray structural(22-26) and ^{15}N (I = 1/2) NMR spectroscopic studies(23, 27-29) have been reported in the literature. In fact, all previous NMR studies of other NO-related compounds utilize ^{15}N as a common NMR probe nucleus.(30-32) Recently, we demonstrated the use of ^{17}O (I = 5/2) as a complementary NMR probe to study NO-related compounds.(33-36) One of the advantages of ^{17}O NMR is that the fast quadrupolar ^{17}O relaxation in solution allows one to collect data very rapidly so that some transient reaction intermediates can be potentially captured. For example, we used ^{17}O NMR to help identify molecular structures of the elusive red-violet and blue intermediates in the Gmelin reaction between nitroprusside and sulfides in aqueous solution.(34) We have also reported a complete multinuclear (^{1}H, ^{13}C, ^{15}N, ^{17}O) NMR characterization of the so-called "red product" from the reaction between nitroprusside and 2-mercaptosuccinic acid.(35) This "red product" can be generally formulated as $[Fe^{II}(CN)_5N(O)SR]^{3-}$ where an RSNO ligand is coordinated to the Fe(II) center via the nitrogen atom. To broaden our knowledge about NMR properties in RSNO compounds, we report herein a solid-state ^{15}N and ^{17}O NMR study of two representative RSNOs: *S*-nitroso *N*-acetylpenicillamine (SNAP) and *S*-nitrosoglutathione (GSNO), see Scheme 1.

III

The primary goal of the study is to experimentally measure the ^{15}N and ^{17}O NMR tensors in RSNO compounds, since such fundamental information has not been reported in the literature.(37-39) Several years ago, solid-state ^{15}N and ^{17}O NMR tensor data were reported for a class of RSNO-related compounds, *C*-nitrosoarenes (Ar—N═O).(40-42) Because R—S—N═O exhibits some bonding properties similar to those seen in Ar—N═O, it would be of interest to compare the ^{15}N and ^{17}O NMR tensors in these two classes of compounds. In addition, characterizing ^{15}N and ^{17}O NMR tensors in RSNO will help build a reasonably sized database for a variety of reaction intermediates encountered in the NO chemistry. In this study, we also perform quantum chemical calculations for two simple RSNO models, *t*-BuSNO and MeSNO (Scheme 1), to further understand the ^{15}N and ^{17}O magnetic shielding tensors in the S—N═O functional group. Common features among the NMR tensor properties between RSNO and Ar—N═O compounds will be examined.

Experimental (Materials and Methods)

The experimental section is usually divided into two sections, Materials and Methods. In some journals or formats (communications, full articles), the bulk of this section is included in the body, in others, it may be in the Appendix or Supplementary Materials.

A tenet of science is reproducibility, and the experimental section of an article must provide sufficient details for replication of the findings. What good is your great new chemistry if no one else can use it? For this reason, this is

Be Precise and Concise

The experimental section can contain grammatical errors that make it hard to tell what was done:

"After standing in boiling water for an hour, examine the flask "

Have someone else read through your methods and see if they can follow the steps.

the most important section to check your grammar and use concise language.

Read articles in the journals related to your subfield to see what types of things should be included. In many articles, there should be details of chemical suppliers, how reactions were performed, and characterization of all new compounds to prove purity (elemental analysis, spectroscopy, X-ray diffraction). In theoretical articles information on computational and mathematical details should be included. Make sure to cite literature for any standard methods.

Results

The Results section is the core of the paper, containing all the experimental data and findings in full. Many articles include a separate section for Results, or this information is combined with the Discussion. Tables and Figures are used for most data, especially if they cannot be simply presented in written form (remember: most readers will skim your paper and only look at the Figures). Present your results systematically and cross-reference all tables and figures in the text.

Descriptive Subheadings

Use "*The Rate of Self-Exchange Decreases with the Polarity of the Solvent*" rather than "*Measurement of Rates*"

This section is organized according to major topics or experiments that were conducted, with *descriptive subheadings*. Make it easy for the reader by writing your subheading as a summary of the result.

Common mistakes

1. Interpreting results rather than reporting

- The results should only contain observations and measurements.
- Results become part of a permanent store of information, while their interpretation can change with time.

2. Tense

- Any focus on past actions requires the past tense. *"The yield for this reaction **was** 80%"*
- Use the present tense when referring to tables and figures in the paper. *"As we **show** in Table 1, the yield for this reaction **was** 80%"*

3. Forgetting to integrate Figures and Tables into the text

- The results section should have some text that highlights important results while cross-referencing the Figures and Tables.
- Example: "*The V(III) complex 2 (Figure 5) displays a rich spectrum with an intense band …*" rather than "*Figure 5 displays the optical spectrum of 2 in acetonitrile.*", which merely restates the figure caption.

Text, Table, or Figure?

How should you present your data to the reader? This question takes consideration of the audience, manuscript type, and the type of data. Read Module 2 for more information on this topic. In any case, Figures or Tables should always be presented as close as possible to the related text and cross-referenced. Tables should have concise and descriptive titles. Figure captions should stand alone in explaining what the figure shows.

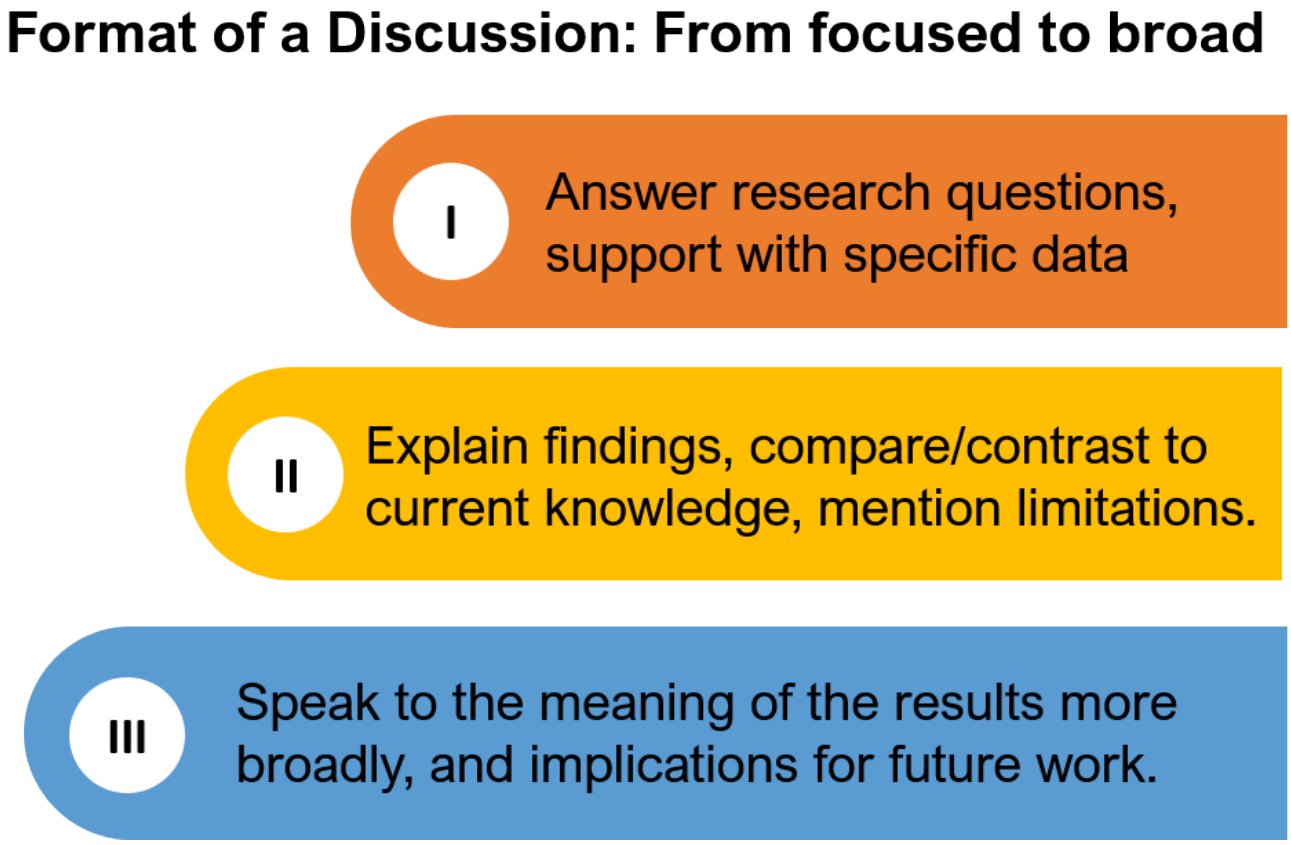
Discussion

In the Discussion section, the authors must interpret their results by relating the findings to earlier results in the field. This section should be written confidently without making sweeping or exaggerated statements. Discuss the theoretical implications of your work, as well as any practical applications.

Suggestions for the discussion:

- state your conclusions as clearly as possible
- summarize your evidence for each conclusion
- do not try and explain every little detail or limitation
- it's okay to have some unexpected results
- claims should be supported by the data (do not exaggerate)
- avoid hedging ("Could be", "Possibly", "Maybe")

The structure of the Discussion is important for the flow of your paper. Start by restating and answering your research questions; this can be done in the Topic Sentences within the paragraphs and by using descriptive subheadings like in the Results section. Continue by supporting these answer statements with your results and data, and explain how the findings relate to your original hypothesis. Aim for an answer to the question: What does it all mean? Compare and contrast your findings to prior work and discuss discrepancies. Briefly describe both limitations in your approach and what the findings might suggest for future studies.



Common Discussion mistakes:

- New results are discussed
- Overly broad statements
- Errors when interpreting inconclusive results
- Ambiguous data sources
- Missing information
- Wrong verb tense

Conclusions

The Conclusions are the shortest part of the article. Briefly summarize the key findings and answers to the research questions, without just repeating the Results section. Often authors will add a new, higher level of analysis. Most importantly, the conclusion should explicitly state the significance of the work.

Some readers will skip straight to the Conclusions if an Abstract is too long! Save writing the conclusion until you have a good draft of the rest of the manuscript so that you can easily write about the "big picture".

Acknowledgements

This is the section to acknowledge any funding or technical supports, or "fruitful conversations" with colleagues.

References

Check the journal's or publisher's referencing style and follow it! Use a citation manager, like EndNote or Mendeley, that allows you to create a list of references in many formats. Make sure to be consistent and do a thorough check of author names, page numbers, etc. before submitting your article. Queen's University has compiled many resources into this Citation Guide.

Supplementary Materials (or Appendix)

This section is a separate document (or if an Appendix, is at the end of the manuscript), and contains extra experimental details (e.g., NMR spectra). Pages are numbered S1, S2, S3... and Figure captions and Table titles are also numbered this way (Figure S1) to distinguish them from the manuscript. Supplementary Materials can also include other file types like X-ray crystallographic datafiles, videos, 3-dimensional models, or anything else.

Tips for Reviews

The main difference between an article and a review is primarily the audience. While articles and communications have a specialized audience, the readership of reviews is broader and may cover several subjects. In this way, writing a review is similar to writing a thesis.

The best advice for writing a Review is to start with an outline, which is often included as a Table of Contents at the start of the paper. The outline will help you stay on track with the goal of the Review.

6.

THESIS

Read time: 4 minutes

Overview

This chapter will give some guidance and resources for thesis writing.

Sections in this chapter

- Get organized
- Audience
- Structure of a thesis
- How to start

Get organized

The thesis is the largest document that graduate students need to write! Efficient writing requires organization, not just while writing but also in your scientific practice.

- Keep your lab notebook updated and organized
- Don't write on scraps of paper, write everything in a notebook!
- Compile good records of literature references (use a Citation Manager)
- Use a system to name all your files
- Keep your electronic files organized and properly named
- If you like to save many drafts, keep an "archive" folder for old drafts
- Always have a backup!!!
- Consider syncing your OneDrive to allow for auto-save
- Become familiar with the "Versions" features in Word

- Become familiar with Styles in Word
- Become familiar with the graphics programs (*e.g.*, ChemDraw)

Audience

Who is the audience of your thesis? Many students struggle with this question and this creates challenges with writing. The answer is that it depends on the section of the thesis!

Your graduate research, which culminates in the thesis, was at least in part funded by taxpayers in the general public. You owe it to the general public to have some part of your thesis that is accessible to their audience. This can be accomplished in the first few paragraphs of the Introduction and helps to ground all readers at the same level before getting into the high-level details.

By the time you are writing your thesis, you are the foremost expert in the research you have done (wow!). However, the downside of this expertise is that you can forget that others, even other experts, don't have your level of knowledge. If you don't keep the audience in mind, you will write your thesis in a way that is only understandable by you (and maybe your supervisor). For almost all thesis revisions, examiners request that the author explain in more detail what was done and use simpler language.

Structure of a thesis

There are also two possible forms of a thesis (Table 9.1): Traditional or Manuscript. The main difference is that in a Manuscript thesis, traditional chapters are replaced with verbatim copies of manuscripts (with the publisher's approval). The manuscript format saves time for students who published several papers throughout their degree and prevents self-plagiarism.

A thesis has a different structure from a journal article, one main difference being that the experimental details are often left until the end in the Appendices (similar to the Supplementary Matierlas in an article).

Table 9.1 Forms of thesis

Traditional Form	Manuscript Form	
Title Page	Title Page	**Front Matter**
Abstract	Abstract	
Co-authorship (if necessary)	Co-authorship (if necessary)	
Acknowledgements	Acknowledgements	
Statement of originality (PhD only)	Statement of originality (PhD only)	
Table of Contents	Table of Contents	
List of Tables	List of Tables	
List of Figures and Schemes	List of Figures and Schemes	
Chapter 1: Introduction	Chapter 1: General Introduction	**Body**
Chapter 2: Literature Review	Chapter 2: Literature Review (optional)	
Chapter 3 to n: Results and Discussion	Chapter 3 to n: Manuscripts	
Chapter n+1: Summary and Conclusions	Chapter n+1: General Discussion and Conclusions	
Bibliography or References	Permissions from publishers	**End Matter**
Appendices	Appendices	

How to start?

Begin writing your thesis early, from the very start of your graduate program. First, you can begin by organizing literature references. Once a month compile your group meeting and conference presentations, annual progress reports, candidacy exam reports, conference abstracts, and early results into a draft. Write a few lines a day or week, whenever you think of something, and this will quickly grow into a large document that will become your first thesis draft.

There are many resources to help you along the way. The School of Graduate Studies has thesis templates, writing retreats, and mental health resources. Student Academic Success Services has a lot to offer for graduate students including a Thesis Manager, Dissertation Bootcamp and Writing Lab, as well as one-on-one consultations.

Seriously, start now!

Do not wait until you are 3 months from finishing to create the first draft of your thesis, or you will quickly get overwhelmed. Start now:

1. Open a file in your word processor (Word, Latex, Google Docs)
2. Write a 'quick & dirty' paragraph about your research plan
3. Title your file "Thesis Working Document"
4. Download a citation manager and it's word processor plug-in

Later on, build up your working document into a draft:

1. Create an outline using headings
2. Create a Table of Contents and learn how to link it to document headings
3. Organize the document into chapter and sections
4. Add references and a bibliography
5. Learn to use fields to automatically update compound numbers and Figure/Table/Scheme numbers.
6. Learn how sections work in the word processor

Give yourself 3-6 months for the final thesis writing and defense process. Check the deadlines for submission for Spring/Fall convocations and tuition fees on the School of Graduate Studies Website.

As early as possible check the Queen's University guidelines for theses. You should also look at past theses from your research group for guidance and format.

Common mistakes to look out for:

- no general introduction
- the incessant use of jargon
- unnecessary fancy words (*e.g.,* "employed" rather than "use")
- not following Graduate School guidelines for format
- incomplete reporting of the literature
- inconsistencies in format, spelling, abbreviations, symbols, references, numbers, facts, etc., especially from chapter to chapter
- no conclusions/suggestions for future work
- no thought was given to the meaning of the results
- too much subdividing of Chapters (e.g. 2.3.4.1.1 The ...)
- the use of "we" instead of "I" – it is your thesis
- failure to proof-read before submitting to supervisor

- not backing up your computer files

7.

THE FIRST DRAFT

Read time: 3 minutes

Overview

This chapter will cover how to write your first draft.

Sections in this chapter

- Planning
- Organization
- Tips

The first draft

Before you can edit, you need a first draft. Writing this draft can be one of the more difficult challenges in the writing process, often you ask yourself "Where do I start?"

Your approach to writing will depend on your personal habits and whether you are writing an abstract, manuscript, book, or thesis. In general, you can try to follow the writing process below:

- **Planning**: identify objective, audience, scope
- **Organization**: create an outline, think about the story
- **First draft**: don't aim for perfection, aim for done
- **Editing**: as recursive revision process for style, cohesion, clarity, completeness, accuracy, etc.
- **Proofreading**: final detailed checking for consistency

Planning

Scientists spend a lot of time planning their research and experiments, but tend to overlook this stage of

writing. Before the writing process begins, and even at the outset of the research project, you should think about the objectives, questions, and audience for your research. Always keep your mind in the "Big Picture".

Organization

Common Journal Article Format

- Introduction
- Methodology
- Results
- Discussion
- Conclusion
- References

The organization of manuscripts and theses often follows a format set by the publisher or by your institution, making it easy to start with a basic outline template (see sidebar). Within these prescribed sections, you need to use knowledge of your research and field to organize your writing.

Later in this module will get into specific format and organization techniques for proposals, manuscripts, and theses. For now, below you will find some general strategies to help you organize your writing.

Tip #1: Use slides to organize your thoughts.

As you saw in the Writing Basics chapter, each paragraph should have a single topic or "key message". You can use PowerPoint so help separate and organize these topics. Create one slide for each key message from your project, and then organize and combine similar topics by moving slides.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=36#video-36-1

Tip #2: Write a single sentence summary of other work related to yours

Chris Campbell, CC BY-NC 2.0

Citation is important for maintaining academic integrity. During your graduate degree or scientific research project, you will find yourself reading dozens of research articles, and you need to keep track of what was done in each and where those ideas came from. It is useful to try to write a single sentence (or two) that summarizes *how the research in the paper relates to your own work*. This can be done the old fashioned way by printing the paper and adding a post-it note to the first page. Or you can use a citation manager (EndNote, Mendeley) or OneNote to keep track electronically.

Tip #3: Record yourself talking about what you want to write

Sometime's it's easier to just talk. Verbal discussion of science is less formal and doesn't require grammar or spelling. Even if you are talking to yourself, it can help you get your ideas flowing. If you want to capture everything, record yourself or use a transcription tool (*e.g.,* in Camtasia) to turn your speech into text.

Tip #4: "Perfect is the enemy of done" –*Catherine Carrigan*

Writing is a challenge for almost everyone, and perfectionism can make it nearly impossible to write your first draft. Remember that you can fix your spelling, grammar, the order of your ideas, and format in the Editing stage and just write as much as possible!

8.

EDITING

Read time: 9 minutes

Overview

Once you have the first draft, it's time to edit! Most people enjoy editing much more than writing. Interpret the word revision as re-VISION: "See" your paper again; look at it objectively, sceptically, as if it is not your own work.

Here, we will use the Point-First approach developed by Ellen B. Zweibel and Virginia McRae to edit our writing in 5 layers, which is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Sections in this chapter

- Editing in Layers
- The Big Picture
- Structure
- Continuity
- Clarity
- Final Proof

Editing in layers

Editing your work especially, a thesis, can be a daunting task. There may be issues with the overall structure and story, problems with clarity, as well as spelling and grammar mistakes.

The Point-First approach involves separating these tasks and editing in five layers:

1. The Big Picture
2. Structure
3. Continuity
4. Clarity
5. Final Proof

You can follow through the Editing in Layers guide online as you edit your work, and use this PDF checklist to keep track of your progress.

Watch the Point-First video below (transcript), to understand why it is important to edit your work in layers rather than trying to edit everything at once.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=146#oembed-1

Video from PointFirstWriting.com by Ellen B. Zweibel and Virginia McRae,

The Big Picture

The first step to editing your work is to consider context, audience, and purpose. Ask yourself: Who are you writing for, and why? Where will this writing be published? What is the expertise of your audience?

SCIENCE WRITING CONTEXTS

INNER CIRCLE	LOCAL OR CHEMISTRY-SPECIFIC
• progress reports • internal documents • emails to colleagues and supervisors • research updates • lab notebook	• annual research updates • department-wide • specialized journals (*e.g., Organic Letters*) • conference proceedings • lab reports
BROAD SCIENCE	**GENERAL PUBLIC**
• science news sites (*e.g.,* CIC News) • broad-readership journals (*e.g., Science*) • grant and scholarship applications • thesis	• popular science magazines (*e.g.,* Wired) • social media • essays (*e.g.,* The Conversation) • news releases

Exercise: The Big Picture Read

Find a sample of your writing, either your first draft or something you already finished. Follow the Point First Checklist items and tasks under #2 "The Big Picture Read" to see how well your writing suits your the context, audience, and purpose.

- What is the context? – a report, journal article, proposal in an application?
- Who are the readers? – present and future readers, their characteristics and needs?
- What is the purpose? – inform, recommend, update, warn, advise or persuade?
- Write a note beside each paragraph on what the paragraph is about. Then use the notes to check that it meets the context, audience, and purpose.

Structure

The structure of your writing can refer to your overall structure, headings, paragraph, or sentence structure. Review the chapters on Sentences and Paragraphs to learn how to write with clarity and structure.

Exercise: Shaping Paragraphs

Find a sample of your writing, or use the paragraph below. Highlight all the important information, then restructure your paragraph so that those sentences are at the beginning or end of the paragraph. Watch the Point First video below to guide you (transcript).

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=146#oembed-2

Writing Sample from Rice University "Chemistry" (CC-BY): *In ionic compounds, electrons are transferred between atoms of different elements to form ions. But this is not the only way that compounds can be formed. Atoms can also make chemical bonds by sharing electrons equally between each other. Such bonds are called covalent bonds. Covalent bonds are formed between two atoms when both have similar tendencies to attract electrons to themselves (i.e., when both atoms have identical or fairly similar ionization energies and electron affinities). For example, two hydrogen atoms bond covalently to form an H_2 molecule; each hydrogen atom in the H_2 molecule has two electrons stabilizing it, giving each atom the same number of valence electrons as the noble gas He.*

Key Takeaways

Find a sample of your writing, either your first draft or something you already finished. Follow the Point First Step-by-Step Approach to editing your structure (halfway down the page), the steps are summarized below:

1. Test your point-first openings: Check the first sentence of each paragraph
2. Cut and paste your headings into a new document: Check the order
3. Audit and revise your headings: Make them descriptive
4. Main idea: Write 1-2 words describing the single point of each paragraph
5. Cut topic sentences and last sentences and paste under headings

Continuity

In this next layer of editing, you can check the flow of your writing at the paragraph level. Each paragraph in your writing should have a single topic, but your writing will seem choppy if you don't build connections from one paragraph to the next. Use clear transition words to connect your paragraphs. Beyond the words, consider how your sentences link paragraphs together and move your ideas along.

Exercise: Check your transitions

Find a sample of your writing or use the sample below. Use the following strategies to check your transitions.

- Highlight all the transition words and phrases. Check for wordiness and repetitiveness, and remove any unnecessary words. [Video explanation]
- Rewrite the second paragraph topic (first) sentence to create a better link to the ending of the first paragraph.

'By and large, organometallic compounds find wide use in commercial reactions, both as homogeneous catalysis and as stoichiometric reagents. For instance, organolithium, organomagnesium, and organoaluminium compounds, examples of which are highly basic and highly reducing, are useful stoichiometrically. These compounds, however, also catalyze many polymerization reactions.

Consequently, almost all industrial processes involving alkene-derived polymers rely on organometallic catalysts. The world's polyethylene and polypropylene are produced, for the most part, via both heterogeneously via Ziegler–Natta catalysis and homogeneously, e.g., via constrained geometry catalysts."

Avoid using ambiguous pronouns that refer to something from far back in the text. A common mistake here is to start a new paragraph by ambiguously referring to something from the previous paragraph. If your reader needs to stop and look back to know what you are talking about, this makes your writing difficult to understand.

Examples of Ambiguous pronouns.

Example 1 (modified from a Wikipedia entry)

> *Metals are shiny and lustrous, at least when freshly prepared, polished, or fractured. Sheets of metal thicker than a few micrometres appear opaque, but gold leaf transmits green light.*
>
> *The solid or liquid state of them largely originates in the capacity of the metal atoms involved to readily lose their outer shell electrons.*

"Them" is in a new paragraph, and the reader may not know what is being referred to, metals or sheets of metals, or gold leaf?

Example 2

> *The alcohol, a derivative of the aldehyde, it has a boiling point of 50 °C.*

Which has a boiling point of 50 °C, the alcohol or the aldehyde? You might know, but the reader will be confused.

Another trap that can break the flow of your writing is Using Too Many Acronyms (UTMA). In your research group or department, there may be a common understanding of some acronyms, and it can be easy to forget that they are not universal! Unfortunately, using unnecessary acronyms like UTMA in your writing slows down the reader because they have to look back in the text. Avoid UTMA!

Use this Point First Transitions Traps checklist to edit your writing transitions thoroughly, including checking the consistency of terms.

Clarity

Now that you've tackled the big picture, structure, and continuity, you can start to look at your words and sentences. In an earlier chapter, we already discussed ways to write with more clarity by controlling sentence structure, using active voice, and ambiguity. Point First has many incredible tools to help you improve clarity in your writing with a focus on these three topics. Clarity can also be an issue on the larger scale if what you wrote is too long. Follow this link to learn how to ruthlessly cut out 10% in 10 minutes!

Subject-Verb-Object Editing

Even if you tried to get this right in your draft, you probably still have some confusing sentences. Find a sample of your writing or use the sample below.

- Highlight the subject, verb, and object in each sentence.
- Are the sentences in the order Subject-Verb-Object?
- If the Subject too far from the Verb?
- Rewrite sentences to improve clarity.

> This morning you, after checking the solvent containers, need to set up the HPLC for analysis. You can refill the solvent if it is less than half full. After I turn on the instrument, you need to record the pressure of the column. If you have a good reason to skip this step, but this goes against our best practices, then you will be responsible if the column fails.

In the example above, the first sentence is hard to follow because the subject is far from the verb and object. The last sentence has the same problem.

Wordiness and Passive Voice

Get rid of the clutter! Cut out or move any content that is irrelevant to the main message of the paragraph. See the example below, which is a modified text from the Wikipedia entry on Marie Curie (word count = 44).

> *Due to the fact that international recognition for her work had been growing to new heights, the Royal Swedish Academy of Sciences, overcoming opposition prompted by the Langevin scandal, honoured her a second time, with the Nobel Prize in Chemistry in the year 1911.*

Suggested rewrite for clarity (word count = 18):

In 1911, The Royal Swedish Academy of Sciences honoured Marie Curie with her second Nobel Prize in Chemistry.

Who did what, and when?

Make sure you don't have any misplaced modifiers! Modifiers are words that modify the meaning of a noun (*e.g.*, "veggie burger"). From the sentence below, it's hard to tell exactly what Alice did this morning, the reaction or the purification.

Alice purified the mixture obtained from a reaction she ran in the glovebox this morning.

For clarity, move the modifier closer to the noun it is modifying.

This morning, Alice purified the mixture obtained from a reaction she ran in the glovebox.

It is very common in science for verbs (e.g., conclude) to be turned into nouns (e.g., conclusion). This might not seem like an issue, but when overused this 'nominalization' can make for boring and passive writing.

Check your own work for the following common nominalizations used in science writing, and search the underlined endings to find them in your own text. Notice how it comes hand in hand with passive voice:

- "calculations were performed..." [verb = calculate]
- "the dependence of..." [verb = depend]
- "the stability of..." [verb = stable]
- "in agreement with..." [verb = agree]

Nominalizations

Rewrite the following sentences to fix unnecessary nominalizations. Then check your own writing! Removing nominalizations has the bonus effect of fixing passive voice and helping with wordiness.

1. The calculations were performed on the cluster using density functional theory (DFT) and are in agreement with prior work.
2. The intention of this approach is to create new materials with high stability.
3. This result showed the dependence of our process on temperature and supported our implementation of the infrared control system.

The Final Proof

Only once you are done editing can you move on to proofreading. Proofreading is a final check for spelling, grammar, and consistency. If you start proofreading too early, you will waste time on words and paragraphs that still need work, or once that may not even make it to your final draft. The next chapter will provide an overview and tips for proofreading, and you can also check the Point First checklist and resources.

Attribution

9.

PROOFREADING

Read time: 1 minute

Overview

Proofreading is the final step to revising your work and should happen after thoroughly editing your writing. The goal of proofreading is to polish your writing; read through to catch any spelling, grammar, punctuation, and consistency of terms. If you find issues with flow, clarity, or wordiness, go back to the editing stage!

Sections in this Chapter

- Steps in Proofreading

Steps to Proofreading

1. **Fresh eyes**. Spend some time away from the document after you finish editing. It helps to have fresh eyes!
2. **Be aware**. If you find yourself making many revisions, *i.e.* editing, either...
   → Stop! go back to the editing stage
   → Pause. You can't keep changing things and editing forever. At some point, you must decide that you are done!
3. **Make a checklist.** Think of common errors you may have made and make a checklist (acronyms, figure and table numbers, common misspellings like their/there, is/of, not/now.)
4. **Print it**. Some people find it much easier to proofread a printed document. Use a larger font and double spacing.
5. **Imagine your reader**. Start by reminding yourself of your audience and keep this context in mind.
6. **Read it backwards (right to left)**. This helps you override your brain's tendency to "fill in" missing words and fix mistakes.
7. **Use spellchecker tools**. Word and Grammarly are two free tools to catch spelling mistakes.
8. **Search for consistency**. If you find an error, use the find and replace feature to look for the same

mistake elsewhere.

9. **Define**. Check that all acronyms, abbreviations, measurement units, and jargon are defined.
10. **Ask for help**. Ask your friends, peers, and supervisor to proofread. Let them know what level of revision you are looking for.

MODULE II

MODULE 2: VISUALS

10.

HOW SHOULD I REPRESENT MY DATA?

Read time: 1 minute

Text, Table, or Figure?

There are many ways to present qualitative or quantitative data to your readers, and this choice can change how well your findings are understood. Simple information can be presented in the text, more data can be laid out into Tables, and complex relationships should be represented as graphs, charts, or other types of Figures. Use the flowchart below (Figure 10.1) to help you decide what is best suited for your data and purpose.

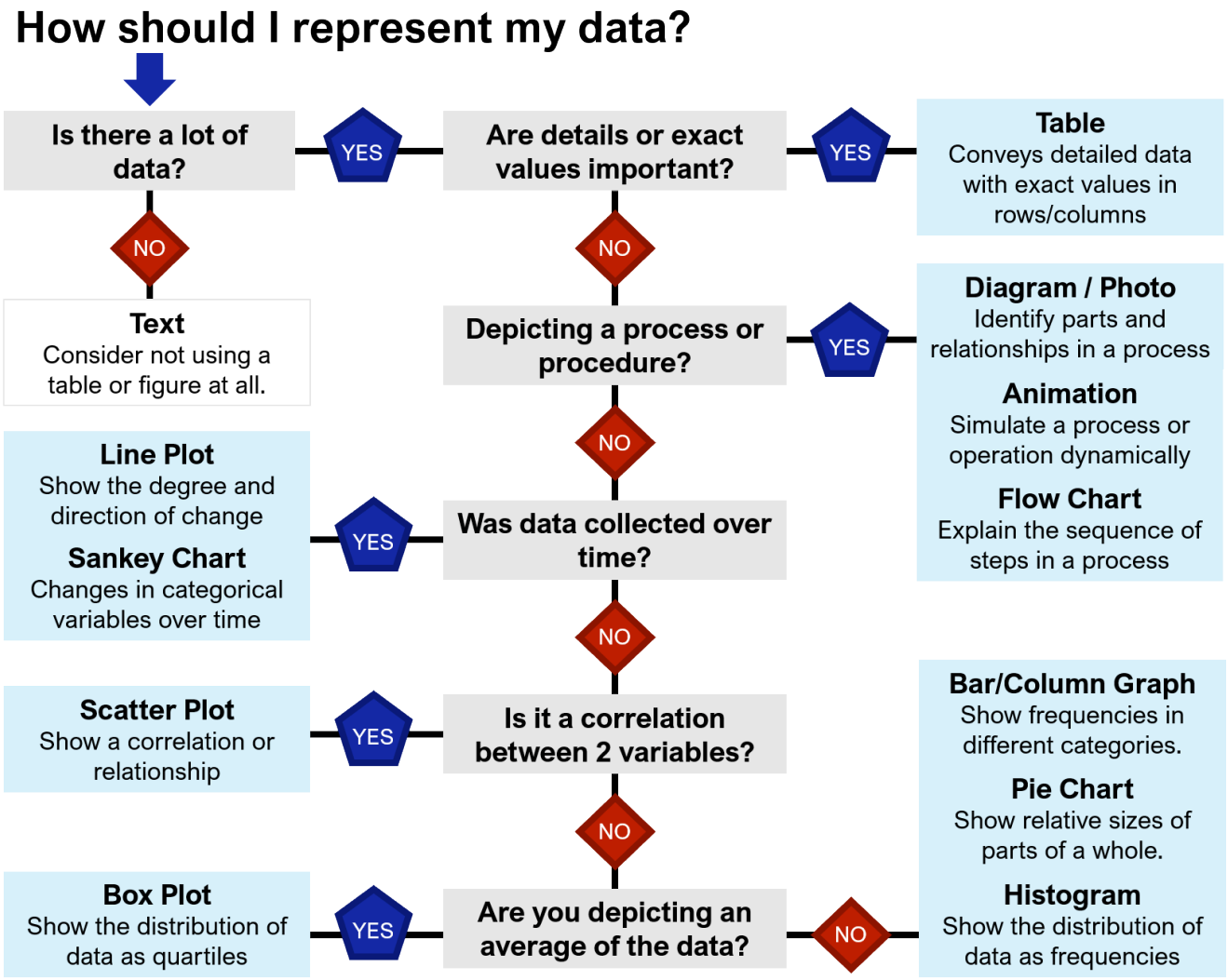
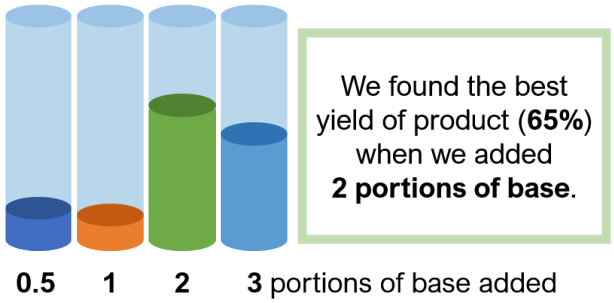


Figure 10.1. Flow chart showing different ways to represent data.

Don't forget your audience

The first thing to consider, as always, is the audience. For a more general audience, like in a popular magazine or website, data can be simplified to the key message and displayed visually (Figure 10.2 left). The same data is better presented in a Table for an audience that wants to know the exact numbers and details (Figure 2.1.2 right).

Audience for data: general public



Audience for data: experts in the field

Entry	Base, **Molar Equivalents**	Isolated Yield (%)
1	Et_3N, **1.0**	5
2	*i*-Pr_3N, **1.0**	15
3	*i*-Pr_3N, **0.5**	17
4	*i*-Pr_3N, **2.0**	65
5	*i*-Pr_3N, **3.0**	52

Figure 10.2. Examples of the same data represented in different ways depending on the needs and expertise of the audience.

11.

TABLES

Read time: 2 minutes

Overview

This chapter discusses the use of tables to show data in science with a focus on the field of chemistry.

Sections in this chapter

- Tables in science
- Table or text?
- Table design

Tables in science

As we saw in the flow chart introducing this module, a table is a good option for presenting a large amount of data and when all of the details and exact values are important. If the data is important but too large for the body of an article, it is included in an Appendix or Supplementary Materials. Figure 11.1 shows the format of a typical figure in a chemistry article or thesis.

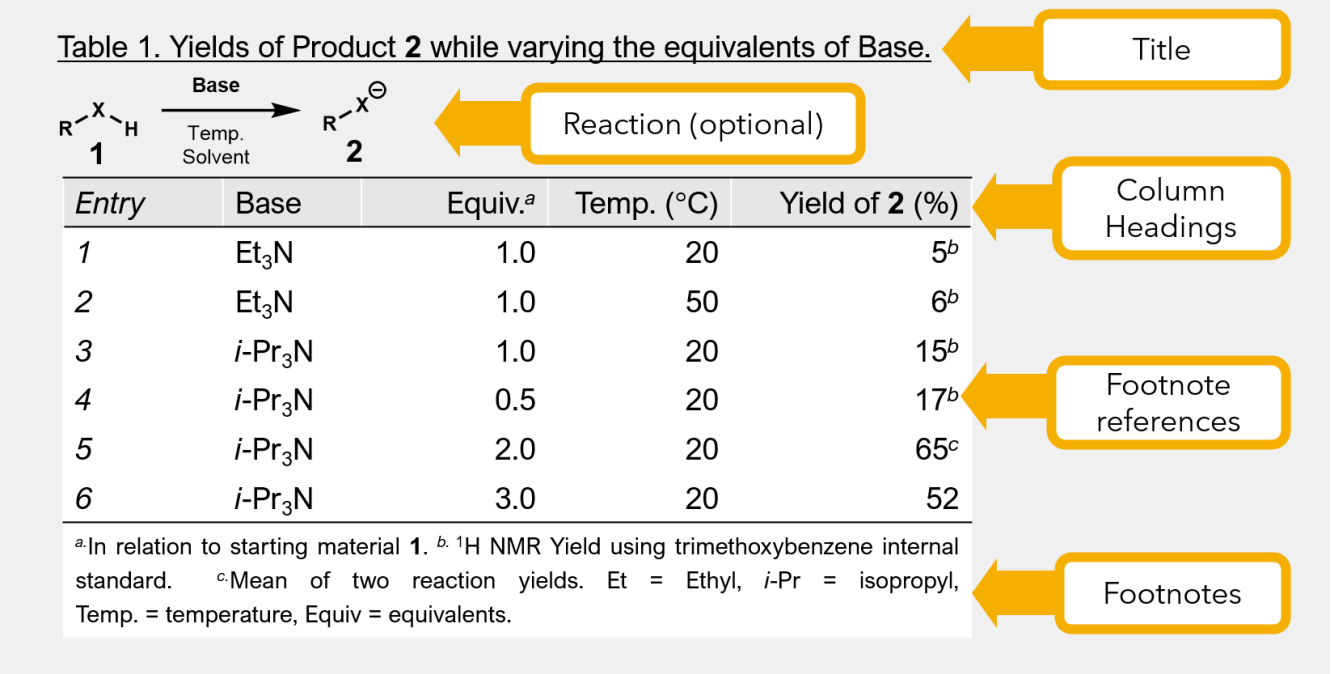


Figure 11.1. A typical table for chemistry reaction data. The subtitle that includes a reaction is sometimes included.

Tables can supplement text and present numbers in a way that conveys meaningful relationships. They should be simple, concise, and use abbreviations or symbols in a way that is consistent with the text. Tables should have at least 3 columns and 4-5 rows, otherwise, the data might be better represented as text.

The title of a table should describe the contents without the reader having to refer to the text (this is where including a reaction diagram subtitle can be useful). Details that don't fit in the table can be included in the footnotes.

Column headings should be limited to two lines and can use abbreviations or symbols, but make sure the units are shown in full.

Text or Table?

The small table below contains data that is better conveyed in a single sentence.

"*Streptomyces coelicolor* grew by 78% (5 experiments) at 24 °C upon aeration of the growth medium, whereas no growth was observed with no aeration."

Table 1. Effect of aeration on growth of *Streptomyces coelicolor*

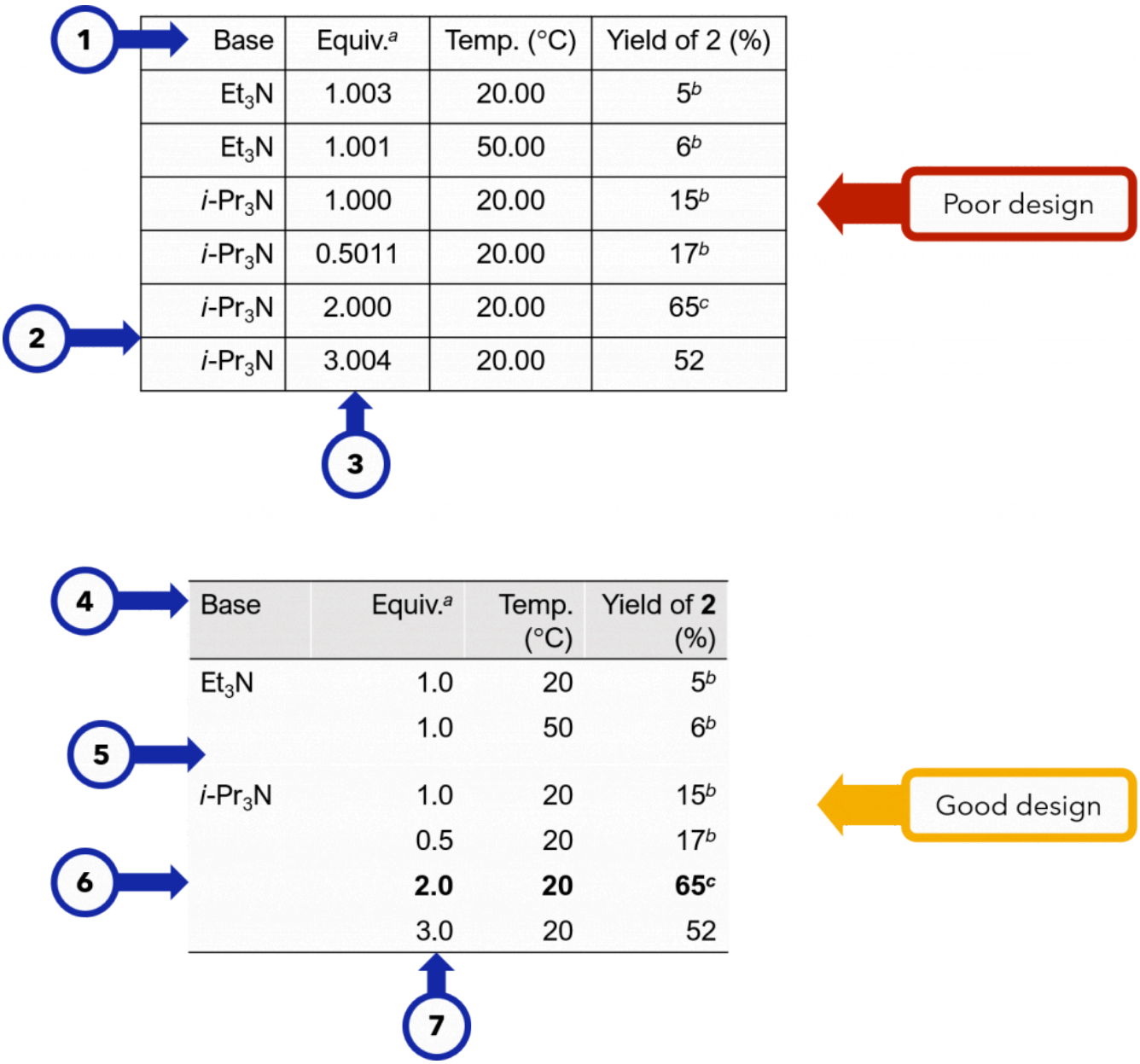
Temp (°C)	No. of expt	Aeration of growth medium	Growth[a]
24	5	+[b]	78
24	5	–	0

[a] As determined by optical density (Klett units).

[b] Symbols: +, 500-ml Erlenmeyer flasks were aerated by having a graduate student blow into the bottles for 15 min out of each hour; –, identical test conditions, except that the aeration was provided by an elderly professor.

Table Design

Tables aren't just cells of rows and columns, they can be designed to help the reader follow and find the most important information. Jon Schwabish published a brilliant guide to better table design (Twitter thread, Article). Let's see how his data principles were used to create the table above, as outlined in Figure 11.2.



Base	Equiv.[a]	Temp. (°C)	Yield of 2 (%)
Et_3N	1.003	20.00	5[b]
Et_3N	1.001	50.00	6[b]
i-Pr_3N	1.000	20.00	15[b]
i-Pr_3N	0.5011	20.00	17[b]
i-Pr_3N	2.000	20.00	65[c]
i-Pr_3N	3.004	20.00	52

Base	Equiv.[a]	Temp. (°C)	Yield of **2** (%)
Et_3N	1.0	20	5[b]
	1.0	50	6[b]
i-Pr_3N	1.0	20	15[b]
	0.5	20	17[b]
	2.0	**20**	**65[c]**
	3.0	20	52

Figure 11.2. Examples of both good and poor table design.

1. **Left-align text**
2. **Only use borders when necessary**
3. **Use the right level of precision**
4. **Make your header row stand out**
5. **remove repetitive data and use white space**
6. **Highlight important results or outliers**
7. **Right-align numbers and always align decimals.**

12.

FIGURES

Read time: 6 minutes

Overview

As we saw in the flow chart introducing this module, Figures (charts, diagrams, illustrations, plots) are shown to represent many forms of data and its trends, including relationships between different variables. This chapter will describe different types of figures and also cautionary examples of misrepresenting data.

Sections in this chapter

- Essential Parts of a Figure
- Diagrams, Photos, Animations, and Flow Charts
- Bar Graphs, Pie Charts, and Histograms
- Box Plots
- Scatter Plots and Line Plots
- Sankey Charts
- Spectra

Essential Parts of a Figure

There are several things that almost every figure should contain (Figure 12.1):

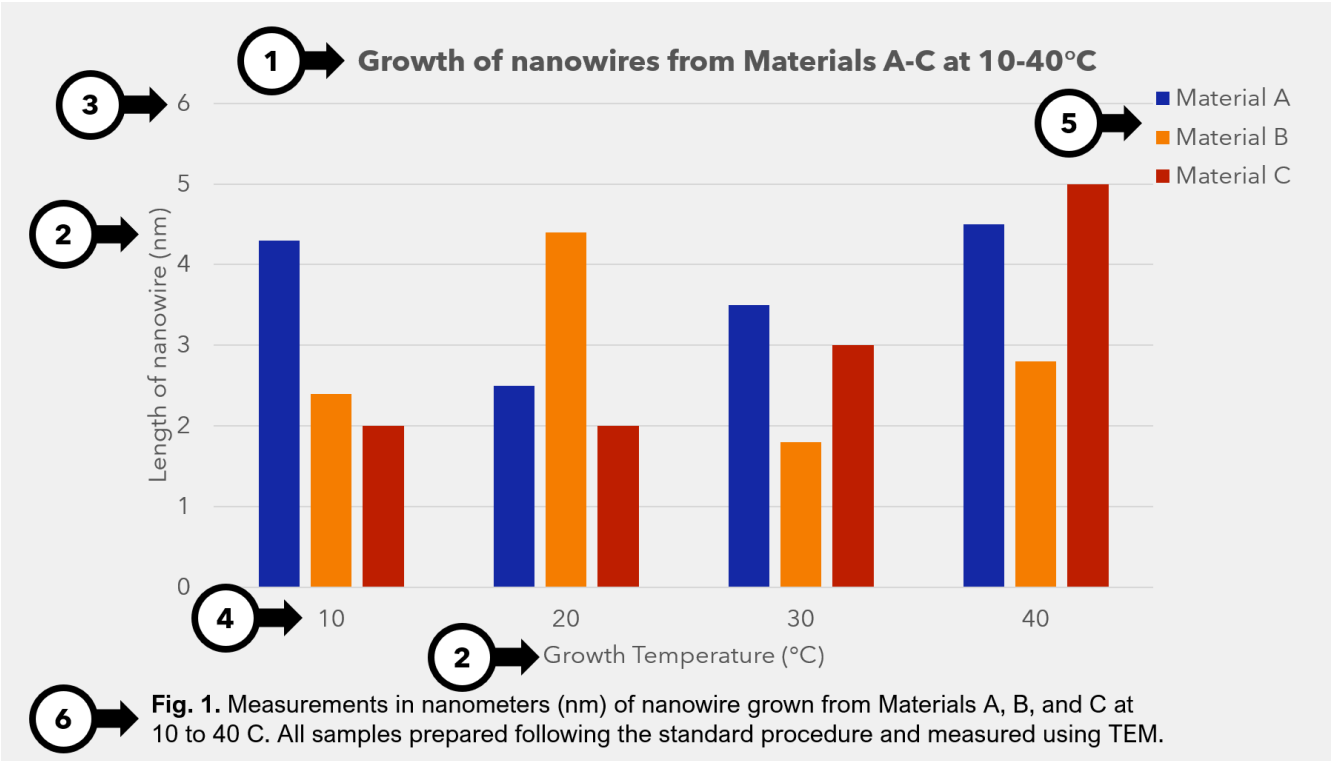


Figure 12.1. Example of a figure and it's key parts.

1. **A title**
2. **Labelled axes with units if applicable**
3. **Appropriate axes scales**
4. **Appropriate precision**
5. **A legend (separate or integrated)**
6. **A caption**

If you are missing any of the above, your figure at best will be confusing, and at worst will mislead the reader and misrepresent your data.

Below are some common mistakes in graphic design. Many of these will be addressed below or in the Chapter on Accessible and Ethical Design.

- The wrong type of figure for the data
- Axis scaled inappropriately (e.g., 0-10 when max. value was 6)
- Labels and text are too small.
- Colours are too light for printing
- Colours are difficult to distinguish in greyscale
- Colours are difficult to distinguish for colour-blind persons
- Axis label is missing units

- Axes numbers have the wrong precision; too much (10.000, 11.000, 12.000) or too little

Diagrams, Photos, Animations, and Flow Charts

These are figures that don't necessarily contain data but convey important information about an instrument, procedure, or process. These types of figures (Figures 12.2, 12.3) are useful in the Introduction to explain an abstract concept, or in the Methods section to show how something works.

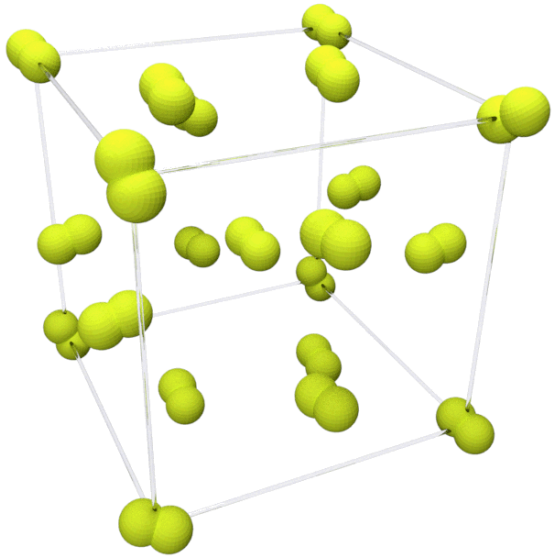


Figure 12.2. Animation of F_2

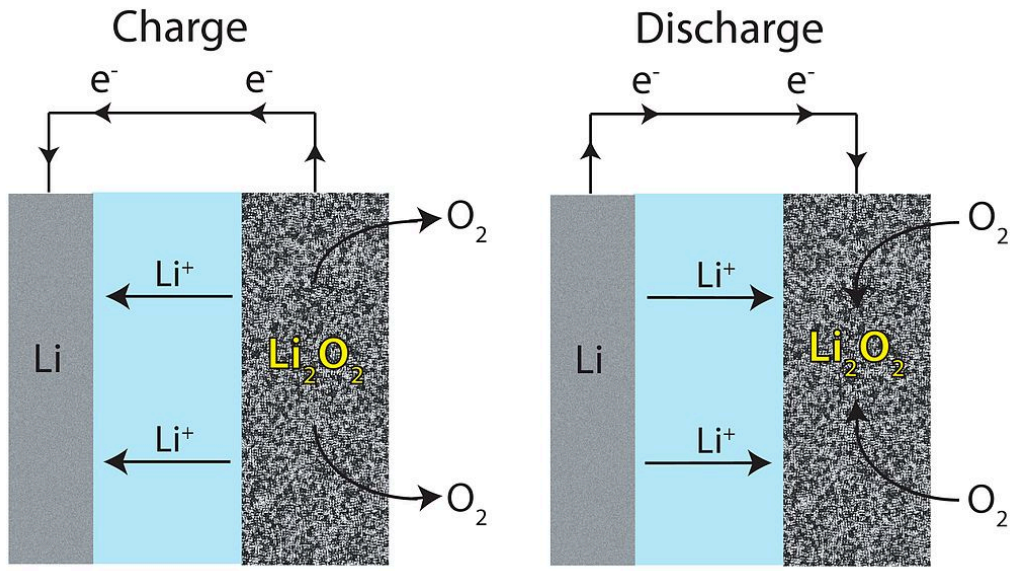


Figure 12.3. Battery Process Diagram with LiO_2 photo

Bar Graphs, Pie Charts, and Histograms

These three types of graphs all show amounts, either frequencies across groups (Bar Graph) or relative to a whole (Pie Chart or Histogram). Bar charts are a clear way of presenting a trend in data. In a vertical bar chart (more common), the measured variable is on the Y-axis while the categorical variable is on the X-axis. Bar charts can be clustered like in Figure 12.1 or stacked like in Figure 12.4A to show different subsets of data.

Histograms show the frequencies (Y-axis) of an occurrence within the data of data split into bins. In Example Figure 12.4B, the data contains a list of hail pellet masses in grams, and the data plots the frequency that the hail pellet was ranged from 1-2.5 g, 2.5-4 g, etc. The selection of bin size can change how the data looks and should be carefully considered. The Pie Chart in Figure 12.4C shows the same data in a different way, but the designer chose to focus on the idea that most hail pellets are 3-6 grams in mass.

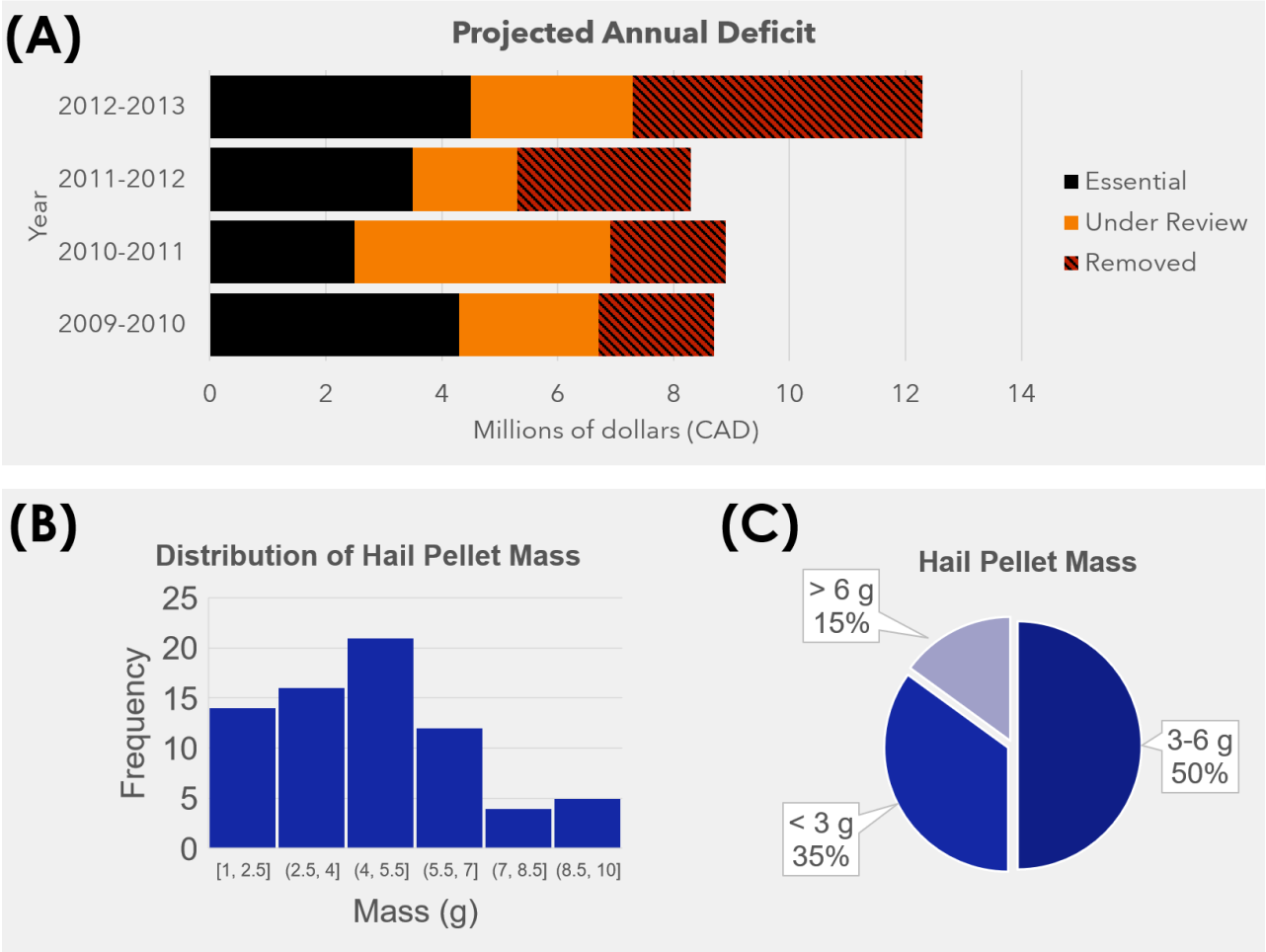


Figure 12.4. (A) Example of a stacked bar chart. Notice that the categories are sorted logically (essential, under review, removed). (B) Examples of Histograms and (C) Pie Charts.

Bar charts should be used to depict amounts or frequencies, but not means. If you are trying to depict means of your data (i.e. multiple measurements averaged within separate categories), it's better to use a Box Plot or another type of graph that shows the *distribution of data*.

Box Plots

Box plots (also called Box and Whisker Plots) and related graphs (Stem and Leaf, Violin) effectively show the distribution of data within categories (Figure 12.5). They contain information about the spread of the data; it's quartiles, the median, the mean, and outliers.

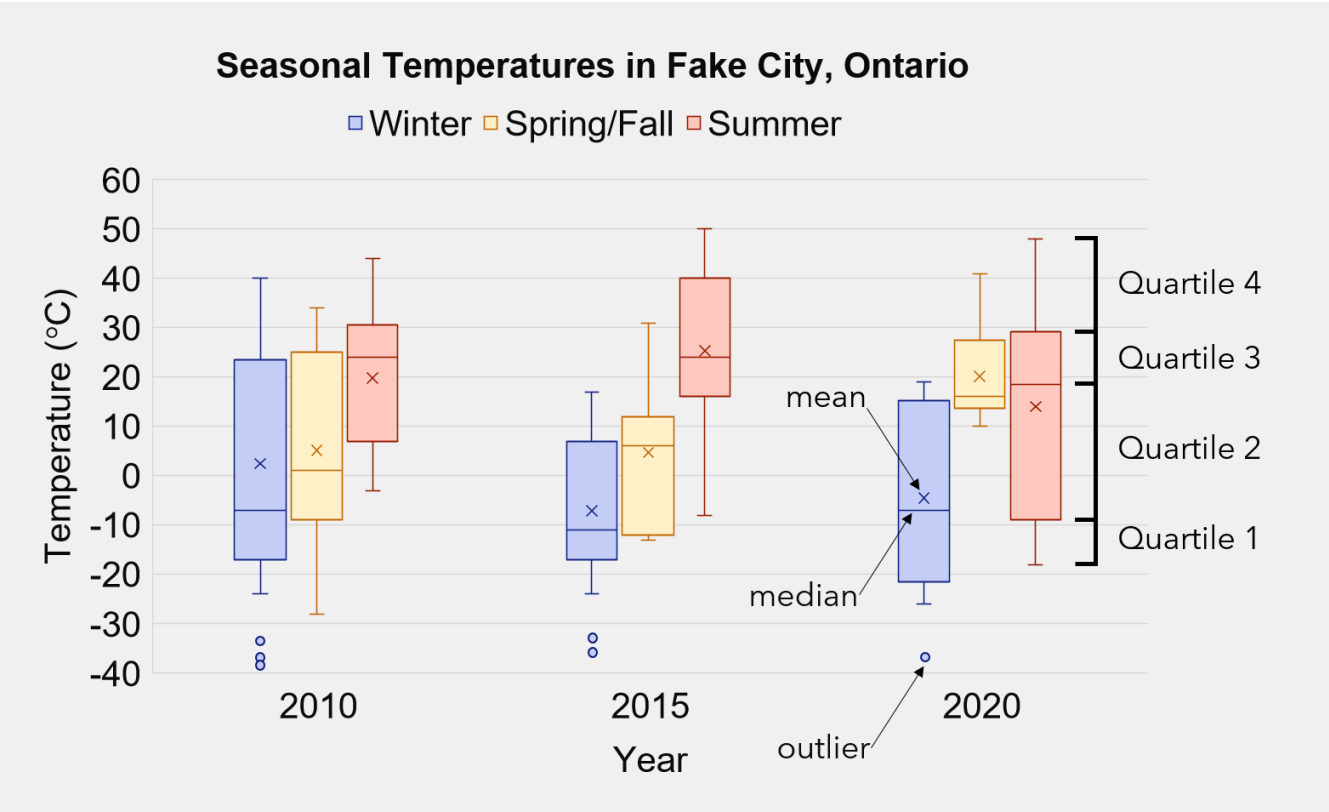


Figure 12.5. Features of a Box Plot

Box Plot vs Bar Chart

Look at the figure below to see the differences between a Box Plot and Bar Chart when showing a collection of data, and it's mean. The Box Plot contains much more information than the Bar Chart, in the same amount of space.

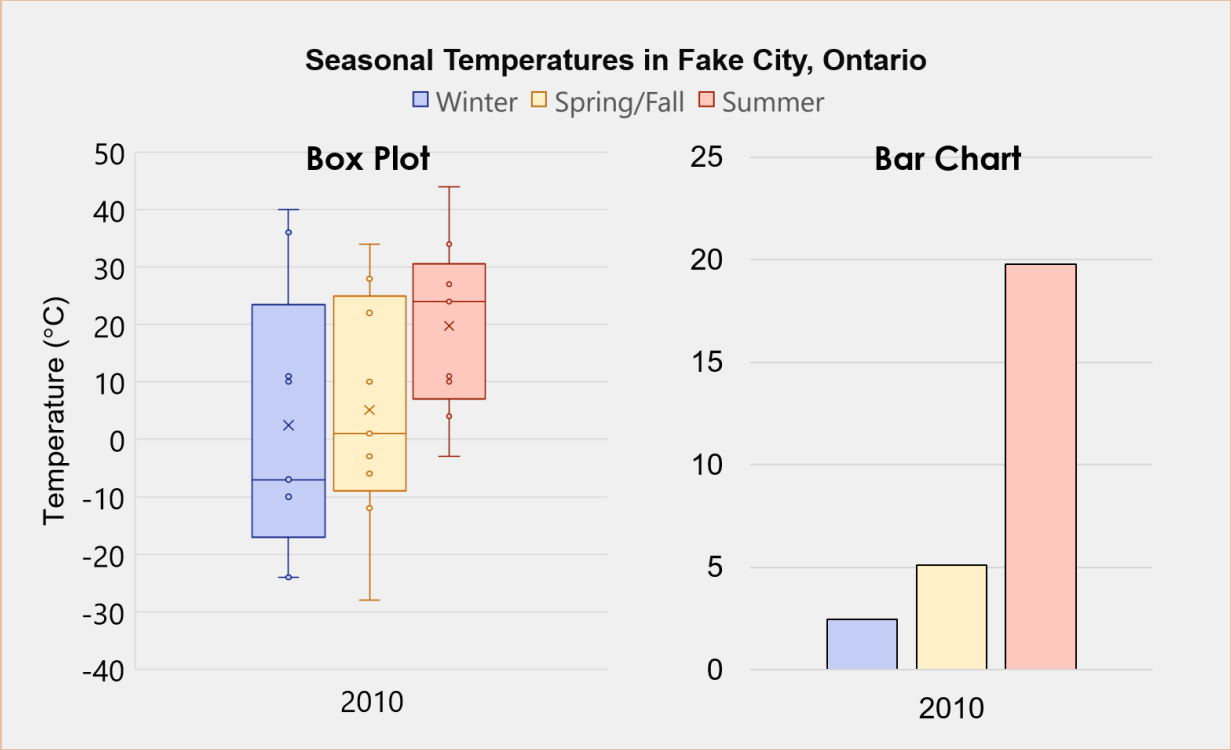


Figure 12.6. Comparing a Box Plot of fake temperature data in the year 2010 versus mean temperatures shown in a Bar Chart.

Scatter Plots and Line Plots

Scatter plots are correlations of two variables plotted as X and Y coordinates (Figure 12.7). Data is usually plotted in this way when we are interested in knowing if there is a relationship between the changes in the two variables. In most cases, there is an independent variable (plotted on the X-axis) and a dependent variable (plotted on the Y-axis).

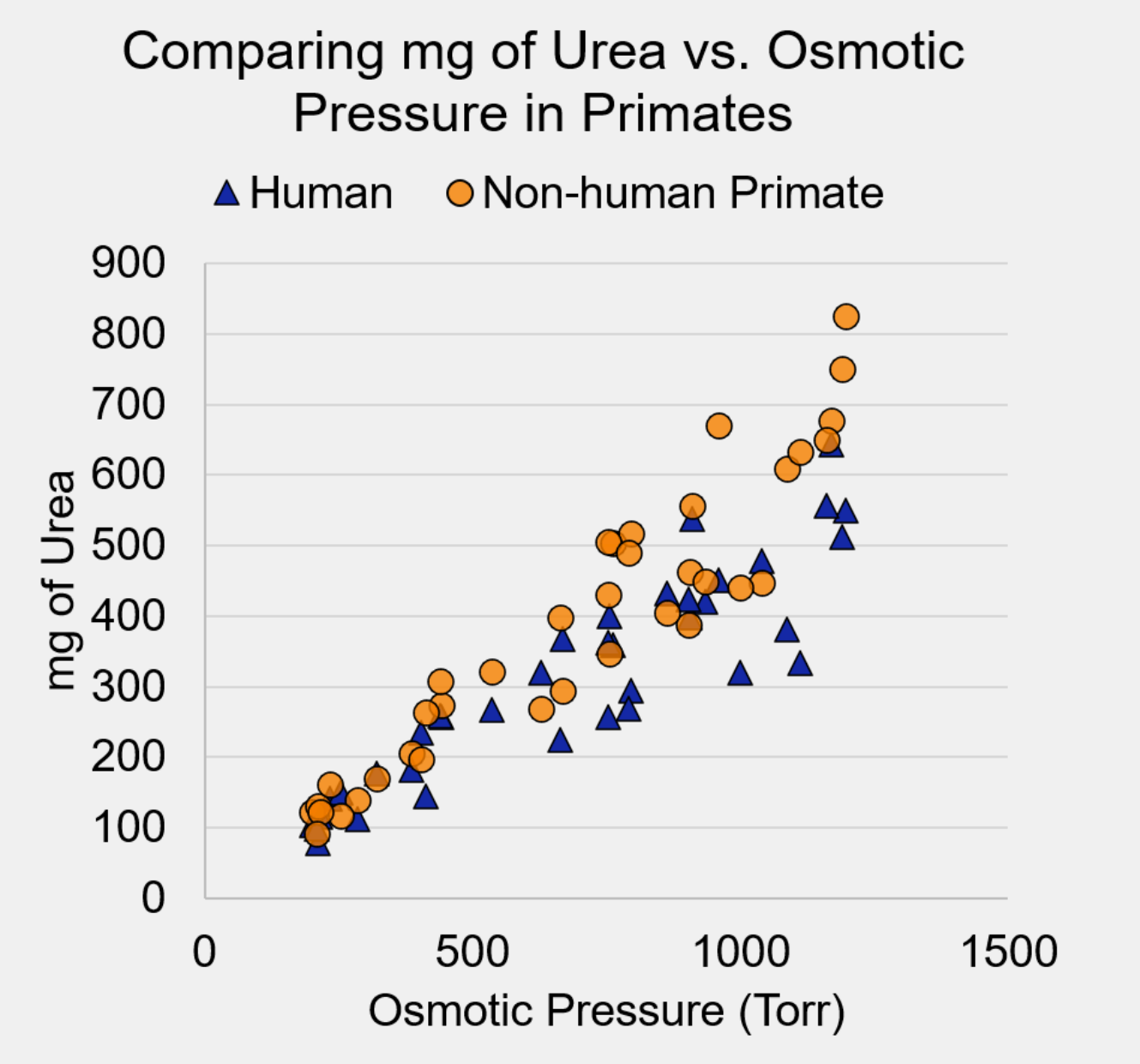


Figure 12.7. An example of a scatter plot showing a linear relationship between osmotic pressure and mg of urea.

A regression line or curve indicates a statistically valid relationship between the two variables, and the regression equation with the statistical parameters are given. Scatter Plots are often misused in this way to imply causation between the two variables (see below).

Correlation vs Causation and Misrepresenting Data

This example of shoddy data analysis was posted by Markus Eichhorn (@markus_eichhorn): [1]

> *"Cucumber consumption has a negative association with COVID deaths. But stay off the lettuce. Yes, it's another shoddy COVID preprint!"*

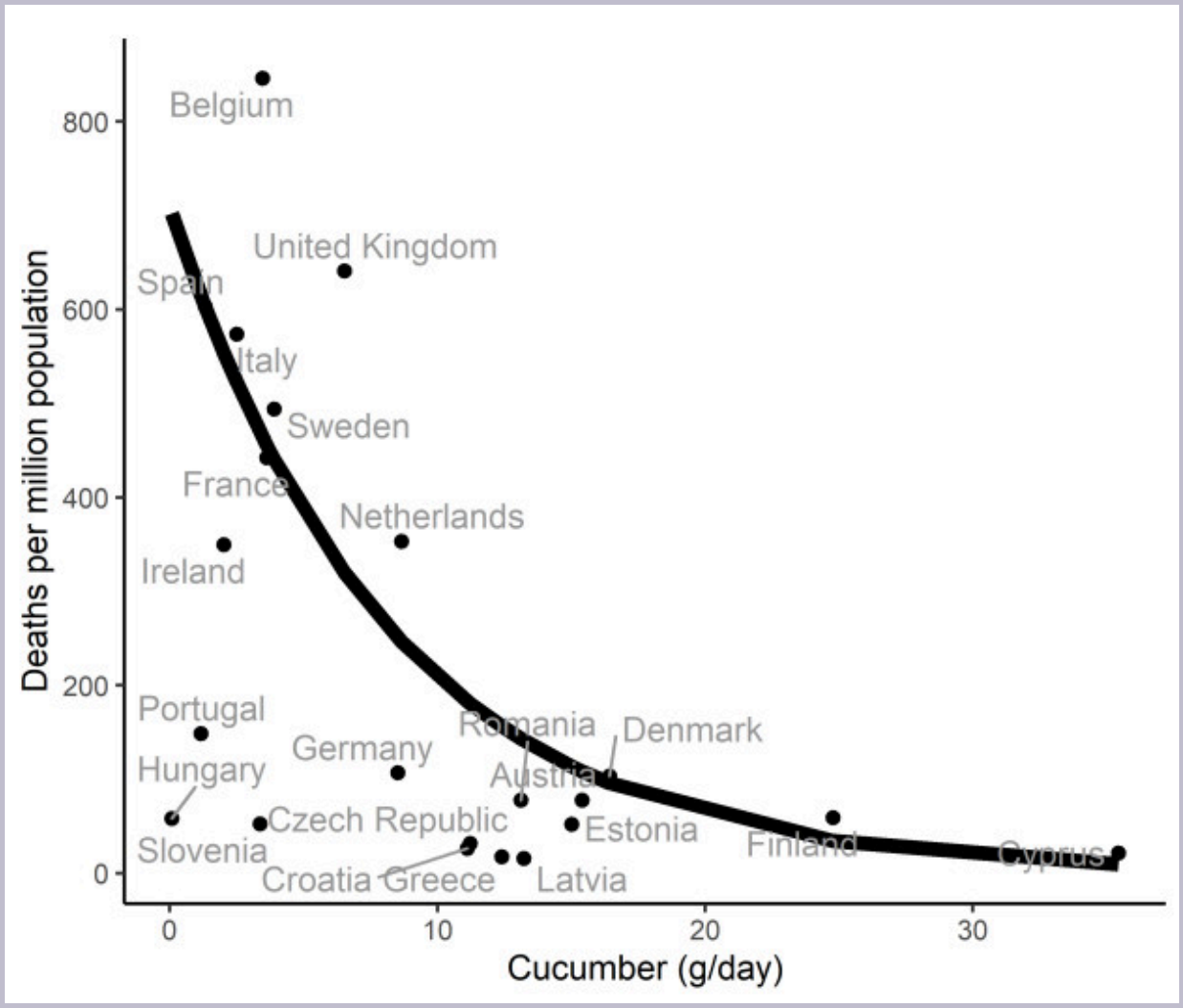


Figure 12.8. Plot showing deaths per million population vs. grams of cucumbers consumed per day.

Scatter plots can have a connecting line between the data points (rather than a regression line). This line **can**

1. https://www.medrxiv.org/content/10.1101/2020.07.17.20155846v1

only be added if each point in the series of related values is from the same source and is dependent on the previous values. DO NOT connect the dots when the measurements are made independently!

Line Plots are similar to scatter plots, but the data on the X-axis can be ordinal rather than continuous. In the example in Figure 12.9, the X-axis of both plots is time. For the Scatter Plot, the time is in minutes and is a continuous scalar variable. In contrast, in the Line Plot the variable is the month, which can is ordinal (has a proper order) but the amount of time within and between each month can vary slightly.

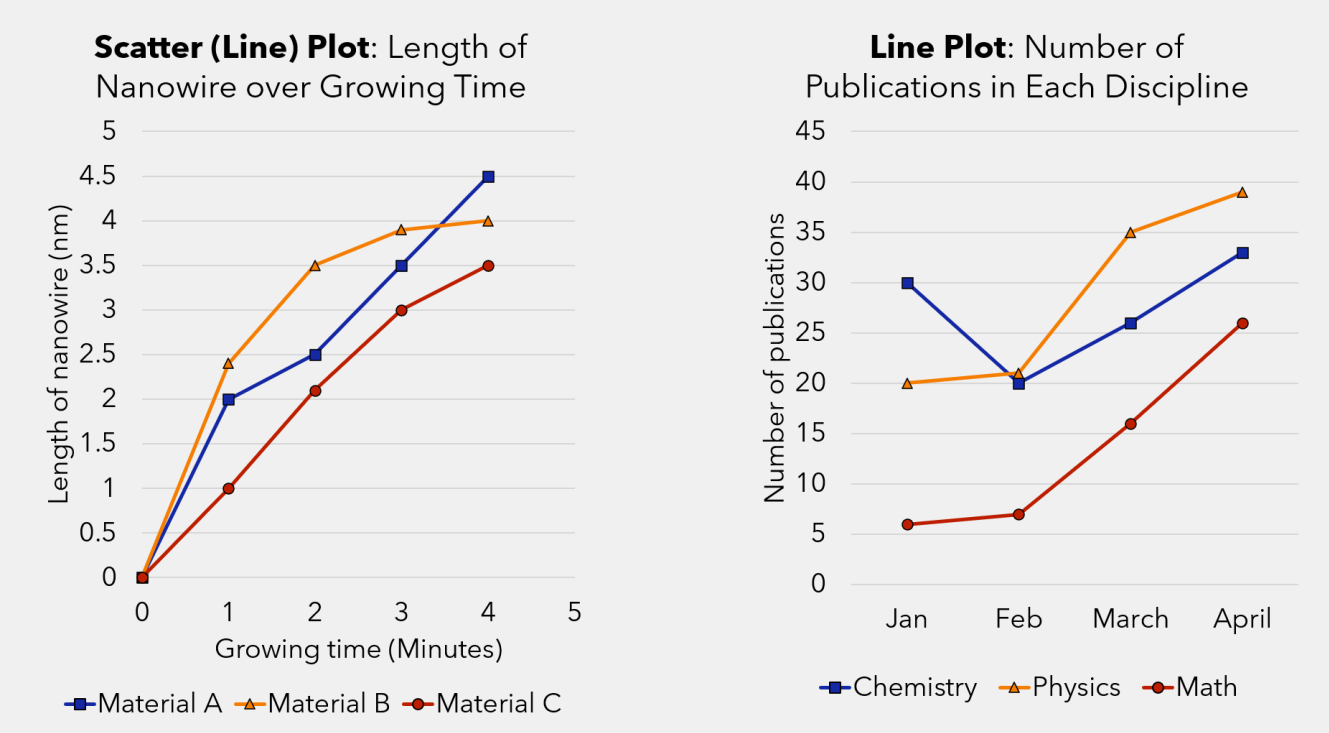


Figure 12.9. An example of different types of line scatter plots with scalar (continuous) and ordinal variables on the X-axis.

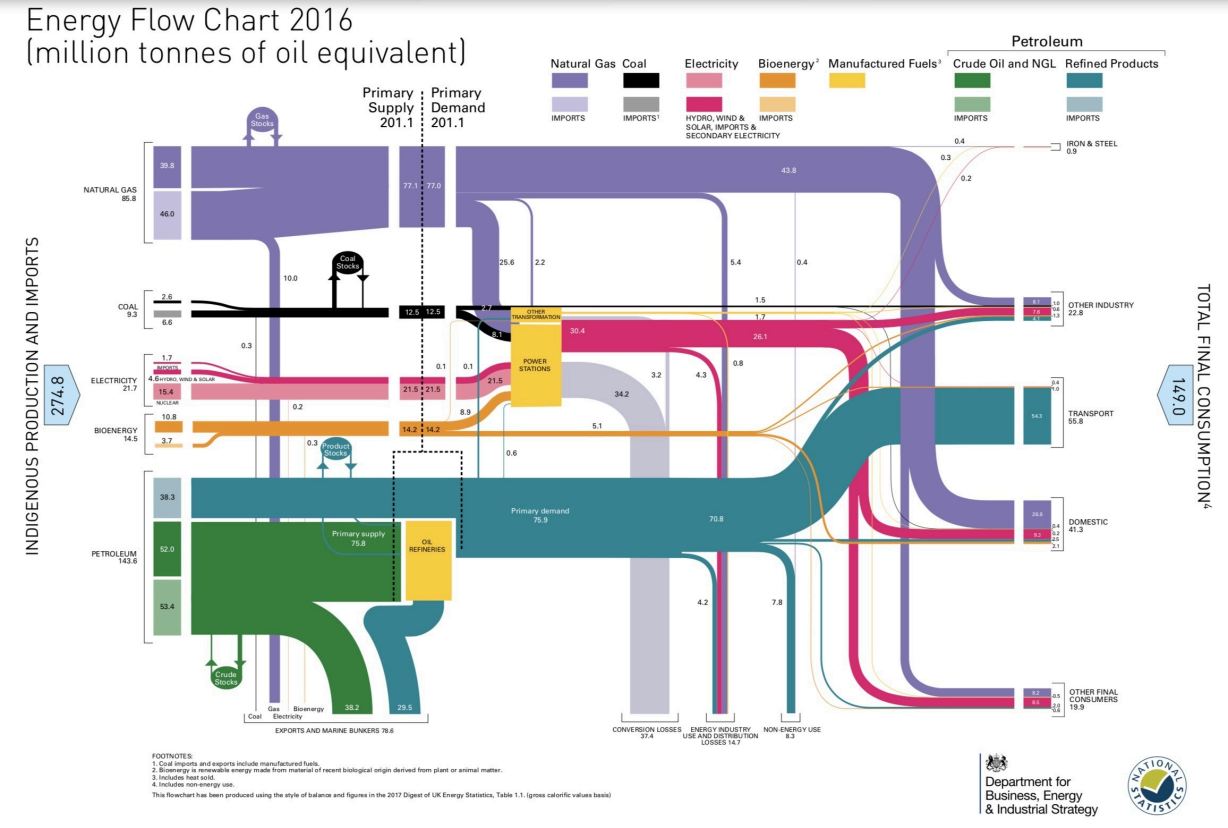
The use of different symbols and different line types (solid, dash, dots) for each data set helps the reader in distinguishing between the different sets. Line plots can also be made that don't show individual data points with markers. These graphs are useful for showing trends, particularly when the independent variable is time**.**

Sankey Charts

Sankey Charts are like diagrams mixed with flow charts and are sometimes called Sankey Diagrams. These types of figures can very effectively show large amounts of data with several variables (see the UK Energy Flowchart below). They are best for showing how something changes *over time* or *throughout a process*.

Charts can effectively show large amounts of data.

The annual UK energy flow chart, in the format of a Sankey diagram, shows a lot of data including amounts of energy (as equivalents of the mass of oil), relative amounts, how it is generated, supply versus consumption, import versus export... Can you imagine trying to see all this information in a black-and-white table?



https://www.gov.uk/government/collections/energy-flow-charts

Spectra

Chemical spectra are also sometimes presented as figures within scientific communications. With spectra, it is important to make sure that the resolution is sufficient when the figure is reduced to the size it will appear

in the printed paper. This is particularly true of axis labels. In the spectrum, label the protons (as they are characterized in your experimental), and ensure that your X-axis is clear with units indicated (Figure 12.10).

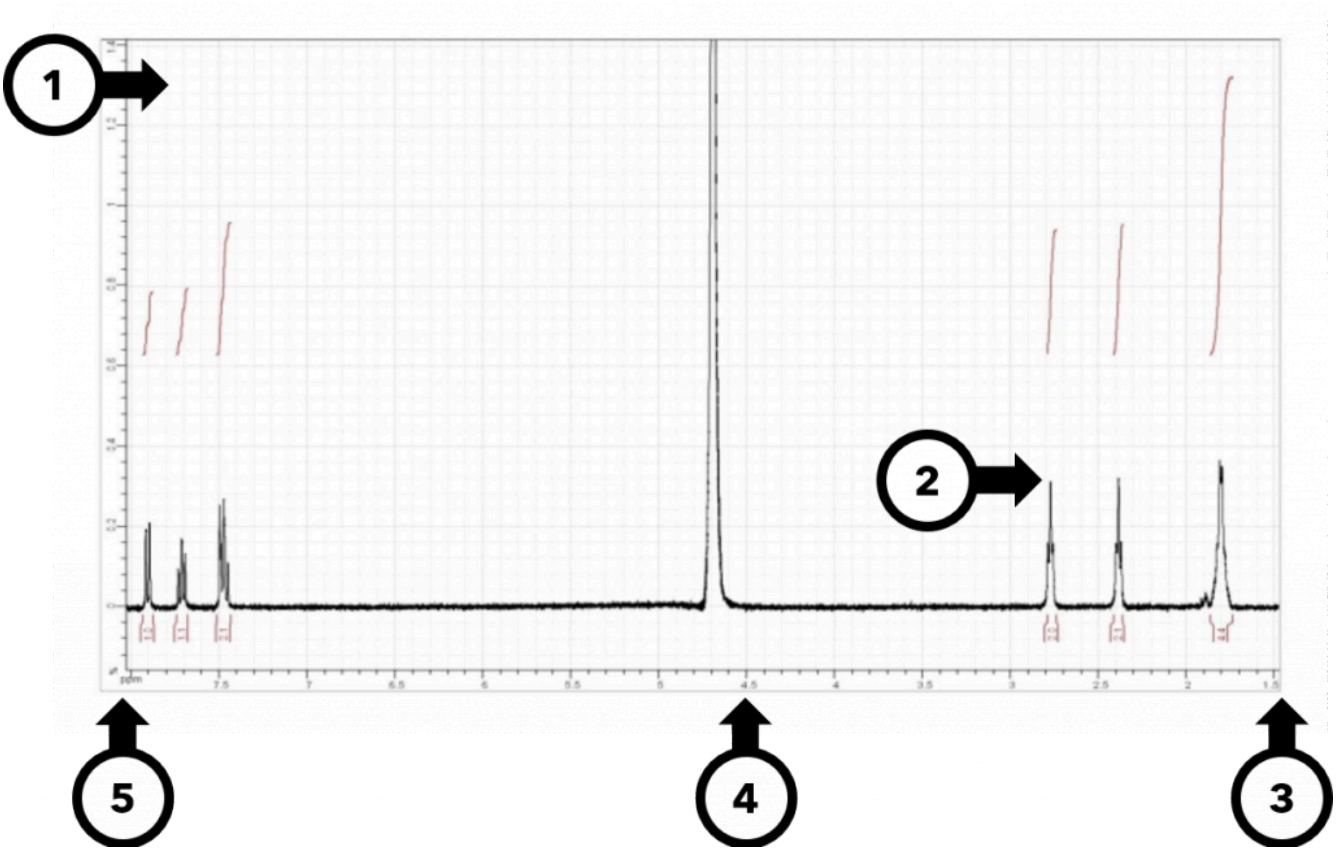


Figure 12.10. Example of a poorly presented spectrum. Here are ways it could be improved: 1) Add a label or compound name or structure to identify the spectrum; 2) Label the protons as they are characterized in your experimental section; 3) Include units and start the spectrum at 0 ppm; 4) The X-axis and Y-axis labels are too small and difficult to read; 5) End the spectrum at 10-11 ppm.

13.

SCHEMES

Read time: 2 minutes

Overview

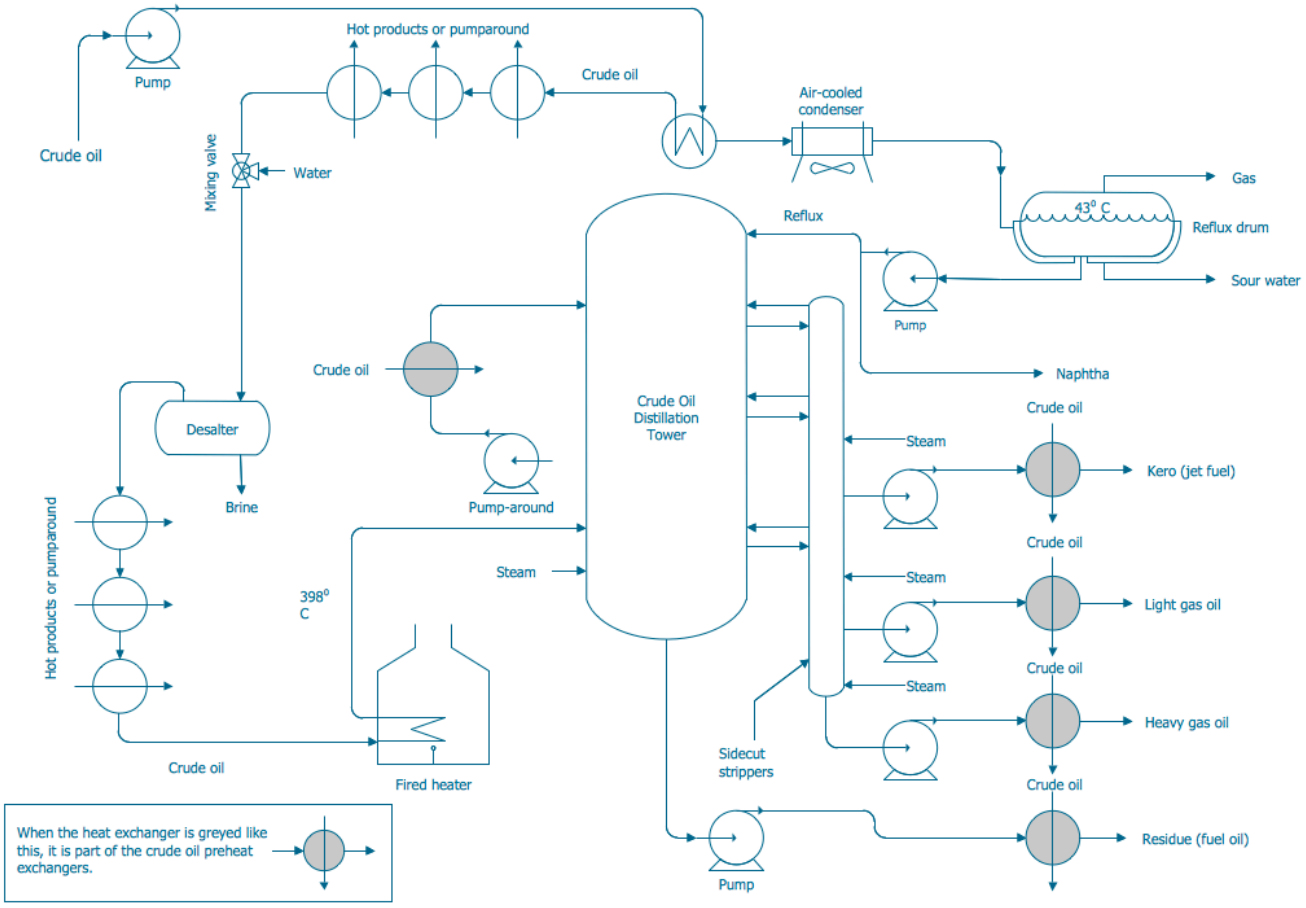
This chapter will briefly discuss the types of schemes.

Sections in this chapter

- Diagrams
- Reaction schemes
- Learning ChemDraw
- Catalytic Cycles
- Keep it simple

Diagrams

Schemes are a type of diagram that shows the steps in a process. In chemical engineering, schemes (or schematics) are often used to explain a process at a macroscopic scale, e.g., the purification of crude oil (Scheme 13.1).

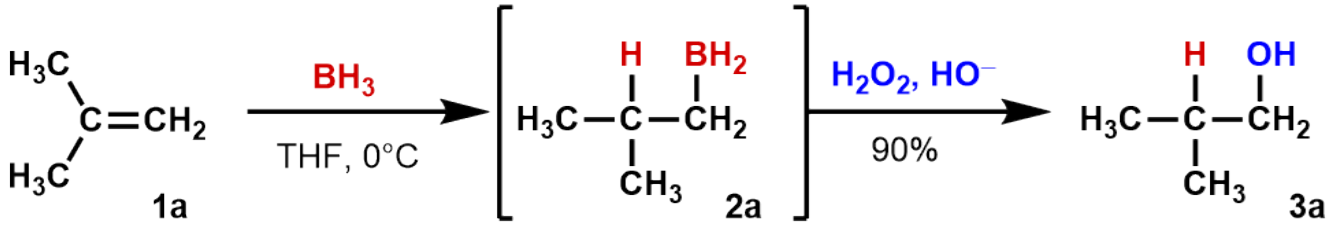


Scheme 13.1. An example of a scheme in chemical engineering, showing the steps in the purification of crude oil into refined petrochemicals (CS Odessa, CC-BY-4.0). The arrows and symbols used in these schemes are standardized, and more details are provided elsewhere in the writing.

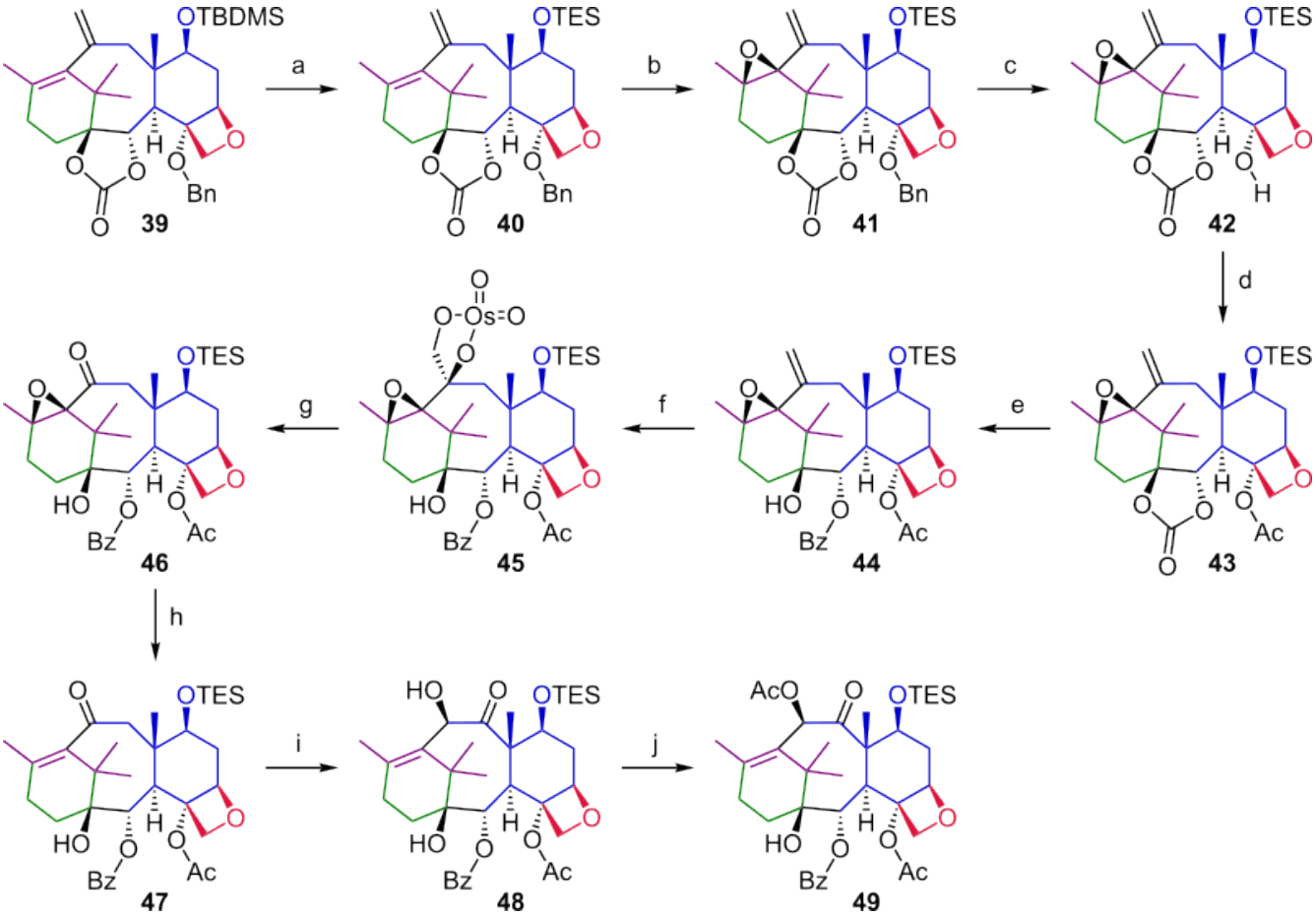
In chemistry, schemes are used to present steps in a chemical reaction pathway (Scheme 13.2) or total synthesis (Scheme 13.3). There are several things to keep in mind when designing these schemes:

- Keep molecules oriented the same way from starting materials to products. In the schemes below, the starting molecule stays consistently in the same orientation across reaction steps.
- Reagents are shown above the arrow
- Conditions, solvents, and yields are shown below the arrow.
- Consider if you want to include reaction details in the scheme, or label them 'a, b, c' and describe the details in the caption.
- Define all short forms and acronyms in the caption (e.g., TES, TBDMS, Bn, THF)
- Use colour cautiously. Colour is a great way to show changes from starting materials to products (Scheme 13.2) or highlight portions of a molecule and where they were derived (Scheme 13.3). It defeats the purpose if everything is highlighted with colour.

Reaction schemes



Scheme 13.2. An example of a scheme showing the steps in an alkene hydroboration-oxidation reaction The carbon frame of the molecule stays in the same orientation throughout the process. Colour is used sparingly.



Scheme 13.3. An example of a scheme used in organic chemistry, the total synthesis of taxol by Danishefyky (Calvero CC-BY-SA 3.0). In this case, details about the reaction steps are given elsewhere in the article or a footnote, and all compounds are numbered.

Learning ChemDraw

Most of your schemes will be made using the program ChemDraw (get it here). This software has a lot of function and capabilities, but there is a learning curve. Read or watch tutorials to help you learn all the features and shortcuts, which will make the processing of creating figures and schemes more efficient! We recommend the ChemDraw Wizard youtube videos to start.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=48#oembed-1

Catalytic Cycles

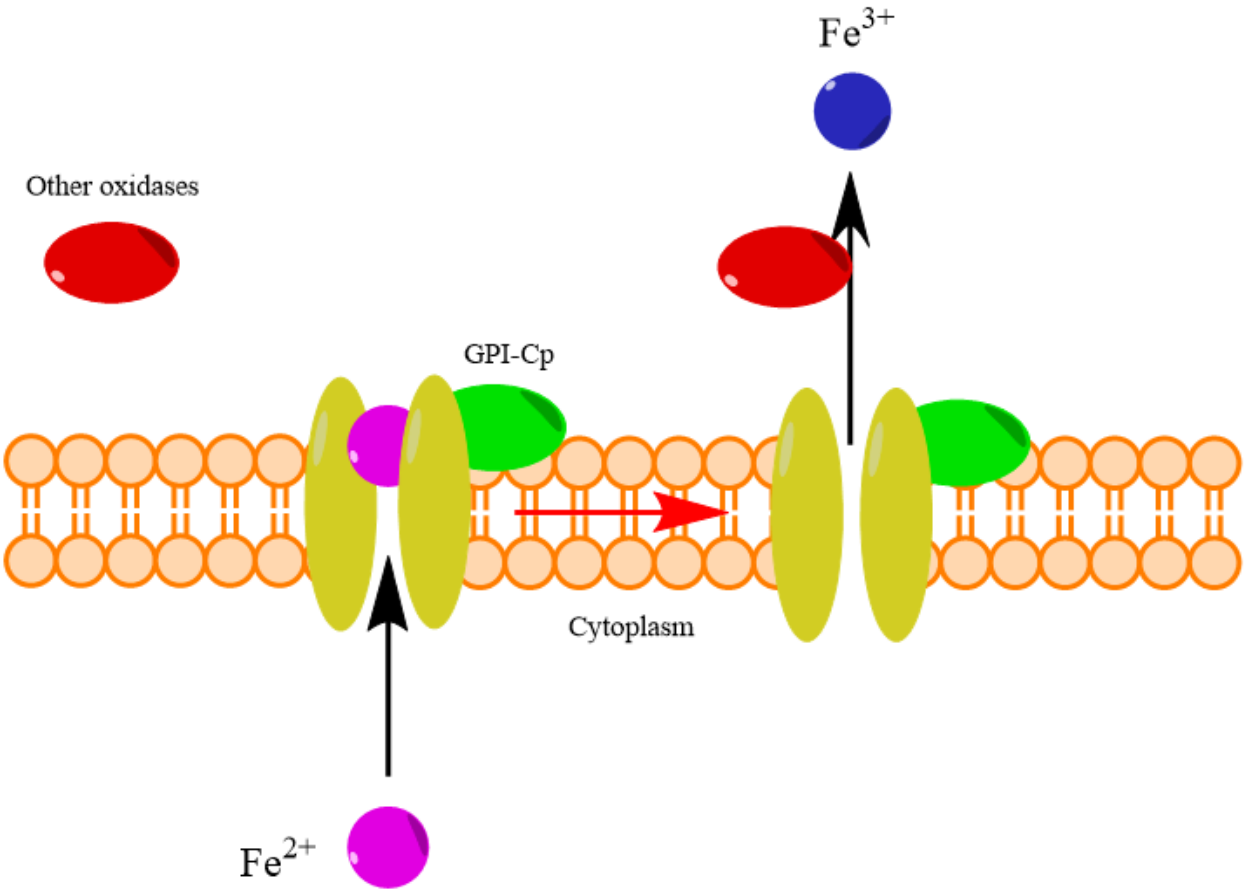
Another type of scheme in chemistry is the catalytic cycle, which shows the process of catalysis in a reaction. There are so many examples of poorly drawn catalytic cycles out there that don't follow this rule: **Catalytic cycles should be nice, clean circles!**

Catalytic Cycle ChemDraw Template

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=48#video-48-1

Keep it simple

The best rule to follow when designing Schemes is to keep it simple. First, think about the message you are trying to convey with the Scheme, then cut out any extra information. Schemes are useful for simplifying how to represent a process, for example showing complex structures and general processes as cartoons like in Scheme 13.4.



Scheme 13.4. An example of a cartoon scheme to show the complex process of iron transport with enzymes in a cell (KH1412 CC-BY-SA 4.0)

14.

ACCESSIBLE AND ETHICAL DESIGN

Read time: 5 minutes

Overview

This chapter will cover two key aspects of communicating data using graphics:

1. **Communicating your data honestly and ethically**
2. **Presenting your data so that it is accessible**

This chapter explains the principles of accessible and ethical graphic design, and includes several examples of what not to do!

Sections in this chapter

- Ethics when communicating data
- Data Falsification
- Examples of misleading data visualization
- Universal Design

Ethics when communicating data

Ethical design requires that graphics be honest and accurate. Scientists should be aware of the many ways that data can be misrepresented. For example, by adjusting the Y-axis scale (Figure 14.1), trends in data can be either exaggerated or made to seem insignificant. Design choices can, either purposefully or inadvertently, introduce bias in favour of the author's interpretation of the data (See the example below).

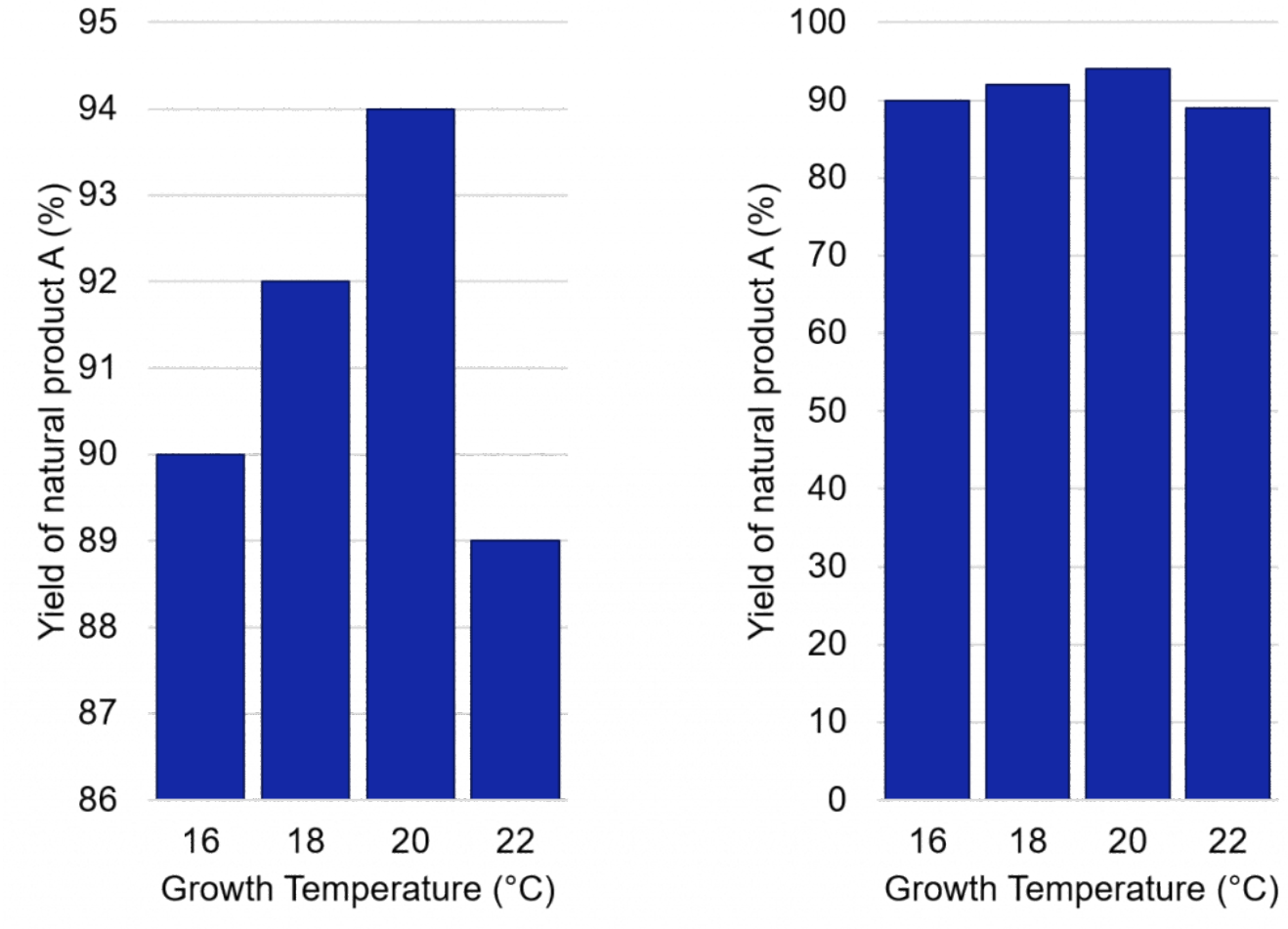
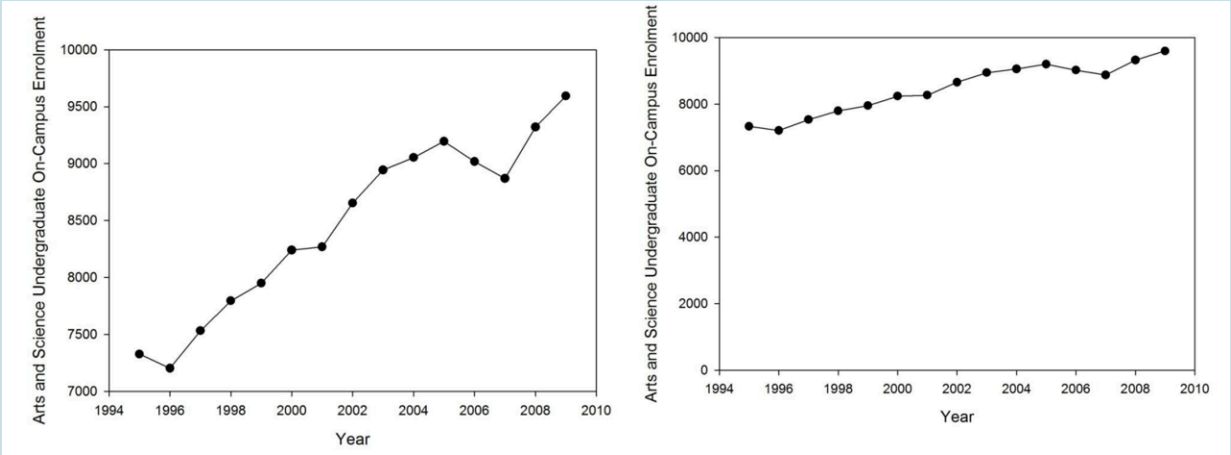


Figure 14.1. These examples show how the choice of Y-axis scale can make it look like there is a significant trend in the data (Left) or like there is no trend at all (Right). Which do you think most accurately and honestly portrays the data?

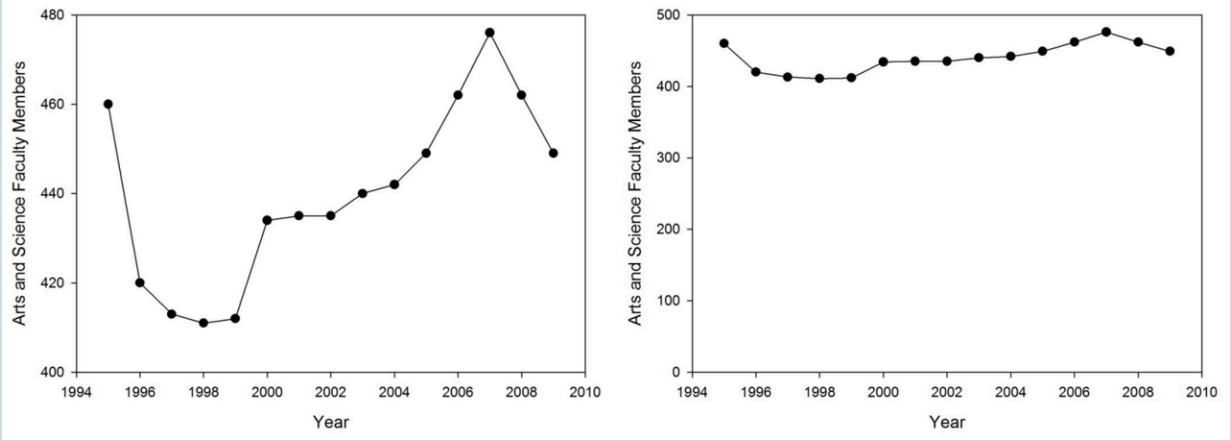
Exercise

Which presents the data more honestly? Which presents it more clearly?

i) The graphs below show the Faculty of Arts and Science student enrolment over several years. The scaling on the left suggests significant increases in enrollment from year to year, while the scaling on the right suggests a modest increase. The plot on the right makes it harder to determine specific numbers for each year.



ii) The graphs below show the number of Faculty of Arts and Science faculty members over several years. The scaling on the left suggests a large fluctations, which a significant drop in the late 1990s. The scaling on the right suggests the opposite, mainly a fairly consistent number of faculty since 1994.



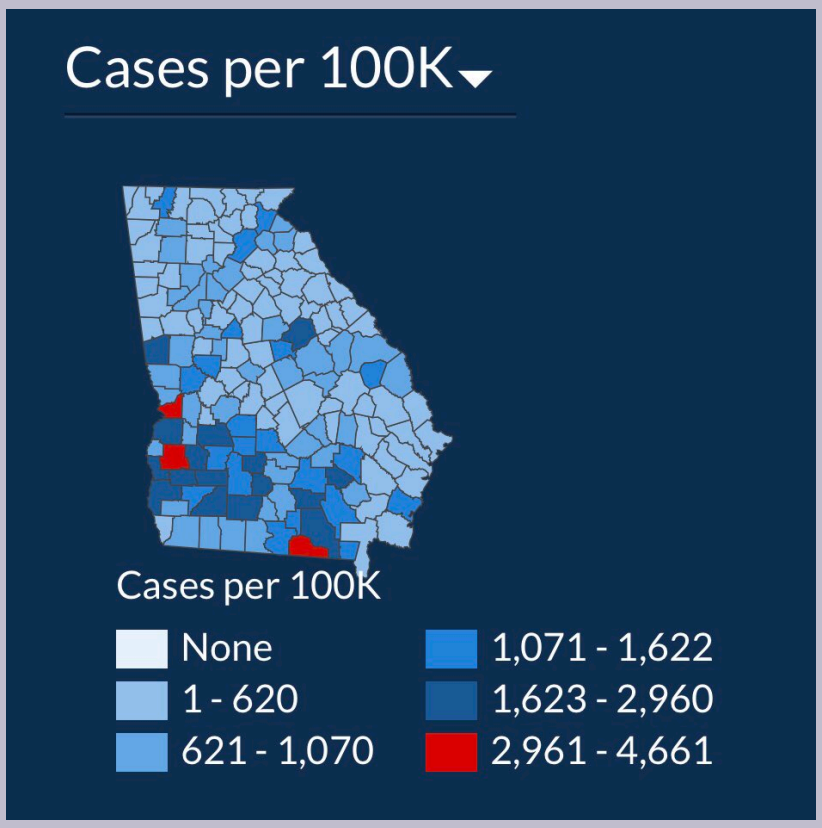
To avoid visual representation:

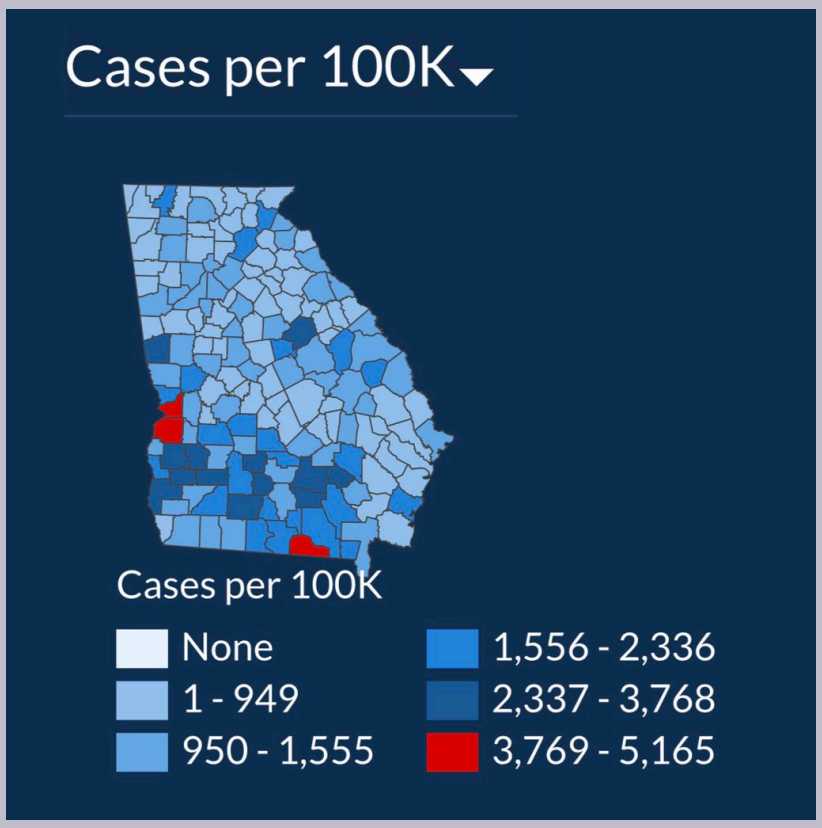
1. Use an appropriate scale, judge if it may be misleading
2. Use the right amount of data: avoid making your visualization overly simple or complicated.
3. State the key message or findings of the visualization in the text (caption or article).

Example of unethical design

This example was brought to light by Andisheh Nouraee (@andishehnouraee):

> *In just 15 days the total number of #COVID19 cases in Georgia is up 49%, but you wouldn't know it from looking at the state's data visualization map of cases. The first map is July 2. The second is today. Do you see a 50% case increase? Can you spot how they're hiding it?*





Data Falsification

The falsification or manipulation of data is a huge breach of academic integrity. There are several high-profile of this occurring over the past few years, as you can see in this ist of scientific misconduct on Wikipedia. Sometimes the intent is clear, to report spectacular findings for individual glory and reputation. Other times, issues with cultural practices or confusion over what constitutes ethical practices are to blame.

Spectra manipulation

NMR spectra are one of the most common places to find data manipulation in chemistry. Some

students are not aware that using the "solvent suppression" feature in *iNMR* constitutes manipulation of data. Be cautious and make sure your peers and coauthors are aware of ethical vs. unethical practices since articles that have manipulation of NMR spectra will be retracted and the authors placed on a watch list.

Don't be fooled by how easy it is to delete peaks!

Journals like *Organic Letters* have hired data analysts to examine spectra and other data submitted to the journal. This caught several papers from a single research group where spectra had been manipulation to remove impurities. This eventually led to corrections in retractions of dozens of papers from the Fukuyama lab, and many other labs as well.

Universal Design

The other side to presenting your data is to make it accessible to all readers. When creating your tables and figures, keep in mind the principle of Universal Design: design that makes the product accessible to all people regardless of age, disability, and other possible barriers. This philosophy for design ensures equality and inclusion for all of human diversity.

Colour & Contrast

Not everyone has the same sensitivity to colour – around 5% of the population experiences some form of colour-blindness. The most common form of colour-blindness makes it difficult to distinguish between some shades of red and green. All readers will benefit if the colours in your data visualization are easy to distinguish in tone, shade, and contrast.[1].

Use resources like ColorBrewer 2.0 and Chroma.js to find or create colour-blind friendly palettes with suitable contrast. Contrast is important for distinguishing colours on the screen, but also for printing in black and white or photocopying. Use tools like Color Oracle or the Coblis — Color Blindness Simulator to check your data visualizations.

1. Wong, B. Points of view: Color blindness. Nat Methods 8, 441 (2011). https://doi.org/10.1038/nmeth.1618

See this blog post by physicist Paul Tol to learn more about colour schemes for accessible design in scientific communication. The image below, from a *Nature Methods* article called "Points of view: Color blindness" by Bang Wong, shows how common colour schemes in scientific articles can be easily fixed to make them accessible to all readers.

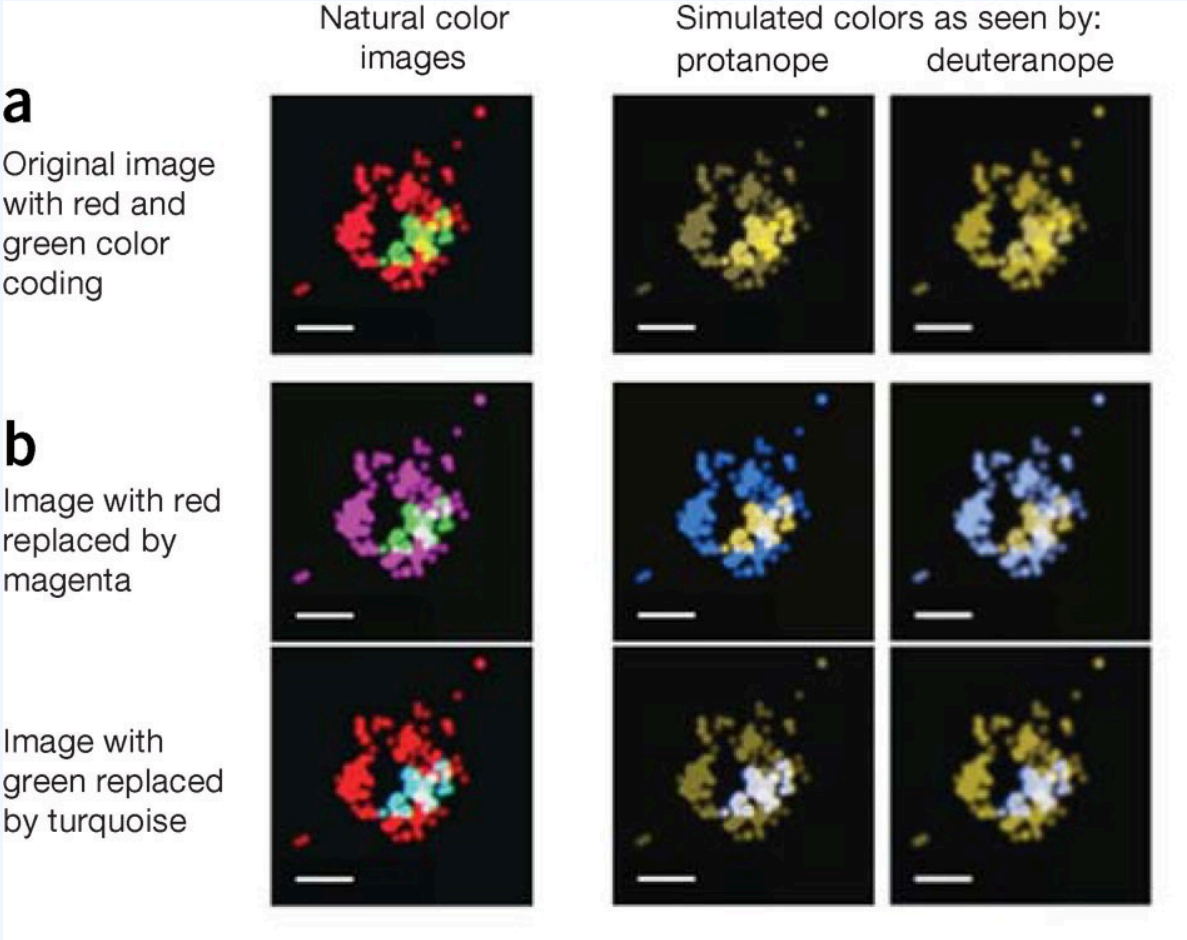


Image above from: Wong, B. Points of view: Color blindness. *Nat Methods* **8,** 441 (2011). https://doi.org/10.1038/nmeth.1618

In your data visualizations, don't use colour alone to convey an idea. Use different shapes for markers, line patterns, and fill textures (Figures 14.2, 14.3). Another tip: instead of having a separate legend, label data series directly on the graph.

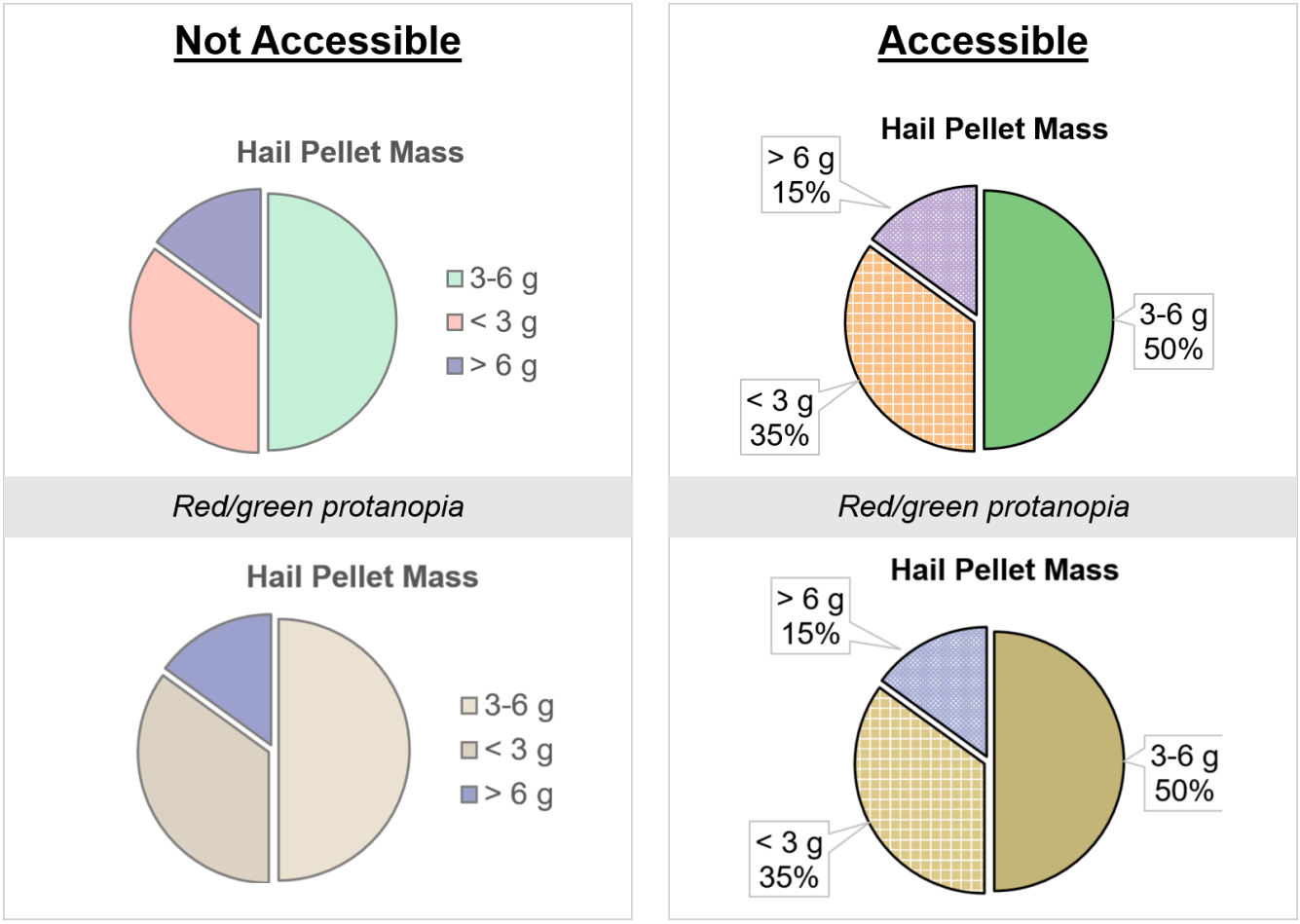


Figure 14.2. This figure shows two versions of a pie chart. The one of the left is inaccessible for persons with common red/green protanopia. The chart also has poor contrast that will cause issues for printing and photocopying. The version on the right uses a colour-blind friendly palette, has increased contrast, and uses a pattern to help distinguish the data. Having data labels on the chart, rather than in a legend, make the chart easier to follow.

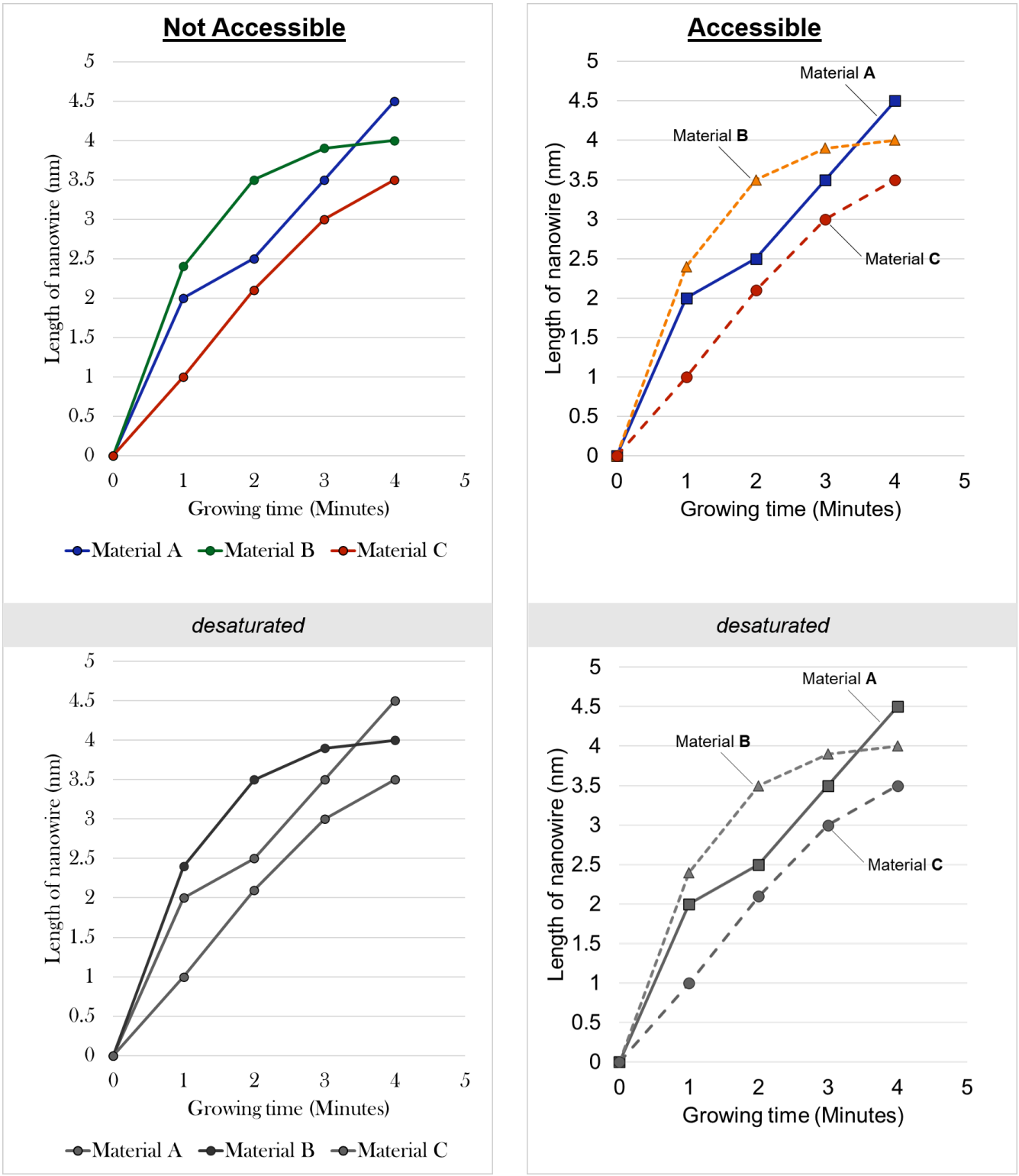


Figure 14.3. This figure shows two versions of a line plot. The one of the left is inaccessible for persons with common red/green protanopia, and overall there is poor contrast between the data series in terms of colour and data markers. The version on the right uses a colour-blind friendly palette, has increased contrast, and uses different markers and lines distinguish the data. Having data labels on the plot, rather than in a legend, make the plot easier to follow.

Text

The text use in your image or caption is important for all readers, but especially those who are visually impaired or have a reading disability. The text should be in an accessible font size and typeface; the Bureau of Internet Accessibility suggests using san-serif fonts like Arial or Helvetica to make the text more readable for all.

Text should also be readable by a screen-reader, which is an application that will 'read' electronic text out loud for the user (see the video below). Make sure your caption is true text and not saved as part of the image file, otherwise it will not be accessible to everyone.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=50#oembed-1

Images online should contain Alt-text, that is, text that describes the image in enough detail for those who are visually impaired. This Alt-text can be a single word or phrase that explains the purpose of the image. Images that are purely decorative don't require Alt-text, but this is almost never the case in scientific communication!

MODULE III

MODULE 3: OUTREACH

15.

KNOWING YOUR AUDIENCE

Read time: 2 minutes

Overview

Earlier in this book, we learned about different contexts and audiences for scientific writing. Module 3: Outreach focuses on communicating science to the general public.

Sections in this chapter

- Outreach and SciComm
- Who is the “general public”?
- Double meanings of words

Outreach and SciComm

Science Communication (SciComm) comes in many shapes and forms, all with the main goal of communicating a scientific concept or discovery to non-experts. You have likely seen SciComm in the form of infographics, articles, radio or podcasts, TikTok videos, and more! It takes skill to effectively communicate science, and there are many scientists who move into this area as a full-time career. SciComm is a form of science outreach, which aims to extend the boundaries of science to include more people. Outreach efforts can also include broader science campaigns (COVID19 Awareness Campaign), events (Science Rendevous), and programs (Let's Talk Science).

Science Communicators and Venues

List of science communicators to check out

- Bill Nye ("Bill Nye the Science Guy")
- Christine Liu – Neuroscientist and artist
- Wendy Zuckerman – Host of *Science Vs.* podcast
- Darrion Nguyen – Science TikTok @lab_shenanigans
- Raychelle Burks – Science writing, TV, and Twitter
- Joe Schwarz – Canadian science writer and radio host

Venues for science communication

- Science Borealis – Canadian science blog
- Beakerhead – magazine, hosts the science version of Burning Man
- Quirks and Quarks – long-running radio show on CBC
- CHEM 13 News – magazine for teachers by uWaterloo
- McGill Office for Science and Society – hosts public lectures and a newsletter

Who is the "general public"?

The term "general public" refers to, well, everyone. Usually, the term is used to describe non-experts and non-scientists, but it's important to keep in mind that this is not a homogenous group. When creating science communications for the general public, ask yourself more about who is your audience:

- Where does my audience live?
- What is their daily experience with the topic?
- Is my audience children, teenagers, or adults?
- What is their profession (*e.g.*, are they teachers)?

Once you have a clear picture of your audience, it's easier to tailor your outreach efforts.[1] You can identify the level of detail, words that your audience may not know (or may have different meanings for), and create something that they will be able to use and learn from. Your work will have a greater impact if your work is designed for one target demographic.

1. http://blogs.nature.com/naturejobs/2015/08/21/science-communication-know-your-audience/

Double meanings

There are words used in science that have different common meanings.[2] Keep these in mind when you are trying to communicate science to non-experts!

	Definition in science	***Use in common language***
Theory	An idea developed over years of experiments, fact collection, and data synthesis, *e.g.,* evolution by natural selection	A hunch
E. Coli	A microorganism with many strains, some harmful, others safe and used as model organisms	Harmful germs
Conductor	A substance that transmits electrical current, heat, or sound	Leader of a musical ensemble or train
Element	A pure substance that cannot be separated into simpler substances	A stovetop, or an aspect of something
Organic	Chemistry of compounds with carbon and hydrogen, related to life	A type of farming to create food following certain regulations
Chemical	A substance (everything is made of)	A toxic or unnatural substance
Novel	New or unique	A book

2. https://pubs.acs.org/doi/pdfplus/10.1021/ac041564e

16.

WRITING AND AUDIO/VISUAL

Read time: 4 minutes

Overview

This chapter gives an overview of science journalism in the form of written articles and audiovisual media.

Sections in this chapter

- Science journalism
- Written media
- Audio/Visual media

Science Journalism

Communicating science or chemistry to a general audience is a challenging but worthwhile pursuit. You can find science journalism in popular science magazines like Wired or National Geographic, in the local newspaper, in sections of Science and Nature, on the radio, and in Podcasts. These venues share new discoveries, show how something works, or profile the lives of scientists.

Written media

There is a stark contrast between technical writing, for theses and articles, and writing for general interest. Science journalism strives for a balance between accuracy and accessibility. Popular science articles are usually short, taking only 5 minutes or less to read, but should have a way for the reader to learn more if they become interested in the topic. The tool at readtime.eu is useful for knowing how long your text takes to read. This paragraph takes around 30 seconds.

Here are some popular venues for chemistry writing geared towards a general audience:

When writing for a general audience, authors must skim or reframe the technical details to explain not just what was done, but WHY, and what are the consequences? Writing for science communication must be more engaging than technical writing. It can also be more subjective, bringing in the author's opinions and interpretations, whereas technical writing usually strives for objectivity.

What makes a good popular science article?

Tim Sandle outlines these eight points for what makes a good 'popular science' article in this OpEd (summarized below):[1]

- Avoid jargon and define all terms
- Go into detail using analogies and metaphors
- Explain the significance
- Represent multiple points of view
- Discuss future applications
- Cite and link to the original research paper
- Mention related research that might interest the reader
- Get direct quotes from the researcher
- Note who funded the research
- Be skeptical
- Respect the reader

Exercises

1. In 100 words or less, explain what a toxin is to a general audience.

Click here to show an answer

Toxins are chemicals that are poisonous. Traditionally, the term 'toxin' was used only for chemicals produced by animals or plants, like snake venom, but recently the term is also given to all kinds of synthetic chemicals.

This broad use of the word "toxin" can be confusing and contributes to people's fear of chemistry and science. It's also not very useful, because no chemicals are inherently poisonous — the dose makes the poison! In this article, we'll use the traditional definition of a toxin, and anything else will be called a "toxicant" or a "chemical".

1. Tim Sandle, March 23 **2016**, "How to write a good science article", *Digital Journal*, Accessed: 2020-08-26

2. Find the mistakes in the following paragraph about a recent article and then rewrite the paragraph.

"A new discovery from the group of Zhe She allows scientists to detect cells and toxins using TLRs. The researchers developed their biosensors on electrode surfaces in a way that they can selectively detect whole bacterial cells with high sensitivity. Their biosensor was able to detect Gram-negative bacterial cells in samples as small a 100 mL. These shelf-stable sensors are ready for real-world applications."

Click here to show an answer

- TLR is not defined for the reader.
- What is the selectivity? The authors describe their sensors as non-specific, but selective for Gram-positive cells.
- The sensor detects Gram-positive cells (Gram-negative was the control)
- They were able to detect against their control at a threshold of 100 CFU (colony forming units, i.e. bacteria) per mL, not in a 100 mL sample
- The shelf-stability of the sensors is described in the paper as a challenge, and it's clear that the sensors are not yet ready for real-world applications.

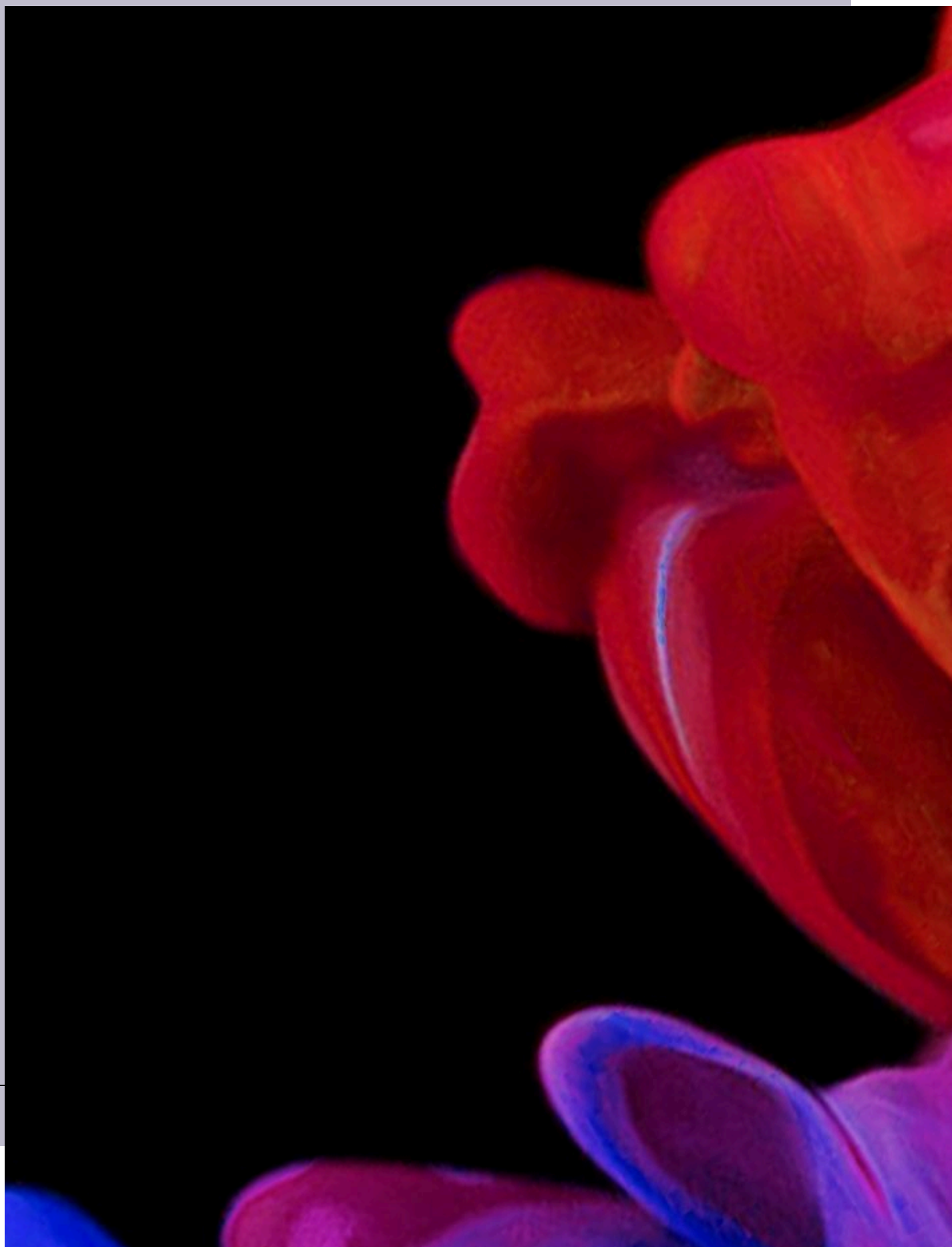
Audio/Visual Media

There is a huge range of audio/visual science communication, with an equally broad audience. Science TV shows like *Bill Nye the Science Guy*, the *Magic School Bus*, or *Daily Planet* communicate science for children and adults alike. More recently, you can find web-based shows designed for effective science communication. Then there are radio shows, including the long-running *CBC Quirks and Quarks* or *Dr. Joe's Montreal show*. Queen's Chemistry Professors are often featured on the "Element of Surprise" radio segment of *All in a Day with Alan Neal*. Recent years have seen a surge in science podcasts, with some setting a high bar with fantastic quality and high journalism and fact-checking standards.[2]

2. Jane C. Hu, Nov. 7, **2016**, "Scientists ride the podcasting wave"

Science Podcasts

Here are links to some excellent science podcasts!



The makings of good science audio are similar to those for science writing: know your audience, avoid jargon, find the key message and communicate the significance! Audio, like a podcast, also usually incorporates some aspect of either 1) Interviewing, or 2) Storytelling. In writing, you may choose interesting images from a research article or related to a science topic, but in audio, these must be described or replaced with sound.

The RadioLab podcast is known for how well they use sound when telling science stories: see this episode in particular (below), where a choir sings in spectral frequencies of rainbows beyond the visible spectrum (19:08 min).

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=55#audio-55-1

To learn more about making science podcasts read this career column by science journalist Katherine Bassil.[3]

3. Katherine Bassil, July 4 **2019**, "Lessons I've learnt from creating a science podcast", doi: 10.1038/d41586-019-02096-4

17.

INFOGRAPHICS

Read time: 4 minutes

Overview

This chapter discusses one specific type of SciComm: The Infographic.

Sections in this chapter

- The rise of infographics
- Creating an infographic
- Examples of infographics
- Science meets art
- Share

The Rise of Infographics

Infographics are visual communications that use icons, illustrations, and limited text. They have a fascinating history and have risen in popularity as a way to visualize "big data", for example,[1] data related to worldwide effects of climate change or global pandemic data. Infographics present these complex systems in a way that makes it easy to see how things relate to one another. By providing a view of the big picture, infographics can give non-experts instant insight that can lead to real change (Figure 17.1).

1. Clive Thompson, July 2016, "The Surprising History of the Infographic", Accessed 2020-08-27

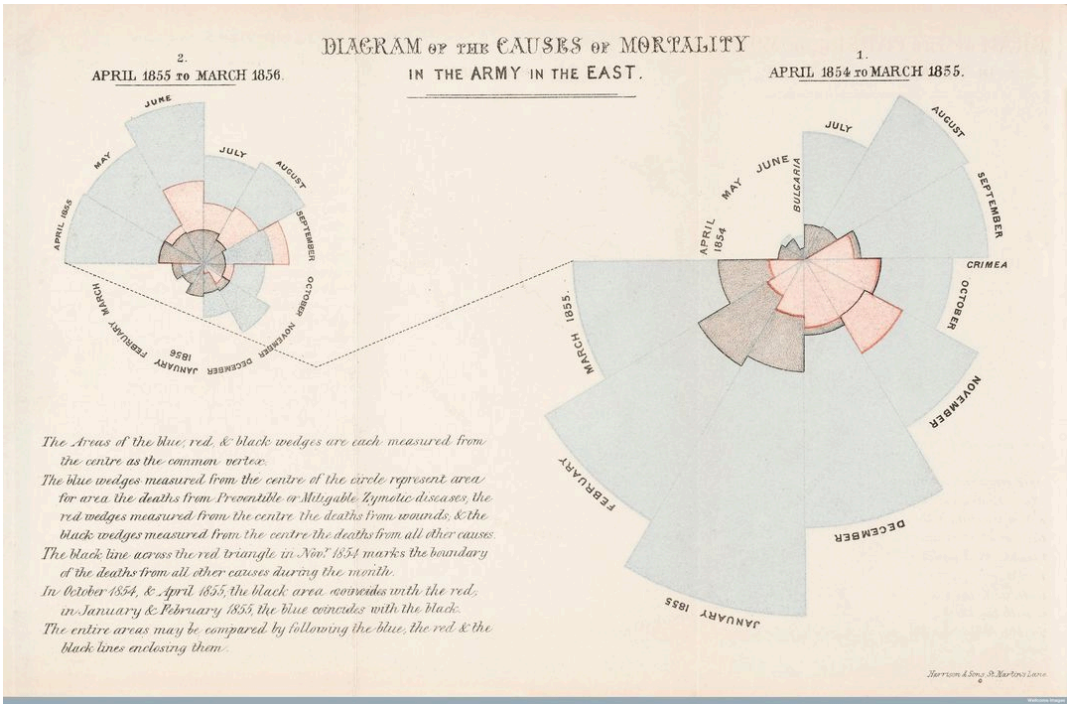


Figure 17.1. An early example of an infographic, created by the nurse Florence Nightingale, which shows causes of mortality during the Crimean War (Wellcome Library, London). Unlike a large table of numbers, this graphic clearly shows how many deaths were due to poor hygiene; this led to quick efforts from the government to improve sanitation conditions.

Creating an Infographic

Infographics are designed to show "big data" in the most minimalistic way, and so the audience, scope, and purpose of the infographic must be well defined in the planning stage.

Purpose

In science, infographics are used to inform, explain, entertain, or to spur action. In the example above, Florence Nightingale had a clear purpose for making her infographic: to get the attention of the government so they would take action to improve sanitary conditions. When creating your own infographic, make sure you have a clear message you are trying to convey to the reader. Knowing the purpose of the infographic will help you know which data and information are essential, and what can be left out.

Audience

Closely linked to the purpose of your infographic is it's intended audience. Who are you trying to convey your

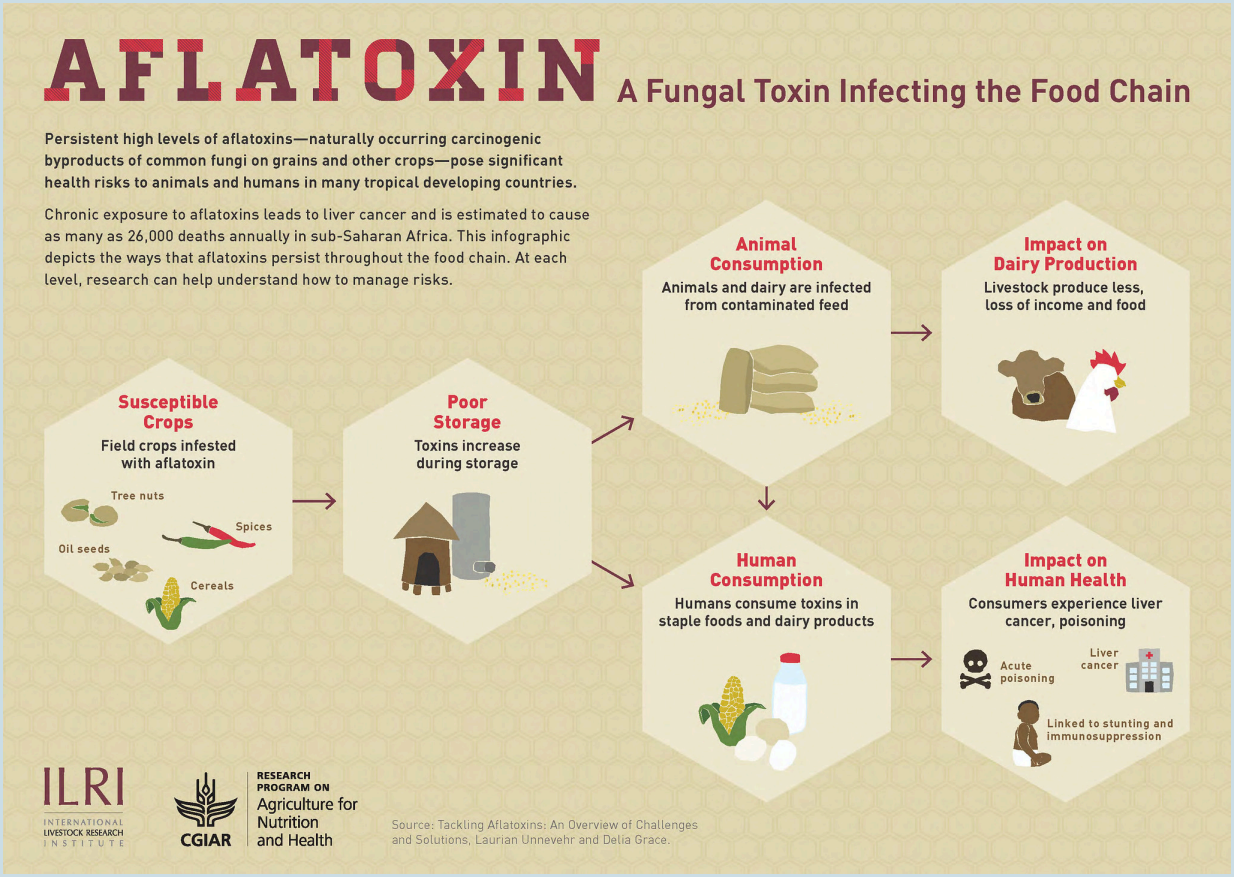
message to? Review the chapter "Knowing your audience" and think about how the age, education, location, and other demographics may influence how you design your infographic.

Scope

The best infographics have some sort of narrative or story that the viewer/reader can follow, one that aligns with the key message and purpose of the visualization. Once you have your audience and purpose, it's easy to define the scope of your infographic and build a narrative. Write a script or storyboard for this narrative. Start with a hook, like an intriguing question, which will draw in the reader to the details.

Purpose, Audience, and Scope

See if you can define the purpose, audience, and scope of these infographics:

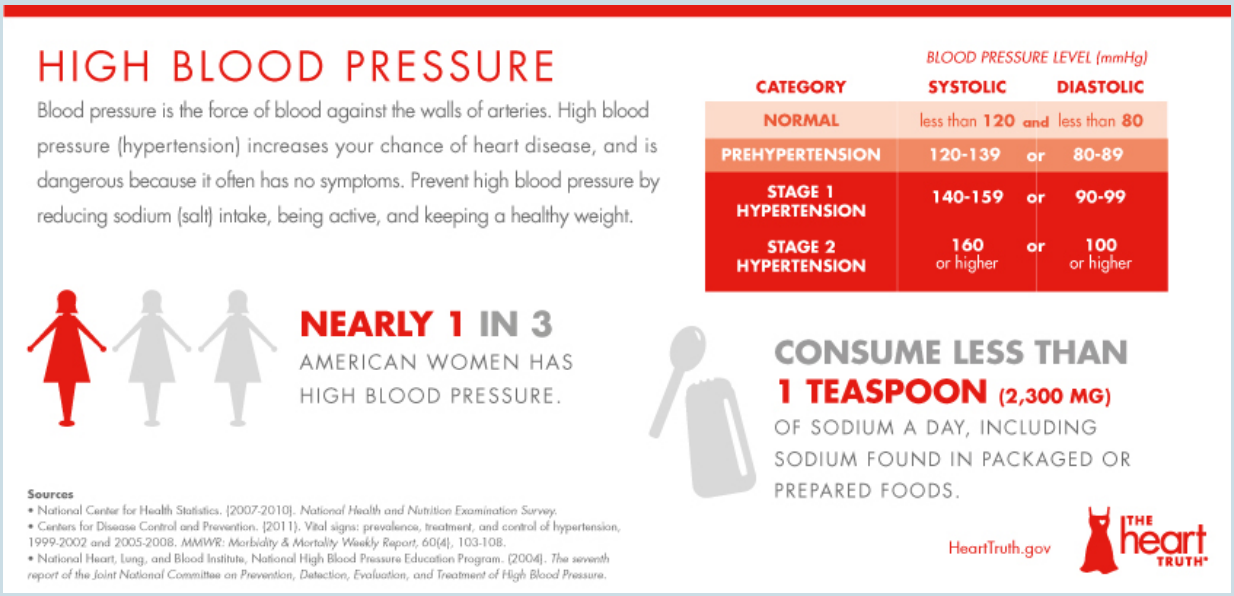


Click here to show an answer

Purpose: Inform and explain

Audience: General but informed public, possible research donors

Scope: Impacts of the fungus on human systems and health in Africa

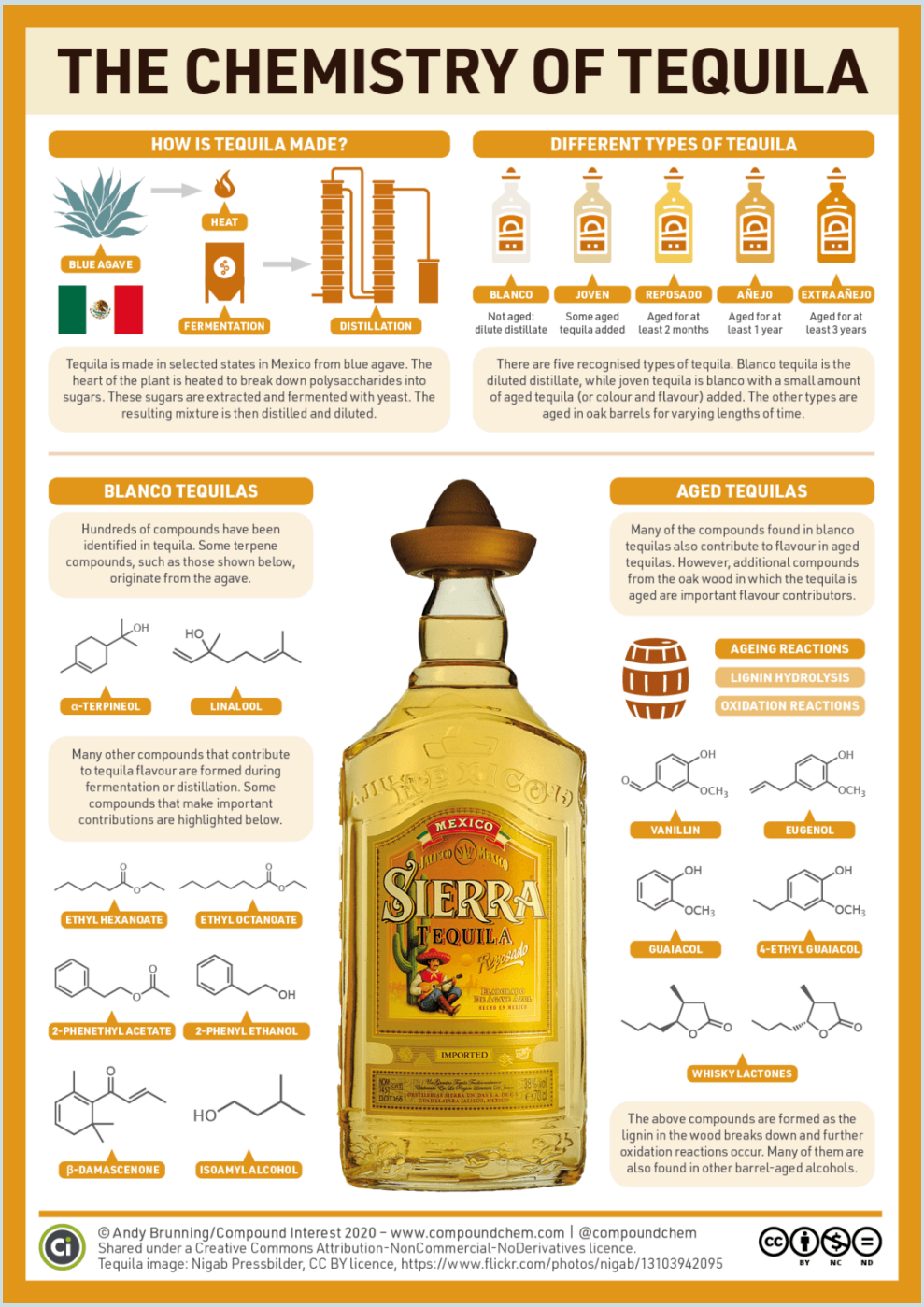


Click here to show an answer

Purpose: Inform and call to action

Audience: Targeted to women

Scope: Inform on the issue and suggest actions for women to take



"The Chemistry of Tequilas" by Andy Brunning is licensed under CC BY-NC-ND

Click here to show an answer

Purpose: Explain, fun

Audience: General public who is interested in food chemistry

Scope: Introduction to tequila and how it's made, then details of the basic chemistry

Science Meets Art

Infographics can be simple, hand-drawn, or complex computer renderings. Many scientists are starting to partner with artists and graphic designers to help them communicate important information and increase the impact of their research (Figure 17.2).[2]

infographic on pesticides

Figure 17.2. The example of a hand-drawn infographic from a recent article describing the importance of collaborating with artists to help increase the impact of research.

Share

Infographics need to be shareable to reach their intended audience. Most infographics are licensed under Creative Commons, a nonprofit organization that provides copyright licenses to creators. You will notice the Creative Commons logos on many of the infographic above. This type of licensing allows creators to choose how they want their work to be used and shared in the public domain.

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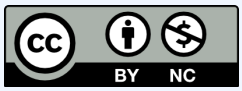
2. Khoury, C.K., Kisel, Y., Kantar, M. et al. Science–graphic art partnerships to increase research impact. Commun Biol 2, 295 (2019). https://doi.org/10.1038/s42003-019-0516-1



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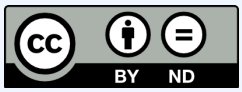

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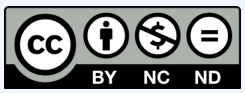

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18.

SOCIAL MEDIA

Reading time: 3 minutes

Overview

This chapter covers some social media venues for science communication.

Sections in this chapter

- Get social
- Twitter threads
- Facebook
- Science TikTok
- Science Youtube

Get Social

Love it or hate it, the most popular venue for science communication is now social media.[1] There are many benefits to science communication using platforms like Twitter, Facebook, Youtube, or TikTok:

- Social media can blend personal experiences, worldwide news, and science topics together in a way that grounds science in reality and brings more diverse voices into the mix.
- The content on these platforms is short, visual (limited text), and engaging – everything that makes for effective story-telling to a general audience.
- It becomes easy to ask questions and discuss science with many people, including Nobel Prize winners, in a less intimidating and informal setting.

There are also some downsides to using social media for science communication, and you're encouraged to

1. Social media for scientists. *Nat Cell Biol* 20, 1329 (**2018**).

read more in this Survival Guide by Science Magazine.[2] This chapter outlines just a handful of examples of effective science communication that use social media but is by no means a comprehensive or up-to-date list. Everyone has their own social media "bubble" and the content of this chapter reflects the author's personal experience.

Twitter Threads

Twitter is a social media and news site that allows users to post images, links, and text under 240 characters called "tweets". As a scientist, you might imagine that it is difficult to convey a complex scientific concept in 240 characters! Science communicators in #ScienceTwitter and #ChemTwitter will create threads of tweets that masterfully draw in the reader to explain a topic. These threads are formatted similarly to research proposals (see the chapter on Proposals): they begin with a hook, some interesting topic, and then dive into the details, before wrapping up with an overview.

Here's a great example of science communication in a Twitter thread by Gwenaëlle (@getneuro) that has music and images:

https://twitter.com/getneuro/status/1299042022955929602

And here's an example of how to promote your newly published research article using a Twitter thread:

https://twitter.com/dsquintana/status/1093814606441648128

There are also creative ways to use polling to create interactive Twitter threads, like Mika McKinnon's (@mikamckinnon) #YouFindaRock:

https://twitter.com/mikamckinnon/status/1288956627408715776

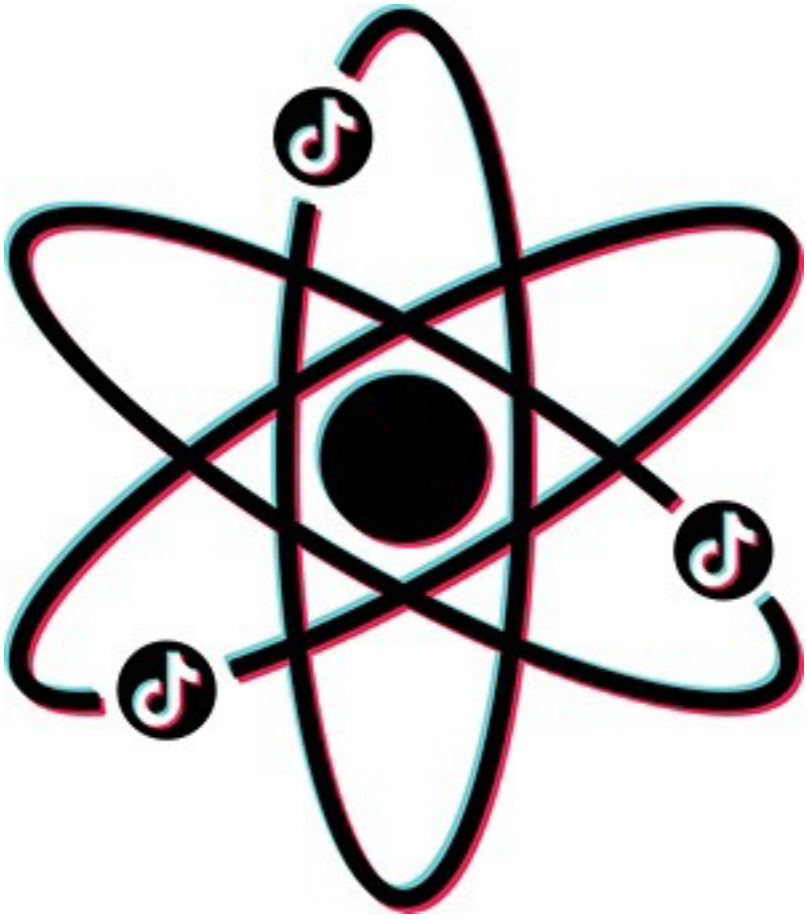
Facebook

Facebook is the default social network in most of North America, and also the main source of news. Links to popular or research articles can be posted on Facebook and discussed or reshared by anyone. Unfortunately, pseudoscience and fake science news are also perpetuated on the same platform, and it can be hard to know what to trust if you are not an expert. As Craig McClain discussed in this PLoS Biology article, scientists doing outreach on Facebook must become "Nerds of Trust" to fight this misinformation.[3]

---

2. "A social media survival guide for scientists" by Neil A. Lewis, Jr., Jay J. Van Bavel , Leah H. Somerville, June Gruber. Nov. 5, 2018. doi:10.1126/science.caredit.aav9607
3. McClain CR (2017) Practices and promises of Facebook for science outreach: Becoming a "Nerd of Trust". PLoS Biol 15(6): e2002020. https://doi.org/10.1371/journal.pbio.2002020

Science TikTok



Credit: C&EN/Shutterstock

As of 2020, TikTok is a new and rapidly growing social platform. Originally designed for lip-syncing to songs, users post short videos with some audio playing in the background. Text usually appears in short speech bubbles that users point to, rather than being spoken out loud. It's become a short and engaging way to post informational videos about science or relatable videos about being a scientist.[4] It's become increasingly important in an age of remote and online learning.[5] Darrion Nguyen (@lab_shenanigans) is one of the most popular people in science TikTok.

https://twitter.com/lab_shenanigans/status/1191751543713910784

4. "Chemists are finding their place on TikTok", Sam Lemonick, February 21, 2020, C&EN Volume 98, Issue 8.
5. "TikToks are teaching Generation Z about science", Rebbecca Mulr, November 5 2019, Massive Science, Accessed 2020-08-27.

Science YouTube

For years now, YouTube has been a go-to platform for science videos. Many Science Channels are targeted toward kids, are replace classic science TV shows of the 90s and earlier. One of the most popular chemistry YouTube channels is "Periodic Videos", where the Einstein-haired Professor Martyn Poliakoff explains all kinds of chemistry to a general audience. This show is targeted towards adults rather than children. Another great channel is by YouTuber Imari Walker, a microplastics researcher and environmental engineer. These channels follow all the science communication tips described in this module: storytelling, knowing your audience, and also flashy science demonstrations!

Periodic Videos: Melting a cheeseburger in hydrochloric acid

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=59#oembed-1

Imari Walker: 10 Facts about Microplastics

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=59#oembed-2

MODULE IV

MODULE 4: PRESENTATIONS

19.

ORAL COMMUNICATION BASICS

Read time: 2 minutes

Overview

Oral communication is fundamentally different than written communication. Your voice has qualities that cannot be communicated in written form, and you use these to your advantage when presenting your research. You can speak more informally and naturally than in written articles or theses. How your voice quality, volume, and pitch affect your listener's engagement and understanding of the message's content.

Sections in this chapter

- Tone
- Volume
- Word choice
- Pitch

Exercise: Watch some videos of good speakers

Ted Talks are a world-renowned series of engaging speakers. **Click here for a playlist of short Ted Talk videos.** Watch the videos and take note of the speaker's tone, volume, word choice, and pitch.

Oral Communication Tips

Tone

Delivering a message with a happy and enthusiastic tone will have a much different impact than serious or sad tones. In most academic situations, it is appropriate to speak with some level of formality, yet avoid sounding stilted or arrogant. Also, check the tone of your words: using words like "Obviously..." can alienate your audience.

Volume

Your voice volume should be normal but ensure your listeners can hear you. If your audience includes English learners, speaking louder and shouting don't help them understand you any better compared with accessible word choices delivered in a normal tone.

Word choice

Use simple words and short, active-voice sentences of 10-to-20 words, as well as avoid idioms (figures of speech) that don't translate literally. Be careful not to use words that you only usually see in written text, like journal articles (e.g., "Therefore,..."), since these will make your presentation sound scripted and unnatural.

Pitch

Pitch refers to the frequency of your voice, which you can raise or lower for effect. A pleasant, natural voice will have some variation in pitch—raised for lighthearted quips and lower for serious statements—to communicate nuances of meaning and keep the listener engaged. A speaker with a flat pitch will sound robotic and bored. Modulating your volume and pitch helps communicate the rich emotions of your messages.

Resources

There are plenty of resources to help you improve your oral communication. See this list from the Government of Canada, or join a public speaking group like Toastmasters.

Attribution

20.

TALKS

Read time: 8 minutes

Overview

This chapter will provide guidance and tips on giving a talk at a conference, seminar, research update, or thesis defence.

Sections in this chapter

- Format and length
- Slides
- Planning your talk
- Tell a story
- Preparing your talk
- Accessibility
- Make it interactive
- Common mistakes

Format and Length

Oral presentations for science communication have many possible formats:

- Conference presentations (15 minutes, 45 minutes)
- Seminars (45-50 minutes)
- Thesis defence (10-20 minutes, or 45-50 minutes)
- Research updates
- Tutorials and Lectures

Most oral presentations at conferences or in a thesis defence are 10-20 minutes in length, whereas invited talks, lectures, or seminars can be longer. The oral presentation should be designed to fit the time period but must allow for the introduction of the speaker, questions at the end of the talk, and technical glitches. In a one-hour time slot, a talk should be 45-50 minutes to allow time for questions and introduction.

A rough guide to the number of slides needed is:

- for a simple slide – one per minute

- for a complex slide – one per two minutes
- calculate where the midpoint of your talk is, to use for reference

Slides

Talks are usually accompanied by visual media, like a PowerPoint slide deck, or in some cases a blackboard/whiteboard (this is considered "old school"). Most universities have PowerPoint and KeyNote templates that you can download and use for research presentations (Click here for Queen's University Templates).

Here are several tips for designing slides (see Figure 20.1):

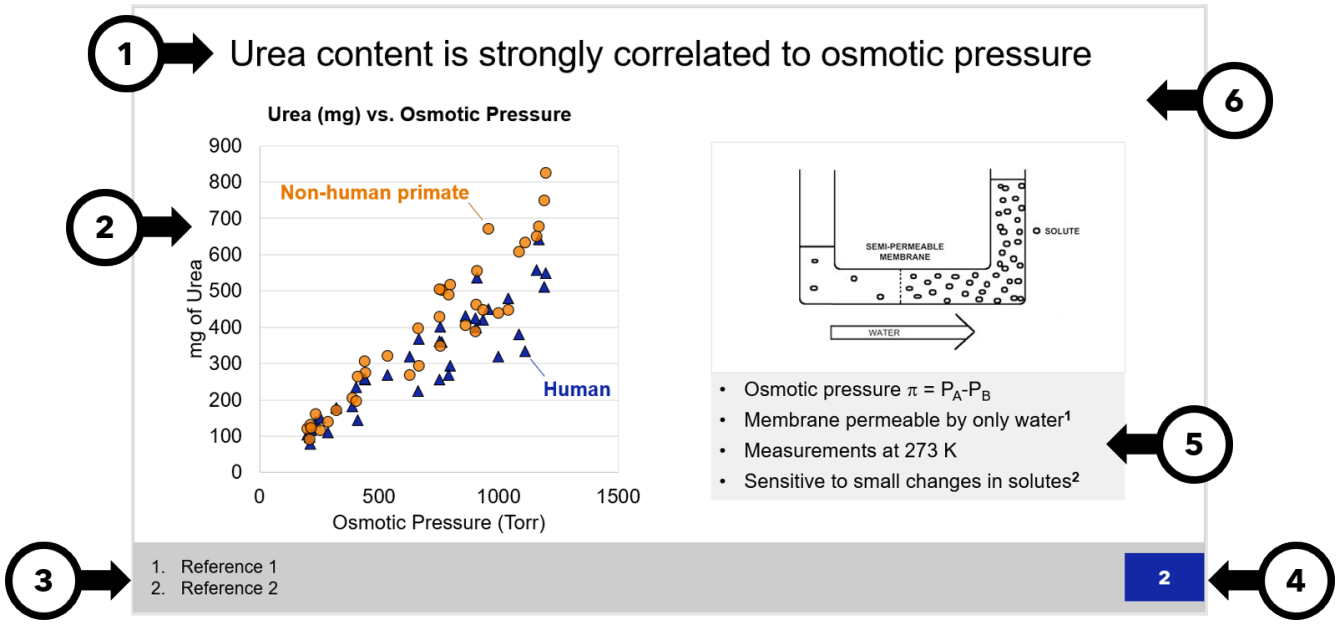


Figure 20.1. Designing a slide for a research talk (see above for notes 1-6).

1. **Write a descriptive title that contains the key message**
2. **Keep text size at 18pt or above, including in graph axes**
3. **Keep a space for references cited in the slide**
4. **Have a large and clear slide number**
5. **Limit text and use bullet points, not paragraphs**
6. **Use plenty of white space to avoid over-crowding**

Planning your talk

Before you start making slides or thinking of what you want to say, take some time to consider the big picture

and plan your talk. As always, consider first who your audience will be: What is their experience or expertise? What will they be interested in? What is their language level? Once you have a clear idea of your intended audience, decide what message you have for them, what you want them to take from your talk. Have a central message that is reflected in your talk's title.

In science, talks can be a venue to showcase your work and effort, and presenters can sometimes get overly ambitious or want to impress the audience (e.g., a thesis defence or interview talk). This mentality can lead to over-loaded talks that try and present too much data, or too many different research projects. In your talk, stick to ONE STORY. This story might be a single research project or a single component of the project. This doesn't mean you can't mention other projects or the broader context of your work, but only that you must stick to your one story for the bulk of the talk.

Tell a story

Since our framework for giving a talk is to *tell a story*, what makes a good story? Some things we've already discussed, including having a clear central message. The second is to embrace conflict. In research, this means describing mistakes or debate that stemmed from your research; often, failure leads to a new discovery, which creates a compelling story.

> "Craft a story that balances clarity and accuracy."
> **Shohini Ghose**, *Wilfrid Laurier University, Waterloo, Canada.*

Once you have your story idea, there are many ways to order a talk — sequential, categorical, problem-solution, *etc* — all involve an introduction, a body, and a conclusion. The introduction is crucial in getting your audience to the same level of background and getting them excited about research. So why is it that the audience often starts to lose interest in the introduction?

Introduction

Too many presenters start their talk, *their story*, by diving into the details. They will explain everything that has been done before their work and define the area of research and its terms. These are important points for the talk, but the issue is that the audience does not know why you are telling them all this information. Even if the audience is interested in the topic, they will disengage if the motivation for the research being presented in the talk is unclear.

The solution to a boring introduction is to start with a hook (Table 20.1). This can be a compelling message

related to the research question, e.g., "Is there a mosquito strategy that could eliminate dengue virus?".[1] Such a question is engaging even to an audience with no prior knowledge because it makes them want to learn more, which leads perfectly into an explanation of what is the dengue virus, why do we want to eliminate it, and what are mosquito strategies? Another way to hook the audience in the introduction is to tease an exciting or surprising result, then explain how it was reached. This is similar to a movie where you see where the characters end up, and then the movie explains how they got there. This approach is excellent for an expert audience, who will understand the importance of the result and want to know all the details that follow.

Table 20.1. How to structure an engaging introduction to your talk

Introduction	**Boring**	**Engaging**
1	"Lanthanide perovskites are.."	**Hook:** "Can molecular design help solve global challenges?"
2	"MOFs are..."	"We are trying to make new MOFs to capture carbon pollution"
3	"These compounds are made using..."	"MOFs are..." "Lanthanide perovskites are.."
4	"We are trying to make new MOFs to capture carbon pollution"	"These compounds are made using..."

Body

This is the bulk of your talk, where you explain your methods, results, and discuss the findings, and it can easily get out of hand if you have lots of data. Keep your keep message clear, and cut out any content that does not support this message. Remember that you can always discuss related content after your talk when the audience asks questions. If you are preparing a slide deck, use this trick: each slide should have a single "key message" that related to the overall goal of the talk. Then, organize the slides so that they flow along with your intended story.

Conclusion

To conclude your talk, bring the audience back to the "big picture" and reiterate your overall message. Bring the focus from the past (what was done) into the present and future. Describe the impact of your work,

1. "The mosquito strategy that could eliminate dengue", by Ewen Callaway, August 27 **2020**, *Nature News*, doi: 10.1038/d41586-020-02492-1

the significance, and what questions remain. For the final slide, make sure to acknowledge your colleagues, collaborators, and those who funded the research. Tell the audience how they can learn more by contacting you or how to find the relevant publications.

Preparing your talk

When preparing your talk, start to develop an outline or storyboard. Create rough versions of your visual aids (slides) and key points on single sheets of papers or on individual PowerPoint slides (Table 20.2). In this process, it can help to try and tell your story out loud. Talk through these ideas with yourself or a colleague, this will give you the opportunity to rearrange the sequence, adjust wording, etc. Use the "Slide Sorter" view in PowerPoint to look at your overall outline and rearrange your story.

Martha Davis provides excellent advice for planning and making visual aids for a talk in her book chapter "Visual Aids to Communication".[2] She suggests being as consistent as possible with how you use colour, symbols, axes, etc. Don't bother numbering your figures, and avoid tables or large paragraphs of text, and make visually appealing figures following the guidance from the chapters in Module 2: Visuals.

Avoid using too many devices for emphasis: the use of too many colours, italics, bold print, or underlining. If these enhancements are overused they will detract attention from the key message of the slide. Instead, use your voice for emphasis.

2. Martha Davis (2005) Chapter 15. "Visual Aids to Communication" in Scientific Papers and Presentations (2nd Ed) https://doi.org/10.1016/B978-012088424-7/50016-9

Table 20.2. Outline for a 15-minute talk with slides (adapted from Davis, 2005)

Slide	What to include	# of slides
Title	Title and subtitle, author, affiliation, date.	1 slide
Forecast	The 'hook'. Describe the nature of the problem, the big research question, and the clear central message.	1 slide
Outline	Optional. Sets out the structure of the talk.	1 slide
Background	Motivations, definitions, related work, and methods (briefly).	3-4 slides
Results	Key findings and insights (focus on 1-2 rather than all). Avoid using text and tables. Interpret the results as you go.	5-6 slides
Summary	Bring the audience back to the big picture, leave them wanting to read more.	1 slide
Future work	Optional. Describe what you plan to do next.	1 slide
Acknowledgements	Thank your colleagues, collaborators, and funding	1 slide
Back-up slides	Optional. Keep some extra slides that you didn't have time to cover, but that might be useful for discussion.	0-3 slides
	Total	*~15 slides*

Accessibility

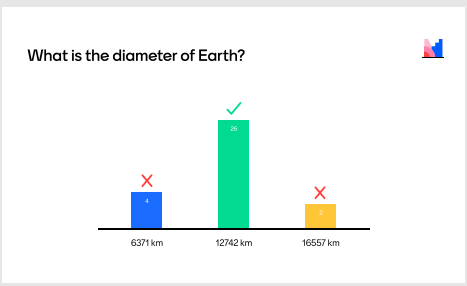
- Although this chapter advised you to limit the text on your slides, you should avoid eliminating text entirely. Text on slides is important for the hearing impaired, just like having close captions in a video.
- It's also important to always use a microphone if it is offered! Don't say "No, I don't need it, I speak loudly". You don't know how well your voice carries in that room, and are likely being offered a microphone for a reason.
- Microphones are sometimes linked to devices like hearing aids that can help those with hearing impairments.
- Make sure your slides follow the best practices for visual accessibility. Check that your colours are distinguishable for the colour-blind.
- Don't overcrowd your slides. Some disabilities make it difficult to look at screens for too long

or to take in too much information at once.

Make it interactive

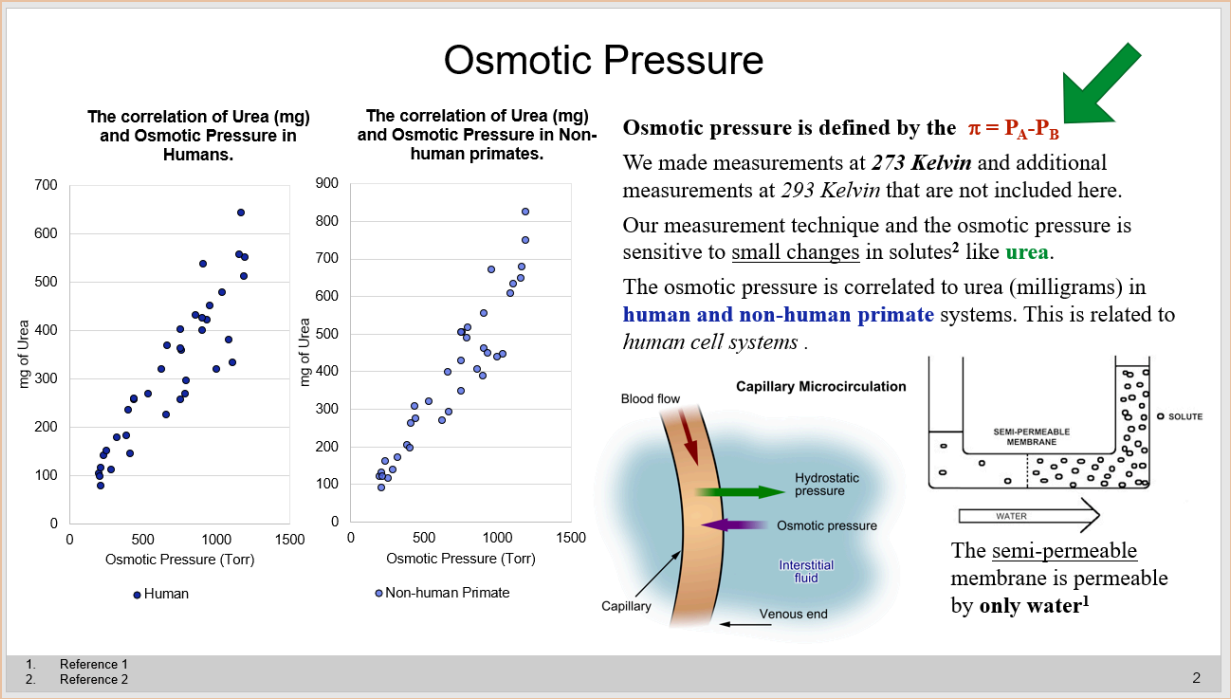
Educational research has proven how activities in the classroom can improve learning outcomes and student engagement. This idea can also be applied to research talks to help bring in our audience and keep them listening throughout your presentation (Table 20.3). Make your presentation interactive by having audience members answer questions either out loud or in their mind, or create time for audience members to discuss something in the middle of your talk. It can be intimidating to give away control of your presentation, but the reward is an engaged audience who feels like they are participating, rather than just listening.

Table 20.3. Strategies to make your talk interactive

Activity	Description	Example
Ask a question verbally	The question can be something for the audience to silently think about, or make it clear if you expect an answer or raised hands.	*"And what do you think happened next?"* *"Does anyone know who first discovered this reaction?"*
Ask a question using polling software	There are some great, easy, and free ways poll your audience from their devices, like Poll Everywhere or Mentimeter	
Think-pair-share	Pose a question, then give your audience a minute to discuss with each other. Ask audience members to share afterwards.	*"Why do we need to use this method? Discuss with your neighbour for a minute, then I want to hear what you all think."*
Demonstration	Ask your audience to do something that helps demonstrate the point you are trying to make.	*"It is hard to remember a phone number if I disrupt your memory with lots of other numbers. Remember this number on the screen, you will need to recall it at the end of the talk"*

Common mistakes

Below is a slide containing some common mistakes people make when creating presentation slides. Can you find them all?



Click here to show an answer

- The slide is over-crowded, there not enough white space
- The title is not descriptive
- Text is too small in the figures and references
- Data points in the figures are small and difficult to distinguish
- Instead of a legend, data could be labelled on the graph
- The two graphs could be combined into one
- Too much text, written in sentences/paragraphs rather than bullets
- Enhancements (bold, underline, italics, colour) are overused
- Red and green may not be accessible to colour-blind audience members
- The slide contains some irrelevant information ("measurements at 293 K are not included here")

- The slide number is small and might get cut off when projected

21.

POSTER PRESENTATIONS

Read time: 8 minutes

Overview

This section will outline how to communicate your scientific research in the format of a poster presentation, and provide guidance on designing your poster.

Sections in this chapter

- Environment and audience
- Poster vs. Talk
- Verbal aspect
- Poster design
- Virtual posters

Environment and audience

Many conferences have poster presentation sessions along with oral presentations. The poster presentation is a format introduced into the *American Chemical Society* meetings in the 1970s. This format allows more people the opportunity to present their work since many posters can be scheduled for the same time period and in one large room.

The format of a poster presentation allows for a one-on-one and in-depth discussion between the presenter and viewer. For this reason, poster sessions are often combined with social mixers, where people can walk around and browse the posters.

Theoretically, the poster audience is more broad and diverse, since many disciplines present in one large room. For this reason, your poster should be readable or understandable in less than 5 minutes by someone not in your field, who has only general knowledge of the research area. People browse posters and look for something that interests them, and on average spend around 90 seconds viewing a single poster. However, the people who actually attend your poster will likely be those who are interested in your work or work in a similar area.

Attaching business cards and one-page copies of your poster allow viewers to contact you later and get the information without having to take notes.

Poster vs. Talk

Table 21.1. Differences between posters and oral presentations (talks)

	Poster	Talk
Mode	Mainly non-verbal, visual	Verbal and visual
Audience	More diverse, passive	Captivated, expressed interest
Content	Contained body of work, a single set of experiments	More broad, with a critical literature review
Presentation	1-5 minutes, but available to view for hours or days	A single 15-20 or 45-50 minute timeslot
Questions	One-on-one, extensive and lively discussion, likely to be interrupted	After the talk, involves the entire audience
Afterwards	Posters can be put on semi-permanent display	Slides archives and used for future talks
Acceptance	All submitted posters are usually accepted at conferences	Abstracts for talks are not always accepted to some conferences

Verbal aspect

Posters are mostly non-verbal and visual, so most of this chapter will discuss poster design. However, the verbal aspect of the poster presentation is where many presenters struggle! The most common mistake is for presenters to launch into a detailed overview of the slides, starting at the introduction and working their way through the poster all the way to the acknowledgements. Even a 5-minute overview is too long at a poster! The issue with this approach is that the viewer cannot listen to you and think critically at the same time, and they lose the autonomy of exploring your visuals at their own pace. Follow these tips for a successful poster presentation:

- If someone shows interest in your poster, smile and introduce yourself, then wait.
- If they start to intently view your poster, let them do this silently without interruption.
- If they turn to you, ask if they would like a short overview of your work.
- Give them a **very, very concise** overview of your work (30 seconds maximum):

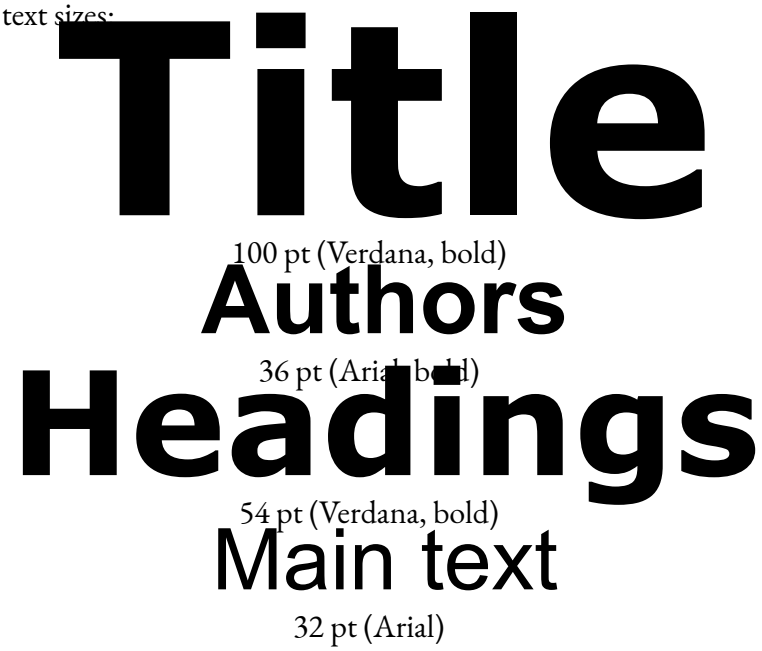
    - Start with the key finding, from your conclusion, and state it in *a single sentence.*
    - Then move on to your motivation and methods and details about the results.
- Make sure to pause and make eye contact, which will let viewers ask questions.
- Ask your viewer questions to gauge their interest and background, and encourage discussion
- Point to relevant things on your poster as you present.

There are some aspects of etiquette to giving poster presentations. First of all, you should be at your poster during the specified times. Socializing with friends should be a lower priority, so if your lab members are hanging around your poster you can politely ask them to give you some space. Stay tuned to social cues from your viewer, and let them view the poster silently if they seem to want that. Lastly, consider waiting until after the presentation for drinks.

Poster design

Format and Size

Posters should be concise, organized, and self-explanatory: the best way to achieve this is to have a central and obvious message. Beyond that, a poster should be easy to view from 1-2 meters away, which means you should limit text to short paragraphs (<20 lines) or bullet points. Remember that you are not writing a full paper! Any text should be in a simple Sans-Serif typeface (*e.g.,* Arial, Verdana, Calibri) with adequate spacing, and large enough to easily read. Consider using a different font style for the title and headings than the main text. Follow this guide for minimum text sizes:



References

28 point (Arial)

Instead of text, use figures, graphs, and charts to visually communicate of your work. Make sure the text labels and axes are large enough to easily read, following the guide above.

Check the conference website for instructions on the acceptable dimensions for posters. The typically allowed dimensions are 90 *cm* (36”) high x 122 *cm* (48”) wide. There are two ways to create your poster (Figure 21.1): 1) print 12-20 regular slides on 8.5″ x 11″ pieces of paper, and arrange them; 2) create a single large poster sheet, either printed on paper or fabric, to fill the whole space.

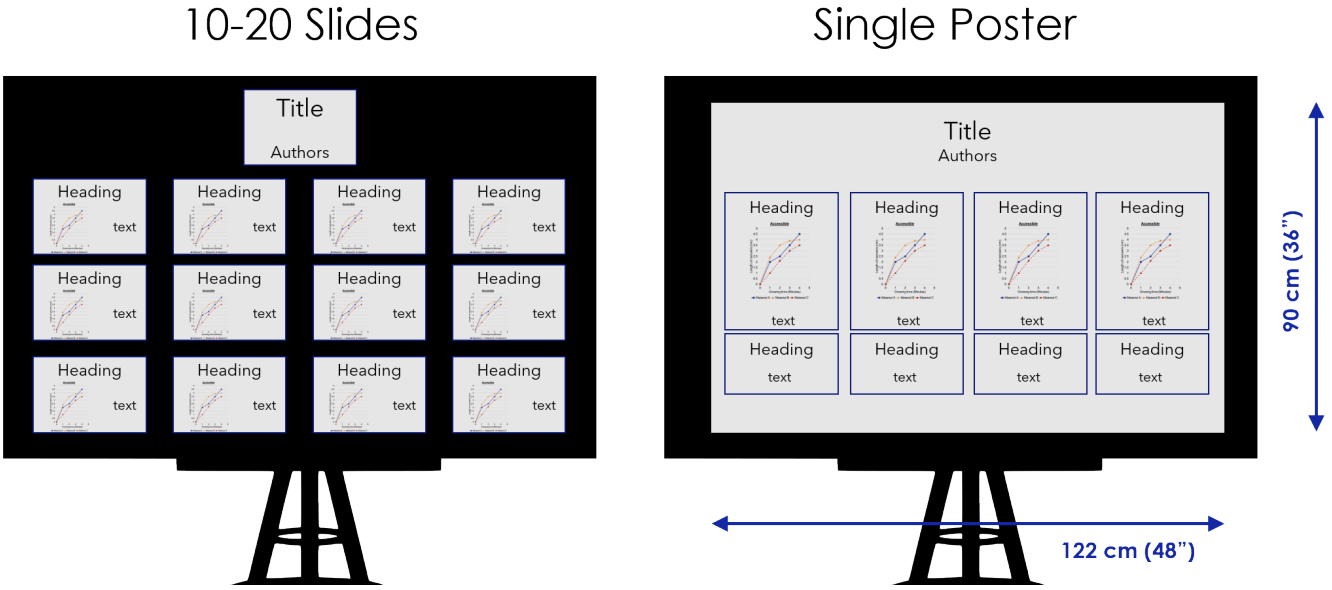


Figure 21.1. Poster formats and size. Posters made from slides are cheaper to print and easier to transport, but single-page posters tend to look more professional and are easier to follow.

Sections

Posters have all the components of a paper, organized into sections. These sections are not always separate on your poster (see below ‘Layout’), but they should be present in one way or another. See Table 21.2. for a list of sections and their descriptions.

Table 21.2. Poster sections

Title and Authors	• A title that describes your conclusion in simple terms (for a lay audience) • Include all author names and underline the presenter. • Also add the affiliation (Department of Chemistry, Queen's University) and an email address.
Introduction	• State your central research question and goals concisely • No need for a long literature review • Include a hypothesis • Define acronyms and explain relevant background information
Methods	• Description, diagram, or flow chart for the procedure used to test the hypothesis • Keep it brief unless the purpose of the poster is to present a new method
Results	• Most important section • Limit the text, use figures and provide representative data • Make visuals as large as possible and easy to follow
Conclusions	• Provide a concise summary • Discuss the significance of results • Did the results support the hypothesis?
References	• Can be listed in smaller type at the bottom of the poster, or integrated throughout the layout. • Include sources of any images used in your poster
Acknowledgements	• Usually placed at the bottom right. • Include the logo of the funding agency and name any collaborators who are not authors

Sections in your poster are outlined by headings. Instead of using section titles like "Introduction", use descriptive headings that tell the viewer the key message of the section (Table 21.3).

Table 21.3. Replacing poster headings with descriptive headings

Title: "Impact of Greenways on Bird Habitat"	⇒	"Can Suburban Greenways Provide High-quality Bird Habitat?"
"Introduction"	⇒	"Birds of concern are in decline"
"Objectives"	⇒	"Objective: Greenway for the birds"
"Results"	⇒	"Nest predators less common in wider greenways"
"Conclusions"	⇒	"Potential solution: Wide corridor, trail near edge"

Layout & Design

A thoughtful layout will provide a natural flow that guides people through your poster. It is best to arrange your poster in blocks of columns, so that the audience reads from left to right, top to bottom using "reader's gravity". You can number each section block or heading to help the reader to follow the flow of the material.

Posters with symmetric layouts and plenty of 'white space' are more visually pleasing, and can also help with flow. Also, place graphics and text to create a symmetrical balance.

Instead of headings like "Introduction", use ***descriptive*** headings to clearly communicate your main points. A lack of headings, plus an asymmetric layout of the material, makes it difficult for the viewer to follow the flow or find a particular section of the poster.

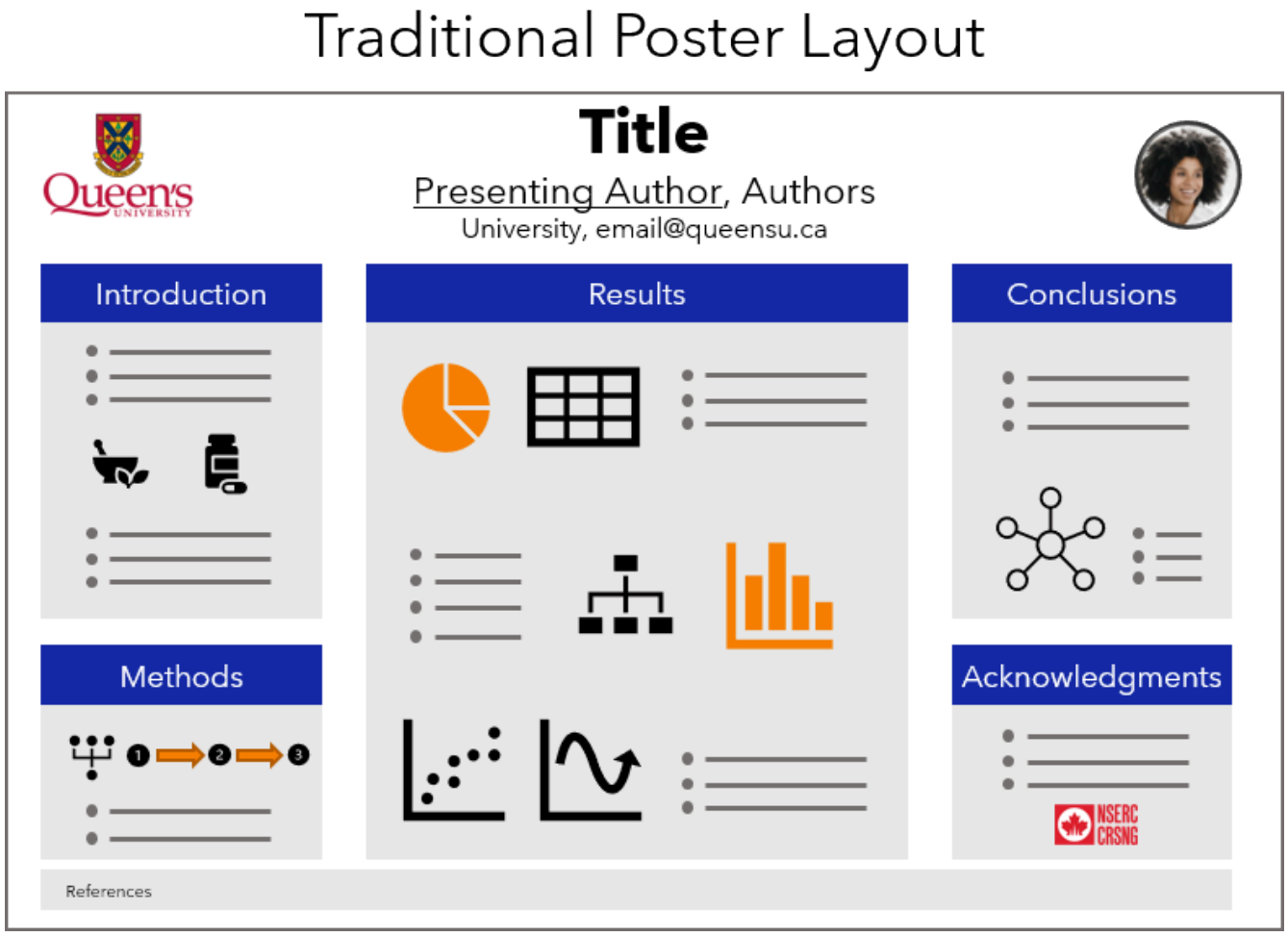


Figure 21.2. A traditional landscape poster layout with 3 columns

A popular traditional poster format (see Figure 21.2) has a landscape layout and three columns: 1) Introduction and Methods, 25% width; 2) Results arena, 50% Width; 3) Conclusions and Acknowledgements, 25% width. A more modern landscape layout (Figure 21.3) was designed by Mike Morrison,[1] which features a large takeaway sidebar with the key message, and a QR code that links to the paper or a website. This modern poster format also works well in a portrait format (Figure 21.4).

1. "Critique: The Morrison billboard poster", Zen Faulkes, April 11, 2019, *Better Posters.* Accessed 2020-08-31

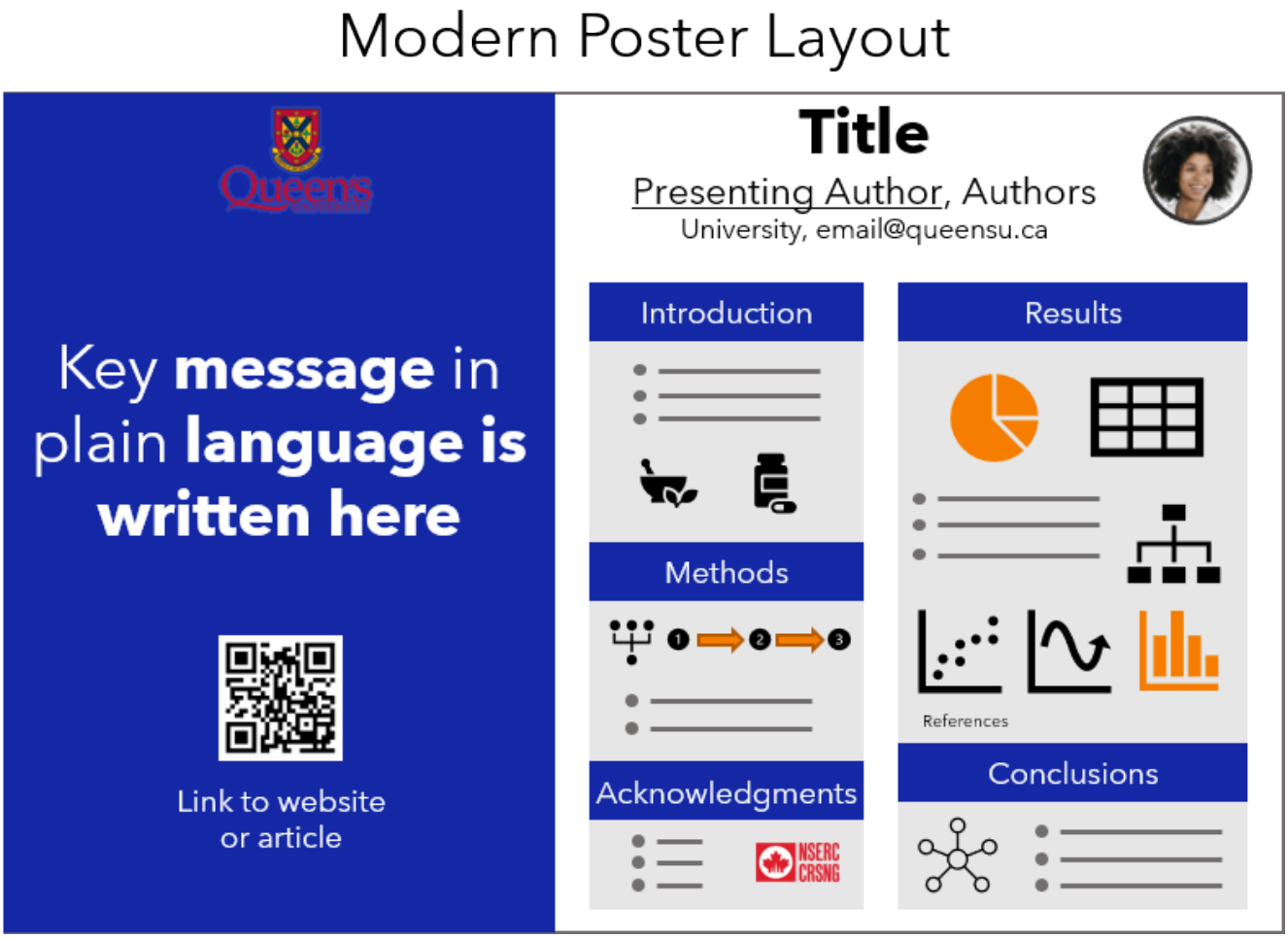


Figure 21.3. A modern landscape poster layout

Figure 21.4. A modern portrait poster layout

Colour

Stick to a theme of 2 or 3 colours, using an accessible colour scheme, and be consistent with the use of colours that have meaning (e.g., in legends). Don't be afraid to use bright colours to attract attention, but if you overuse them you will wear out readers' eyes. For the body of your poster, use a light coloured background and dark coloured text. Dark backgrounds with light letters can become tiring to read but are often used for headings.

Don't start from scratch

There are many poster templates available online! Here are some PowerPoint templates and guides:

BetterPosters.blogspot.com landscape template
BetterPosters.blogspot.com portrait template
BetterPosters.blogspot.com Twitter template
Queen's Chemistry Landscape Poster Template
Queen's Chemistry Portrait Poster Template

Virtual posters

Online conferences and symposia are becoming more common, including virtual poster sessions. Virtual posters can have animations, videos, and audio narration. These posters can take many formats, but one common format is for the RSC Poster Day on Twitter. They published this guide to creating a version of your poster on Twitter, and how to identify your work using the right hashtag (*e.g.,* #RSCOrganic, #RSCAnalytical).

Here are some links to the 2020 winners of #RSCPoster Day.
https://twitter.com/kellybrown_94/status/1234811116204830726
https://twitter.com/_julioterra/status/1234827681964929024
https://twitter.com/LizzieRAshton/status/1234795169310003205

22.

THE 3 MINUTE THESIS

Read time: 2 minutes

Overview

This chapter will provide an overview of the 3 Minute Thesis oral presentation format.

Sections in this chapter

- What is it?
- 3MT tips
- 3MT examples
- Resources

What is it?

The three-minute thesis (3MT) is a new format of research presentation that builds on the classic "elevator pitch". The challenge in this type of presentation is to explain your research to an intelligent non-specialist audience in under 3 minutes with limited visual aids. Often there are specific rules for the visual aid: a single 4:3 slide, no animations or video, and no props.

For a successful 3MT talk, you need to follow completely different rules from normal scientific presentations. You can skip common things like introducing yourself, thanking all your lab mates and colleagues, or funding. You typically don't show data unless it is presented in a very simple figure.

Because of the challenge involved with presenting years of detailed research in only three minutes, Universities hold cross-faculty 3MT competitions. The first was founded by the University of Queensland, Australia, where you can find many great resources and videos.

3MT Tips

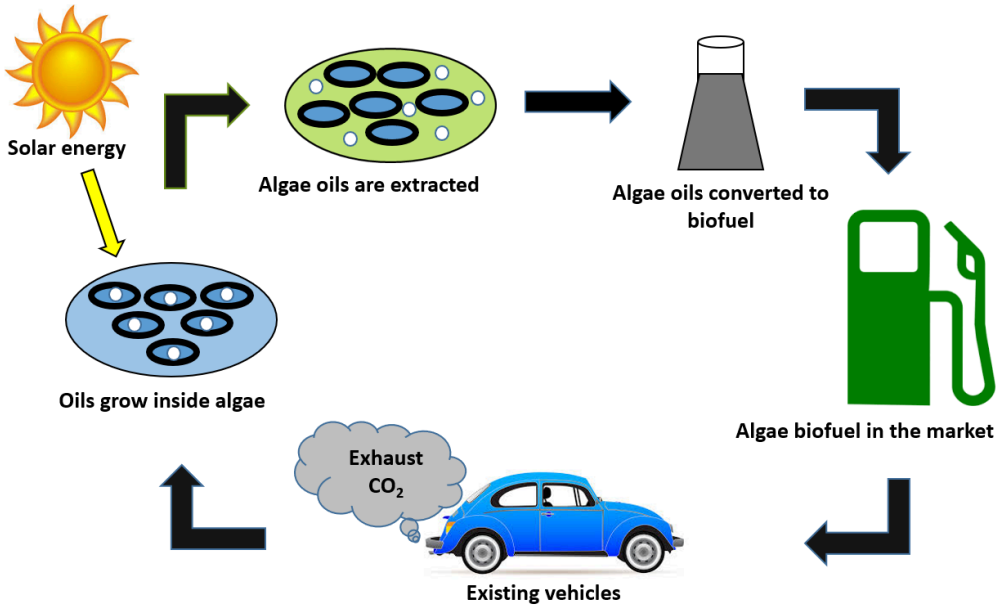
The tips below were adapted from "10 Hints for Improving Presentations for the Three Minute Thesis" by Danielle Fischer at Charles Darwin University (Full PDF here):

1. Don't introduce yourself, don't do acknowledgements, don't show data.
2. Start by introducing how your research relates to the bigger picture. Try to think of why any person might be interested in your work.
3. Only include relevant things on your slide and make sure images are good quality. Carefully design your slide, don't overcrowd it or use too much colour.
4. Use simple and familiar analogies.
5. Speak with an excited and engaged manner.
6. Don't wear anything distracting.
7. Use body language: smiling, gestures, movement, and eye-contact.
8. Finish by bringing the audience back to the big picture.
9. Practice and get feedback from a wide variety of people.
10. Use your time, but don't go over it.

Examples

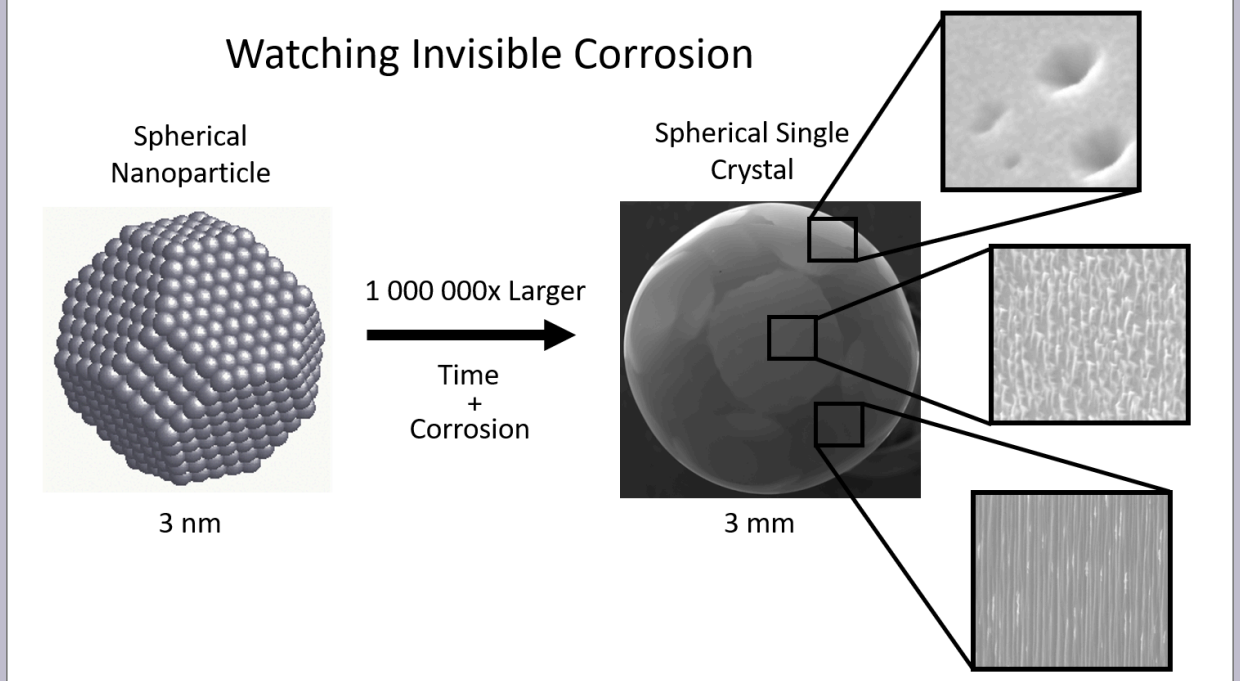
These are some 3MT slides made by previous CHEM 803 students.

3MT Example 1



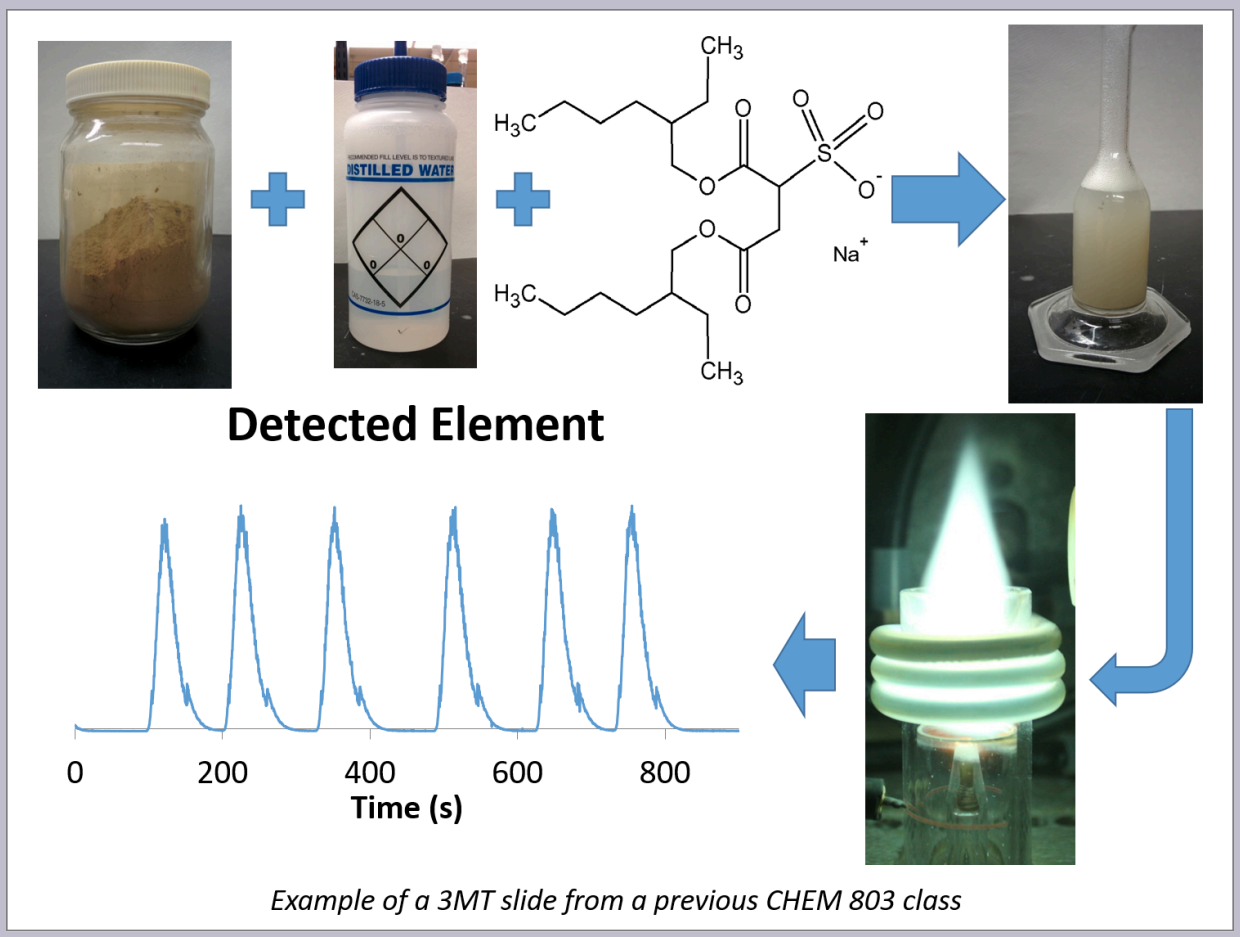
Example of a 3MT slide from a previous CHEM 803 class

3MT Example 2



Example of a 3MT slide from a previous CHEM 803 class

3MT Example 3



Example of a 3MT slide from a previous CHEM 803 class

Resources

There are many resources online about preparing a 3MT presentation. Below are some links to helpful videos, award-winning 3MT talks, and the many resources provided by Queen's University.

Helpful Videos

These videos were prepared by are owned by Australian National University.

3MT: THREE TIPS TO HELP YOU PREPARE A WINNING PRESENTATION

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=70#oembed-1

3MT: THE THREE MOST COMMON MISTAKES

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=70#oembed-2

Award-winning 3MT

These are videos of some award-winning 3MT talks. The first one has the best title, it's simple and concise!

- **Wind turbines and climate change – Rosemary Barnes**

- **Hypoxia-activated pro-drugs: A novel approach for breast cancer treatment – Jasdeep Saggar**
- **The Development of Anti-body-Drug Conjugate to Specifically Target and Soften the Crystalline Lens in vivo – Gah-Jone Won**

Check out the Queen's University 2020 Competition results, where you'll find two award-winning 3MT talks from our Chemistry Department by Morgan Lehtinen and Alastair Kierulf. [In the video at this link, click "Playlist" to find their talks]

MODULE V

MODULE 5: INTERPERSONAL COMMUNICATION

23.

EMAILING

Reading time: 12 minutes

Overview

This chapter goes over each part of an email message, with suggestions and tips. The end of the chapter discusses how to proofread your emails and make communication by email more efficient.

Sections in this chapter

- Email address
- Expectations
- Parts of an email
- Make your emails efficient

Email Address

Your email address will create an impression, and it's important that you send from the right email address in a professional context. Use your Queen's university email to look professional and make it clear that you are affiliated with Queen's as a student. Consider creating a straightforward NetID Email Alias such as firstname.lastname@queensu.ca. It's probably time to retire your teenage joke email address. A potential employer or other professionals who get an email from crazy.unicorn.gal@yahoo.com is going to delete it without even opening it.

Expectations

People treat email communication in different ways and will have **different expectations** for the punctuality of responses. You can manage other's expectations by making it clear how you use email, and if other forms of communication may be more efficient for urgent matters. You may need to conform to the expectations of your supervisors or be okay with not meeting their expectations.

For example, Prof. Bongers treats email as an **asynchronous and non-urgent** communication. This means that

she will respond to emails as soon as she has time, but they are not the top priority. In the case of an urgent matter, she prefers a phone call or text message which is less formal and easy to reply to quickly.

Be aware that some people believe the "business standard" is to reply within 24 hours, and the availability of email on the smartphones that almost everyone carries in their pockets has reduced that expectation to **a few hours**. What if you can't reply within the expected number of hours? The courteous course of action is to reply as soon as possible with a brief message saying that you'll be turning your attention to this matter as soon as you can.

Should it be an email?

We are often over-run with emails, which turns our inbox into a daunting list of tasks. Don't send an email if a phone call or chat message would be more appropriate or solve the situation quickly. For groups and teamwork, consider using collaborative communication tools like Teams or Slack channels.

Parts of an Email

Subject Line

The subject line should be **clear and accurately summarize** your email in 3-7 words. Your subject line shouldn't be too vague, nor so long and detailed that its eight-plus words will be cut off by your inbox layout. Include short dates and times, any more details about specific times and places, for instance, should really be in the message itself rather than in the subject line (see Table 23.1). If your email contains a question, consider posing it as the subject line. Also, avoid using words in your subject line that might make your email look like spam. A subject line such as *Hello* or *That thing we talked about* might appear to be a hook to get you to open an email that contains a malware virus.

Table 23.1. Subject line length and detail

Too Short	Just Right	Too Long and Detailed
Problem	Problem with your product order	Problem with your order for an LG washer and dryer submitted on April 29 at 11:31pm
Meeting	Rescheduling Nov. 6 meeting	Rescheduling our 3pm November 6 meeting for 11am November 8
Parking Permits	Summer parking permit pickup	When to pick up your summer parking permits from security
Lunch	Lunch today @ 1 PM?	Are you free today at 12:30 or 1PM for lunch at the Caf?

Notice that appropriately sized subject lines typically abbreviate where they can and avoid articles (*the, a, an)*, capitalization beyond the first word and excessive adjectives. Whatever you do, don't leave your subject line blank!

Opening Salutation

When a reader opens your email, its opening salutation indicates not only who the message is for but also it's level of formality. As you can see in Table 23.2 below, opening with *Dear [Full Name]* strikes a respectful tone when writing to someone for the first time in a professional context. When greeting someone you've emailed before, *Hello [First name]:* maintains a semi-formal tone. When you're more casually addressing a familiar colleague, a simple *Hi [First name],* is just fine.

Table 23.2: Opening Salutation Examples

First-time Formality	Ongoing Semi-formal	Informal
Dear Dr. Melody Nelson: *Dear Prof. Nelson:*	*Hello, Melody:* *Hello again, Melody:* *Thanks, Melody.* (in response to something given)	*Hi Mel,* *Hey Mel,* *Mel,*

Depending on the nature of the message, you can use alternative greeting possibilities. If you're thanking someone for information they've sent you, you can do so right away in the greeting; e.g., *Many thanks for the contact list, Maggie*. When your email exchange turns into a back-and-forth thread involving several emails, it's customary to drop the salutation altogether and treat each message as if it were a text message even in formal situations.

Formality also dictates whether you use the recipient's first name or full name in your salutation and if you should use their title. If the person emailed you first, always check how they signed off and use that as a guide to address them. Always use a title and full name when emailing a Professor for the first time, *e.g., Dear Professor Nelson*, and see how they respond before switching to an informal salutation. If you're addressing a group, a simple *Hello, all: or Hello, team:* will do.

Recipients

If you have a primary recipient in mind but want others to see it, you can include the others in the CC (carbon copy) line. If confidentiality requires that recipients shouldn't see one another's addresses, BCC (blind carbon copy) them instead. Be selective with whom you CC, however. Yes, it's good to keep your manager in the loop, but you may want to do this only at the beginning and the end of a project's email "paper" trail. If in doubt, speak with your manager about their preferences for being CC'd.

Never "reply all" so that everyone included in the "To" line and CC'd sees your reply unless your response includes information that everyone absolutely must-see. Bear in mind that, concerning **email security**, no matter who you select as the primary or secondary (CC'd) recipients of your email, always assume that it may be forwarded on to other people, including those you might not want to see it.

Message

In most cases, you can use a **Direct-approach** and get right to the point in the opening sentence immediately below the salutation (Table 23.3). This approach takes practice: try reading your emails over after you write them, and often you will find a lot of extraneous information.

Indirect-approach emails should be rare and only sent in extenuating circumstances, like when delivering bad news or addressing a sensitive topic. In such cases, the opening should use strategies that buffer the message and ease the recipient into the bad news or set the proper context for discussing the sensitive topic.

Table 23.3. Direct vs. Indirect Approach

Sample Direct Opening	Sample Indirect Opening
We have reviewed your application and are pleased to offer you the position of retail sales manager at the East 32nd and 4th Street location of Swansong Clothing.	Thank you very much for your application to the retail sales manager position at the East 32nd and 4th Street location of Swansong Clothing. Though we received a large volume of high-quality applications for this position, we were impressed by your experience and qualifications.

Unlike novels, people don't enjoy reading emails. Keep emails brief by sticking to one topic per email. Check that the subject line still relates to the topic (which helps for searching later), and if you have a second topic you must cover with the same recipient(s), send it in a separate email. One-sentence paragraphs and bullet-point lists can help. If your message gets large, moving it into an attached document is better than writing several screens of large paragraphs.

An email closing usually includes **action information** such as deadlines or direction on what to do with the information in the message. If your email message requests recipients to fill out a linked survey to determine a good meeting time, for instance, you would end by saying, *Please fill out the Doodle survey by 4pm Friday, May 18*. Always provide some due date for action information, even if it's not urgent, e.g., *It would be best to have your feedback by Friday*. If the message doesn't call for action, close with a statement of goodwill like *Let me know* if *you have any questions,* or *Thanks again for your feedback.*

Closing Valediction

A courteous closing to an email involves a combination of a pleasant sign-off word or phrase and your name. As

with the opening salutation, the closing depends on the nature and formality of the message, as shown in Table 23.4 below. Your first email to someone in a professional context should end with a formal closing salutation. Later emails to the same person can use a semi-formal closing, and if it is a long and informal message thread, you may omit the valediction entirely and just sign off with your name or first initial. Including your first name after the valediction says "Let's be on a first-name basis" if you weren't already, green-lighting your recipient to address you by your first name in their reply. Don't omit your name even if you use an email signature.

Table 23.4. Valediction examples

Formal	Semiformal	Informal
Best wishes,	*Best,*	*All good things,*
Kind regards,	*Get better soon,*	*Thanks,*
Much appreciated,	*Good luck,*	*Bye for now,*
Sincerely,	*Take care,*	*Cheers,*
Warm regards,	*Many thanks,*	*Ciao,*

e-Signature

The e-signature that automatically appears at the very bottom of your email is like the business card and includes all relevant contact information. There are a lot of possible formats to use for an e-signature, which can include the details given in Table 23.5 below.

Table 23.5. e-Signature example

E-signature Parts	Example
Full Name, Role/Credentials	**Jessica Day**, PhD Candidate
Company Name	Department of Chemistry, Queen's University
Company address	90 Bader Lane, Kingston, ON, Canada
Phone Number(s)	555-555-2297 (cell)
Company website, Email address	queensu.ca | jessica.day@queensu.ca

Attachments

Email's ability to help you send and receive documents makes it an indispensable tool for any business. Bear in mind a few best practices when attaching documents:

- Always **announce an attachment** in an email message. For instance, "*Please find attached the minutes from today's departmental meeting*"
- **Never leave a message blank** when attaching a document in an email to someone else, it will be

marked as spam.

- Ensure that your **attachment size**, if it's many megabytes (MB), is still less than your email provider's maximum allowable for sending and receiving.
- You can choose to **share a link** to a large file in OneDrive or GoogleDrive instead of attaching a copy to the email.
- Always **check to ensure that you've attached a document** as part of your editing process (because you probably forgot!).

Make your emails efficient

Emailing is notoriously inefficient, but it doesn't have to be that way. Be direct, brief, and prevent back-and-forth by being proactive (Table 23.6)! If your message has an action item, always **suggest a deadline**. If you are trying to schedule a meeting, always **suggest a few available times first**. It may feel weird or presumptuous at first to suggest deadlines to others, like to your boss, but it is really helpful to others and helps manage expectations.

Table 23.6. Being proactive for efficient emails

Vague	***Proactive***
Can you please review my conference abstract?	Can you please review my conference abstract? It would be great to have your feedback by Thursday afternoon.
Can we meet sometime next week?	Are you available to meet next Thursday afternoon? I could also meet Friday morning.

Before hitting the Send button, follow through on the revision and proofreading process described in the earlier modules.

- Did you greet the person appropriately and spell their name correctly?
- Did you get across your message clearly using a direct approach?
- Have you struck the appropriate tone and formality? You want to be direct, but not come across as angry or rude. Review the advice about netiquette.
- Have you used extra words and or included irrelevant information?
- Did you proactively suggest deadlines and meeting times?
- Prevent yourself from hitting "send" too early by adding a delay, or add the recipient's email to the

message last.

Editing a poorly written email

Poorly Written Email Example

hey, think you made a mistake marking my last assinement i did what is supposed to do if its cuz i didnt get it in by the 5th its cuz i had a bad breakup it was so bad i had to see a councilor thats why i havnt bin around hope you understand. should of said that earlier maybe. oh and whens the next thing due. let me know as soon as u get this ok thanks bye

Improved Email Example

Hello, Professor Morgan:

Could you please clarify why I failed the previous assignment?

I believe I followed the instructions but may have been confused about the due date while dealing with some personal issues. If so, I apologize for my late submission and understand if that's the reason for the fail. I just wanted to confirm that that's the reason and whether there's anything I can do to make up for it.

I assure you it won't happen again, and I'll pay closer attention to the syllabus deadlines from now on.

Much appreciated,

Taylor

The poorly written message in the example above has the look of a hastily and angrily written text message. This email, however, calls for a much more formal, tactful, courteous, and apologetic approach. The undifferentiated wall of text omits the opening and closing salutations. Issues include the lack of capitalization, poor spelling (e.g., *councilor* instead of *counsellor*), run-on sentences, lack of punctuation, and unnecessary personal details. The writer is ultimately unclear about what they want; if it's an explanation for why they failed, then they must be upfront about that.

The improved email corrects the problems of the first draft starting with properly framing the message. It benefits from a more courteous tone in a message that starts with a clear and polite request for information in the opening. The supporting detail in the message body and apologetic tone are also improved.

Exercises

1. Take one of the worst emails you've ever seen. It could be from a friend, colleague, family member, professional, or other.

- Copy and paste it into a blank document, but change the name of its author and don't include their real email address (protect their confidentiality).
- Use MS Word's Track Changes comment feature to identify as many organizational errors as you can.
- Again using Track Changes, correct all of the stylistic and writing errors.

2. Let's say you just graduated from your program and have been putting your name out there, applying to job postings, networking, and letting friends and colleagues know that you're on the job market. You get an out-of-the-blue email from someone named Dr. Emily Conway, the friend of a friend, who is looking for someone with your skills to join their research group. Dr. Conway's email asks you three questions in the message body:

- Our mutual friend mentioned you just graduated from college. What program? How'd you do?
- What types of research projects have you done in the past? What are you interested in doing in the future?
- Can you send a sample of your writing?

Dr. Conway closes her email asking if you'd like to meet to discuss the opportunity in more detail and signs off as Emily.
Draft a formal response email that abides by the conventions of a formal email.

Attribution

24.

CONVERSATION

Overview

A successful career in science depends on having advanced interpersonal skills. Everyone has the capacity to learn, develop, practice, and apply verbal and nonverbal skills to benefit their community and themselves. This chapter describes conversations as an essential communication tool in science.

Sections in this chapter

- Your voice
- The five stages of conversations
- Conversations in science
- Improving your conversation skills
- Telephone and voicemail
- Chat and text

Your voice

Your voice continues to enjoy a privileged place in your communication toolbox, being the first one you use in your infancy when you cry for food and attention the moment you're born. Since then, you've developed richly expressive verbal skills that make your voice your most essential communication tool. When trying to make a point very clearly and emphatically, slowing down your pace so that the listener focuses on each word, raising your volume to jolt the listener into paying closer attention, and dropping your pitch to sound more authoritative all have advantages over using all-caps, bold, italics, and/or underlining in an email. For sheer expressiveness and precision in communicating meaning, your voice is your go-to communication tool.

The five stages of conversations

A skilled professional knows when to speak, when to listen, and when stop speaking before the audience stops listening. Though expectations may differ depending on the field, level, knowledge, and experience, conversation skills are important in daily life, when presenting, and during job interviews. Steven Beebe, Susan

Beebe, and Mark Redmond (2002) break conversation down into five stages that we will adapt here for our discussion.[1]

1. INITIATION

As the first stage of conversation, initiation requires you to be open to interact and perhaps use small talk to help "break the ice". You may communicate openness with nonverbal signals such as approaching someone, stopping a few feet away, facing them, making eye contact, and smiling. Initiation of conversation can be difficult for introverts in unfamiliar settings.

2. PREVIEW

The preview verbally or nonverbally indicates the conversation topic, *e.g.,* "*Can I ask you about how I can safely perform this procedure?*" Like emailing, a Direct-approach is usually appropriate, but for sensitive topics, you may want to indirectly preview the topic. For instance, a manager needing to talk to an employee about being late for work too often might start off by saying, *"That was some nightmare traffic on the highway this morning, eh?"*

3. BUSINESS

At this stage, you can get to the point. You may signal to your conversation partner that you have three points you need to cover, much like outlining an agenda at a meeting. This may sound formal at first, but in listening to casual conversations, you'll often find a natural but unacknowledged list of subtopics leading to a central point, which helps the conversation from getting off track.

4. FEEDBACK

Similar to the preview stage, this feedback allows speakers to clarify, restate, or discuss the talking points to arrive at mutual understanding. In some cultures, the points and their feedback may recycle several times, or a simple "Are we good?" might be all that's necessary at the feedback stage. Communication across cultures may require extra time to ensure a mutual understanding.

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1. Steven Beebe, Susan Beebe, and Mark Redmond (2002).

5. CLOSING

Accepting feedback on both sides of the conversation often signals the transition to the conversation's conclusion. Closings mirror the initiation stage in that they can be signalled verbally (*e.g., "Okay, thanks! Bye"*) and nonverbally, such as stepping back and turning your feet and body in the direction of where you're about to go next in preparation to disengage while still facing and speaking with the other. If words like "okay, one last thing" are used, the listener expects a conclusion in the very near future, and they will have mentally shifted to the next order of business. Mentioning a time, date, or place for future communication clearly signals that the conversation, although currently concluded, will continue later.

Conversations in Science

There are so many different settings in science where conversations occur. Consider how you would treat each of the conversations in Table 24.1 differently based on the situation.

Table 24.1. Contexts for science communication

Communicating ...	Considerations	Typical formality
with peers	You can more easily use local terminology and jargon due to a common understanding.	Informal
with your supervisor	Also have a common understanding. Make sure to be honest about what you know/don't know.	Semi-formal or Informal
with scientists in your field	For example at a conference or research seminar. Asking questions after a research talk.	Semi-formal to Formal
with scientists in other fields	Also at conferences and poster presentations. May have different cultures and terminology.	Semi-formal to Formal
with your family or the general public	They won't know scientific jargon and may have different definitions of words like "theory"	Usually informal but depends on context

Improving your conversation skills

If you prefer to text rather than talk to people most because you grew up in the smartphone era, you could be out of practice for interacting with people in person. You may also find it difficult to communicate science

with others; there are several generations of adults who grew up without smartphones and therefore tend to prefer talking over texting. The onus rests largely on you to improve your conversation skills, and luckily there are vast resources available online. For instance, we can draw on a very accessible TEDtalk by Celeste Headlee, a talk-radio host and author of We Need to Talk: How to Have Conversations That Matter (2017). We'll adapt her well-viewed speech 10 Ways to Have a Better Conversation (2016) for our own purposes below and build on them with a few points of our own.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://ecampusontario.pressbooks.pub/scientificcommunication/?p=80#oembed-1

1. **Be Present**: Devote your undivided attention to the person you're speaking with and don't multitask.
2. **Be prepared to learn**: A conversation is a dialogue, not a monologue where you simply unload your opinion.
3. **Ask open-ended questions**: The more vague your questions are, the more freedom you give your conversation partner to answer on their own terms. Avoid "yes/no" questions.
4. **Go with the flow**: Respond to your conversation partner's main points rather than with some digressive story you were reminded of by one of their minor points.
5. **Admit to not knowing**: Make your confession of ignorance an opportunity to learn rather than claim to know something you don't.
6. **Honour the uniqueness of their experience**: When the speaker relates something that happened to them, resist the urge to make it about you by equating their experience with yours.
7. **Cut yourself off before repeating yourself**: If you have only one point to make, "hit it and quit it" rather than saying the same thing over and over, even if you change the words.
8. **Stay out of the weeds**: Focus on your main points and don't get caught up in details.
9. **Listen**: A conversation is a dialogue, not a monologue, and therefore requires that you actively pay attention to what the speaker says.
10. **Be brief**: People are busy and have things to do, so if your conversation detains them for longer than they have time for, you will stretch their patience.

Headlee concludes that these tips are all variations on being interested in what people have to teach you (TED, 2016). If you add the following to Headlee's advice, you stand a good chance of improving your conversation skills.

Mirror the speaker

You may have occasionally caught yourself automatically imitating your conversation partner's posture, facial expression, and manner of speaking. Coined the "chameleon effect" by psychologists, mirroring is unconscious physical behaviour motivated by our desire to fit in so our conversation partner identifies with and likes us (Chartrand & Bargh, 1999). Though it happens unconsciously, mirroring deliberately has been found to be especially effective in job interviews, though only if the person being mirrored doesn't notice the imitator doing it. If you can be subtle and natural about it, intentional mirroring forces you to read your conversation partner's verbal and nonverbal messages closely.

Correctly Pronounce Names

The importance of pronunciation is nowhere more important than with people's names. If someone's name looks difficult to pronounce on paper, simply asking them how they prefer their name to be pronounced is better than confidently mispronouncing it. Keep trying until you get it right — it's their identity and they deserve to be called the correct name.

Avoid one-way conversations

A conversation isn't a monologue where you fire words at a wall until you have nothing left to say. It's more like a game of volleyball, tennis, or ping-pong where possession of the speech right is exchanged back and forth. If it's a friendly game, the objective is to volley words for as long as it's fun or productive. This may mean asking a good question, which lobs the speech over the net to your conversation partner. They answer and can either ask you a feedback question in return or you can respond to their answer with a statement. Every time you speak, you must set up your conversation partner to be able to respond with either a statement or question and expect them to do the same. A conversation must be a dynamic process where both sides make a determined, concerted effort to keep it going until the objective has been reached or the clock runs down.

Telephone and voicemail

The simplest form of voice conversation is a telephone call because there are no nonverbal cues. Sometimes a quick phone call can save people from the back-and-forth of many emails over days. Phone calls are also useful for private conversations that you may not want to have in writing. As the response from the receiver to the sender, feedback is also an essential element of phone conversations. Taking turns in the conversation can sometimes be awkward when you can't see when your conversation partner is about to speak.

When you lack the nonverbal context of your conversation partner being able to see how you say what you say, ensure that your voice accurately communicates your message. Without nonverbals, your choice of words and how you say them, including spacing or pausing, pace, rhythm, articulation, and pronunciation are more relevant than when you talk in person. Consider these five points:

1. **Speak slowly** and articulate your words clearly.
2. **Use vivid terms** to create interest and communicate descriptions.
3. **Be specific**. Don't assume that they will catch your specific information the first time. Repeat as necessary, especially addresses and phone numbers.
4. **Keep it private**. Avoid calls in a crowded elevator, for instance.
5. **Silence** devices when in a meeting or eating with colleagues.

When you phone someone but are sent to voicemail because they don't pick up, switch to monologue mode and simply say what the call is about in concise, clear terms. Anything that needs discussion must be saved for the actual conversation, especially anything of a sensitive nature. Add your contact information, even if you think the person already knows your phone number, and say it twice slowly so that the listener has additional time to get a pen and paper if they're still looking for them the first time you say it. When you receive a voicemail, return the call as soon as possible, since a phone call implies a sense of urgency.

Chat and Text

Conversations through chat and text messages have aspects of both email or in-person conversations. They are like in-person or telephone conversations in that they tend to be informal; after initial salutations, you don't continue saying "Hello, Name" even if the conversation takes place over several days. The conversation may be ended by "Ok, thanks", or may not have a natural end and be left hanging to be picked up later even for a different topic. Grammar and punctuation are also less important on chat and text message because many people know what these conversations are made using small keyboards on smartphones. Like emails, chat and text messages are more commonly used for asynchronous communication. Chats and text messages are efficient modes of communication for quick questions and requests with people close to you, or to request more formal meetings.

Attribution

25.

TEACHING

Reading time: 13 minutes

Overview

By the end of this Chapter, you will be able to identify various ways to communicate with the course professor, students, and other TAs. You'll learn about how to communicate in the common context for teaching: the tutorial session.

Sections in this chapter

- Communicating with the course professor
- Communicating with students
- Working with other TAs
- What to do if you get sick
- Your role
- How to prepare for a tutorial
- What to include in a tutorial
- Synchronous facilitation options
- Asynchronous facilitation options

Communicating with the course professor

The course professor will typically contact you in the week before classes start. You don't have to wait, though! Do feel free to contact them first. During an initial meeting with the course professor, you will ideally receive a copy of the course syllabus, access to the course's learning management system (OnQ at Queen's), and have a discussion about roles and responsibilities in the course. Remember that you are supported by a union, that can also provide you will answers to questions.

Questions to ask:

General

- What are my responsibilities in the course?
  - What are the timelines for accomplishing each task (e.g., responding to students' emails, marking)?
  - What are the dates and times I am expected to be teaching?
  - What are the safety procedures in the department?

- What technologies will be used in the course (*e.g.,* Teams, Zoom)?
  - What should my level of expertise be in using these tools?
  - Where do I go to learn to use these tools?
  - Do I have access to be able to share digital materials with the professor and students?
- Should I attend classes?
  - If so, what is my role during classes (*e.g.,* attendee to learn the material and expectations, facilitator to help monitor and respond to questions in the chat, help facilitate breakout groups)
- What are some ways I can balance my TA position with my academic obligations?

Tutorials

- How do you envision tutorials to be run?
- Are there examples of past material that I can use?
  - Other TAs can offer insight from their experiences and provide feedback and resources

Marking

- What kind of marking will be involved?
- How is the marking done and returned to students (*e.g.,* marking scheme, rubric, marking software)?
- What are the timelines/deadlines?

Communication

- What is the best way to communicate with you?
- Would you like to receive feedback about how the course is going? If so, how should I share that feedback (*e.g.,* survey, email every week with ideas)?

What to do if you get sick

If you get sick, email the course professor as soon as possible to tell them that you are sick and what aspects you will not be able to complete. It's helpful if you can find yourself a replacement for the task you will be missing; ask another TA in the course if you can trade a session.

Communicating with students

Email

You can tell students in the course both the **methods** they can use to communicate with you and the **response times** to expect. For example: you might say that students can **email** you with questions and that you check email every 24 hours. You can ask for the course code to be included in the email subject line (e.g., CHEM112 Tutorial question). Alternatively, you may say that you prefer that communication goes through another channel, such as a discussion forum set up by the course professor.

Sessions

Hold **tutorial sessions** or **office hours** either in person or via videoconferencing (*e.g.,* Teams, Zoom, Mondays 1–2 pm EST). For virtual office hours or tutorials, audio connections can be challenging and uneven, so some students may not be able to follow live presentations reliably. It's a good idea to **record sessions** and post them later on the course's site. This way, students can access materials even if they are in different time zones or have challenges at home that prevent them from participating at scheduled times.

In science, it can be difficult to communicate without drawing. For in-person tutorials, make sure your room is equipped with a chalkboard or whiteboard, and use this instead of creating PowerPoint slides. It's important to get the students drawing and writing with you because this helps improve memory.[1] If your sessions are online include some way to illustrate concepts visually. The minimalist approach is to draw something on a piece of paper and hold it up in front of a webcam. Better approaches would rely on having a whiteboard or blackboard on a wall behind you, or you could use digital writing (e.g., connect an iPad to your computer, and share the screen in Zoom).

Discussion forums

- **Be present** by regularly answering questions at scheduled times.
- You **don't have to answer every single question or answer immediately.** Waiting even a few hours can give other students a chance to reply. You may want to have a faster response rate the day before a major assessment.
- **Encourage students to answer each others' questions**. For example, you could respond to a post

1. Memory research

asking about how to study with: what have others found works for them? What are others focusing on?

- As with email, **be clear about the response times** to expect and what happens on weekends (e.g., that you check the forum on weekdays only).
- You may want to **summarize key errors**, questions, or messages that you are seeing or receiving repeatedly. A summary message can help those who are on the forum less frequently or who are feeling overwhelmed with knowing what to focus on.
- You can **give more strength to students' contributions** with simple statements such as "I agree!" or "Thank you for that contribution". The RISE model below (Figure 25.1) provides ideas to give even more constructive suggestions.
- **Share information on feedback** with students to promote helpful and respectful online discussions and reshare when a refresher is needed, such as the RISE model below.

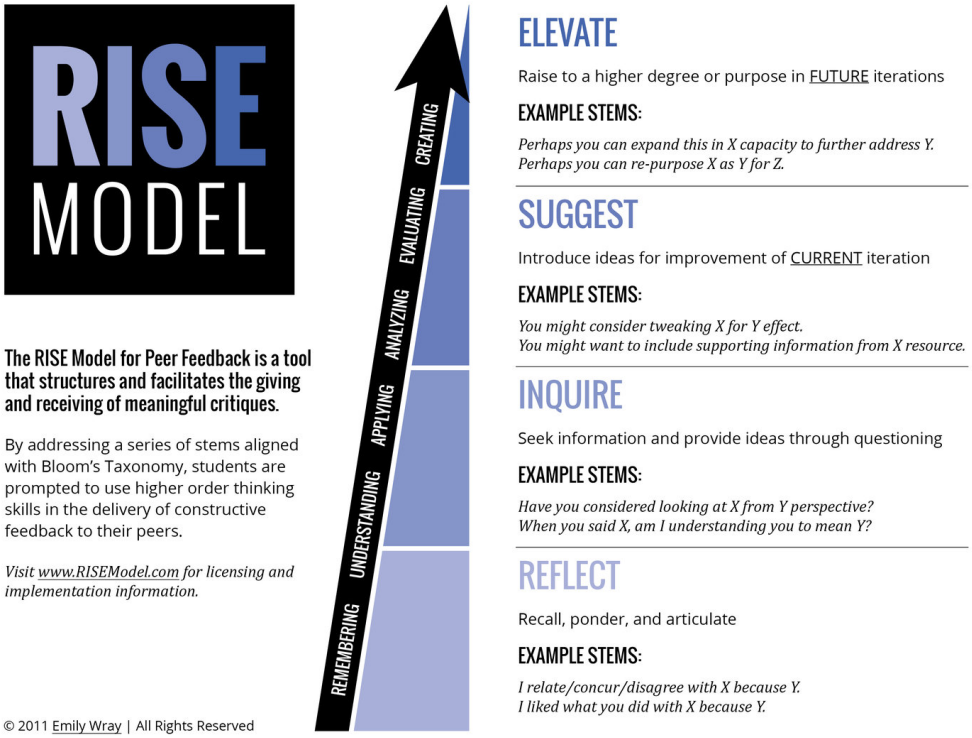

Figure 25.1. This graphic suggests types of feedback from simplest to most sophisticated (PDF).

Working with other TAs

You may be working with other TAs in the course and to give a tutorial. If that's the case, **meet ahead of time to plan** how you want to give the session, your vision, timelines, and each person's roles. Meetings can be done using videoconferencing (e.g., Teams, Zoom), which have a chat function to share documents/links and allow

screen-sharing. Some TAs you might work with could have more experience in a particular course, however, most TAs won't have much experience with remote courses.

Your role as a TA

As a Teaching Assistant (TA) your role is to **work with students to help them learn and apply the course content** to various types of application problems and to answer their course-related questions. You can include a review of the course content and solve application problems within a tutorial session — the relative amount of each depends on what the students need most to learn successfully and will be decided by you and the course professor, with input from students. **Get familiar with the software** used in the course (e.g., OnQ, Teams, Zoom). Most of your time is spent preparing for and conducting the tutorial, however, you are also expected to answer student emails and proctor exams.

Keep things simple by starting with the essentials and introduce new aspects slowly, such as new technologies or questions types. Look into this website for tools to help science students improve their own learning: https://www.learningscientists.org/

What's different in remote sessions?

Tutorials conducted remotely require that all in-person communication with students will be replaced by online-only communication (*e.g.,* emails, discussion forums), Tutorials are a community built among students and TAs, so special attention to building a community online can help maintain this important support for students in a remote course. Remember that most students, professors, and other TAs will also be unfamiliar with participating in a remote course. For example, students may not know the appropriate way to ask a question in a remote session. Patience and clear communication are key. Asking for **regular feedback** from students and modifying your approach accordingly can help.

In a remote learning environment, **explaining concepts to a purely digital classroom can feel strange**. For example, you might be speaking to dozens of people whose cameras are all switched off and whose microphones are muted. In other words, you will be teaching in the absence of any audio or visual feedback from your audience that they are following along with your presentation (Figure 25.2.), or even being able to tell for certain that anyone is paying the slightest attention. This is simply disconcerting.

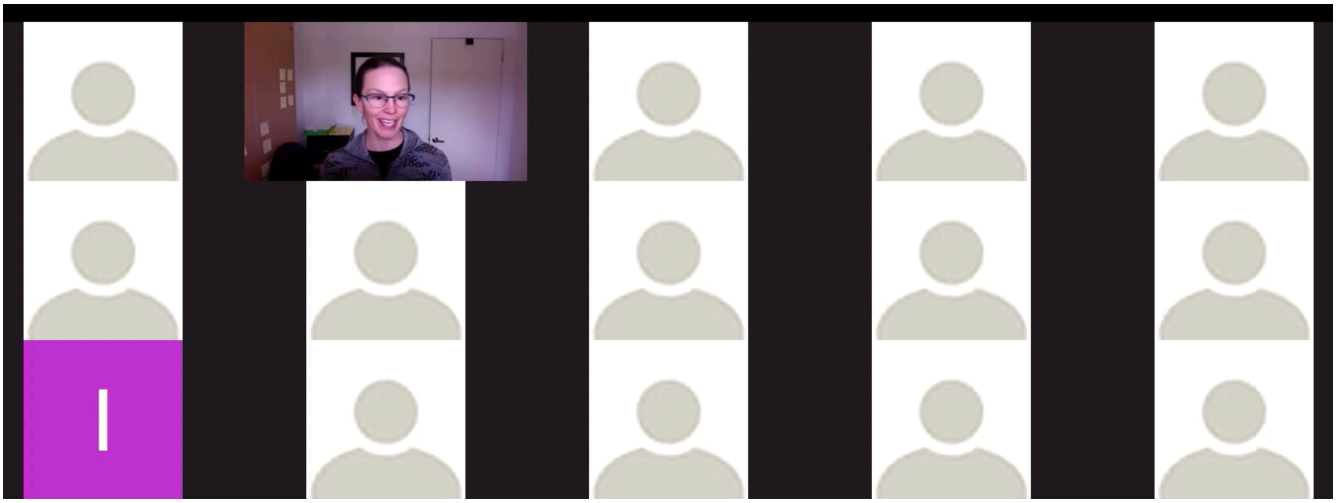

Figure 25.2. Videoconferencing with cameras off can feel strange.

A simple thing to do is to ask students to keep their cameras on so you can tell that there are real people on the other side of your digital connection (Figure 25.3.), although **it is always okay for students to decline to use video.** You can also use strategies to make sessions more interactive, occasionally asking questions (e.g. "Are you following along with concept X? Please respond in the Chat space.") or adding informal interludes where students answer a poll (e.g., Menti) to participate in a questionnaire to assess whether they are grasping concepts. More details about interactivity can be found below.

Figure 25.3. By inviting (not forcing) students to keep their cameras on, we feel more like we're in a regular classroom, with real people. Note: photo shared with students' permission.

Prepare for a tutorial

Five aspects to consider :

- **Communication**: make sure you have clear expectations from the course professor about your role and communicate clear expectations to the students.
- **Course information**: read through the course syllabus, identifying key learning outcomes, and review the course calendar.
- **Content**: figure out what course content is available to you (*e.g.*, course notes, problem sets, practice exams, textbook, previous tutorial content from other TAs)
- **Technology**: determine your access to the necessary equipment to conduct the tutorial and to complete related TA requirements (e.g., answering emails, online office hours).
    - Videoconferencing apps, webcam (built-in or external), microphone (built-in or external), headphones, video-recording device, video-editing software, screen-recording software, digital writing software, tablet, scanner.

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- **Method of facilitation**: choose how you want to conduct your tutorial based on the course, the students' needs abilities, your personal preference and abilities, and your access to the relevant technologies
    - Once you choose a method, you can always modify it as you go depending on feedback (formal or informal) to tailor the tutorial to students' learning needs.

What to include in a tutorial

First, **identifying the learning outcomes** you would like to address helps to organize the general content. Learning outcomes are normally listed in the course syllabus or associated course texts (e.g., textbook, PowerPoint notes). Next, choosing how you can best help students achieve these learning outcomes can maximize the time spent in tutorials. Consider how to balance the review of relevant theories and topics with hands-on practice problems.

Reviewing theory can look very similar to brief lectures (e.g., Ellipses and Kepler's Laws). Content for theory review can be adapted from the course notes, textbook, or any other relevant physical or online text. Providing students with different exposure to the course material than that from their lectures or notes can help fill gaps in their understanding. Digging

deeper into some concepts, providing a broader view of others, or connecting a series of concepts may help students depending on the specific content and student. In general, keep the review brief and leave plenty of time for practice problems.

Practicing application problems can look very similar to exams (e.g., How To Draw An Ellipse). Practice problems can be copied from textbooks, problem sets (posted by the professor or from previous courses), or a variety of online resources. Having the associated answer key can simplify your preparation for the tutorial. Remember, the goal of going over practice problems with students is not just to reach the correct answer, but also to **teach them how they can complete similar problems on their own**. Pay special attention to how you choose to solve the problems and explain this with audio and visual cues to the students. Helping students prepare to solve problems on their own will require you to review your answers for each problem prior to the tutorial, making sure you understand each step well enough to explain it in detail. This preparation can also help you identify potential issues or mistakes, which you can also include in your explanation.

Once you know **what you want to accomplish** in a tutorial, you then need to **choose how** you will do that. *Online facilitation options* (below) discusses the synchronous and asynchronous options for remote tutorials.

Teaching Resources

Discipline-specific teaching approaches and resources can help you map the materials needed to create an tutorial. These approaches mainly focus on chemistry but could be transferrable to other disciplines.

Beginner: use PhET simulations and ACS virtual stimulations. Use ChemDraw to draw out mechanisms. Share screen with students and vice versa.

Take a look at the compiled list of resources for organic chemistry.

Intermediate: the ChemCollective is a collection of virtual labs, scenario-based learning activities, tutorials, and concept tests that TAs can use as content for pre-labs, alternative practice problems, and for in-class activities for individuals and teams. They include resources for chemistry topics in stoichiometry, thermochemistry, kinetics, e quilibrium, acid-base
chemistry, solubility, electrochemistry, analyti cal chemistry/lab techniques, physical chemistry, and properties of solution.

Advanced: CSD Teaching Subset can provide students the chance to visualize and manipulate molecules in 3D and to work with real measured data. There are several entries in the Teaching Subset that have been classified by various concepts such as: fundamental chemistry, drug molecules, symmetry, MOFs.

Additionally, the chemical engineering series

of Wolfram System Modeler allows you to design, construct, and analyze process machinery.

Online facilitation options

Synchronous options

A synchronous tutorial involves live streaming (videoconferencing) and is great for increasing student engagement and building community, although such a format can be hard on learners and TAs with limits to their technology, or in different time zones. Further, students' can be overwhelmed with too many things to keep track of. The synchronous format also imposes a fixed pace onto students, who may find it too fast or too slow.

What to do in the 15 – 30 minutes before a synchronous tutorial

- Set up and check your webcam and microphone. If you will be using digital writing, check your digital writing software and tools.
- Review the activities and timeline
    - If you have slides to screenshare, ensure they are open and ready on your

computer.
    - If you are answering practice problems, have them ready for use — *consider sharing these with students beforehand*

- Get set up early — start the videoconferencing session 5 – 10 minutes early. This can help avoid late starts due to technical issues and gives you and students a chance to chat in an informal setting.
    - Monitor the chat (and waiting room if this feature is used).

What to do in the first 10 – 20 minutes of a synchronous tutorial

- Start on time (end on time, too)
- Introduce yourself to the class.
- Review your expecations for online communication with the students (new environment = new expectations!)
- Review how students can best participate and follow along (e.g., how to ask a question, how to prepare, how to take notes)
- Use check-in activities (in breakout rooms for large groups) to promote

community among students.
- Discuss common questions or problems from students that you have seen in emails or the discussion forum.
- Quickly review content covered in the last tutorial and state intended learning outcomes for this tutorial

Asynchronous options

An asynchronous tutorial involves recording audio and/or visuals or providing additional notes for students without any online student presence during recording. Asynchronous options are great for reducing individual barriers to learning because students can watch/listen on their own time, pausing when needed. This format can be hard for learners and TAs because of reduced student engagement with their TAs and other students and difficulties adapting to self-paced learning.

What to do in the 15 – 30 minutes before an asynchronous tutorial recording

- Set up and check your webcam and microphone. If you will be using digital writing, check your digital

writing software and tools.
- Review the activities and timeline for the tutorial
    - If you have slides or a PDF to screenshare, ensure they are open and ready on your computer.
    - If you are answering practice problems, have them ready for use —*consider sharing a version without any answers with students beforehand*
- Preparation will improve the flow and reduce the amount of video editing required after the tutorial is recorded.

What to do in the first 10 – 30 minutes of an asynchronous tutorial recording

- Introduce yourself to the class
- Explain how you would like to receive questions or feedback from students (e.g., discussion forum, email, anonymous questionnaire)
- Review how students can best follow along during a recorded tutorial (e.g., how to prepare, how to take notes).
- Discuss common questions or problems from students that you have seen in emails, the discussion

forum, etc.

    - Remember, students can't ask you questions in real time in this format, so you might need to take extra time to review questions from previous tutoprials.
    - You can also consider breaking the video into two recordings: one for previous content and one for new content.

- Quickly review content covered in the last tutorial and state intended learning outcomes for this tutorial.

26.

COLLABORATION

Reading time: 7 minutes

Overview

Science rarely occurs in a vacuum (metaphorically, of course). Throughout your scientific career, and beyond, you will need to collaborate with others to achieve the best science. This chapter briefly provides communication skills for teamwork and collaboration in research.

Sections in this chapter

- The power of a team
- Team management
- Meeting Documents: Agendas and Minutes
- Collaborative Writing

The power of a team

It is widely accepted that cooperative teams have greater efficiency and give better results than working alone. Why, then, are some people reluctant to engage in teamwork? Perhaps this reluctance stems from ineffective or dysfunctional teamwork experiences in the past. Often the culprit in these situations is not a "poor team player" or an "inability to get along with others." More likely it was caused by one of two things: misaligned goals or confusion over roles. For teamwork to be effective, all members of the team must understand and share the goals of the project, and all members must fully understand their roles—what is expected of them, and how they will be held accountable. An effective team leader will make sure that goals and roles are fully understood by all team members.

"Introduction to Teamwork," a section in *Designing Engineers*, by Susan McCahan *et al*.[1] provides a detailed description of the stages of the Tuckman Model of Team Development (Figure 26.1) and the need for

1. S. McCahan, P. Anderson, M. Kortschot, P. E. Weiss, and K. A. Woodhouse, "Introduction to teamwork," in Designing Engineers: An Introductory Text, Hoboken, NJ: Wiley, 2015, pp. 219-246.

effective communications at each stage.[2] A team, according to McCahan *et al*., "is a group of people who come together to work in an interrelated manner towards a common goal." They go on to differentiate a team from a group by noting that a team is connected by "a common purpose or goal and the reliance on the skills of all the members to meet the goal". In other words, team members see themselves as part of a collective working towards a common goal rather than individuals working on separate tasks that may lead to an end product. In order to work effectively, team members need to communicate clearly and constructively and learn how to deal with crises and conflicts that will inevitably arise.

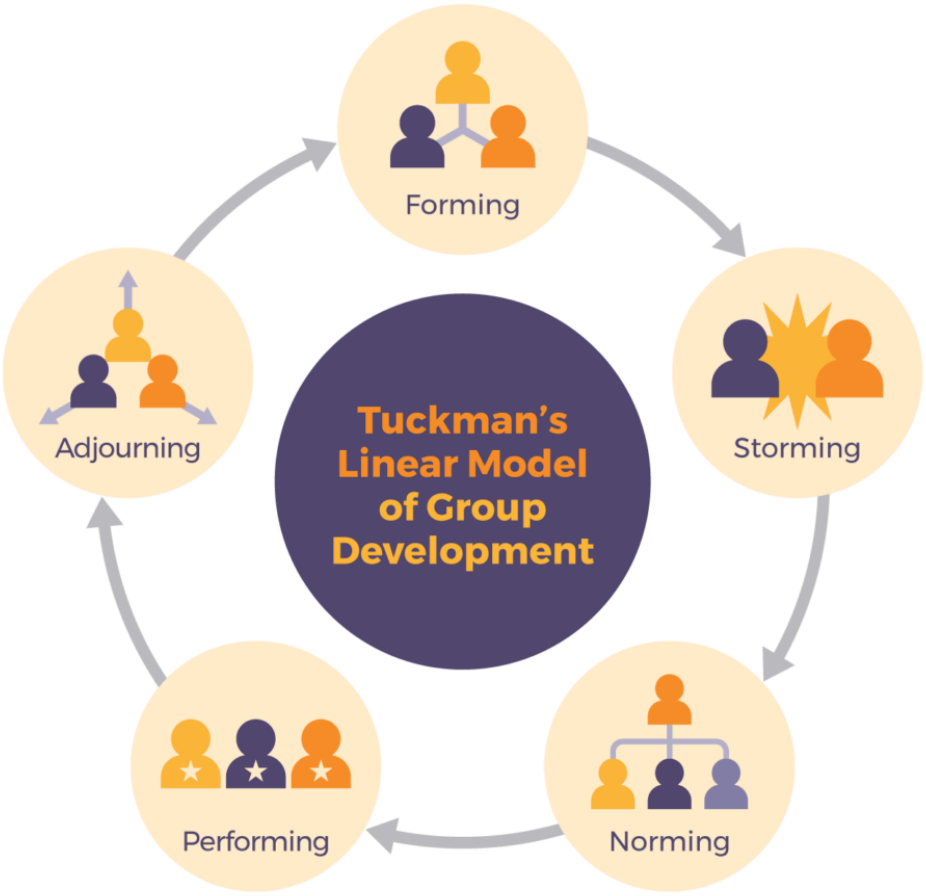

Figure 26.1 The Stages of the Tuckman Model.

2. eCampus Ontario. "Tuckman's Linear Model of group development", in Communication for Business Professionals - Canadian Edition [Online]. eCampus Ontario, 2018. Available: https://ecampusontario.pressbooks.pub/commbusprofcdn/. CC-BY-SA.

EXERCISE: Reflect on your previous teamwork experience

Think of a time when you had to work with others to produce something – a poster, presentation, document, *etc.* Briefly describe what the task was and then consider the following questions:

1. What was the team's overall goal?
2. What was your job within the group?
3. How were the jobs distributed?
4. How well did your group function? Did anyone on the team behave in ways that McCahan *et al.* characterize as "hitchhikers, hijackers, isolationists, and enablers"?[3]
5. Was the outcome successful?
6. Would you happily work with those teammates again on another project? Why or why not?
7. How would you rate your overall experience and why?

Team management

Some common benefits of working in teams include increased productivity, increased innovation, and increased efficiency. Excellent teams have a synergy that makes them more than simply the sum of their parts. The term "team intelligence" refers to the fact that collectively, teams have more knowledge and skill than the single individuals working separately. However, challenges can also arise when working in a team. Conflicts within a team do occur and often they begin as a result of poor communication and weak focus. Some ways to handle these challenges include the following:

- **Elect a team leader:** the team leader will act as the hub for communication and tasks and provide direction and guidance for the team. This should be someone who has earned the team's respect and who can be persuasive and tactful.
- **Ensure the goal is clear:** a team is governed by the goal that everyone works to achieve. It is important that the goal is clearly understood and agreed upon by everyone on the team.

3. [4]
4. [3]

- **Establish team rules:** as a team, determine the rules by which the team will operate. These should include expectations around time, meetings, attendance, communication, decision-making, contribution, and mechanisms to warn and/or fire a team member or quit a team.
- **Assign responsibilities:** as part of the breakdown of tasks, members should be assigned responsibility for certain tasks, which means that they are the primary leads in preventing and addressing issues that come up in that area.
- **Set agendas for meetings and keep minutes:** to ensure that team meeting time is useful and achieves its purpose, plan an agenda for each meeting to help keep everyone on task. In addition, have someone take minutes to record decisions that are made. This record helps prevent repetition and ensures work actually gets done.
- **Determine the timing for tasks:** task timing involves two aspects: the duration for completing the task and the timing of the task in relation to the other tasks. Typically, tasks take longer than you think they will so it is often better to add 25% to your duration estimate. Professionals often use **Gantt Charts** to outline these tasks and the time they will take within the overall project scale.
- **Manage communications:** if a problem arises with someone on the team, the team leader should speak privately to the person and clearly indicate what needs to change and why. The focus should be on the behaviour, not on the person's character. Issues should be dealt with quickly rather than left to deteriorate further. If this does not solve the problem, seek help from experts in conflict resolution.
- Use tools to collaborate. There are also many software programs and apps that can help teams manage projects. Students often use Google docs to work collaboratively on a document or project. **Slack**, **Teams,** and **Asana** are free popular web-based options for task management. Whatever tool you choose to use, it should be something that all members can access and understand.

Meeting Documents: Agendas and Minutes

What happens at team meetings should be planned and recorded for future reference. **Agendas** and **Minutes** are documents that do this. A meeting also should have a chair (the person who keeps things on track) and a recorder (who records what happened and what decisions were made). The Agenda is the plan for what you want to discuss and accomplish at the meeting. It is usually made up of a list of items, sometimes with a time frame for each item.

Example Agenda

CHEM 282 Team Meeting Agenda

Date:

Place and time:

Members:

_____-

1. Updates from each team member (progress) (5 min each)
2. Develop work plan for upcoming week (15 min)
3. Determine next meeting time (5 min)
4. Work on Milestone 3 together (45 min)
5. Matters arising

Minutes follow up on the agenda by recording what decisions were made and what important topics were discussed. One person is responsible for recording the events of the meeting and distributing the minutes to each member (via email usually). That way, no one should forget what tasks they agreed to complete and when.

Example Minutes

Biochemistry Labs Team Meeting Minutes

Thursday, Feb 15, 2016

Room 205, 3:30-4:45

Present: Jaime, Chris, Renee

Regrets: Joe (has the flu)

_____-

- All team members have completed last week's work plan (Joe emailed a report, as she is sick)
- In the coming week, we plan to complete the following:

Task	Who will do it?
1. Interview Facilities Management contact	Renee
2. Research instrument optons	(Joe?)
3. Design a survey/questionnaire	Chris
4. Do a site visit	Jaime

- Next meeting: next Thursday, Feb 21, after seminar
- Excellent progress during the meeting; Joe will follow up on researching instrument options
- Meeting adjourned 4:50

Collaborative Writing

You have likely had at least one opportunity to work and write collaboratively with others, as this is an increasingly common way to work, both in school and in the workplace. Scientists and engineers work collaboratively to gather, organize, manage and disseminate information. This information is often carefully analyzed and used to make important decisions, so it is critical that team members collaborate effectively in managing these communications tasks.

Like any kind of teamwork, collaborative writing requires the entire team to be focused on a common objective; according to Lowry *et al*., an effective team "negotiates, coordinates, and communicates during the creation of a common document."[5] The collaborative writing process is iterative and social, meaning the team works together and moves back and forth throughout the process.

Collaborative writing using computers, until recently, was nothing short of a nightmare. Working together on a document could cause file conflicts, deletions, and extra work to find out what changes were made. Now, if you have the right set-up, multiple people can edit a document at the same time without file conflicts (e.g., in Google Docs or Teams). Alternatively, there are systems for "checking out" files, so that they cannot be opened and edited by more than one person at once. With file versioning in Microsoft Office 365, it's now easier to keep old versions of documents without having to save a new draft each time you make changes.

5. P.B. Lowry, A. Curtis, and M.R. Lowry, "Building a taxonomy and nomenclature of collaborative writing to improve interdisciplinary research and practice," *Journal of Business Communication*, vol. 41, 2004, pp. 66-97. DOI: https://doi.org/10.1177/0021943603259363

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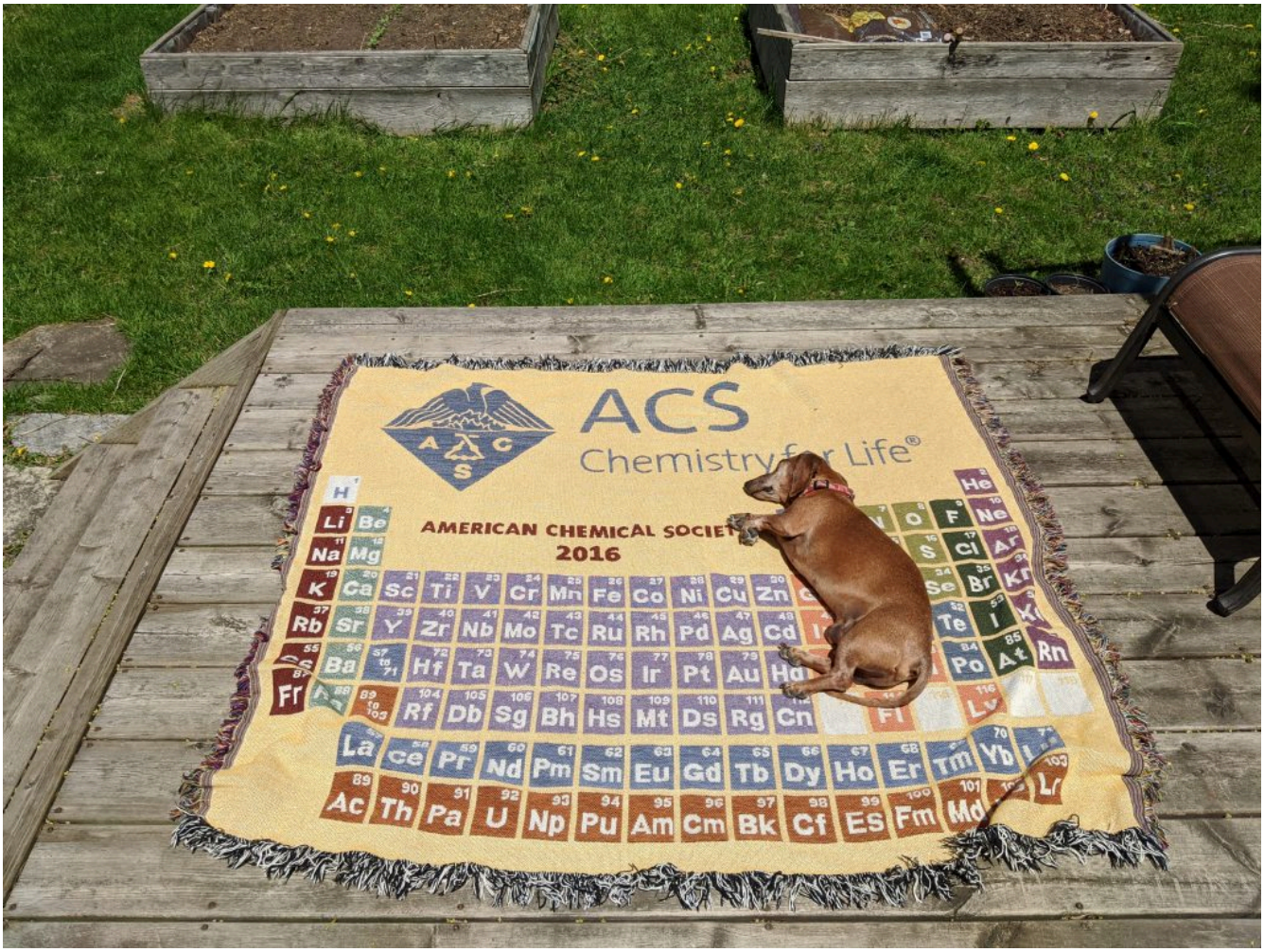

RESOURCES

Online Writing Resources

- American Chemical Society Style Guide
- Point-first Proofreading Guide
- Thesis whisperer (with links to more resources)
- Student Academic Success Services (SASS) has one-on-one appointments, a dissertation boot camp, writing labs, and Additional Language support, and Academic Writing Skills Guides.
- SASS Assignment Planner tool
- SASS Thesis Manager
- The Old Reader RSS feed
- Mendeley free reference manager

Online Data Visualization Resources

- Guide to using colour in data visualization
- Tableau data visualization
- Google DataStudio
- D3.js data visualization
- TOC ROFL

Books and Articles

- Light & Air & Time & Space, by Helen Sword (2019)
- Science communication made simple
- Scientific Approach to Writing for Engineers and Scientists – R. E. Berger (2014)
- How to write and illustrate a scientific paper – B. Gustavii (2003) WZ345.G87 (Bracken Library)
- ACS Nano article on Self-Plagiarism

Workshops and Classes

- Toastmasters at Queen's – public speaking club
- Expanding Horizons Workshops
    - Dissertation Boot Camp
    - Effective Communication with your Supervisor
    - Tips on Applying for Scholarships
- Graduate courses on Writing/Teaching
- Centre for Teaching and Learning
- Science Librarian – Michael White

Other Queen's University Resources

- School of Graduate Studies (SGS) Habitat – resources for mental health, recreation, academic support, family, living in Kingston.
- Queen's University International Centre (QUIC)
- Four Directions Indigenous Student Centre
- Queen's Graduate Chemistry Society – many resources for new grad students!
- Queen's Chemistry Inclusivity, Diversity, Equity, and Awareness Society (IDEAS)