Resources for Improving Graduate Writing

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This material was compiled for the School of Natural Resource Sciences at North Dakota State University to improve graduate education. Specifically, the goal was to provide a resource for incorporating more writing and critical thinking into SNRS graduate coursework.

Resources included (a detailed list is included on the next page)

1. **Reference for writing improvement**

This guide enumerates a series of common writing errors, provides a brief discussion of each error, and provides a strategy for improvement. Additionally, the guide includes annotated examples of original and revised versions of most errors, as well as a list of useful resources to consult for further writing questions.

The reference guide can be applied with a lot of flexibility, depending on the preference of each instructor. The intended use of the guide is for instructors to use as a rubric-like ***resource for providing feedback***. For example, if a student is doing a poor job structuring their paragraphs, the instructor can refer them to this guide (Problem II), rather than spending time fixing each students' work. Not only will this reduce time actually grading assignments, but also (in a perfect world) it will reduce time spent during class/office hours teaching the students the concepts covered in the guide.

2. **Individual handouts**

Each handout included addresses a different aspect of writing. The material was created with the intention of incorporating it into a semester-long writing project (see below). So it occasionally references that project. However, each handout can also be used individually, addressing whatever topic the instructor chooses to focus on.

The handouts are mostly devised to advise the student on ***performing a specific task***. Some are related to writing (e.g., how to construct and assess a sentence), while others may help them develop skills useful in their educational career (e.g., how to find scientific literature). Again, one goal of the handouts is to ***reduce instructor time investment*** by providing a resource to guide students through a given task.

3. **Example: semester-long project**

This project is one example of how this material could be incorporated into an existing class with the goals of ***1) including more writing*** (and reading) and ***2) enhancing material covered in classes*** with outside information. It includes an overview of a semester-long project consisting of nine exercises for the students to complete. With a little planning from the instructor, the project could ***reinforce course content*** by making students read and write more about the topic. Each exercise (with two exceptions) can be accompanied by at least one handout, which can guide the students in successfully completing the exercise without time invested by the instructor.

The most important aspect of this example-project is that it incorporates ***low-stakes writing assignments*** of ***different types*** (e.g., bullet points, paragraphs, outlines, full-length papers) ***many times*** throughout the semester. The goal is not simply to have the students write a great full-length paper at the end of the semester. Rather, the goal is to introduce them to the idea of writing as an iterative process; they have to read what they write, think about what is good, and decide what needs improvement.

Future vision

These materials are meant to be a dynamic resource that can be amended or supplemented when instructors identify a need. This added information may be additional handouts or sections in the guide. One crucial way the guide can be expanded would be to include more annotated examples of student writing. Seeing other students work and, more importantly, seeing how it can be revised is a great way to help students improve.

REFERENCE FOR WRITING IMPROVEMENT

INDIVIDUAL HANDOUTS

EXAMPLE: SEMESTER-LONG PROJECT

Reference for writing improvement

No one writes perfectly. Period. More realistically, no one writes well on their first try (or their second, or their tenth try). Each time we write a draft, we need to revisit it to identify what we have done well and what we need to improve on.

This guide includes list of common areas that need improvement. We can use this guide in two ways. First, ***before we write***, we can consult this list to ***identify potential problems*** before we create them. Second, ***after we write***, we consult this list to assess our writing and find ***areas that need more attention***.

How to use this guide:

- Your instructor will reference either a problem or a number on your written assignments
- Look up that number or problem to identify what area needs to be improved
- Find that number on the attached handouts to find some strategies for improvement

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Problem I: Argument is not clear (Focus)

1. Writing focus is not identified
2. Focus of the writing is difficult to understand
3. Focus is too broad
4. Statement of focus is out of place

Problem II: Argument does not flow (Structure)

5. Paragraphs/sentences lack relationships
6. Paragraphs/sentences are out of place

Problem III: Misused words (Clarity)

7. Confuse one word for another
8. Use misleading connotations
9. Apply a word incorrectly

Problem IV: Too many words (Concision)

10. Using phrases when a word is enough
11. Redundancies
12. Conversational writing

Problem V: Improper grammar (Grammar)

13. Subject-verb agreement
14. Sentences
15. Commas
16. Other punctuation

Problem VI: Not conforming to readers' expectations (Scientific convention)

17. Improper citations
18. Plagiarism
19. Passive vs. active voice
20. Numbers

Problem I: Argument is not clear (Focus)

Writing without a clear argument is the result of a lack of focus in our writing. When we do not properly focus on our subject matter, our argument is not readily apparent. We need to clearly state our argument in terms that are accessible to our readers. Otherwise, they will not understand the purpose of our writing, get frustrated, and stop reading.

The problem of focus can occur at any scale in our writing. Perhaps our document lacks an overall, coherent message. This problem would need a revamped thesis statement. Maybe our argument makes sense throughout much of the document, but we have a paragraph or two that are giving us trouble. To improve these, we need to look at the topic sentence of each paragraph. If we are having trouble staying focused within some specific sentences, we may need to revisit the 'actor → action → result' format of our sentence to ensure that they are all related to one another (see Sentences handout).

Four common ways writers lose focus are stated below, and strategies for addressing them are provided at three different scales.

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1. Writing focus is not identified

Writing without a focus is writing without a purpose. The most important question to ask before writing anything is 'What is the point?' If you read your work and cannot answer that question, our writing lacks focus. Writing without a focus will not succeed. If you cannot identify a purpose, you will get frustrated and stop trying to improve your work, and you will not successfully communicate anything to your audience.

The generic purpose of writing is to convey relevant information in a compelling, easy-to-understand way. Whenever you write, you can return to this formula by asking two simple questions.

- **What is the point?**
  What is the relevant information that you are trying to convey to your audience?
- **How do you support that point?**
  What information can you add to support or contextualize that point?

If you cannot answer those questions, the rest of the writing process will not be fruitful. Below is a list of questions to ask yourself to help answer those questions, separated based on what scale of writing you are considering.

Strategy for improvement:

Document

- What is the overall objective of my document?
- What information am I trying to convey, and is that explicitly stated?
- Do I have a thesis statement?

Paragraph (consult Paragraphs handout)

- What is this paragraph about?
- Do I clearly state what information addressing?
- Does my paragraph have a topic sentence?

Sentence (consult Sentences handout)

- What is the purpose of this sentence?
- Are my readers familiar with the actor and action of this sentence?
- Do I need to provide them with more information for the sentence to make sense?

2. Focus of the writing is difficult to understand One of three reasons is often the cause of a hard-to-understand focus.

- We are not entirely convinced what the focus should be, so we cannot convey it to the reader.

- We may know what our focus is, but our writing does not reflect those ideas to the reader. This problem is typically caused by not providing enough information to your reader. Remember, a reader does not have the benefit of your background knowledge, so we need to ***provide enough context*** for the focus to make sense.

  Additionally, this lack of understanding can be caused by indirect writing. Oftentimes, writers will try to make simple information sound more impressive by embellishing the wording or by being too circumspect. ***Be direct in what you mean to say***. Being understandable is the most important aspect of writing. Remember, simplicity can have its own elegance, as well.

- Our word choice, grammatical constructions, or sentence structure make the sentence difficult to understand.

Strategy for improvement:

- Return to your prewriting steps, especially the outline. Revisit the objectives for your writing, and try to ***distill those objectives down into one or two sentences***.
- Ensure that you provide enough context for your reader. Be direct in what you mean to say

EXAMPLE

Original: Considering treated soil in comparison with native soil, the responses of grain quantity and quality may indicate that appropriate fertilizer management may mitigate any loss of fertility caused by TD treatment. However, this assumption may not be valid for two reasons. First, this study utilized plastic bags to prevent leaching throughout the duration of the experiment. Since TD treated soils may be more likely to leach SOC when saturated (O'Brien et al. 2016), losses of plant available nutrients would also likely occur. Under field conditions, quantifying these losses to account for them with fertilizer application rates would be very difficult in non-irrigated environments. Second, even though cation exchange capacity and exchangeable cations are not affected by treatment (Roh et al. 2000), the TD process reduces SOC Considering the soil

mixtures, the findings suggest either the presence of absence of a mechanism in the TD100 that is not occurring in the soil mixtures.

Revised: While no differences in wheat grain production or quality were observed in the greenhouse study, these responses may not be valid under field conditions for two reasons. First, this study utilized plastic bags to prevent leaching, eliminating the elevated risk of nutrient loss in the treated soils (O'Brien et al., 2016). Second, the treated soil contains less SOC (Sierra et al. 2016; O'Brien et al. 2016), a property that is associated with decreased plant growth in a wide variety of conditions due to its importance in nutrient cycling (Lal 2006). Without these controlled conditions, treated soils will unlikely be able to match quantity or quality of native topsoil, even with appropriate fertilizer management.

This example shows a paragraph in which the author is not sure what the focus is. It appears that two arguments exist in this paragraph: 1) the responses in the treated soil and native topsoil may not be valid in field conditions, 2) the responses in the mixtures are caused by a different mechanism. Thus, the paragraph should be improved by directly stating the first argument, supporting it, and moving the second argument to a new paragraph. Further, the supporting sentences can be more direct by removing some clauses that are not directly relevant to the topic.

3. Focus is too broad

Having too broad a focus is tantamount to having no focus at all. We cannot discuss everything that relates to our topic, so we need to narrow our focus and decide what our specific topic is. This task can be difficult because our focus shifts at each scale of writing. Below is a list of questions to help you narrow down your focus at different scales of writing.

Strategy for improvement:

Document

- What is the overall objective of my document, and is it explicitly stated?
- Does my thesis statement include *only* the information I am going to cover?
- Do I introduce material in my thesis statement that I will not address again?

Paragraph (consult Paragraphs handout)

- Does this paragraph introduce and discuss one idea?
- Is that idea clearly stated as a topic sentence?
- Do my supporting sentences address a more specific scope than the topic sentence?

Sentence (consult Sentences handout)

What is the purpose of this sentence?

- Does this sentence relate to the topic sentence of the paragraph? To the thesis statement of the document?
- Are my readers familiar with the actor and action of this sentence?
- Do I need to provide them with more information for the sentence to make sense?

EXAMPLES

Original: There are a few specific plants that have a frequency of experiencing nutrient deficiencies due to their high requirement of some element.

Revised: Some plants, such as soybeans, wheat, and oats, frequently experience Mn deficiency due to high Mn requirements in their life cycles.

The first sentence is true, but it is too broad to be meaningful. The purpose of the sentence is to discuss specific plants (soybeans, etc.) with a specific deficiency (Mn).

Original: Treated soils produced similar amounts of biomass and grain, and soil health in the treated soils, as indicated by soil respiration and microbial dynamics, was slightly diminished compared to native topsoil.
Revised: Treated soil and native topsoil produced similar amounts of biomass and grain. AND
Revised: Soil respiration in the treated soil was diminished compared to the topsoil, likely caused by alterations in the soil microbial community.

This sentence is a classic example of a topic sentence for a paragraph including too much information. The two topics in the original sentence (biomass/grain and soil respiration) can be related, but that discussion will be too much for a single paragraph. The author will be better served by splitting the sentence (and, ultimately, the paragraph) into two separate thoughts (two topic sentence, two paragraphs).

4. Statement of focus is out of place

Scientific writing is especially formulaic (see Introduction handout, Writing process handout), so readers have certain expectations about where to find the statement of focus. Generally, two positions are available to the writer. Both are useful techniques, and more information about both is provided in the Paragraphs handout.

- Statement of focus ***first***. The subsequent writing will then <u>support or develop</u> that statement.
- Statement of focus ***last***. The preceding sentences will <u>build the story</u> to the reach the focal point.

<u>Strategy for improvement:</u>

- Identify ***what and where your statement of focus*** is, whether it be a thesis statement of a document, a topic sentence of a paragraph, or the single actor of a sentence.
- Determine if the rest of your writing is better suited to ***developing*** your statement of focus or ***building*** towards it. Then, place the statement of focus in the appropriate location.

EXAMPLES

Selecting appropriate methods to study butterflies is increasingly important as they decline. New data will be used to make policy decisions vital to managing butterfly populations, and it must provide quantifiable, unbiased information. Without methods that provide rigorous data, comparing findings from numerous studies to identify patterns is impossible. Thus, employing appropriate methods will allow researchers to create effective conservation plans that lead to improved management for butterflies.

This example shows a typical statement-of-focus ***first*** structure. A clear focus is stated in the first sentence: selecting appropriate methods is important. The next three sentences all support that statement, i.e., they answer *why* selecting appropriate methods is important.

Many previous studies fail to include fire characteristics, even though including characteristics can improve the overall understanding of fire ecology (Engle et al. 1989). More research is beginning to include these parameters to improve interpretation and application of results (Ohrtman et al. 2015), but field studies are still limited by constraints like size and replication. We believe MFB techniques should be used to increase replication and to allow for manipulation of specific fire characteristics to determine their implications on plant and soil responses to fire.

This example shows a typical statement-of-focus ***last*** structure. In this paragraph, the first two sentences are identifying weaknesses in current research techniques—they do not include fire characteristics, and they are limited by logistical constraints. The final sentence is the focus, which is that MFB techniques should be used to address those weaknesses. Thus, the first two sentences ***build towards*** the final focal point of the paragraph.

Problem II: Argument does not flow (Structure)

Arguments should flow from one word to the next, one sentence to the next, and one paragraph from the next. This flow is accomplished by having a clear focus and supplying a logical progression of thoughts to support or develop that focus. Even transferring a logical progression of thoughts from an outline to an actual is tricky. Not only is it difficult to do directly, but as we write, our argument usually shifts so that the outline does not accurately reflect our new thought process. Thus, we must continually return to the structure of our writing to avoid fragmented, disjointed arguments.

Some common difficulties in creating a coherent narrative are identified below, along with strategies for improvement.

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5. Paragraphs/sentences lack relationships

Having a strong focus and good supporting information is not enough to create a well-structured argument. Scientific writing is not only about conveying a series of facts but also about identifying relationships between those facts to lead to a conclusion.

Generally, these relationships are described by their importance and by their ***function***. Facts of equal importance are given independent clauses, either complete sentences or compound sentences, while facts of lesser importance are presented in subordinate clauses, often set off with a prepositional phrase. Whether they be coordinating or subordinating, these relationships are usually of ***causation and consequence*** or ***similarity and dissimilarity***.

Words signifying a relationship of: ***Causation or consequence***

Consequently	*Subsequently*	*Therefore*
Because	*Since*	*For*
Thereafter	*So*	*Then*
Thus	*Hence*	*As*

Words signifying a relationship of: ***Similarity or dissimilarity***

Similarly	*Moreover*	*Despite*
Nonetheless	*Not only…*	*But also*
And	*Yet*	*However*
Although	*Additionally*	*Conversely*

Strategy for improvement:

- Reread your work and identify some of these phrases. If you find them, ensure that they are describing the relationships that you want them to.
- If you do not find these words relating your sentences to one another, find places to insert them.
- Identify independent and subordinate clauses in your writing and ask ‘are they emphasizing the points that you want them to?’

EXAMPLE

Original: Nitrates are highly soluble. They are susceptible to leaching.

Revised: Because nitrates are highly soluble, they are susceptible to leaching. *OR*

Revised: Nitrates are susceptible to leaching because they are highly soluble.

The solubility of nitrates are directly related to their risk of leaching. Combining these two sentences tells the story better and helps the writing flow.

Problem II: Argument does not flow (Structure)

**An excellent discussion of transitions (with examples) is available through the University of North Carolina Writing Center (https://writingcenter.unc.edu/tips-and-tools/transitions/)

6. Paragraphs/sentences are out of place

In our first several drafts, we will find many words, sentences, and paragraphs out of place. This problem occurs as we are getting our thoughts on paper, so we should not be discouraged. Moving a sentence or paragraph to a better place is a lot easier than writing a brand new one.

Strategy for improvement:

- Identify the focus of each paragraph. Then, for each sentence, ask 'does this sentence relate to the focus?' Perhaps the sentence just needs to be moved to a different paragraph.
- Make sure that each paragraph sticks to only one idea (revisit Paragraphs handout)
- Should the information be included at all? (see below, number 8)
- Ask 'will the sentences fit better in place if they are related to one another with a transition word?' (see above, number 5).

EXAMPLE

Original: [1] Butterflies, being charismatic and playing a role in ecosystem processes, are one the most studied group of insects (New et al. 1995, Thomas et al. 2009). [2] Intermediately, they contribute to ecosystem services through tropic interactions (Guppy and Shepard 2001) and add to overall biodiversity (Blair 1999). [3] Besides contributing to ecosystem services, butterflies are also used as biological indicators (Winfree et al. 2011, Roy et al. 2015) to study environmental concerns like climate change (Potts et al. 2010) and pesticides (Hoang et al. 2011). [4] However, butterflies are more commonly associated with services like pollination (Davis et al. 2008, Cardinale et al. 2012) and cultural aesthetics (Lopez-Hoffman 2010). [5] Recently, there have been concerns on the ability of butterflies to continue to act as indicators and contribute to ecosystem services because they are facing broad declines (Thomas et al. 2004), especially in grasslands (Swengel et al. 2011, Hardersen 2014).

Revised: Butterflies are one the most studied group of insects (New et al. 1995, Thomas et al. 2009) due to their role in ecosystem processes. They are most commonly associated with services like pollination (Davis et al. 2008, Cardinale et al. 2012) and cultural aesthetics (Lopez-Hoffman 2010). However, they contribute more widely to ecosystem services through tropic interactions (Guppy and Shepard 2001) and add to overall biodiversity (Blair 1999). Additionally, butterflies are used as biological indicators (Winfree et al. 2011, Roy et al. 2015) to study environmental concerns like climate change (Potts et al. 2010) and pesticides (Hoang et al. 2011). Recently, there have been concerns on the ability of butterflies to continue to contribute to ecosystem services and act as indicators because they are facing broad declines (Thomas et al. 2004), especially in grasslands (Swengel et al. 2011, Hardersen 2014).

The focus of the paragraph is 'Butterflies are studied because they contribute to ecosystem services and serve as biological indicators'. All sentences (but not all words in each sentence) do address this focus. However, they do not relate well to one another in the original draft, primarily because they are not **grouped like-with-like**. In the revision, all sentences pertaining to ecosystem services are grouped together. These sentences are then related to the role of butterflies as indicator species using **a transition word**, *additionally*. Finally, *ecosystem services* and *indicators* are switched in the final sentence to **maintain the same order** of thoughts.

Problem III: Misused words (Clarity)

Words are the building blocks of writing, so if the words we use do not make sense, then our writing as a whole will suffer. Our readers will have trouble understanding our message when do the following:

7. Confuse one word for another 8. Use misleading connotations 9. Apply a word incorrectly

Below is a list of commonly misused or mistaken words, but by no means is it exhaustive. The best way to avoid misusing words is to consult a dictionary whenever writing (or reading), of which many are available online. The **Oxford English Dictionary** (www.oed.com) is *the* definitive reference, but it can be inaccessible at times. Another good choice is the **Oxford Living Dictionary** (en.oxforddictionaries.com).

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i. ***accept vs. except***

accept – to receive, to take in (usually used as a verb)
except – with the exclusion of, other than, but (usually used as a preposition)

ii. ***affect vs. effect***

affect – to influence (v.)
effect – to bring about, to accomplish (n.)

iii. ***allusion vs. illusion***

allusion – an indirect mention (n.)
illusion – a false impression (n.) **iv.**

alternate vs. alternatively

alternate – one after the other (v.)
alternative – on instead of the other (n.)

v. ***among vs. between***

among – use when describing relationships within or of a group
between – use when only two parties are involved, or when describing relationship between individuals

vi. ***comprise vs. constitute***

comprise – to include or contain (v.)
constitute – to be part of the whole (v.)
*The whole comprises the parts. The parts constitute the whole.

vii. ***different from vs. different than***

almost always use *different from* **viii.**

e.g. vs. i.e.

e.g. (exempli grati) – for example
i.e. (id est) – that is, in other words **ix.**

etc.

etc. (et cetera) – and others (thus, stating 'and etc.' is redundant)

x. ***farther vs. further***

farther – relates to distance (adv.) *further* –
definition of degree or extent (adv.)

xi. ***fewer vs. less***

fewer – use for countable individuals
less – use for quantities

xii. ***imply vs. infer***

imply – to suggest, to throw out a suggestion (v.)
infer – to conclude, to take in a suggestion (v.)

xiii. ***its vs it's*** *its* – the possessive form of the pronoun *it* Problem III: Misused words (Clarity)

it's – the contraction for *it is* or *it has* **xiv.**

principal vs. principle

principal – first in order of importance (n. or adj.)
principle – a rule, law, or fundamental truth (n.)

xv. *significant*

when used in scientific writing, *significant* often implies some statistical inference. Be cautious when using in other situations.

xvi. ***that vs. which***

that – sets off a clause that is essential to the meaning of a sentence; does not require commas
which – sets off a clause that can be omitted and the sentence still makes sense; requires commas

xvii. ***there vs. their vs. they're***

there – at a place or position, at a point in time, in that respect (adv.)
their – possessive form of pronoun *they*
they're – contraction for *they are* or *they were* **xviii. *unique*** means 'one of a kind', so something cannot be 'most unique' or 'very unique'.

xix. ***who's vs. whose***

who's – contraction for *who is*
whose – interrogative pronoun for *who*, possessive pronoun for *who* (or sometimes *which*)

xx. ***your vs. you're***

your – possessive form for pronoun *you*
you're – contraction for *you are* or *you were*

xxi. ***using a 'verb and' construction, e.g., try and vs. try to***

The appropriate use of the infinitive is 'try to'; spoken language sounds like *try and*, but it should not be written that way.

xxii. ***using a 'verb of' construction, e.g., could of vs. could have***

The appropriate construction is *could have*; spoken language sounds like *could of*, but it should not be written that way.

**For an extensive list of examples for commonly confused words and other errors, see the Dr. Brians' website through Washington State University: https://brians.wsu.edu/common-errors/

Problem IV: Too many words (Concision)

Every writer experiences Problem IV every time they write, because no one is capable of finding the best wording on the first draft. Addressing this problem means revising our writing to be as concise as possible. Concise writing is preferable in almost every instance, as it indicates that our arguments have been presented as simply as possible. Unnecessary words can distract the reader from the focus of the work, so pruning those words makes the writing easier to understand.

This problem is a necessary consequence of the writing process, as the first step is getting thoughts onto paper. Writing concisely is not a priority for first drafts. Therefore, we should not be discouraged if we are cutting lots of words from our initial drafts. In fact, being able to condense a first draft to a fraction of its original form is a sign of a ***very good writer***, not a bad one.

Below are several common instances in which writers can reduce words and improve their writing. A list of strategies for finding and revising these instances is provided at the end.

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10. Using phrases when one word is enough

Formal writing can often be tainted by wordiness because people conceive that 'more is better' for both word amount and complexity. Writers will use phrases to describe single words to make their writing seem more important. In fact, the opposite is usually true. Using fewer, simpler words will make your writing both more pleasurable to read and easier to understand.

Below is a list of constructions that do not add relevant information. In most cases, the prepositional phrase identifies a relationship that is implied already.

Tall in stature…	*Blue in color…*	*Few in number…*
Plan in advance…	*Both of them…*	*Assemble in a group…*

Strategy for improvement:

- Avoid using adjectives (and adverbs) that add do not add relevant information to the story
- Avoid using several words when one will express the same information

EXAMPLES

Original: Soil heating has been shown in several studies to reduce soil organic matter (Terefe et al. 2008).
Revised: Soil heating reduces soil organic matter (Terefe et al., 2008).

Stating that something *has been shown to reduce* means that it *reduces*, so *has been shown to* can be omitted. When discussing the findings of other research, identifying that those findings come from another study (e.g., *in several studies*) is implied and can be omitted.

Original: Plant communities of low sunken areas were dominated by different species than the upland areas.
Revised: Plant communities of depressions were dominated by different species than upland areas.

A *low sunken area*, by definition, is a *depression*. Using that single word is both more descriptive and more concise.

Original: The amount of bacteria present in these soils that can convert ammonium to nitrite is extremely limited in number.
Revised: Few bacteria in these soils can convert ammonium to nitrite.

The original used the phrase *extremely limited in number* to describe a concept contained in one short word, *few*. Additionally, the revised version avoids the construction *The amount of*, which does not add relevant information. *Few* is more concise and more exact.

11. Redundancies

Redundant writing adds words by conveying the same message more than once. Most redundancies occur at the sentence scale, but writers must be cognizant of redundancies at all scales of writing, as they can manifest throughout a document. At the sentence scale, redundancy usually occurs when the writer uses two words that mean the same thing. At the paragraph (or document) scale, redundancy occurs when two sentences (or paragraphs) are used to convey the same information.

Most redundancies are the result of indecisiveness or attempts to show emphasis. An indecisive writer will describe something using two words that mean the same thing because they have not decided which word they really want. Similarly, a writer may try to show emphasis by using several words that mean the same thing to drive the point home. In these cases, using a strong word or a modifier is usually preferable.

Below is a list of phrases with modifiers that mean the same thing as what they are modifying.

More superior…	*Then…afterward*	*Early beginnings…*
Refer back…	*Final conclusion…*	*Most, but not all,…*
Merge together…	*Repeating again and again…*	*Very crucial…*
Extremely unique…	*End result…*	*Begin introducing…*

Strategy for improvement:

At the sentence scale:

- Avoid describing one concept with two words that state same thing
- Avoid using a modifier that means the same thing as what it is modifying ***At the paragraph/document scale:***
- Identify the purpose of each sentence in a paragraph (or paragraph in a document), and make sure that no two purposes are the same
- If two sentences (or paragraphs) are performing the same purpose, try to merge them into one.

EXAMPLES

Original: The nitrogen cycle is complicated and complex.

Revised: The nitrogen cycle is complex.

Complicated and complex mean roughly the same thing (although they have slightly different connotations), so just one of them will suffice. Alternatively, the writer may be trying to impart the cycle is really complicated, so they added another word with similar meaning.

Original: We suggest using MFB techniques to increase replication and allow for more manipulation of specific fire characteristics to determine their implications on plant and soil responses to fire. Overall, MFB techniques allow us to increase reproducibility when studying fire ecology, specifically fire-plant interactions, which provide greater confidence to apply small-scale study results to larger landscapes.

Revised: We suggest using MFB techniques to increase replication and allow for more manipulation of specific fire characteristics. Overall, these benefits make MFB techniques useful in studying fire ecology, specifically fire-plant interactions, which provide greater confidence to apply small-scale study results to larger landscapes.

These two sentences say essentially the same thing in the original. They both contain the benefits of

MFB techniques (*replication* and ease of *manipulation*), as well as the implications of those benefits (i.e., better understanding of fire ecology). In the revised version, the first sentence includes only the benefits, and the second sentence includes only the implications.

**A good list of redundancies is available through grammarist.com (http://grammarist.com/redundancies/)

12. Conversational writing

Because scientific writers strive for succinct, clear phrasing, conversational style is not acceptable. When speaking, people can adapt, rephrase, or completely restart a thought. Writing does not have the same flexibility, so directly stating the argument is critical. Small asides, idioms, filler-words, and metaphors can get in the way of a direct argument.

i. Over-qualifying the argument

Consider the phrase: 'It is interesting that…' If something *is* interesting, trust that your readers will agree. Further, this statement implies that everything else *is not* interesting. ii. Writing about your opinion

Although scientific writing is impartial, every writer imbues their opinions in their work. If you are making a claim, that claim is clearly your opinion and does not need to be stated as such.

iii. Stating that something is obvious/critical/necessary

If you are writing about it, the importance is implied; otherwise, why write about it at all?

Below is a list of common phrases that should be removed.

It is interesting that…	*In my opinion…*	*Of course…*
At this point…	*It goes without saying…*	*With no rhyme or reason…*
For all intents and purposes…	*Bottom line…*	*Few and far between…*

Some of the individual problems for concision have simple strategies for improvement, but most are difficult to separate from one another. Below is a list that you should help you address any 'wordiness' issues when you are rewriting.

Removing words is easy when someone points out to you that they are unnecessary. The more difficult step, especially in your own writing, is identifying when words are present but not accomplishing anything. Use the list of troublesome words above and the strategies below to trim your word count.

Strategy for improvement:

- Highlight the actor, action, and result of each sentence. Remove any words that do not contribute to the message.
- Place brackets around any word that you can remove and not lose the meaning of the sentence. These words can usually be deleted.
- Make verbs active as often as possible.
- Reduce phrases to words
- Use specific or exact wording
- Avoid too many adjectives or adverbs Reduce qualifiers
- Avoid beginning with 'It is' or 'There are'

Remember: removing a few words will not always feel like a great accomplishment. Trimming a few words from each sentence can sometimes feel like a meaningless endeavor. However, the benefits of

writing concisely are the result of a cumulative effort to ***reread your work, think about what you want to say, and choose the right words to say it.***

**A good list of examples and considerations for making your point more concisely is available at Purdue OWL (https://owl.english.purdue.edu/owl/resource/572/01/)

EXAMPLES

- **Highlight the actor, action, and result of each sentence. Remove any words that do not contribute to the message.**

Original: The alteration in all of the physical characteristics examined in this study are likely the result of the great decrease in soil organic carbon that accompanied the heating process.
Revised: The alteration in physical characteristics are likely the result of decreased soil organic carbon after heating.

- **Place brackets around any word that you can remove and not lose the meaning of the sentence. These words can usually be deleted.**

Original: [Some] insight into these [complex] interactions may be gained from [thorough] examination of [extensive] studies looking at the effects of laboratory heating.
Revised: Insight into these interactions may be gained by examining laboratory-heating studies.

- **Make verbs active as often as possible.**

Original: Soil organic matter was reduced by soil heating. Revised:
Soil heating reduced soil organic matter.

- **Reduce phrases to words**

Original: Evaporation is highest on soils without any vegetation, residue, or other surface cover. Revised:
Evaporation is highest on bare soils.

- **Use specific or exact wording**

Original: Peer reviewed publications investigating prescribed fires in grasslands have increased dramatically from approximately two articles in 1990 to over 65 articles in 2014.
Revised: Peer reviewed publications investigating prescribed fires in grasslands increased from two articles in 1990 to 67 articles in 2014.

- **Avoid too many adjectives or adverbs**

Original: Water movement in these soils may be the most crucial consideration in determining the incredible value of this process in productive agricultural systems.
Revised: Soil water movement is critical in determining the value of the process in agricultural systems.

- **Reduce qualifiers**

Original: Although it can be somewhat hard to measure, the microbial community plays a very important role in the nitrogen cycle.
Revised: Although difficult to measure, the microbial community plays a critical role in the nitrogen cycle.

- **Avoid beginning with 'It is' or 'There are'**

Original: There are a few specific plants that have a frequency of experiencing Mn deficiency due to their high requirement of the element.

Revised: Plants with high Mn requirements experience Mn deficiency more frequently than plants with low Mn requirements.

Problem V: Improper grammar (Grammar)

During our scientific writing, we can take two separate views of grammar. First, we can pretty much ignore it for most of the process. ***For our first (many) drafts, our grammar only has to be good enough that our writing is understandable.*** Beyond that, worrying about correcting everything is a waste of time, because we will probably rewrite everything anyway. Eventually, though, we will come to a 'final' draft. ***For our final draft, we will need to revise more closely for grammatical errors.*** However, when we write simple, focused documents, good grammar typically follows, so we will not have too much to do.

Whether fixing grammar enough to make your writing understandable or going through it writing with a fine-toothed comb, we will want to check for the following common errors.

**The list below is far from exhaustive, and they are broad rules of usage. For specific instances, you will be better served to google your problem. Chances are, if you have a grammar question, 1000 other people have had the same one.

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13. Subject-verb agreement

The number of the subject must agree with the number of the verb (e.g., singular subject – singular verb, plural subject – plural verb). This rule is most often violated when writers make their sentence structure too complex. Most writers will identify subject-verb agreement correctly when the verb is placed immediately after the subject, but they struggle when subject and verb are separated.

Strategy for improvement:

- Highlight the subject and verb for each sentence, ignoring the rest of the words. Not only will this practice ensure subject-verb agreement, but it will also help you find unnecessary words.
- When writing, try to place the action (verb) as close to the actor (subject) as possible.

EXAMPLES

Original: No significant differences between prescribed fire treatments and the amount of bluegrass control in the first year after fire was observed.

Revised: No significant differences were observed between prescribed fire treatments and the amount of bluegrass control in the first year after fire.

The subject (*differences*) is plural, but the verb (*was*) is singular. The verb is revised (*were*) to match the subject. This mistake likely occurred because the verb was separated from the subject by 16 words. Placing the directly next to the subject makes it much easier to catch these errors.

Original: The balance of other nutrients such as iron, phosphorus, zinc, molybdenum, silica, and sulfur play key roles in how available manganese is for plant uptake.

Revised: The balance of other nutrients, such as iron, phosphorus, zinc, molybdenum, silica, and sulfur, plays key roles in how available manganese is for plant uptake.

The subject of this sentence is the *balance* of the nutrients, <u>not</u> the nutrients themselves. Thus, the subject is singular, so the verb (play) must match that. This confusion was likely caused by the list of nutrients between the subject and verb. Part of that confusion is alleviated by including commas after *nutrients* and *sulfur* to indicate non-essential information.

**More examples on subject-verb agreement can be found at the SUNY ESC Online writing center

(https://www.esc.edu/online-writing-center/resources/grammar/nouns-verbs/)

14. Sentences

Readers get confused or distracted when something is presented as a sentence, but it is not actually a sentence. Both incomplete sentences and run-on sentences are common throughout the writing process, and finding them and revising them are critical to making writing understandable.

A complete sentence does not need to be complex. It needs i) a subject, ii) a verb, and iii) to *not* be subordinated to another series of words.

Incomplete sentences

Incomplete sentences, or sentence fragments, lack one of the three attributes of a complete sentence. While all writers occasionally forget to include subject or verb, the vast majority of incomplete sentences are the result of subordination errors. Expressing a thought as subordinate to another clause requires that the other clause also be included.

Examples of words that often signify subordination are:

After	*Although*	*Because*	*Before*
Despite	*Unless*	*Until*	*That*
While	*Since*	*Even though*	*As*

Run-on sentences

A run-on sentence, or fused sentence, is a combination of several independent clauses in a single sentence. They most often occur when writers are composing complex sentences. These can be avoided by limiting each sentence to expressing a single thought (see Sentences handout). Commonly, these can be fixed by adding a period.

Strategy for improvement:

- Identify subject and verb in each sentence
- Look to join clauses if you are missing either a subject or verb
- Insert a period if you have two sets of subject and verbs in a single sentence When joining independent clauses with a comma, a conjunction is also needed.
- Identify words that express subordination in your writing, and ensure that they are accompanied by independent clauses

EXAMPLES

Original: A healthy soil is stable. With resilience to stress, biological diversity, and consistent nutrient cycling.

Revised: A healthy soil is stable, with resilience to stress, biological diversity, and consistent nutrient cycling. The original writing includes one independent and one subordinate clause. The first clause has a subject (*soil*) and verb (*is*), while the second clause has neither. Thus, these clauses need to be connected with a comma.

*Original:*There are nine essential micronutrients required for plant growth, manganese is one of them.

Revised: There are nine essential micronutrients required for plant growth, and Manganese is one of them.

Revised: There are nine essential micronutrients required for plant growth. Manganese is one of them.

Best revision: Manganese is one of nine micronutrients essential for plant growth.

The original sentence is a combination of two independent clauses, as both have a subject and verb. So, they should be connected with either 1) a comma and coordinated conjunction or 2) a period. The best revision combines the two thoughts into a single sentence with greatly reduced word count.

**For more examples of run-on sentences, see Purdue OWL (https://owl.english.purdue.edu/engagement/2/1/33/)
**For more examples of sentence fragments, see Richmond Writer's Web (http://writing2.richmond.edu/writing/wweb/fragment.html)

15. Commas

Commas are the most common (and most misused) punctuation mark. Below is a list of circumstances in which you ***should*** use a comma.

- Join independent clauses (with conjunction)

Manganese deficiency had no effect on the number of leaves produced by barley plants, but Mn deficient plants produced fewer tillers.

- After introductory clauses

Compared to soils with high surface cover, bare soil environments have increased evaporation.

- Set off non-essential clauses within a sentence

Native species, especially blue grama and needle-and-thread, increased the first growing season after fire.

- Separate items in a list of 3 or more (final comma optional) Hydrocarbons can affect the physical, chemical, and biological properties of a soil.

- Separate two or more coordinate adjectives

Thermal desorption is a rapid, reliable, cost-effective method to remediate petroleum hydrocarbons.

- Set off geographical names, dates, and addresses

The research was conducted on private land near DeLamere, North Dakota..

Strategy for improvement:

- For each comma in your writing, ask if it performs one of the functions on the list above. If not consider removing it or replacing it with a different punctuation mark.

EXAMPLES

Original: We found prescribed fire to be a viable option for temporary bluegrass suppression even in areas with upwards of 50% bluegrass canopy cover.

Revised: We found prescribed fire to be a viable option for temporary bluegrass suppression, even in areas with upwards of 50% bluegrass canopy cover.

A comma is required after *suppression*. The information is not essential to the meaning of the sentence, so it should be set off by a comma.

Original: Once crude oil is introduced to the soil environment the hydrocarbons can undergo biodegradation volatilization or leaching.

Revised: Once crude oil is introduced to the soil environment, the hydrocarbons can undergo biodegradation, volatilization, or leaching.

A comma is required after *environment* because it is a non-essential, introductory clause. Commas are also required after *biodegradation* and *volatilization* (optional), as they are items in a list.

Original: Decomposition is a major step, when converting plant organic matter into plant available nitrogren.

Original: Decomposition is a major step when converting plant organic matter into plant available nitrogren.

The comma after *step* should be omitted because the remaining information is essential to the meaning of the sentence.

**Many more examples of both correct and incorrect comma usage can be found through the Purdue OWL (https://owl.english.purdue.edu/owl/resource/607/02/)

16. Other punctuation

Below is a list of common punctuation marks and their functions, along with examples for each.

Apostrophe

- To form the possessive of nouns

The possessive of nouns is most commonly formed by simply adding *'s*. Possessive plural nouns already ending in *s* may be formed by adding only the apostrophe (i.e., *s'*). A notable exception to this is the word *its*. *Its* is the possessive pronoun of *it*, while *it's* is the contraction of *it is*.

Researcher's lab… professor's class…

- To signify the omission of letters in contractions (most scientific writing avoids contractions)

It is = it' s they are = they're was not = wasn't

Colon

- To introduce a list of times that are not incorporated to the flow of the sentence

Four common minerals contribute the most manganese to the environment: pyrolusite, rhodocrosite, rhodonite, and hausmannite.

- To separate independent clauses in which the second explains the first

This study quantified evaporation and soil temperature over time under three rates of hydromulch to answer the question: does hydromulch reduce evaporation and moderate temperature fluctuations? For times and ratios

Non-preference isotherms for homovalent exchanges were assumed 1:1 lines.

Semicolon

- To separate independent clauses in which a conjunction is omitted

Selenium is an important element for humans and animals; it is not a required nutrient for plants.

- To separate independent clauses linked by a transition

When plants are manganese deficient, crop maturity is delayed or even halted; consequently, crop yields are reduced.

- To separate items in lists with internal commas

The three treatments were: 1) disturbed native, non-contaminated topsoil; thermal desorption-treated subsoil material; and a 1:1 mixture, by volume, of native topsoil and thermal desorption-treated subsoil material.

Parentheses

- To include additional information not integral to the meaning of the sentence

We observed higher rates of survival of cool-season natives (especially prairie junegrass and green needlegrass) at lower fuel loads.

- For abbreviations and acronyms

North Dakota Agricultural Network (NDAWN) potential evapotranspiration (PET) For citations of scientific literature

Native mixed-grass prairies are adapted to periodic disturbances by fire (Vermeire et al. 2014)…

Dash (several types exist, and they each perform specific functions)

- - Hyphen: to form compound terms

Drought-like conditions cool-season grass semi-arid region

- – en dash: to represent a span of numbers

Daily G values (0.97 – 1.45 MJ m^{-2} d^{-1}) were much lower than those found in Alberta…

— em dash: can take the place of a comma, parentheses, or colons.

Burning in the summer or early fall may be more successful at controlling bluegrass because conditions are drier—growing-season precipitation and soil water content is typically lowest in August through October.

**Find more on punctuation at Purdue OWL (https://owl.english.purdue.edu/owl/resource/566/1/) and the Ottawa Writing Centre (http://arts.uottawa.ca/writingcentre/en/hypergrammar/punctuation)

Problem VI: Not conforming to readers' expectations (Scientific convention)

For the most part, scientific writing is just writing, regardless of subject matter. We need to consider our focus, structure, clarity, concision, and grammar whether we are writing about nematode-fungi interactions or Aristotelian ethics. However, readers of scientific literature do have some preconceived notions about what writing should look like. Meeting these expectations will please our readers and make our work more understandable.

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16. Improper citations

Science is a continual process of building on previous work. When writing about your work, you will reference what has been done before, how it was done, and what they found. A good document always elucidates its relevance in the scientific literature, and it can only do so by referencing other work. You will cite often, so you will need to know ***what to cite*** and ***how to cite***.

Learning what, when, and how to cite can be tricky, but it becomes natural once you practice it enough. Consider the following bullet points to ensure that your citations are correct.

- **Cite any facts or ideas that you take from an outside source <u>every time</u> you use one.** In addition to acknowledging the original authors, citations legitimize your work by showing your reader that you understand how your work fits in with the existing body of knowledge.

- **Summarize ideas that you cite, do not use direct quotes.**

Your aim should be to smoothly incorporate the information that you cite. Direct quotes break up your prose, and they take away an opportunity for you to create relationships between the cited information and your story.

- **Cite at the end of the thought or sentence**

Citations should be placed near the information to be cited, but they should not be placed in the middle of the idea, effectively breaking up the writing flow. Try to insert citations only at the end of a thought, whether that is immediately before a period, comma, semicolon, dash, etc.

- **Format for citations is variable, so be sure to confirm what is required**

Nearly all scientific journals encourage in-text, parenthetical citations, while a minority use footnotes. Generally, the last name of the author and the year of publication are sufficient for in-text citation, while more information is required in the Literature Cited or References sections.

<u>Strategy for improvement:</u>

- Cite the <u>first time</u> that you write something, so you do not have to go back to find it later.
- Confirm what format citations need to be in *before* starting to write
- Take detailed notes when researching to ensure that you cite all information that you include

17. Plagiarism

Plagiarism occurs when a writer uses the words or ideas of others without giving credit. While intentional plagiarism undoubtedly occurs, in some cases, young writer do not know they are plagiarizing, or they can be lazy with citations. Notably, we are plagiarizing when we use words, ideas, or concepts of another writer. Additionally, plagiarism applies to structure, so we are guilty of it if you follow the same general structure but just change a few words. For more information, consult one of the numerous guides available that thoroughly cover the topic of plagiarism.

Resources for citations and information about plagiarism

Citing sources – NDSU Center for Writers

This website includes more than fifteen links to resources about plagiarism. They include documents and videos about what plagiarism is, how to avoid it, and the consequences of doing it. This site also includes dozens of links to style guides that show appropriate formatting.

https://www.ndsu.edu/cfwriters/citing_sources/

Avoiding plagiarism, self-plagiarism, and other questionable writing practices: a guide to ethical writing – Created for Office of Research Integrity by Miguel Roig, St. John's University

This comprehensive (71 page) document considers all aspects of plagiarism, citations, and ethical writing.

It is an excellent resource to search for some specific concerns with plagiarism, guided by headings in the Table of Contents. It also includes a brief overview of the document with '28 guidelines at a glance'. You can consult these guidelines first, and they can guide you to the parts of the document that are most relevant to your questions.

https://ori.hhs.gov/avoiding-plagiarism-self-plagiarism-and-other-questionable-writing-practicesguide-ethical-writing

Common types of plagiarism – Bowdoin College

This website clearly defines the different types of plagiarism, including direct, self, mosaic, and accidental plagiarism. It provides links to examples of plagiarism, as well. This resource provides similar information to the larger document above, but in more succinct format. Further, this site includes links to guides about how and when to cite (further supplement to above no. 19), contrasts quoting vs. paraphrasing, and lists some common style guides.

https://www.bowdoin.edu/studentaffairs/academic-honesty/common-types.shtml

Strategy for improvement:

The greatest confusion for plagiarism stems from determining what 'common knowledge' is that does not need to be cited. Avoid that confusion as often as possible by following these rules:

- If you didn't think it up on your own, cite the source
- If you did not know the information/concept before reading a source, cite it.
- When in doubt, cite.
- Continue to revisit the plagiarism guides listed here

**Most colleges and universities have resources for plagiarism, so many more examples and guides are available with a simple internet search.

18. Passive vs. active voice

For many instructors, the passive vs. active voice issue is a major pet peeve. Generally, active voice is preferred over passive. Active voice is more commonly used in everyday communication, and readers are familiar with the construction. Since the subject is the actor, active voice forces us to write clearly sentences, based on the Sentences guide. Alternatively, passive voice can create awkward, wordy sentences that are more difficult to understand.

Passive voice is most often used when the agent of an action is irrelevant to the outcome, or when the agent is so obvious as to render identification unnecessary. Thus, scientific writing often employs passive voice because it allows the authors to distance themselves from the writing and the conclusions. The findings are what is relevant, not the researchers who conducted the experiment. However, the use of first person pronouns (e.g., we) in scientific writing is becoming more acceptable, so passive voice is growing less common.

In a passive sentence, the action is done to the subject.

The experiment was conducted by the researchers.

In an active sentence, the subject does the action.

The researchers conducted the experiment.

Strategy for improvement:

- Decide if you need to use active or passive voice
- Identify passive voice by finding forms of the verb *to be* (e.g., is, was, were, are, have been)
- Revisit the Sentences handout and ensure that the actor is doing the action. Above all, ***be consistent.***

EXAMPLES

Original: Petroleum hydrocarbons are volatilized by heating in the thermal desorption unit.

Revised: Heating in the thermal desorption unit volatilizes petroleum hydrocarbons. The heating (actor) causes the hydrocarbons to volatilize (action).

Original: Evaporation was reduced by hydromulch application.

Revised: Hydromulch application reduced evaporation.

The hydromulch (actor) reduced (action) evaporation.

Original: Fewer tillers were produced in manganese deficient plants.

Revised: Manganese deficient plants produced fewer tillers. The plants (actor) produced (action) tillers.

Original: No significant differences were observed the first year after fire.

Revised: We did not observe any significant differences the first year after fire.

The researchers (actor) are implied in this sentence to observe (action) differences. In this example, either could be acceptable depending on the audience. Some audiences prefer to use active voice and personal pronouns, whereas other audience prefer to avoid personal pronouns and must use passive voice.

**More information and examples of passive and active voice are found in the University of Illinois Grammar Handbook: http://www.cws.illinois.edu/workshop/writers/activevoice/

19. Numbers

Scientific writing contains abundant references to numbers. They may be part of experimental designs, listed in procedures, or measured in experiments. Several rules exist to guide you on how to write properly about numbers.

Use words:

- If you can write out the number in two or three words

We found eight different grass species… NOT We found 8 different grass species…

- At the beginning of a sentence

Seven sites were burned in the spring… NOT 7 sites were burned in spring…

- If the number is less than ten

Soil temperature was reduced for six days… NOT Soil temperature was reduced for 6 days…

- Describing the order of events

First, we identified areas at risk of compaction… NOT 1st, we identified areas…

Use numerals:

- If you cannot write out the number in two or three words

We observed 137 species… NOT We observed one hundred and thirty-seven species..

- When reporting exact values measured quantities (e.g., length, mass)

The tallest plant was 14 cm tall… NOT The tallest plant was fourteen cm tall…

- If there is a decimal

Plots received 6.7 cm of rain… NOT Plots received six point seven cm of rain…

- For dates, times, and percentages

Collection began at 6:30 am… NOT Collection began at six-thirty am…

Use a combination:

- If two numerals are placed next to each other and could be confusing

We took eleven 25 g samples…
We emptied twenty 10 L buckets…
We removed forty-seven 6 cm soil samples…

Strategy for improvement:

- Whenever you need to write about a number, consult this list to determine if you should use words, numerals, or a combination.

**For more information and examples about writing with numbers, consult the Purdue OWL: https://owl.english.purdue.edu/owl/resource/593/01/

List of Useful Resources for Scientific Writing

ONLINE RESOURCE	DESCRIPTION
http://writing-speech.dartmouth.edu/teaching/firstyear-writing-pedagogies-methods-design/teachingwriting-process	**"Teaching writing as process" – Dartmouth Institute for Writing and Rhetoric** In-depth exploration of theory behind ways to teach writing. An excellent resource when thinking about writing as a process. Aimed more towards instructors than students
https://owl.english.purdue.edu/owl	**Purdue Online Writing Lab** • A great place to start when looking for information on writing. It covers a wide variety of topics and offers a good introduction to each. • Depth of explanations and amount of examples vary from topic to topic, so not always the best place for complicated questions.
http://writing2.richmond.edu/writing/wweb.html	**University of Richmond Writer's Web** • Another broadly useable site with links to a large number of topics, including some short videos and audio recordings with explanations. • Similar to the Purdue OWL with emphasis on different concepts
http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf	**"Sentence structure of technical writing" – powerpoint from MIT writing lab** • Short, easy to digest overview to the writing process. Covers many of the same topics as the reference guide, with slightly different takes. • Several good examples, and a few lists of words and phrases to avoid.
http://www.cws.illinois.edu/workshop/writers/	**"The Grammar Handbook" – University of Illinois** • A good reference for basic grammar issues. If students are unclear on some of the topics covered in the reference guide, this is a good site to find the answers. • Clean, easy to use site for fast answers. Also links to some general writing tips.
https://brians.wsu.edu/common-errors/	**"Common writing errors" – site created by Washington State University professor** ***Extensive*** list of commonly confused or troublesome words, phrases, or concepts. Arranged alphabetically and easy to search.
http://arts.uottawa.ca/writingcentre/en/hypergrammar	**"Hypergrammar" – Writing Centre at University of Ottawa** Links under 'Hypergrammar' tab to several writing issues. This site provides a lot of examples for the concepts discussed in the reference guide.
https://www.esc.edu/online-writing-center/	**SUNY Empire State College Online Writing Center** • Another broadly usable writing resource with links on a variety of writing topics (similar to Purdue OWL and Richmond WW) • Provides several exercises and worksheets where you can test your understanding

https://www.hamilton.edu/academics/centers/writing/seven-sins-of-writing	**"The seven deadly sins of writing" – Hamilton College** • A list of seven common writing problems with examples and strategies for improvement

List of Useful Resources for Scientific Writing

A note on other online resources

Hundreds of other websites are available with advice on word choice, writing style, grammatical preference, and more. Two of the more popular sites are:

1. Tips from Grammar Girl (https://www.quickanddirtytips.com/education/grammar)
2. English Stack Exchange (https://english.stackexchange.com/).

These sites are full of good information, but you should be wary of using them as definitive references. A good practice is to consult several of these sites on the same topic. If they all agree, then you may be confident of the information, if not, you may want to refer to one of the more regulated sources listed above (and below).

HARDCOPY RESOURCE	DESCRIPTION
Writing Science* • by Joshua Schimel •	Focuses on writing as a storytelling to keep readers interested Entirely focused on scientific writing • Excellent examples on all aspects of writing, building from words all the way up to document scale structure and flow • Annotation of good, bad, and ugly writing examples to show how the author thinks during revisions
The Little English Handbook* • by Corbett and Finkle •	Well-organized reference for specific writing concerns Offers many annotated examples for each of 75 writing topics • Contains a wide range of content, not just scientific writing
The Elements of Style* • by Strunk and White •	A classic book in the teaching of writing, still with many relevant examples Excellent list of 21 practices to consider while writing • Often assumes a level of understanding about grammatical structures and vocabulary, so it may not be accessible to every writer
On Writing Well* • by William Zinsser •	A 'big picture' resource that discusses style and usage Several paragraph (and longer) length examples with discussion, but not explicitly annotated
Woe is I • by Patricia T. O'Connor •	Grammar book written for a popular audience, with a little humor thrown in Not as comprehensive as some other books, but accessible to most readers • Many examples in 'this vs. that' form

**** Indicates title is available at NDSU Main Library (as of 5.1.18)***

A note on other hardcopy resources

This list is far from exhaustive. The NDSU library has hundreds of books devoted to teaching writing, with dozens of those focused on writing in the sciences. Visit the library to search out these books, for you will likely find one addressing any specific concern you might have. Some examples:

1. **The Craft of Scientific Writing*** by Michael Alley
2. **How to Write a Sentence: and How to Read One*** by Stanley Fish

Individual Handouts

INTRODUCTION

Writing is a skill

Writing is a critical skill that we will all use throughout our lives. To be sure, some of us will write more than others will, but none of us will avoid it entirely. This writing may be formal, as in journal articles, books, or technical reports. It may be applied to a wide audience, such as extension publications or newspaper or magazine articles. It may even be personal communications, as in letters, emails, blog posts, or even social media. All types of writing require a different skillset, but they all strive for the same goal: communication. Thus, if we are not capable of writing clearly, we cannot not communicate well, and we will be less successful in whatever career path we follow.

As a scientist, you are a professional writer – Joshua Schimel, Writing Science

Skills need to be developed

Writing is a skill (or a craft), just as playing the guitar, painting a canvas, building a house, or baking a loaf of bread are skills. No one has an innate skill of 'being a good writer'. One does not simply *know* how to write well, but rather everyone learns by practicing. Like any other skill, people begin with a range of proficiencies, but good writers become good by continually practicing their writing.

Practice isn't the thing you do once you're good. It's the thing you do that makes you good. – Malcom Gladwell, Outliers

Roadblocks to success

Two major roadblocks to becoming a successful writer are lack of confidence or fear of failure, both of which often arise after previous, self-perceived 'failed' writing attempts. The first step to overcoming these roadblocks to understand that everyone 'fails' when they write. Great writers have terrible first drafts, but they have the patience and persistence to continue improving those drafts. The second step is to recognize that these are not 'failures' at all. A bad first draft is the only way to get to a better second one.

Every first draft is perfect because all the first draft has to do is exist. It's perfect in its existence. The only way it could be imperfect would be to NOT exist.
– Jane Smiley

The path forward

Two ways exist to become better writers. First, we simply have to practice writing, and keep practicing. Second, we need to read more, both things that are written well and things that need to be improved. The measure of our improvement will be how well we can force ourselves to continue writing, reading, and rewriting. In this way, perseverance is the only thing that distinguishes a good writer from a bad writer.

When others tell you that you are not a good writer (or you tell that to yourself), then you are less likely to put the time in to try to write anything well. These statements become self-fulfilling prophecies because you do not practice writing, and so you cannot improve. Everyone is capable of writing well, and everyone needs lots of practice to be able to do so. The hardest part is often the first step of simply getting something on the page.

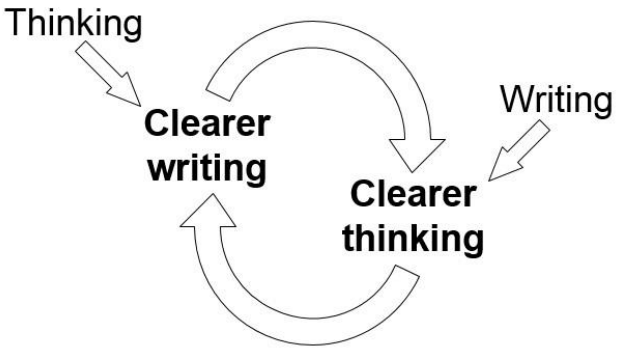
Write. Rewrite. When not writing or rewriting, read. I know of no shortcuts.
– Larry L. King

Misconceptions about writing

Before we start practicing, we need to identify two common misconceptions. Freeing ourselves from these misconceptions should give us a clearer idea of what writing is, and it may help us avoid unrealistic expectations.

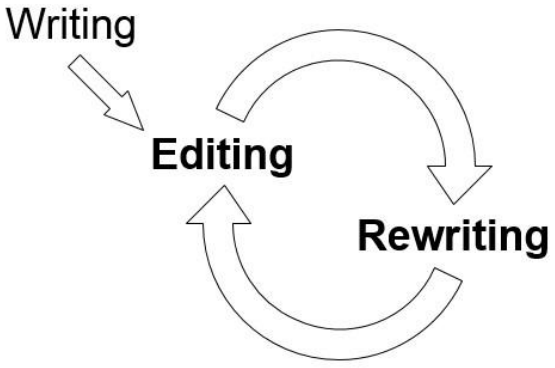
Write to think, and think to write

An old axiom of writing states: 'you have to think clearly to write clearly'. While this idea has some merit, it is not exactly true. Rather, consider that writing and thinking coexist on a continuous process of improvement. By thinking more clearly, your writing becomes clearer. Similarly, by writing more clearly, your thinking becomes even clearer. Regardless of which step you begin with, you will fall into the cycle of continual improvement as you go back and forth.



Writing is a process

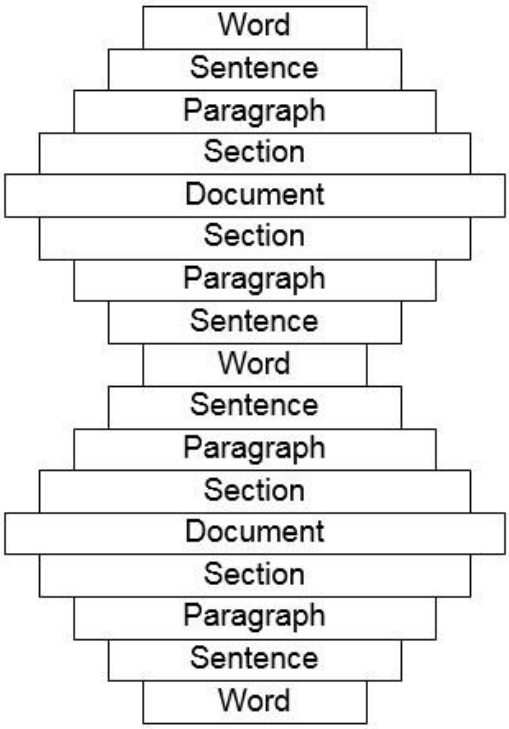
The second misconception is more central to what 'writing' ***is***. You may think that to write, you sit down at your computer, type something, and then you are done writing. This act is only the first (and probably the least time-consuming) step of the writing process. When we say 'writing', we really mean 'the writing process', which includes numerous rounds of editing and rewriting. No one (and that means NO ONE) writes a first draft that they are happy with. In fact, most people are not happy with their fifth draft. Remember, we are never 'done' with writing, but rather we just pick a point to stop, just as an artist is never 'done' with a painting, or a musician is never 'done' composing a song.



Every writer follows some version of this process. Take comfort in knowing that those people others call ‘good writers’ are doing the same things that you are. Just writing and editing, and rewriting and editing, and rewriting…until they cannot take it anymore.

Writing at different scales

Writing happens at a variety of scales and scopes. We will constantly switch lenses to consider content, clarity, and flow of words, sentences, paragraphs, groups of paragraphs, and entire documents. During these exercises, we will build our writing skills by focusing on individual sentences and individual paragraphs. Once we gain experience in these two building blocks, we can feel comfortable approaching any type of writing assignment/project.



Practice, practice, practice

What we will do this semester is practice reading and practice writing. And we will start right now. Write a few paragraphs about:

1. What do you think about when someone brings up ‘writing’? Are you confident? Anxious? Terrified? Indifferent? Uncomfortable?
2. What do you think about your own writing skills? What are your strengths and weaknesses?
3. Any other open-ended question to get people writing.

Do not think too hard about it before you start writing. Remember, simply putting your thoughts on paper can spur on additional thoughts, or make your original thoughts clearer. Also, do not stress about how your first draft looks. The point of the exercise is to get something on the page.

APPROACHING SCIENTIFIC LITERATURE

What is scientific literature?

Broadly, scientific literature is the collection of publications that document the findings of scientific research. This collection comprises many types of documents, including primary, secondary, tertiary, and gray literature. These terms describe the nature of the information each document contains, and they will be discussed further in another guide (Finding Scientific Literature).

What is a peer-reviewed article?

One important grouping in the scientific literature is peer-reviewed articles. These articles are especially important because they have been screened by numerous scientists, which makes their findings more reliable. More information about the peer-review process is included in the Finding Scientific Literature guide. For the purposes of this exercise, you can trust that your instructor has provided you with a peerreviewed article.

What types of peer-reviewed articles are there?

The peer-review process is applied in a variety of circumstances to facilitate scientific discussion. However, the two most common types are:

1. Research articles – these articles describe original research, with the primary information pertaining to a ***specific experiment*** (or survey, investigation, etc.) or set of experiments.
2. Literature review – these articles utilize information from numerous other articles to ***synthesize existing knowledge*** on a topic, often with the aim of adding a new insight or concept to the discourse.

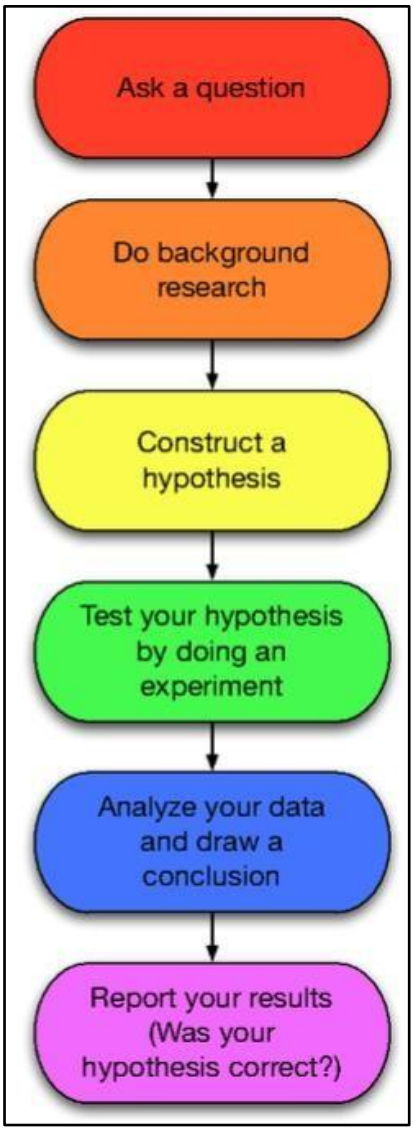
Although not discussed in this module, these two categories can be subdivided further to include research notes, commentaries, short communications, meta-analyses, and more.

How should you approach reading these articles?

Reading these articles can be intimidating to those just starting out in their scientific careers. The articles are very formal, and they often contain unfamiliar, discipline-specific jargon. ***However, all scientific writing is formulaic, so once you understand the formula, reading it becomes much easier.***

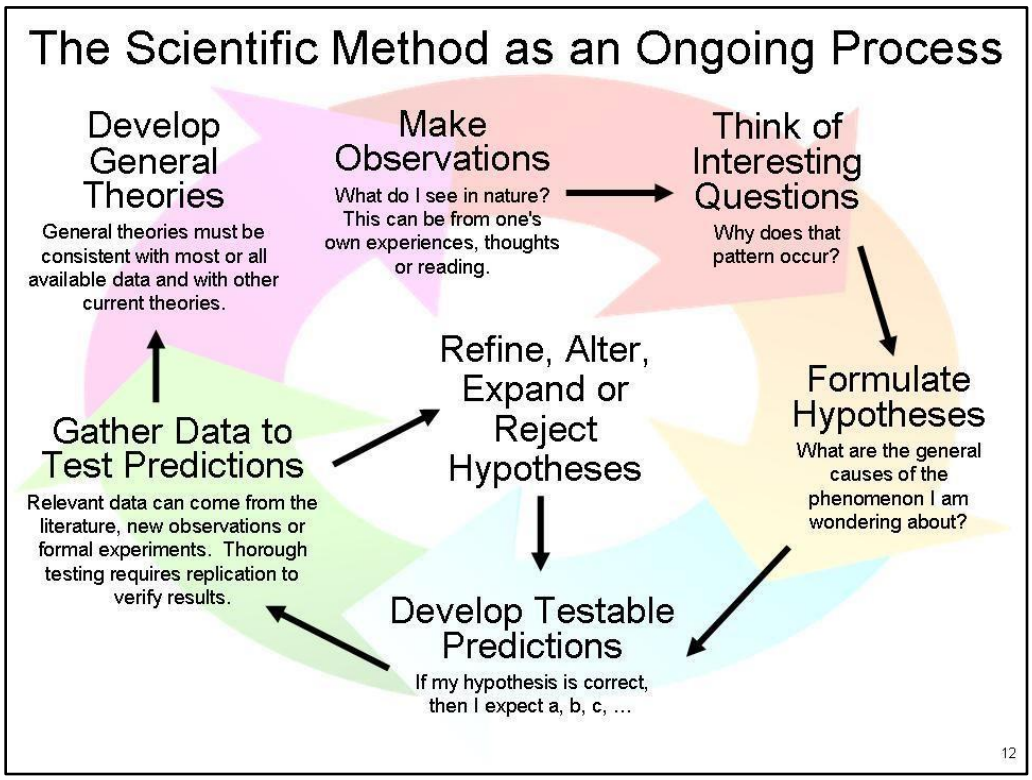
The Formula

Remember, scientific literature is describing scientific research. Thus, all literature follows the ***scientific method.***



Left: Simplistic representation of the traditional steps describing the scientific method.

Below: A more complex diagram showing the continuous nature of the scientific method.



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The reporting of these results and conclusions takes the form of a peer-reviewed article. These articles describe the steps of the scientific method, and they are typically broken into the sections shown in the table below.

Section	Steps of SM addressed
Abstract	Summary of entire process
Introduction	Ask a question; Do background research; Construct a hypothesis
Materials and Methods	Describe how the hypothesis is tested
Results	Analyze the data
Discussion	Draw conclusions

Abstract

The abstract is a concise description of the entire article, touching on context, methodology, results, and conclusions. It is typically short, ranging from 150 – 300 words, but it contains enough information to be understood as a stand-alone blurb, without any context from the article.

What questions does the abstract answer?

Because the abstract is a compressed version of the entire article, it should answer all of the questions associated with the scientific method. **What was done and why? How? What were the findings? What do the findings mean?**

The abstract is typically the first part of an article that you will read and possibly the *only* part that you read. Often, after reading an abstract you may decide that the paper is not relevant to you or your research question. However, for papers that *are* relevant, **reading only the abstract is not a substitute for reading the entire paper**. Properly interpreting the results, understanding context of the conclusions, and highlighting the subtleties in the implications are all parts of the paper that cannot be crammed into the 250 words of the abstract.

Introduction

As the heading implies, the Introduction *introduces* the reader to the topic of the paper. A good introduction will often begin with a broad concept or theory that is relatable to a wide audience, and then it will narrow the scope to the specific research question being addressed. The research question is stated, and its importance is justified. The context for the research is provided by reporting previous or related research and identifying the knowledge gap that is filled. Finally, the Introduction can often conclude with a paragraph (or several sentences) stating the hypotheses or objectives of the research.

What questions does this section answer?

- What is the research question?
- Why is it important (justification)?
- What work has already been done on this topic?
- How does this research fill a knowledge gap?
- What are the aims/objectives/hypotheses of this study?

Materials and Methods

The Materials and Methods section outlines how the study was conducted. The purpose of this section is to describe the methodology with enough detail so that others can reproduce the study. It includes detailed information about any experimental procedures used, adequately defines treatments, and provides location/time information, if applicable.

What questions does this section answer?

- What materials were used?
- How was the study conducted?

The Materials and Methods section is often the most tedious sections to read because of the amount of detail that is included. This attention to detail is especially important during the peer-review process, as only studies that use (and fully document) appropriate methodology can produce reliable results. However, in many circumstances, skimming this section can often be acceptable. You may often return to the Materials and Methods section while reading the Results or Discussion to understand the context in which the findings occurred.

Results

The Results section presents the key findings of the paper, which are usually reported as summaries of the data collected. They are presented in three ways: i) in the body of the text; ii) in tables; and iii) in figures. Notably, this section exclusively includes the key findings of the study, which should be highlighted and presented with enough context to understand them. However, no interpretations are included in this section.

What questions does this section answer?

- What were the key findings of the study?

The Results section can also be tedious to read, especially if you are unfamiliar with the topic. However, this section is one of the most important when determining the usefulness of the authors' conclusions. Look at the data they present and determine if you agree with their assessment, or ask if they may be reading too much into their data. Oftentimes, the Results and Discussion are combined into one section, so that the results can be contextualized as they are being presented.

Discussion

The Discussion section is where the key findings are interpreted and related to other studies. The Results will be used as evidence for the statements in the discussion, and outside literature will be included to compare with or substantiate the authors' claims. This section should relate back to the research question and hypotheses presented in the Introduction.

What questions does this section answer?

- What do the findings mean?
- Why did you find the results that you did?
- How do these results relate to other studies?
- Was your hypothesis correct?

Depending on the article format, the Discussion may include a final 'conclusions' paragraph that offers a succinct description of the broad implications of the study. This information may also be offset under another section, such as a 'Conclusions' or 'Implications'.

Summarizing an article

A good rule of thumb to abide by when summarizing an article is to tie it all back to the scientific method. Ask the questions listed below, and use this guide to determine where to find them within the article.

- What is the research question?
- How did the article address the question?
- What did they find out?
- What do the findings mean?

SENTENCES

What is a sentence?

In its characteristically verbose, sometimes inaccessible way, the Oxford English Dictionary (*the* definitive reference) defines 'sentence':

A series of words in connected speech or writing, forming the grammatically complete expression of a single thought; in popular use often, such a portion of a composition or utterance as extends from one full stop to another. In Grammar, the verbal expression of a proposition, question, command, or request, containing normally a subject and a predicate (though either of these may be omitted by ellipsis).

We all implicitly know what a sentence is, even if we cannot define it in these terms. We use sentences constantly, both written and verbal, to communicate with others in our daily lives. However, revisiting the formal definition can remind us the components of a sentence, and it should help us *write better sentences.*

***From this definition, we see that each sentence is**:*

1. An expression of a single thought
2. A unit of composition with grammatical requirements

What is the aim of a sentence?

Before thinking about how to write a good sentence, step back and consider ***'What am I trying to do?'*** In our scientific writing, we are clearly trying to convey some sort of knowledge, whether it be the results of an experiment, the implications of some findings, or the description of some concept. People read scientific literature because they are interested in the knowledge it is trying to convey. Nonetheless, tedious, dispassionate subject matter can still drive readers away. Thus, the writing must tell a story to keep readers engaged and make it easy for them to understand.

Each sentence should convey relevant information in a compelling, easy to-understand way.

How does this information help us write better sentences?

Writing is, without question, a creative endeavor, and infinite possibilities exist when forming words into sentences. Identifying the goal of our sentences makes the process of writing less daunting, and it helps us identify some relevant questions to make our sentences the best they can be.

Sentence checklist

- Does my sentence tell a compelling story?
- Does my sentence express a single thought?
- Is my sentence grammatically correct?
- Is my sentence easy to understand?

Before writing anything, remember:

Even the best writers do not accomplish all these tasks on the first try (or even the sixth try), so be prepared for many rounds of editing and rewriting. Do not be discouraged that your sentences are not perfect the first time. One of the hardest steps to take can be the first one: getting something written on the paper. From there, you can assess what you have written and change what needs changing.

Approaching the sentence checklist

The checklist is presented in a linear manner, but writing is a cyclic process and almost never a linear progression. You will always be moving between the items as you write, but, at the beginning, you should proceed with these checklist questions in order. Always begin by trying to tell a compelling story about a single idea. You should not be too concerned with formal grammatical structure for your first several drafts. While you want your sentences to be grammatically correct, you will change your writing many times throughout the process, so stressing about grammar each draft can take away from the overall goal of the sentence.

1. Does my sentence tell a compelling story?

Each sentence should tell its own story, and this story will tie in with the broader stories of the paragraph, the section, and, ultimately, the entire document. Every story (and every sentence) needs some key components. First, it needs an **actor** that the story is about. It needs some sort of **action**, describing what the subject is doing or what is being done to the actor. Finally, it needs a **result**, describing the consequence of what was done.

For a story (and a sentence) to be accessible, engaging, and compelling, the readers should be familiar with the actor, understand the action, and find some significance in the result.

What does this mean when you are writing a sentence?

The actor should be an item, concept, or process that the reader understands. This understanding may come from general knowledge, in the instance of talking about an elephant or a fireplace. Subjects that are not common knowledge may be introduced to a reader by defining it in a previous (or the current) sentence.

The action should be something familiar to the reader. Often, this can be a simple matter of vocabulary, such as in the instance of 'walk' or 'photograph', or else defining the action can be the topic of another sentence. One of the more common difficulties with the action is separating it too far from the subject. When too many prepositions, adjectives, or subordinate clauses separate the action from the subject, understanding the sentence becomes much more difficult.

The result (*i.e.*, resolution, consequence) is the highlight of the sentence or the climax of the story. This point is where we can add new or important information about the subject that is critical to the story. We usually put the resolution at the end of the sentence because that is where readers expect the focus to be. Thus, new and important information that we want the readers to notice and remember should be put in this 'power' position at the end of the sentence.

Typical structure for a compelling story

- Begin with a familiar actor.
- Perform a familiar action.
- Conclude with new, relevant information.

A note on sentence structure

That being said, not every sentence will follow that structure. To keep readers entertained and engaged, you should use various sentence structures. Nonetheless, nearly all our sentences will follow the "subject → action → resolution" template, and you should usually start with these as a first draft. Varying sentence structure becomes more meaningful when understanding each sentence in the context of a whole paragraph.

2. Does my sentence express a single thought?

Sentences are the vessels of our thoughts, and only one thought should fit in one sentence. In terms of telling a story, a sentence with more than one idea inside it makes the story confusing. However, if you follow the previously introduced structure for telling a story, expressing a single thought comes naturally.

Describing one subject (or one set of subjects) doing one thing leading to one result necessarily results in a sentence about a single thought. The relationships in this template are essential. When an actor performs an action, the result of the sentence must be the consequence of that action. If the result of the sentence is unrelated to the action or the consequence of another action, then the sentence no longer describes only one thought.

Writers can get themselves in trouble by attempting to describe multiple or complex actions or phenomena in a single sentence. When deciding to do this, all the actors (or actions, or results) must be related, and those relationships must be familiar to the reader. Even compound sentences should still have only one idea. Keeping to a single idea is important whether the sentence is five words long or 20 words long (although anything above 25 words may be a little excessive).

Checklist for expressing a single thought

- Is the result of the sentence a consequence of the action to/by the actor?
- For multiple actors, are they related? Is the relationship clear?
- For multiple actions, are they related? Are they meaningful to the result?
- For multiple results, are they caused by the action(s) described?

3. Is my sentence grammatically correct?

By understanding grammar at the end of the process rather than at the beginning, you may find that much of your work is done. Many definitions of a sentence include only the grammatical aspect, that is, a sentence must contain a subject, a verb, and a predicate. The structure for storytelling mimics that of proper grammar. Actor is a subject, action as the verb, and result as the predicate. This template works very well for simply constructed sentences. Introducing more complex sentence structure makes it more difficult to ensure that the sentence is grammatically correct. Short, simple sentences are a good way to begin your writing, and you can liven things up as you go back to edit.

For specific grammatical concerns, word choice, and other common difficulties with writing mechanics, consult the writing guide distributed at the beginning of the semester.

4. Is my sentence easy to understand?

For sentences to fulfill their purpose, they must be understandable. For sentences to be good sentences, they must be easy to understand. Using the sentence checklist, you will address many of the areas that often make sentences confusing. You will be discussing actor(s) and action(s) that are familiar to the reader. You will ensure that the result of the sentence is a consequence of the action. The sentence will describe a single, coherent expression of thought, and it will be grammatically correct enough that the reader can understand the thought expressed.

At this point, you are double-checking each step in the process. The nature of the process is to break down the sentence into smaller parts, but the product is a complete sentence. Thus, this final check is a reevaluation of how all the smaller parts fit together to create a single, easily understandable sentence.

Examples

***Original* (22 words)**

However, there are still questions that remain on the timing of fire that are more appropriate to the control of Kentucky bluegrass. ***Revised* (13 words)**

However, questions remain regarding how the timing of fire affects Kentucky bluegrass response.

Purpose: A setup for stating objectives of research.
Focus: Identifying unanswered questions about how Kentucky bluegrass responds to timing of fire.
Assessment: The purpose and focus are clear, but excessive wording makes it harder to understand.

- Remove *there are* to make *questions* the subject of the sentence, which is aligned with the purpose.
- Remove *still* because it is redundant with *remain*.
- Change *on* to *regarding*. *On* is acceptable, but *regarding* portrays the meaning of the sentence better.
- Remove *appropriate* and *control* when describing Kentucky bluegrass management. These words indicate a value judgement (*appropriate*) and a specific concept (*control*) that cannot be explained in this sentence. Although the words are familiar to the reader, their discipline-specific connotations cannot be conveyed in this sentence. The revised version is more neutral.

***Original* (18 words)**

Permanganate oxidizable C has not been studied TD systems; therefore, changes to labile C may disrupt microbial activities.

***Revised* (22 words)**

Monitoring POXC in TD-treated soils, which has not yet been done, is valuable because changes to labile C may disrupt microbial activities.

Purpose: Identify the importance of studying POXC
Focus: It is important because 1) it has not been studied before, and 2) it is a way to monitor labile C.
Assessment: The purpose is not fulfilled because the order of the information is presented in a confusing way, and the two clauses are not related properly.

- A previous sentence has identified that POXC is a rapid, inexpensive way to quantify labile C, so it can be the 'familiar' opening to the sentence.
- The fact that POXC has not been studied before is less important than the rest of the information, so it is set off by commas in a subordinate clause.
- *Therefore* is removed. The relationship in the original sentence: 'POXC has not been studied *therefore* changes to labile C disrupt activities' indicates that the lack of study *causes* labile C to disrupt microbes.
- A better relationship is built by using *because*. Monitoring POXC is *valuable* both *because* it has not been done before and *because* changes to labile C disrupt microbes.

***Original* (33 words)**

When these spills, leaks, or malfunctions occur on land used for agricultural production, some sort of remediation is required to return the land to its previous level of productivity within a reasonable timeframe.

***Revised* (18 words)**

When these releases occur on agricultural land, remediation may be required to quickly return the land to productivity.

Purpose: A transition from discussing oil spills (previous sentences) to remediation (following sentences)
Focus: State that remediation is required on contaminated agricultural land
Assessment: The information is clear, but it can be stripped down to perform the purpose more efficiently.

- Replace *spills, leaks, or malfunctions* with *releases*. The method of release is not the important part of the sentence, so the original clause is essentially redundant.
- Replace *land used for agricultural production* with *agricultural land*. Use words instead of phrases.
- Remove *some sort of* because it is better to use exact phrasing.
- Using the verb *to return* in this context implies that it will return to its previous state, so *previous level of productivity* is redundant.
- Replace *within a reasonable timeframe* with *quickly*. Even though neither way states an exact amount of time, using one word is more efficient than four words.

***Original* (21 words)**

The rhizobium-legume relationship is not only dependent for the nitrogen cycle, but it also helps the plants to grow and develop.

***Revised* (19 words)**

The rhizobium-legume relationship is important not only in the overall nitrogen cycle but also in plant growth and development.

Purpose: Stress the importance of rhizobium-legume relationship in N-cycle and plant growth
Focus: Importance of rhizobium-legume relationship
Assessment: This sentence is unclear because of the vague actor-action-result relationship. The word 'dependent' is used incorrectly, which throws off the rest of the sentence. The sentence should be rewritten so that the actor, *rhizobium-legume relationship,* and its action, *is important*, lead to the purpose of the sentence. That purpose, and result of the actor-action-result template, is to inform the reader that the relationship is important in two ways, the overall N-cycle and, more specifically, plant growth.

- Replace *dependent* with *important*. The N-cycle *depends* on the rhizobium-legume relationship, but the relationship is *important* in the N-cycle.
- Remove the comma after *cycle* and *it* in the second clause to make it a simpler sentence. The two roles of the rhizobium-legume relationship are explicitly linked, so they can be included in the same independent clause.
- Reordered wording to make *not only…but also* construction.

WRITING AS A PROCESS

As we saw in the Introduction, understanding writing as a process, rather than a single act, is essential. Our writing → editing → rewriting cycle is a good way to consider that process, but it does omit some critical steps. Namely, it skips the entire process of prewriting. Reading, brainstorming, and outlining are

necessary steps to perform before any writing actually takes place. Further, rewriting is a broad category and one word is too simplistic to describe all that it entails.

We separate the process into three distinct stages, each of which contains several phases. The process is presented sequentially here, but, like all aspects of writing, these stages and phases are not linear in the actual practice of writing. Rather, you will organize your ideas, write them down, and then read a paper that changes your perspective. Then you will rewrite to include your new idea, edit it for clarity, and then go back to find additional context. This is a fluid, continuous process, and each step is important both on its own and as part of a whole.

Phases of writing

- Invention (prewriting)
- Composition (writing)
- Revision (rewriting)

Invention (Prewriting)

Prewriting begins with **1) reading** relevant information. Reading informs us on the topic, and it exposes us to other styles and thought-processes. This exposure helps us to clarify our own thinking, as well as to borrow strategies from other writers that we find to be useful. Thus, the reading spurs us to **2) generate ideas** about our topic. Often, this step is taught as brainstorming, and numerous techniques for encouraging these ideas are available.

Next, we need to **3) organize our ideas**. Most commonly, this organization takes the form of an outline. Outlines vary widely in their level of formality, and writers vary widely in how close they stick to them. Some writers think more spatially and organize words in a meaningful orientation, such as underneath 'umbrella' keywords or by connecting them with arrows on a flow chart.

However, ideas do not exist in a vacuum. When we write, we need to **4) contextualize our ideas**, especially in scientific disciplines. Almost all our writing will be to answer a research question, so we need to discuss how our ideas relate to other research that has been done on the topic. This process involves asking questions like: What previous work has been done? Does our argument agree or disagree with previous findings? What is the scope of our work? What are some implications of our work? What questions are still unanswered?

Finally, this process comes down to a point by **5) writing a thesis sentence**. The thesis sentence is the most direct statement in your paper; it identifies the topic and defines the scope of the paper. This sentence may be the most frustrating one to write, but to write a good paper, you need a good thesis sentence.

Steps in Invention phase (prewriting)

3. Reading
4. Generating ideas
5. Organizing ideas
6. Contextualizing ideas
7. Writing a thesis statement/sentence

Composition (writing)

This step is what people generally think about when they hear the word 'writing', but it actually constitutes very little time in our process. For some writers, though, this stage can be the most stressful. Looking at a blank piece of paper can induce fear, anxiety, or even rage. To avoid these feelings, it is often best to write small amounts frequently rather than writing a long assignment or project all at once. This stage is also when we start to see our organized ideas (from the previous stage) turning into a written structure, so it can inspire some hope (and relief).

Revision

Rewriting these drafts is the essence of writing, and the purpose of this rewriting can be divided into two major categories.

Rewriting for yourself

When we are attached to something we created, changing it never feels like it is something we are doing for ourselves. Although you may not initially feel like you are rewriting for yourself, you realize how true it is once you become comfortable with the process.

Rewriting for yourself means that you are revising your arguments, your structure, or your conclusions. Changing these things obviously helps the reader understand what you are trying to say, but, much more importantly, it helps *you* understand what you are trying to say. This process is the embodiment of our circular feedback between clear writing and clear thinking.

Questions to ask – rewriting for yourself

- What is my thesis? Is it clearly stated?
- Do my arguments address my thesis? Do they address *only* my thesis?
- Viewed individually, do each of my paragraphs make sense?
- Does each paragraph have a topic and stick to it?
- Does each paragraph contribute to the overall story of the document?
- Do my paragraphs flow together, or are they disjointed individuals?

Rewriting for your reader

Once you have convinced yourself of your argument and can clearly understand it, you can start to determine if the reader can understand it. Rewriting for yourself requires the skill of being critical of your own thinking. Rewriting for your reader requires you to be able to read and understand your arguments without the benefit your background knowledge.

This step usually includes addressing the clarity of your arguments by looking at things like word choice, sentence structure, and wordiness. These revisions should all be aimed at making it more enjoyable for the reader by making it easier to understand. Additionally, this step includes proofreading for mistakes or mechanical errors in your writing. Grammatical errors and improper vocabulary need to be fixed because they distract readers from the arguments within the paper.

Questions to ask – rewriting for your reader

- Have I said what I intended to say?
- Have I provided enough information to support the argument?
- Does my argument follow a logical progression?
- Is my document easy to read?
- Does my writing style (e.g., word choice, sentence structure, grammatical errors) distract from the argument?

PARAGRAPHS

What is a paragraph? From the Oxford English Dictionary (*the* definitive reference):

A distinct passage or section of a text, usually composed of several sentences, dealing with a particular point, a short episode in a narrative, a single piece of direct speech, etc.

Like the sentence, we all know what a paragraph is, even if we cannot recite the formal definition. The paragraph is especially important because it is the most common unit of composition. Each paragraph comprises several sentences but, as a unit, acts as the smallest vessel of cohesive argument. Thus, when we talk about writing, enormous emphasis must be placed on paragraphs.

***From this definition, we see that each paragraph is**:*

8. Focused on a single topic
9. A distinct section of several sentences

What is the aim of a paragraph? As when writing a sentence, we should always consider '***What am I trying to do?***' before attempting to write a paragraph. In fact, the aim of the paragraph is the exact same as the aim of a sentence. The primary difference is that the paragraph comprises several sentences, so the writer has more words to use when conveying that information. For that reason, paragraphs can be much more flexible than sentences, but they are also much more difficult to compose well.

Each paragraph should convey relevant information in a compelling, easy to-understand way.

How does this information help us write better paragraphs? Since the goals of the paragraph and the sentence line up so well, the 'Sentence checklist' can be (and is) duplicated for the goals of the paragraph.

Paragraph checklist

- Does my paragraph tell a compelling story?
- Does my paragraph express a single thought?
- Is my paragraph grammatically correct?
- Is my paragraph easy to understand?

However, accomplishing each of these goals is much more difficult for a paragraph than for a sentence. Sentences perform the role of storytelling within the paragraph, so writing good sentences is critical. However, not only does the writer need to write good sentences, but the writer must also fit them all together to form one cohesive progression of thoughts focused on a single topic.

Role of sentences in a paragraph

- Topic sentence – states the main idea
- Support the main idea
- Develop the main idea with strong evidence
- Consider its relationship with other sentences in the paragraph

Formulaic writing

We may note that the aims of our sentences and the aims or our paragraphs are identical. These aims hold true at larger scales, too, from word – sentence – paragraph – section – document. Even as we, as writers, shift our focus between these scales, we have a fixed goal to work towards. We are always striving to achieve accessible, unified writing that shares important information.

Approaching the paragraph checklist

Since paragraphs include the relationship of several sentences, we may need to plan more before writing a complete paragraph. For a sentence, we may generally know what we want to say, and we can just start writing. From there, we can revise until we are happy with the product. This approach is certainly possible with a paragraph, but we may be more successful if we plan before just jumping into writing.

1. Does my paragraph tell a compelling story?

Each paragraph has a story, which is informed by the sentences within it and informs the broader story of the section or document it is a part of. The story of the paragraph differs from the stories of each sentence primarily in scale. Whereas a sentence has only a few words to build a storyline, a paragraph has several sentences. In fact, in our scientific writing, the story of each paragraph can often be told in one sentence, the topic sentence. The remaining sentences then support, refute, expand on, or qualify the story in the topic sentence.

Despite this difference in scale, every paragraph has the same components of a good sentence. First, it needs a familiar subject that the audience knows already or can be easily introduced to. It needs some sort of action, clearly describing what the subject is doing, or what is being done to the subject. Finally, it needs a result, describing the consequence of what was done and avoiding any superfluous information.

The actor is the topic sentence of the paragraph. In the case of a sentence, the actor is usually the subject, a noun. For a paragraph, the actor can be a single item, but it may also be a complete statement. The topic sentence is a statement that the reader is familiar with.

The action of a paragraph is the sentences that perform the roles listed above, namely, support or develop the topic of the sentence, or else relate that topic to the rest of the document. This component is often where stories (i.e., paragraphs) can become disjointed by wandering off topic. Writers should be very careful to ensure that the action directly relates to the actor.

The result is the climax of the paragraph where the topic of the sentence is resolved or a conclusion is stated. As with a sentence, the end of the paragraph is where the stress is, so that is where the new information is placed (in most cases) or the topic is resolved.

Topic sentence first

Paragraphs take two general structures when stating the topic. First, the opening sentence of a paragraph can clearly state the topic of the paragraph, making it a topic sentence. This strategy is the most common throughout scientific writing, and we are familiar with it because it has been drilled into our heads in every English class since 1st grade. We state what the topic is, and then we provide evidence to support it or qualify it. Since this structure is so familiar to us, we expect that to find the topic there. Thus, if we read the first sentence of the paragraph, we have a good idea of what it will be about.

Information is interpreted more easily and more uniformly if it is placed where most readers expect to find it – Gopen and Swan

Topic sentence last

Occasionally, beginning with the topic sentence can hinder the story of a paragraph. When a topic sentence includes new, complex, or difficult material, placing it as the lead of a paragraph can confuse and frustrate readers. Confused and frustrated readers stop reading. In these instances, the author may weave together several sentences of more familiar material before reaching the climax of the story, the topic sentence, at the end. This structure is less common than placing the topic sentence first, but it can be a very powerful tool for making a significant or concluding point. Remember, the topic-last format is best employed to make an important point, or to have the final word on a topic. If every paragraph is structured that way, then it is difficult to transition between them.

Good writing includes a combination of these two structures, as varying paragraph structure is just as important as varying sentence structure. One of the most effective ways for a writer to highlight the importance of a paragraph is to make it different from the preceding ones. However, be sure that you vary your structure purposefully, as doing so too frequently can also be confusing.

Pitfalls of not varying paragraph structure

'Topic sentence first' paragraphs only

- Readers become bored
- Readers are confused by new, complex or difficult topics
- Readers do not readily identify important paragraphs

'Topic sentence last' paragraphs only

- Readers do not readily identify the topic of the sentence
- Transitions between paragraphs are difficult
- Forming a cohesive narrative is difficult

2. Does my paragraph express a single thought?

Staying on topic throughout an entire paragraph is much more difficult than staying on topic in a sentence. This difficulty arises from the change in scope. Paragraphs are, by their nature, broader in scope than sentences, so they afford the author more choices in what to include. This increased flexibility comes with a greater danger of wandering off-topic. Since it comprises several sentences, some writers have a tendency to cram several topics into one paragraph. Critically, the focus of the paragraph must remain on a single topic.

Further, sentences about things other than the topic can confuse the reader, as they deflect the attention away from the point of the paragraph. These sentences may be related but are not necessarily relevant to the topic of the paragraph.

Authors often stress about decisions on what information should be included. Sometimes it is even harder to choose *not* to include something. This culling is an important part of the editing process, and we should never think it is a waste of time to write a sentence and then delete it. More often than not, the sentences that do not work well in one paragraph are perfectly suited somewhere else in the document.

Checklist for expressing a single thought

- Is my topic sentence clear? Is it where the reader expects it?
- Do each of my sentences express a single idea?
- Identify the relationship between each sentence and the topic.
- Does my paragraph lead to a single conclusion/resolution?
- Is the resolution a consequence of the other sentences?

3. Is my paragraph grammatically correct?

At the paragraph scale, logical structure is more important than grammatical errors. Creating a clear, coherent progression of thoughts will make our work readable, despite any grammatical mistakes included. Nonetheless, grammar is important in our final drafts, because poor grammar can often lead to ambiguity in our arguments. Additionally, grammatical errors or misused scientific conventions can cause readers to stop reading.

Again, grammar is one of the last things we worry about when writing, primarily because our writing changes so much throughout the rewriting process that it is a waste of time to focus on grammar too much too early. However, in any draft meant for public consumption, at least basic grammatical issues should be corrected.

For specific grammatical concerns, word choice, and other common difficulties with writing mechanics, consult the writing guide distributed at the beginning of the semester.

4. Is my paragraph easy to understand?

The aim of our writing is to disseminate information, and if the paragraphs that we write are not easy to understand, we will not attain our goal. We used the 'Sentence checklist' to determine if our sentences were easy to understand, and we can use the same process for the paragraphs. If the paragraph tells a compelling story about a single topic and is grammatically sound, then the paragraph is likely easy to understand. Once you have produced something that is understandable, it is your job as a scientist to ensure that the content is correct or that the logic is sound.

Working at the paragraph scope means that we have to begin shifting in scales and scopes of our understanding. One way to approach the question 'Is my paragraph easy to understand?' is to look at each sentence to ensure that it passes the 'Sentence checklist'. However, each sentence can make sense on its own but the whole paragraph might not be understandable. Again, the final assessment needs to evaluate how each sentence fits together to create a single, easily understandable paragraph.

Example

There are nine essential micronutrients required for plant growth, manganese is one of them. This element can be found in rocks, soil, and water but crustal rock is the major source of manganese. Other sources that mobilize Mn are ocean spray, forest fires, vegetation, and volcanic activity. Manganese plays many important roles ranging from chloroplast formation and photosynthesis to the synthesis of enzymes. The most common form of manganese is in mineral form which weathers over time, adding manganese to the soil. Most soils will not have a problem controlling manganese levels, but problems can occur in acidic soils. When soils are acidic, manganese becomes too available for the plant, and the plant will uptake an excessive amount of manganese which leads to toxicity. When manganese is not available in adequate amounts to the plant, the opposite will happen, which is a deficiency. A deficiency of manganese will often result in decreased crop yields, stunted plant growth, and death of the plant if the deficiency is extreme.

Initial assessment:
Generally, this paragraph performs its role of conveying information (importance of Mn in plant growth) in an accessible way. It contains a single thought (with some ancillary information), and the grammar and word choice is sufficient to understand the argument. Overall, the paragraph is understandable, and it represents a very good first (or second or third) draft. As a unit, the paragraph is acceptable, but many of its components can be improved.

What is the actor?

The actor in this paragraph is Mn, and the topic statement is the first sentence. It implies that the focus of the paragraph will be on the role of Mn in plant growth.

What is the action?
The action in this paragraph is all supporting the topic sentence. Each sentence should relate to how Mn affects plant growth.

What is the result?
The result, or the purpose of this paragraph, is to conclude that Mn-deficiency harms plant growth.

Does the paragraph express a single thought?
All but two sentences relates to the topic of 'Mn and plant growth'. The second sentence introduces the origin of Mn in soils but does not relate that information to plant growth, as does the fourth. These sentences can be removed or rewritten to convey that information in a way related to the overall topic.

Does each sentence express a single thought?
Yes, this aspect is a strength of this paragraph.

Does each sentence build to the conclusion?
With the exception of the second and fourth sentences, each sentence exists as a progression of thoughts to the conclusion that Mn deficiency is bad for plant growth.

Is the paragraph easy to understand?
The purpose of the paragraph is clear, but unnecessary information (second and fourth sentences) and unclear wording (throughout) keep this from being easily understandable.

A revised version may be:
Manganese is one of nine micronutrients essential for plant growth. It is commonly found in mineral form in soils, with sufficient concentrations provided by the weathering of crustal rock. Having soil with enough plant-available Mn is crucial because it plays a role in many aspects of plant growth, including chloroplast formation, photosynthesis, and enzyme synthesis. Acidic soils are susceptible to problems with plant-available Mn supply because Mn availability increases as pH decreases. This increase causes plants take up the available Mn in excessive amounts, which leads to Mn toxicity. Conversely, in soils without adequate plant-available Mn, plants become Mn deficient. Deficiency in Mn often results in decreased crop yields, stunted plant growth, and, in extreme cases, plant mortality.

Annotations of revisions:

Sentence 1: Removed *There are* construction to make the sentence more direct. **Sentence 2:** Combined the two sentences about origin of Mn in soils, and included a note about sufficient levels to make the information relevant to this paragraph. **Sentence 3:** Restates the importance of Mn in plant growth (relatively unchanged) **Sentence 4:** Explicitly states the relationship between acidic soils and Mn, whereas the original only implied this relationship.
Sentence 5: Splitting the original sentence makes the causal relationship between acidic soils and Mn toxicity more clear.
Sentence 6, 7: Relatively unchanged.

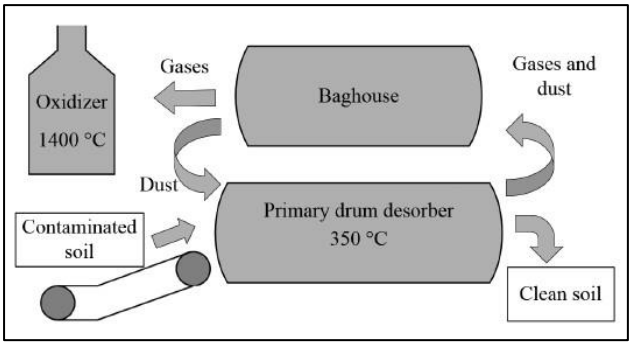
INTERPRETING SCIENTIFIC FIGURES

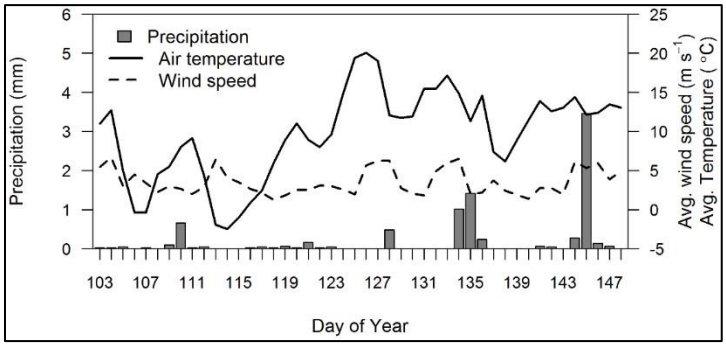
What is a scientific figure?

A scientific figure is any graphical representation of data, coming in the form of a plot, picture, map, diagram, or more. The goal of a figure is to tell, or be part of telling, a meaningful story to the audience.

What types of information do figures show?

Figures showing concepts, flow charts, or pictures are all crucial in scientific literature, popular press, or private industry. However, they do not necessarily show data. These figures may also require some practice to be interpret, but the focus of this module will be on figures that display data.





The figure of the left shows a conceptual diagram, which can be helpful to illustrate processes for readers, but it does not show data. The figure on the right, alternatively, displays data from several climate variables on a single plot.

Data

Data is a difficult concept to describe, but we all seem to know it when we see it. Broadly, it is a collection of items that relay information. As scientists, data typically (but not always) takes the form of numerical observations from our experiments and studies. We classify types of data based on their nature, and we use that classification to determine how best to display that data in a figure.

***Data classification**:*

- Qualitative – numerical information
- Quantitative – words, narratives, or concepts

OR

- Categorical – data that fit into a category, either numerical or text
- Continuous – numerical data that can take any value on a given scale

Essential elements of a figure

Figures are incredibly versatile tools, and so they can tell the same story in many ways. If 30 people were given the same data and told to make a figure, we would likely see 30 different figures, with some quite similar to one another and others entirely unique. Nonetheless, all figures share some essential elements that make them familiar to us.

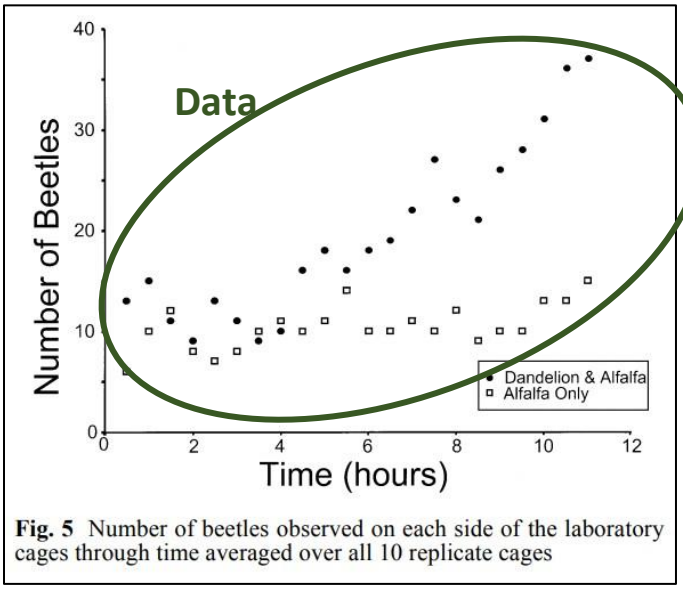


Fig. 5 Number of beetles observed on each side of the laboratory cages through time averaged over all 10 replicate cages

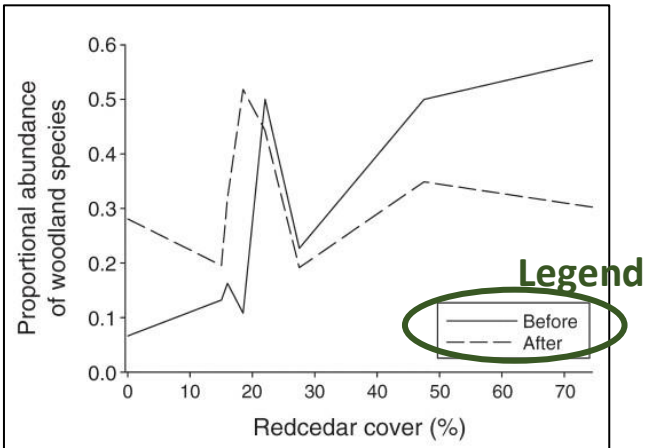
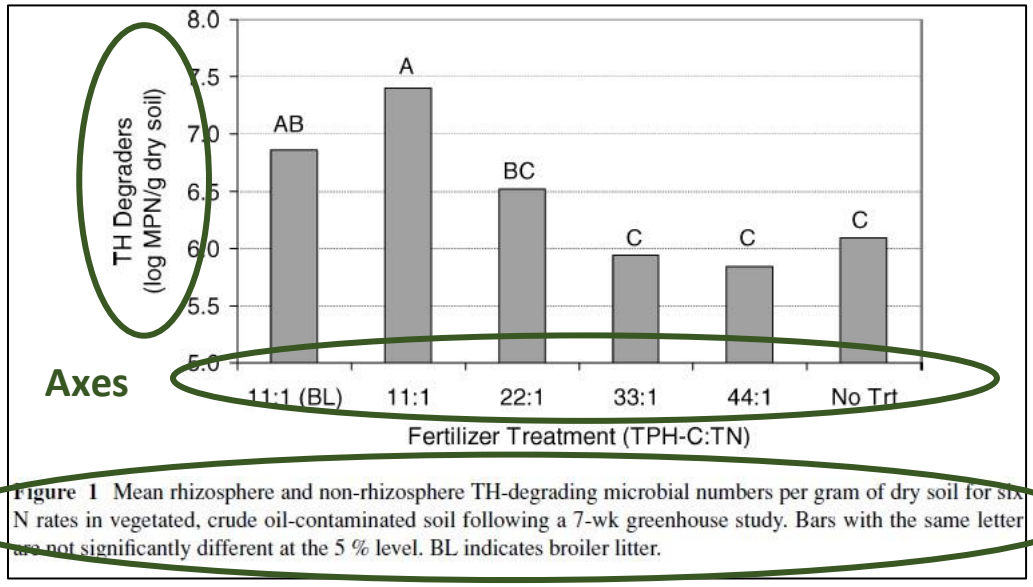


FIG. 6. Proportional abundance of woodland- and grassland-associated small mammals captured on eight sites in north-central Oklahoma, USA, along a gradient of redcedar encroachment before and after experimental redcedar removal.



Caption

Figure 1 Mean rhizosphere and non-rhizosphere TH-degrading microbial numbers per gram of dry soil for six N rates in vegetated, crude oil-contaminated soil following a 7-wk greenhouse study. Bars with the same letter are not significantly different at the 5 % level. BL indicates broiler litter.

Why are all these figures identifiable?

Because they contain:

- **DATA** contained on the plot.
- Horizontal and vertical (x- and y-) **AXES**.
- A **CAPTION** that provides information that is required to understand the figure. **LEGENDS** to differentiate the groups, when more than one is shown

1. **Data**

As we have seen already, the focal point of any figure is the **data**. This data will take the form of points, symbols, lines, bars, and boxes. Additional information on the specific types of figures is included later.

2. Axes

Descriptive **axes** are required for any figure to be meaningful. Axes denote what information is being shown and at what scale. A complete* set of axes include:

A. Horizontal axis (x) and vertical axis (y)
This figure is actually four plots combined. However, each plot is identified by a separate x- and y-axis.

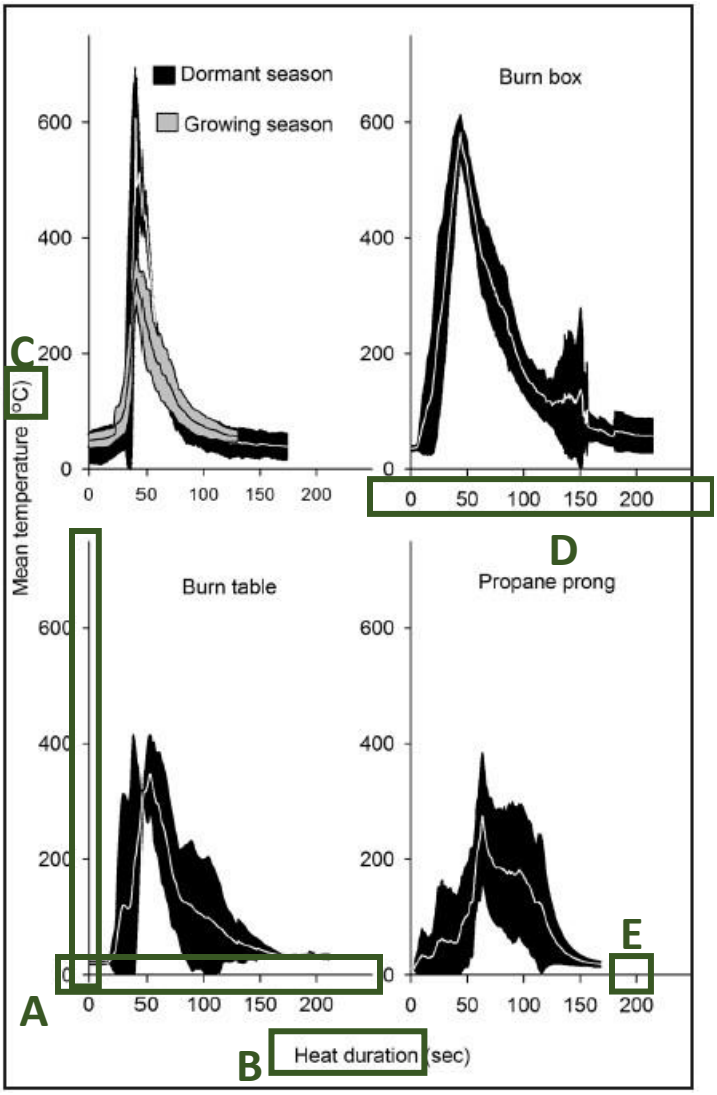
B. Labels – denote the variable or data represented
Both axes must be labelled. Because this figure has four of the same axes, the labels are required only once. **C. Units – included with title**
Axis labels must include units (if applicable) to be meaningful.

D. Scale – denoted by numbers or text along the axis Both axes must include a scale (continuous variables) or identifier (categorical variable).

E. Tick marks/other identifier of increment
Axes should be incremented by tick marks or some other identifier to mark the location of the scaling units.

F. Axes should be consistent throughout the figure
When several plots are shown together, scale should remain consistent. Here, heat duration ranges from 0 – 250 s, and temperature ranges from 0 – 700 C, on all four plots. If plots do not share the same scale, this should be identified in some way on the plot and in the caption.

*One example of each element is offset in **GREEN boxes**



A. Define the axes
The caption defines the variables shown on the figure axes, as well as the units, to make it clear what data is included in the plot. If any of this information is abbreviated on the figure, they should be fully written in the caption.

B. Define the groups/categories
The caption identifies the different groups or categories of data, often corresponding to different treatments of a study. This information is included, even if it is on a legend in the plot. Any abbreviations should be fully written. **C. Include information about data collection** The caption often makes some mention of time, date, location, or method of collection to make the plot more meaningful.

D. Additional annotation (e.g., statistical inference)
The caption further explains any annotation on the plot. Adding letters or text regarding statistical analyses or inference is common, so that information is included in the caption.

3. Caption

The caption is a written description of what the figure portrays. When the caption and the figure are combined, they should include enough information to be meaningful without any additional context from the document it came from.
A good caption should:

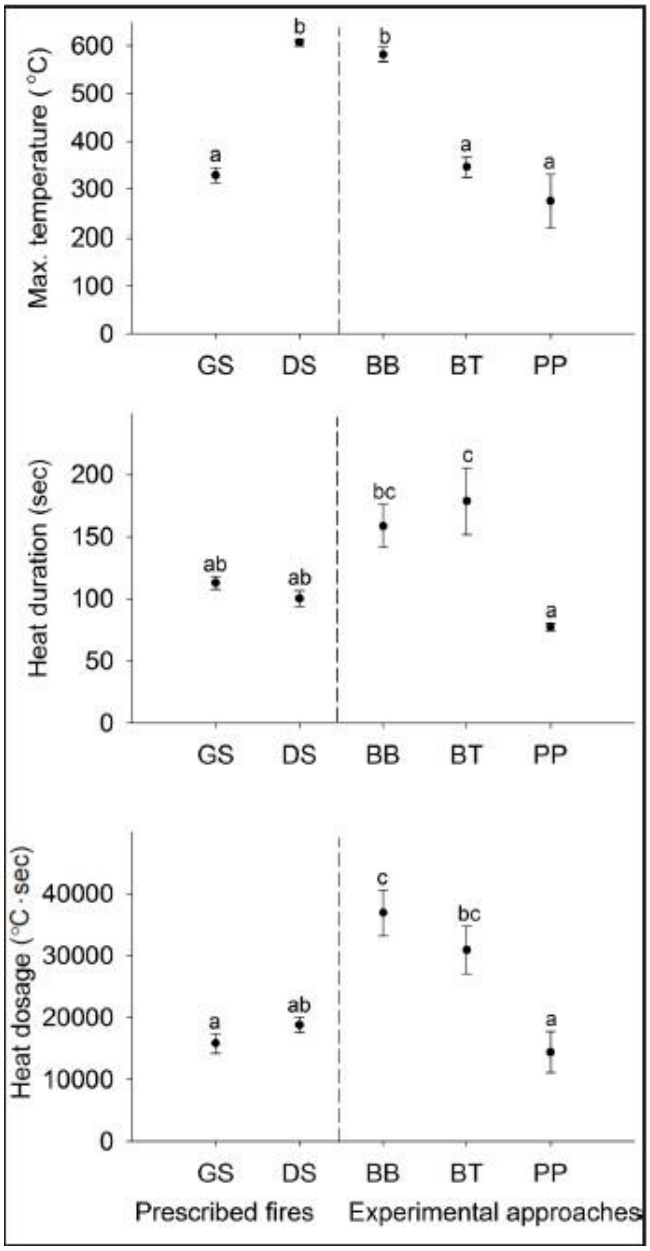
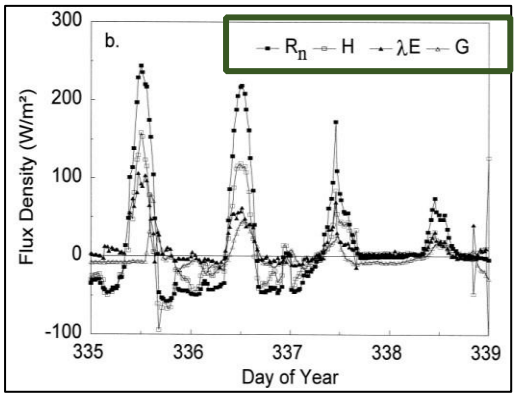
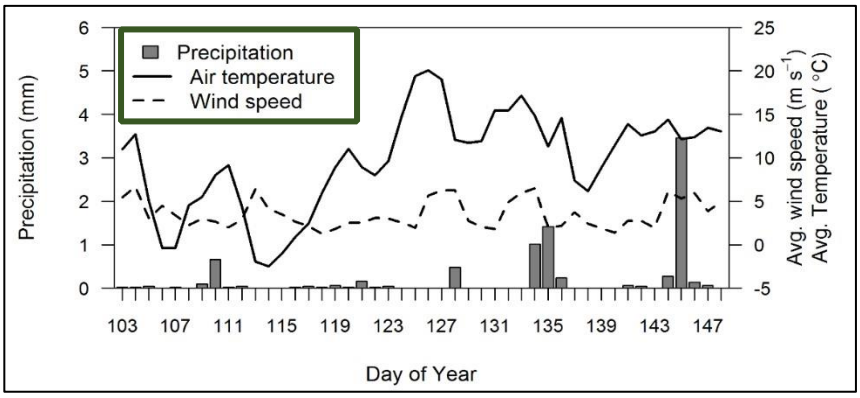


Figure 3. Mean maximum temperature, total heat duration, and heat dosage for growing -season (GS) and dormantseason (DS) prescribed fires and burn box (BB), burn table (BT), and propane prong (PP) approaches in Montana, North Dakota, and Oklahoma, USA, from 2012 to 2014. Error bars are shown for each mean. Different letters correspond to a difference at α = 0.05 within each measurement across fires from the post -hoc Tukey test.

4. Legends

Legends are required to identify the symbology of the data represented. This often comes in the form of different colors, point symbols, line types, or bar/box textures. Without these identifiers, different groupings within the plot cannot be distinguished.



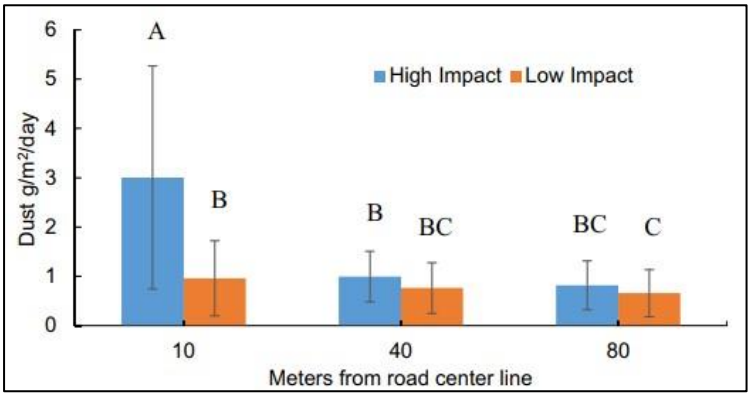


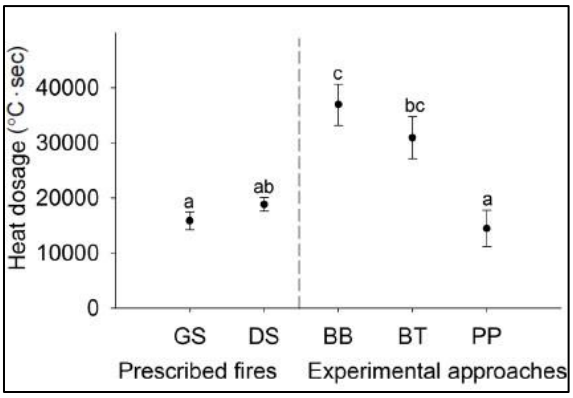
Additional, non-essential elements

Figures also include additional information that may not be required to interpret the data, but it adds meaning to the story the figure aims to tell. In scientific literature, this information is often related to statistical inference based on tests described in the methods. Some common manifestations of this are:

1. ***Measures of variance***
   a. Standard deviation is a measure of the variability of the data. It is best used to describe the range of the data.
   b. Standard error is calculated from the standard deviation, but it takes into account sample size. It is best used to describe how well the sample mean represents the population mean.
   c. Confidence intervals are a range of values that is likely to include a parameter with a specified level of confidence.
2. ***Letters or symbols related to statistical analyses***

Letters or symbols to indicate statistical relationships are especially common in bar plots and box plots, which typically display categorical data. Generally, each bar or box is labelled with a letter (or symbol), and those boxes/bars with the same letter (or symbol) are not statistically different* from one another, while those with different letters (or symbols) are.



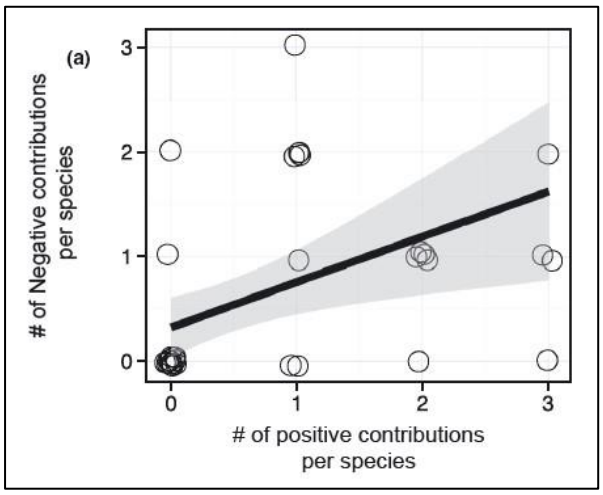


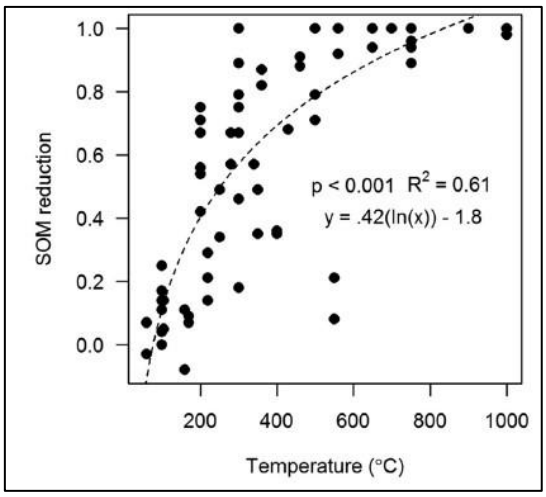
On both of these figures, the measures of variance are represented by bars surrounding the top of the bar plots (left) or each point (right). Further, statistical differences between groups are identified by different letters associated with each bar or point.

3. ***Regression (trend) lines***

Regression lines are commonly used in scatterplots to describe correlations between the variables in a quantifiable way. Trends can be linear or non-linear (e.g., quadratic, logarithmic, exponential), and the

lines are drawn through the scatterplot. The trend lines are drawn from equations calculated to minimize the variation of the observed values from the calculated line. The goodness of fit of these models are typically described by the coefficient of determination, R^2. A high R^2 indicates that the trend line follows the observed values very closely, while a low R^2 indicates more variation between the observed values and the predicted values.





4. Additional text and annotations

Text is often added to figures to highlight a certain point or event, elucidate group differences, or provide ancillary information. Oftentimes, this information is related to statistics, providing regression equations, R^2 values, or p values. Text may also be added to supplement group identification supplied by the legend.

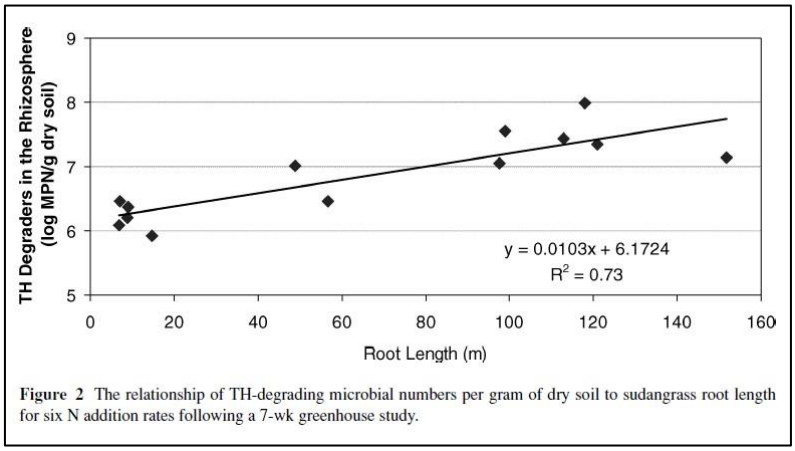
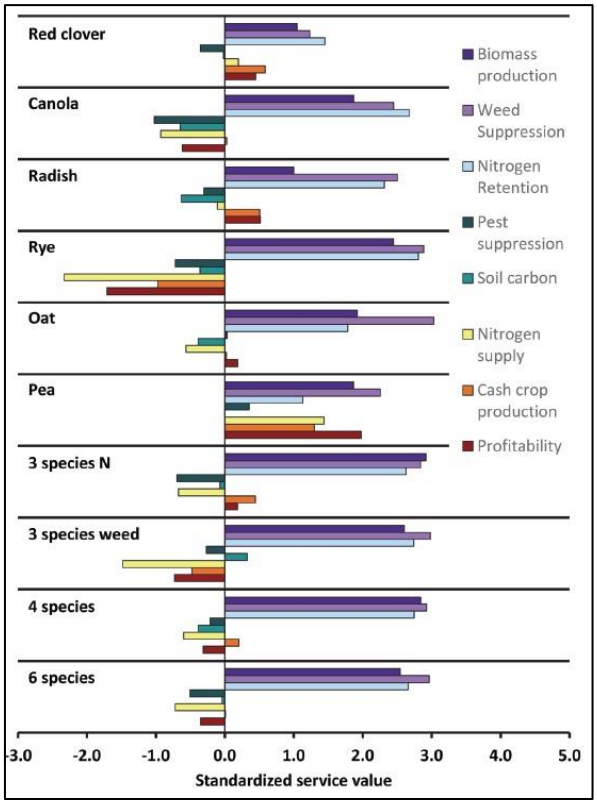


Figure 2 The relationship of TH-degrading microbial numbers per gram of dry soil to sudangrass root length for six N addition rates following a 7-wk greenhouse study.

The figure above shows the regression equation and R^2 value as text, while the text is used on the right to identify different groups that are not identified in the legend.



How to interpret a figure

Now that we can identify the parts of a figure, we can begin to assess the information that is actually being displayed. When you see a figure, you should approach it is a two-step process.

1. Determine what the figure is displaying.

This step is the basic understanding of the figure that comes from understanding what a figure is and what each part represents. We can accomplish this step by asking:

- What type of figure is it?
- Is it a complete figure? Are all of the elements included and easy to understand?
- What type of data is displayed?
- What additional information is included?
- Does the caption thoroughly explain the figure?

2. Determine the primary message of the figure.

As we have seen with scientific writing, the purpose of a figure is to tell a clear, compelling story to convey some sort of message. Determining this message can sometimes be complicated because the method of displaying data is unique to each figure type. However, a well-made figure tells an easily understandable story because everything is where the viewer expects it to be. The most important message of the figure should be the most eye-catching aspect to the figure. Thus, to determine the message of any type of figure, we can ask:

- What is the first thing your eyes are drawn to?
- What are the general relationships among the data?
- Are there any outliers?
- How much variation is present in the data?
- How does the scale of the figure add context to the message?

- Is any scientific notation or additional text included?

Four common types of figures

Scatterplot

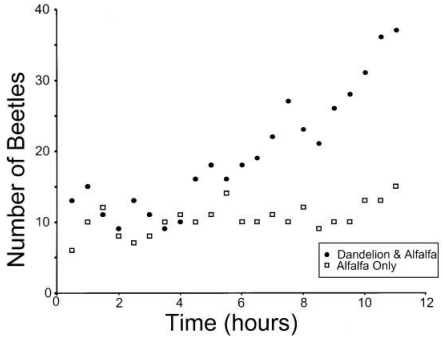
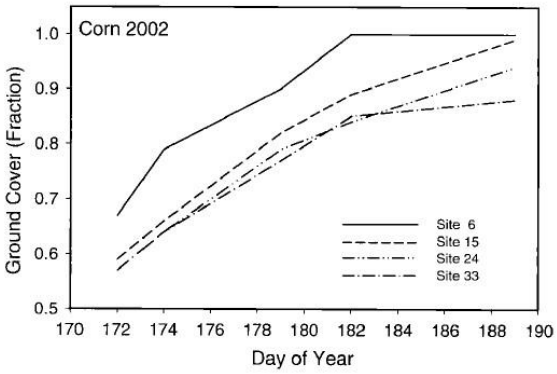
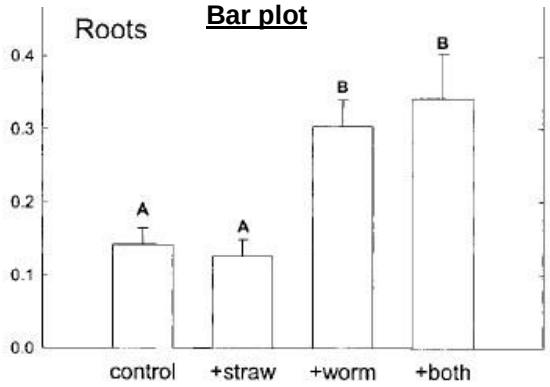


Fig. 5 Number of beetles observed on each side of the laboratory cages through time averaged over all 10 replicate cages

Line plot

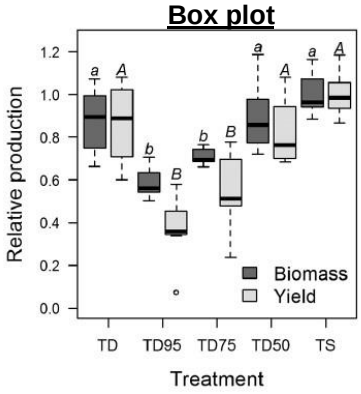


Bar plot



Examples – Scatterplot

Box plot



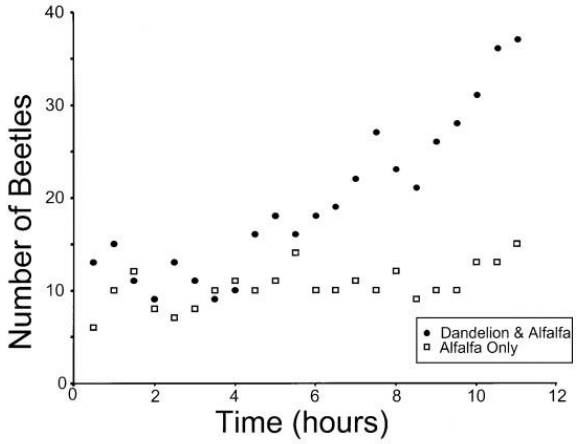


Fig. 5 Number of beetles observed on each side of the laboratory cages through time averaged over all 10 replicate cages

Step 1:

- **What type of figure is it?** Scatter plot with two groups of points
- **Is it a complete figure? Are all of the elements included and easy to understand?** Yes, axes are labelled with units and scale. A legend identifies the two groups of points, and a caption further describes what is shown.
- **What type of data is displayed?** Continuous on both x-axis and y-axis.
- **What additional information is included?** No additional elements.
- **Does the caption thoroughly explain the figure?**

Yes, caption clearly explains what data is displayed in the figure.

Step 2:

- **What is the first thing your eyes are drawn to?**

Splitting of filled circles and open boxes on the right side of the plot. (this will be different for each person)

- **What are the general relationships among the data?**

As time (x) increases, number of beetles (y) generally increase. They increase faster for closed circles than for open squares.

- **Are there any outliers?**

No clear outliers are present.

- **How much variation is present in the data?**

Some variation is occurring, as not all points are in a straight line. However, variation is not so wide as to hide the general trend.

- **How does the scale of the figure add context to the message?**

We know that this is a study looking at daily trends rather than monthly or seasonally. And we know that the number of beetles can easily be counted, so the size of the area is likely not too large.

- **Is any scientific notation or additional text included?**

No notation or other elements of statistical inference are included.

Examples – Line plot

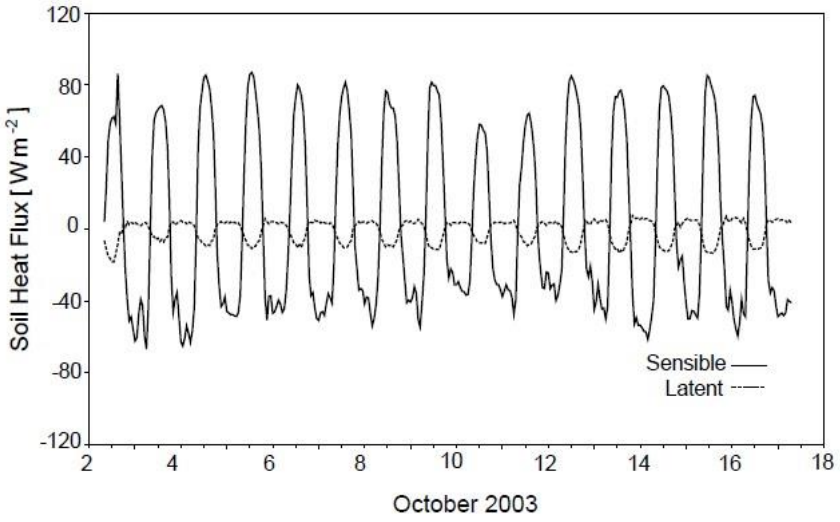


Figure 4 Simulated energy flux due to conduction (sensible) and vapor transfer (latent flux), at 2 cm soil depth.

Step 1:

- **What type of figure is it?**

Line plot showing a time series of two different variables, sensible and latent fluxes.

- **Is it a complete figure? Are all of the elements included and easy to understand?** Yes, axes are labelled with units and scale. A legend identifies the two lines of points, and a caption further describes what is shown.
- **What type of data is displayed?** Continuous on both x-axis and y-axis.
- **What additional information is included?** No additional elements.
- **Does the caption thoroughly explain the figure?**

Yes, caption clearly explains what data is displayed in the figure.

Step 2:

- **What is the first thing your eyes are drawn to?**

The large difference in magnitude between the two variables, as well as the clear diurnal trends. (this will be different for each person)

- **What are the general relationships among the data?**

Both variables show diurnal trends of increasing and decreasing at different times of the day. The trends are inverse, such that as latent increases, sensible decreases, and vice versa. Further, the magnitude (both maximums and minimums) of variation is much higher in sensible. **Are there any outliers?**

No clear outliers are present.

- **How much variation is present in the data?**

The diurnal trends are evident, but the peaks are consistent throughout the figure, especially for the latent. Sensible peaks are slightly lower between 10 Oct and 12 Oct.

- **How does the scale of the figure add context to the message?**

We can determine that, for the month of October, these variables change daily, but the monthly trends appear consistent.

- **Is any scientific notation or additional text included?**

No notation or other elements of statistical inference are included.

Examples – Bar plot

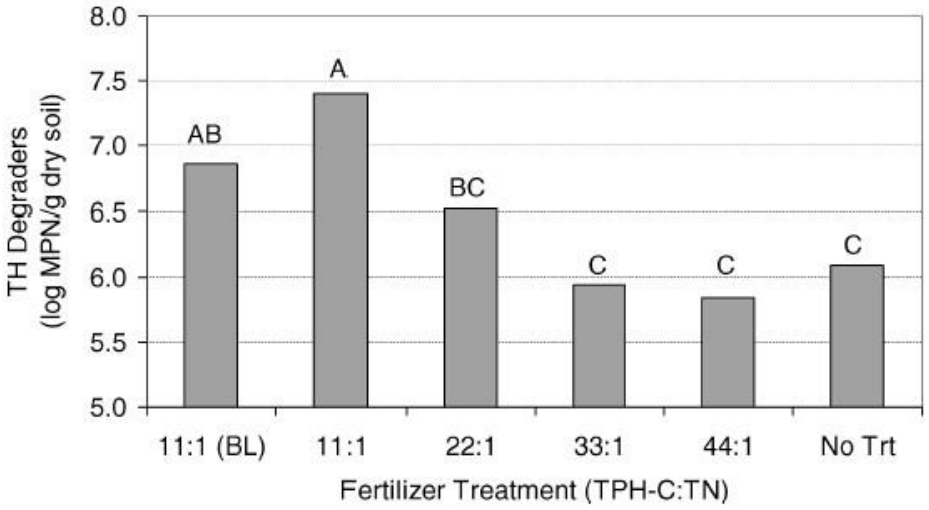


Figure 1 Mean rhizosphere and non-rhizosphere TH-degrading microbial numbers per gram of dry soil for six N rates in vegetated, crude oil-contaminated soil following a 7-wk greenhouse study. Bars with the same letter are not significantly different at the 5 % level. BL indicates broiler litter.

Kirkpatrick et al., 2008

Step 1:

- **What type of figure is it?**

Bar plot showing several categories with of a single response group.

- **Is it a complete figure? Are all of the elements included and easy to understand?** Yes, axes are labelled with units and scale. A legend identifies the two lines of points, and a caption further describes what is shown.
- **What type of data is displayed?**

Continuous on the y-axis and categorical on the x-axis.

- **What additional information is included?** Letters are included above each bar.
- **Does the caption thoroughly explain the figure?**

Yes, caption clearly explains what data is displayed in the figure, including the statistical inference. However, the abbreviation TH is not defined.

Step 2:

- **What is the first thing your eyes are drawn to?**

Bars on the left side of the figure are higher than those on the right. (This will be different for each person) **What are the general relationships among the data?**

Treatments with lower TPH-C:TN ratios have higher amounts of TH-degraders. As fertilizer ratio increases, TH decreases until ratio hits 33:1, above which TH-degrader amount remains consistent.

 Are there any outliers?

No clear outliers are present.

- **How much variation is present in the data?**

No measure of variation within each treatment is included. Variation among the treatments is indicated by the scale of the plot and the letters denoting statistical inference.

- **How does the scale of the figure add context to the message?**

Log scales are useful when showing data that span several orders of magnitude. They are also often used when transforming data to fit a normal distribution to meet assumptions required for analysis. **Is any scientific notation or additional text included?**

From the caption, we see that bars with different letters indicate significant statistical difference between the categories. Thus, 11:1 treatment is statistically higher than the 22:1 treatment (they do not share a letter) but not statistically different from the 11:1BL treatment (they share the letter “A”)

INTERPRETING SCIENTIFIC TABLES

What is a scientific table?

A table is a series of columns and rows that present information as either numbers or text. Tables are best used i) when displaying large amounts of numerical data, and ii) when the absolute values reported are important, rather than just the relationships between different groups. As with all components of scientific writing, tables are used to tell a meaningful story to the reader. Thus, the purpose of each table should be clear, and each table should be easily interpreted.

Essential elements of a table

Tables can be widely variable, but they are generally recognizable because they contain rows and columns of information. To properly tell a story to the reader, they must also contain several other elements.

1. **Body of information**
2. **Table caption**
3. **Column (and row) headings**
4. **Column (and row) units**
5. **Footnotes/legend to define symbols**
6. **Lines separating different parts of the table**
7. **Letters and symbols for statistical inference**

1. Body of information

The body of a table is the information that is being reported, taking the form of rows and columns of numbers and text. Although conveying this information is the purpose of the table, it does not make any sense without the context added by the other elements of the table. Tables are organized around the two types of information they show. First, they show groups or categories of interest. Second, they show attributes of those groups or categories, most often measured variables.

Most commonly, the groups/categories of information are displayed in rows, and the attributes are displayed in columns. In some cases, this setup may not be an efficient use of page space, so tables can show the attributes as rows and the categories as columns.

In the example below, the body of the text is identified by brackets. The body is arranged so that the rows represent groups, and the columns represent measured attributes.

Table 3. Proportion of water-stable aggregates within each size distribution.

Soil†	Size distribution‡			
	LM	SM	m	Total aggregation
	g sand free aggregate g^{-1} soil			
TS	0.05 ± 0.007a§	0.18 ± 0.004a	0.27 ± 0.013a	0.50 ± 0.012a
TS-TD	0.05 ± 0.008a	0.15 ± 0.006b	0.21 ± 0.007b	0.41 ± 0.010b
SS	0.01 ± 0.006b	0.12 ± 0.008c	0.29 ± 0.005a	0.41 ± 0.004b
SS-TD	0.04 ± 0.004a	0.11 ± 0.003c	0.24 ± 0.006b	0.39 ± 0.008b

† TS, topsoil; TS-TD, thermal desorption–treated topsoil; SS, subsoil; SS-TD, thermal desorption–treated subsoil.

‡ LM, 2000–8000 µm; SM, 250–2000 µm; m, 53–250 µm; total aggregation, 53–8000 µm.

§ Different letters within columns indicate significance at $\alpha = 0.05$ (Tukey's HSD test).

Table 1. Selected soil properties of native, noncontaminated topsoil (TS) and contaminated subsoil material treated by thermal desorption (TD) at time of planting. Standard error included in parentheses. Both TS and TD were the same materials in Studies 1 and 2. The values for the soil mixtures in both studies can be calculated using the TS:TD ratio of each treatment.

Caption

Column heading

Property†	Units	Soil	
		TS	TD
Sand	g kg^{-1}	454 (23)	434 (17)
Silt	g kg^{-1}	330 (90)	326 (14)
Clay	g kg^{-1}	219 (22)	239 (9)
SOC	g kg^{-1}	30 (4)	1.5 (0.7)

2. Table caption

Table captions should be detailed enough such that the table can be understood without reading the accompanying text. A good caption should define the groups/categories, identify the type of information being shown, mention important information about data collection, and address additional annotations (e.g., statistical inference).

In the example above, the caption defines i) what the attributes are (selected soil properties), ii) the different groups (TS and TD), iii) when the values were measured (time of planting), and iv) what values in the parentheses indicate (standard error).

3. Column (and row) headings

Column headings should clearly define what information is included in each column. If abbreviations are used, they should be defined in either the caption or footnotes. Bars should be included linking similar columns together under a common heading, while those without a relationship should not be linked with bars.

In the example above, the column headings are shown in bold above the body of the table in a shaded box. The headings clearly define what each column shows. Notably, the bars link the different soil types (TS and TD) beneath the 'Soil' heading, but they do not link either the property or units columns together.

4. Column (and row) units

The values of each column and row should be associated with units. Units can be defined in the column or row headings, or they can be displayed in a separate row/column. Columns with the same unit can be grouped together with bars.

In the example above, the units are shown in their own column, with each row corresponding to a separate soil property.

5. Footnotes to define abbreviations and symbology

Given the lack of space in columns and rows, abbreviations and symbology are common. Each time an abbreviation or symbol is used, it must be defined, either in the caption or in footnotes at the bottom of the table.

In the example below, footnotes are used to define the abbreviations in both the groups (soil types) and the attributes (aggregate size distribution). Additionally, the footnotes indicate the statistical test used to infer significant differences among the groups (Tukey's HSD test).

6. Bars separating different parts of the table

Bars (or lines) are used in tables to link similar items and separate dissimilar ones. As seen above, bars can link columns together, and not linking columns indicates that they do not share a relationship. Similarly, bars may be drawn across larger portions of the table to indicate different parts of the table. A bar is nearly always drawn to separate column headings from the body of the table, and a bar is nearly always drawn across the bottom of the table to signify its conclusion and separate it from the footnotes. Bars within the body of the table can be used to separate different groups or types of information.

In the example below, bars are used to i) separate the top of the table from the caption, ii) set off the column headings, iii) link the size distribution columns, iv) indicate that all of the size distributions share the same units, and v) separate the table from the footnotes below.

7. Letters and symbols for statistical inference

Symbology is often used to indicated statistical inference in tables, namely when the values in one group are significantly different from those in another group. These differences may be indicated by symbols or by letters. Additionally, some tables include measures of variance, such as standard deviation, offset by parentheses, italics, or ± symbols.

In the example below, letters are used to indicate statistical significance with each column using Tukey's HSD test (information from footnotes). Thus, within each column, groups with the same letter *are not* statistically different, while groups that do not share a letter *are* significantly different from one another.

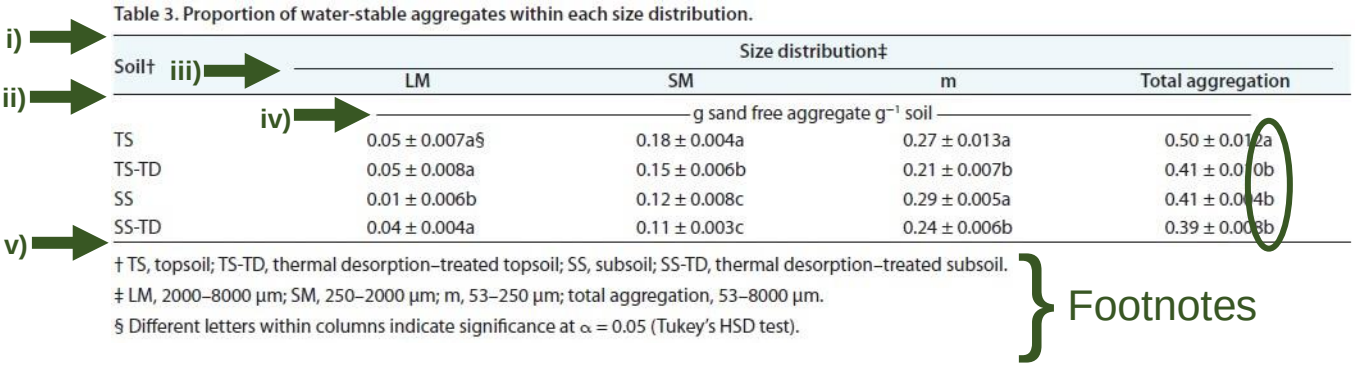


Table 3. Proportion of water-stable aggregates within each size distribution.

i)

Soil† iii)	Size distribution‡			
ii)	LM	SM	m	Total aggregation
iv)	g sand free aggregate g^{-1} soil			
TS	0.05 ± 0.007a§	0.18 ± 0.004a	0.27 ± 0.013a	0.50 ± 0.012a
TS-TD	0.05 ± 0.008a	0.15 ± 0.006b	0.21 ± 0.007b	0.41 ± 0.010b
SS	0.01 ± 0.006b	0.12 ± 0.008c	0.29 ± 0.005a	0.41 ± 0.004b
SS-TD	0.04 ± 0.004a	0.11 ± 0.003c	0.24 ± 0.006b	0.39 ± 0.003b

v)

† TS, topsoil; TS-TD, thermal desorption–treated topsoil; SS, subsoil; SS-TD, thermal desorption–treated subsoil.
‡ LM, 2000–8000 µm; SM, 250–2000 µm; m, 53–250 µm; total aggregation, 53–8000 µm.
§ Different letters within columns indicate significance at $\alpha = 0.05$ (Tukey's HSD test).

Footnotes

How to interpret a table

Now that we can identify the parts of a table, we can begin to assess the information that is actually being displayed. When you see a table, you should approach it is a two-step process.

1. **Determine what the table is displaying.**

This step is the basic understanding of the table that comes from understanding what a table is and what each part represents. We can accomplish this step by asking:

- Is it a complete table? Are all of the elements included and easy to understand?
- What type of data is displayed?
- How are the data grouped?
- What additional information is included?
- Does the caption thoroughly explain the table?

2. **Determine the primary message of the table.**

As we have seen with scientific writing, the purpose of a table is to tell a clear, compelling story to convey some sort of message. Determining this message in a table can sometimes be complicated because tables are commonly used to display large amounts of data. However, a well-made table draws the reader's attention to the important data and tells an easily understandable story. For a figure, the most important message of the figure should be the most eye-catching aspect, but a table places the most important information at the top. The first few rows hold the most important information because readers approach tables from top to bottom. Thus, to determine the message of any type of table, we can ask:

- What is the first thing reported in the table?
- Do the values reported make sense?
- What are the general relationships among the data?

- Is any statistical notation or measure of variance included?

Caveat for tables

While figures will usually be used to show some important relationship in the data, tables may not always play such a critical role. Often, tables are used as a tool to report large amounts of data to i) set the stage for more important results, ii) demonstrate that the researchers accounted for a given number of variables, or iii) provide ancillary information to support a claim in the main document. Thus, we should not seek to make every table seem more important than it is. Some tables play ancillary roles to the primary storyline, and that is perfectly acceptable. In these cases, identify the information the table provides, relate it to the main argument in the document, and move on.

Example

Table 8. Gibb's free energies (ΔG_{ex}) and Vanselow selectivity coefficients (K_{ex}) for the untreated, noncontaminated topsoil profile (TS), the thermally desorbed, noncontaminated topsoil profile (TS-TD), the untreated, noncontaminated subsoil profile (SS), and the thermally desorbed, noncontaminated subsoil profile (SS-TD) of the Ca–Mg, Ca–K, and Mg–K exchanges.

Exchange reaction	Treatment	K_{ex}	ΔG_{ex} (kJ mol^{-1})
Ca–Mg	TS	0.8 (0.01)†A‡	0.52 (0.04)A
	TS-TD	0.9 (0.02)B	0.32 (0.06)B
	SS	1.3 (0.04)a	-0.70 (0.07)a
	SS-TD	1.4 (0.04)b	-0.86 (0.08)b
Ca–K	TS	6.5 (0.13)A	−4.63 (0.05)A
	TS-TD	8.7 (0.14)B	−5.35 (0.04)B
	SS	19.3 (1.52)a	−7.33 (0.20)a
	SS-TD	18.2 (0.33)a	−7.18 (0.04)a
Mg–K	TS	9.8 (0.29)A	−5.66 (0.07)A
	TS-TD	8.6 (0.11)B	−5.35 (0.03)B
	SS	7.3 (0.29)a	−4.92 (0.10)a
	SS-TD	8.2 (0.24)b	−5.21 (0.07)b

† Values in parentheses are SD.

‡ Capital letters indicate significant differences ($p < 0.05$) between untreated and thermal desorption (TD)-treated topsoils within the respective exchange reactions and columns. Lowercase letters indicate significant differences ($p < 0.05$) between untreated and TD-treated subsoils within the respective exchange reactions and columns.

Step 1:

- **Is it a complete table? Are all of the elements included and easy to understand?** Yes, it includes a table body, caption, column headings, units, footnotes, bars for separation, and symbology for statistical inference.
- **What type of data is displayed?**

Numerical values represent the Gibb's free energies and Vanselow selectivity coefficients for three exchange reactions. These values are shown for four different treatments.

How are the data grouped?

Reading from left to right, the first grouping is by exchange reaction. A second, sub-grouping is by soil treatment.

- **What additional information is included?**

Footnotes show that a measure of variance (standard deviation) are included with the mean values, as well as letters for statistical inference.

- **Does the caption thoroughly explain the table?**

The caption (and footnotes) define all of the elements of the table, and they provide enough information to understand what the table is showing.

Table 8. Gibb's free energies (ΔG_{ex}) and Vanselow selectivity coefficients (K_{ex}) for the untreated, noncontaminated topsoil profile (TS), the thermally desorbed, noncontaminated topsoil profile (TS-TD), the untreated, noncontaminated subsoil profile (SS), and the thermally desorbed, noncontaminated subsoil profile (SS-TD) of the Ca–Mg, Ca–K, and Mg–K exchanges.

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	SS-TD	8.2 (0.24)b	–5.21 (0.07)b

† Values in parentheses are SD.

‡ Capital letters indicate significant differences ($p < 0.05$) between untreated and thermal desorption (TD)-treated topsoils within the respective exchange reactions and columns. Lowercase letters indicate significant differences ($p < 0.05$) between untreated and TD-treated subsoils within the respective exchange reactions and columns.

Step 2:

- **What is the first thing reported in the table?**

The first reaction is Ca-Mg, and the first two treatments are TS and TS-TD. Placing these items first suggests that they may be the most important to telling the story in the rest of the document.

- **Do the values reported make sense?**

These attributes are likely unfamiliar to the general reader, so they may not have an idea for what reasonable values should be. However, scrutinizing the data shown in the table, the reader can identify that, while some differences exist, no huge outliers are present that could call the validity of the data into question.

- **What are the general relationships among the data?**

The absolute values (and variance) are lowest in the Ca-Mg reaction, intermediate in the Mg-K reaction, and highest in the Ca-K reaction. In the Ca-Mg and Ca-K reactions, the TS values are lower than SS, but not in the Mg-K. Similarly, no clear relationship between TS and TS-TD or SS and SS-TD are evident, as sometimes they are higher and sometimes lower for both attributes.

- **Is any statistical notation or measure of variance included?**

Standard deviation is included, and it is generally consistent between both attributes. Statistical testing occurs separately between the TS and TS-TD and SS and SS-TD for each exchange reaction. Notably, K_{ex} is typically higher in both TS-TD and SS-TD than TS and SS, respectively, while G is typically lower.

FINDING SCIENTIFIC LITERATURE

Why is being able to find it important?

Up to now, we have been given articles to read that are legitimate sources of information relevant to our topic. Being able to read and understand those articles we are given is critical to evaluating our topic, but equally important is being able to find that information ourselves. A huge part of being a good scientist is understanding what has been done already. To do that, we must be able to search, find, and contextualize the existing knowledge on our topic.

Before we search, decide what to search for

Diving right in to a search is appealing because it feels like accomplishing something. It may be a good tactic when we are doing preliminary searches to see what is available about a given topic. However, spending too much time searching (and reading) without a plan can end up wasting a lot of time. Either we will read a lot of irrelevant content, or we may find content from dubious sources that we cannot use anyway.

*We are always searching for **relevant content** found in **legitimate sources.***

Relevant content

The most important step in finding relevant content is determining your research question. Once you have a clear research question, you can start assessing whether or not articles you find are relevant. The degree of relevance will be different for each type of question. For some questions (e.g., crop response to fertilizer rates), hundreds of studies and reviews have been done on that subject. Finding relevant information then becomes identifying studies with similar local considerations, such as climate, soil type, plant community, etc. For other topics (e.g., thermal desorption implications for soil reclamation), very little work has been done. Thus, the scope of relevant literature becomes much broader and requires some inference to be applied to your project.

When determining if a source is relevant, remember:

- Your research question may change as you learn more about it.
- Since your question may change, keep an open mind about relevance.
- It is always better to have more sources than you need than not enough.

Legitimate source

As we all know, we can find support for almost any claim on the internet. With this overload of information, the fact-based sources can be over-shadowed by non-fact based sources. For scientists, using trustworthy sources is of the utmost importance to validate our work and uphold our credibility. Thus, when we look for information to corroborate, justify, contextualize, or refute our own work, we need to be skilled at determining which sources are legitimate and which should be ignored.

When determining if a source is legitimate, ask:

- What type of source is it?
- What category does it fall in?
- Where was it found?

1. What type of source is it?

The backbone of scientific advancement is the peer-review process, wherein each scientist's work is scrutinized and critiqued by a group of peers. This process is far from perfect, but it does offer a standard of legitimacy for published work. Since it has been reviewed by other experts, peer-reviewed literature is the most legitimate source that we can use; we prefer it to other types.

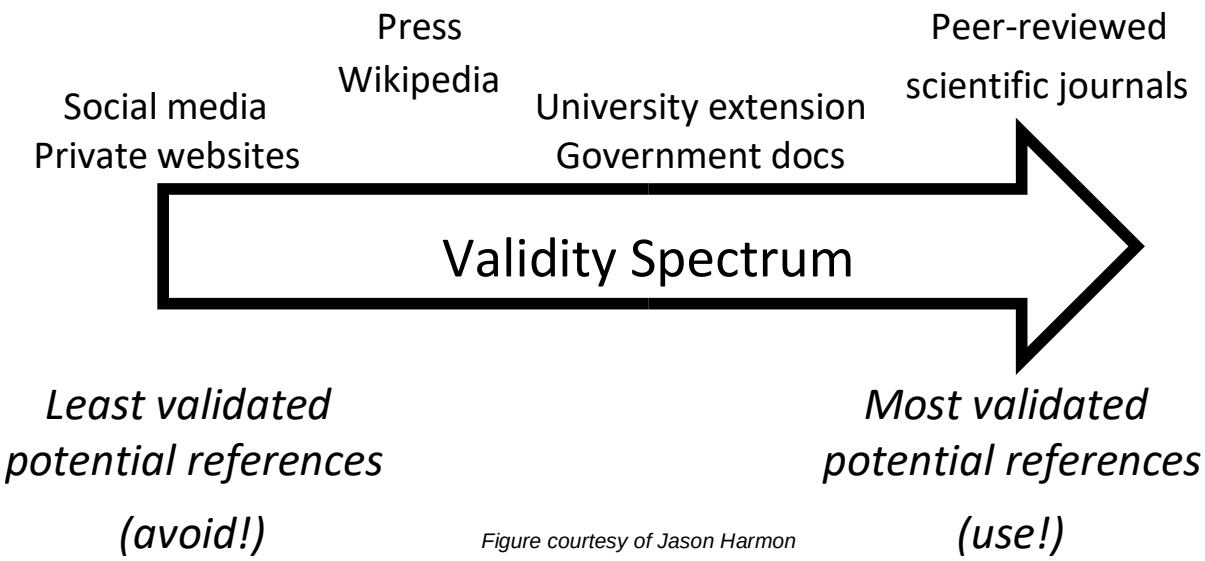


Figure courtesy of Jason Harmon

The figure above shows a validity spectrum for references defined by how much external, objective validation the reference has received. We should make sure to use the most validated references possible from the most trusted sources (right side of the spectrum).

2. What category does it fall in?

We see that peer-reviewed scientific journals is the farthest to the right of our validity spectrum, so we try to use these sources whenever possible. We use these sources so frequently that we actually divide them into two sub-categories.

- ***Primary literature***: articles that document a specific research project (e.g., research articles)
- ***Secondary literature***: articles that synthesize the knowledge found in primary literature but not associated with an actual experiment (e.g., literature reviews, meta-analyses)

Two additional categories for possibly usable sources are:

- ***Tertiary literature***: publications that are based on primary and secondary literature but that are written to be accessible to a lay audience (e.g., popular press articles about science, textbooks)
- ***Grey literature***: sources of information that are not published but may be generated by experts (e.g., government documents, student dissertations, conference proceedings)

As noted on the spectrum above, ***do not use*** Wikipedia, private websites, or social media.

3. Where was it found?

Identifying the source of information is critical in evaluating its legitimacy. Many types of 'grey literature', such as government reports or university extension documents, may be produced by experts and acceptable for use. Others, however, could be inappropriate, such as a report posted by an individual on a blog. The information may have some merit, but it is not acceptable for use in scientific discourse.

- ***Is the information linked on a government or university website?***

These sites often have some oversight for what is posted.

- ***Is the author clearly acknowledged? Can we find information about the author?***

Documents authored by respected people or institutions may be acceptable, even if they have not gone through peer-review.

Where should we look?

Once we have an idea of what we are looking for (that is, we have a clearly defined research question and an understanding of source legitimacy), we can start an actual search. Nearly all of our research will be done through online resources, whether they be through NDSU libraries, Web of Science, Google Scholar, or others. However, remember that the ***actual*** library exists, and it offers some excellent services.

1. NDSU Library – physical location

- Use the research librarians

The librarians are the greatest resource found at the library. They can answer questions you have, and they can guide you in areas that you have not considered yet. Additionally, an Agricultural Sciences Librarian (currently Nicole Juve) is available to guide students from SNRS in discipline specific research.

- Look at actual books

Sometimes the immense amount of information available through internet searches can be overwhelming. When you are immersing yourself in a new topic, that inundation of information can be counterproductive. Go to the library and find a book on your topic, even if it is from several years ago. The authors of these books sifted through all of the available information and chose to include what was important, so they may be a good tool to guide further inquiry.

- Accessing older information

For some research questions, especially those locally based, old material is essential. The library has archives of old journals, newspapers, and government documents that have not been scanned into digital copies.

2. NDSU Library – online resources

- Search physical resources

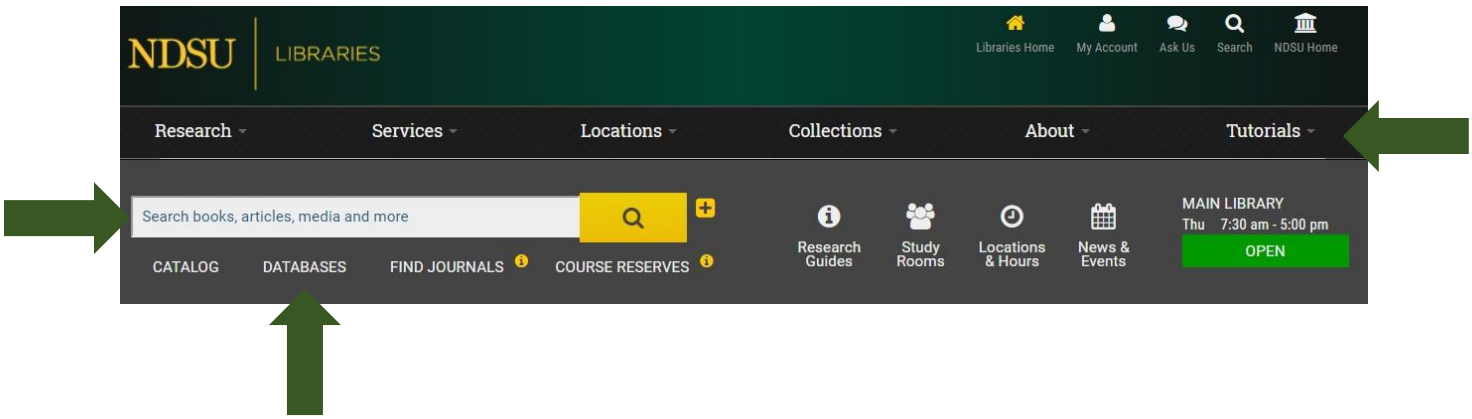
Akin to an old card catalog, we can search NDSU library materials through the main website. This search includes both physical and digital materials.

- Tutorials

The NDSU Librarians created numerous guides (similar to this one, but much more exhaustive) that will help us find sources, write about them, and even complete other assignments. Use these tutorials to help you get the most out of the library resources.

- Links to databases

The databases that we can access through NSDU Libraries will be the most important way to find legitimate sources. We gain access to thousands of scientific journals, abstracts, conference proceedings, and more. Within each database, we can specify what type of information we are searching for (e.g., peer-reviewed, literature reviews).



Web of Science*
Web of Science is a database created and managed by Thomson Reuters (a private company). NDSU and other universities subscribe to their services so that their students can use the database to find references.

Strengths
One of the real strengths of Web of Science is that it is (mostly) trying to give you *just* references from peer-reviewed scholarly journals. Sometimes journals seem like they would be appropriate on the surface but might not actually be peer-reviewed. Web of Science solves that problem in that they are only going to give you results from reputable, validated sources. Sometimes we say that the journals that produce these potential references are "indexed" because they are included in databases like Web of Science. Now, some smaller but still reputable and peer-reviewed journals are not indexed, but that number seems to be decreasing all the time. You can always go to a journal's web site and evaluate them for yourself. Do they say they are indexed? Do they seem to have reputable scientists on their editorial board (those are the official, objective gatekeepers)? Moreover, you should feel free to ask your mentor or peers if a journal in your field is appropriate.

A word of warning: Web of Science is going to make you feel good about returning results from peerreviewed journals, but that does not mean that every reference it gives you is primary or even secondary literature. For example, some journals publish abstracts for presentations at scientific conferences. Others publish longer articles that are called "proceedings" that are also closely tied to a talk that was given. Both of these things may or may not have had the same level of peer-review and professional scrutiny that we want. Moreover, some journals publish opinion pieces that again may or may not have any level of peer-review. I am not saying you need to be dubious (again, all references are a chance to learn), but I am saying that you should pay attention to what you are looking at or reading. Most results are going to be peer-reviewed articles that present new data or are appropriate reviews of the literature, but there will be occasional exceptions. With a little experience, you will be able to quickly pick out the rare exceptions that are not peer-reviewed references.

How do I find Web of Science?
The quick answer is: http://apps.webofknowledge.com. This will probably work, especially if you are on NDSU campus.
If you are off campus, you may find it easier to go through the NDSU Libraries home page: https://library.ndsu.edu/. There you can pick "Databases" and then "Web of Science". You'll notice that you can choose between core collection and all databases. That is something you can also choose from within the page and I will mention the choice again in a moment (for now choosing either one will be okay). The benefit of going through the library is that at some point it should ask you to enter in your NDSU login information. This will confirm that you are a student and have access to all of the library's resources.

How do I use Web of Science?

As a starting-off point, I am going to give you a video by Thompson Reuters (the company that makes Web of Science). I also have a few notes and one important thing I want to emphasize that I will list after the link. You may want to look at those before or during the video:
https://www.youtube.com/watch?v=Ulfu0njSZN0

The video discusses choosing between their different database options. Generally, you should not have trouble finding what you need using the core collection, but you might find other benefits of using a different data base depending on your field or what you are looking for.

It may seem a little counter-intuitive, but your search on Web of Science is rarely going to be enough. Even after you get good at using all the tricks and features, you are going to find that you will want to use your search as a stepping-stone to finding more references. This might be because you just never thought to look for information in a certain way or maybe because one idea will lead to another idea that you had not even thought about. **The bottom line for you is that you really want to take advantage of the features that allow you to get more references from your search.** Specifically, make sure to notice the features highlighted in the box below

Web of Science features that help you find additional references (beyond standard searches)

1. **Access keywords from articles**. There is no one perfect way to categorize papers and so looking at (and using) slightly different keywords that you discover from different papers can help you find additional useful references. It is almost like getting a referral, "If you like this article you might like more articles in this category."
2. **Cited references.** All peer-reviewed papers will have their own references that they cite. These can be a gold mine for finding additional helpful articles. Moreover, you will have the paper itself to help you understand why that paper's author(s) thought that reference was useful or interesting.
3. **Times cited**. This is a big and important one. Say you find a great article that is super relevant and important to your work. Odds are, that article did not just come out last week. That means that other scientists may have read that article and thought it was important too. The “times cited” link gives you a list of all the published articles that cited that first article. You do not necessarily know why they cited it, so some things on the list are not going to be helpful. Nonetheless, it can be powerful tool for finding more articles that are useful.

The video also spends time talking about Open Access. Open Access means that a specific article can be read free of charge by anyone. It has pros (everyone can read it) and cons (the authors have to pay a lot to get it published).

How do I read/access these articles?

One of the great things about using databases like Web of Science that are integrated with NDSU library is that you can get easy access to most of the references you find in the database. Clicking on "Find it" will open up an NDSU library page that shows you your options for getting that article. In most cases (hopefully) you are going to see something that says "Full text available at....". Click on that link and you should be all set (many times, it takes you right to the article, but occasionally you have to dig around a bit). Sometimes it will give you multiple "Full text available" options.

Sometimes, you will just receive a link to "Request through Interlibrary Loan". That means that NDSU does not have access to this journal, but they can get you a copy of what you need from another library. This is a free service and normally only takes a day or two (depending on how hard the source is to find) for them to find a pdf of the article you need. Please check out this tutorial by NDSU Libraries on how to use interlibrary loan. This is another of their multi-page tutorials: https://library.ndsu.edu/tutorials/howuse-interlibrary-loan

As archaic as this is to talk about, there may be some references that aren't available electronically, but the library does have a hard copy of. If you do find a book or other reference that you want the hard copy in your hand you can check out another NDSU Libraries tutorial: https://library.ndsu.edu/tutorials/howfind-book-shelf or feel free to talk to a librarian.

Google scholar* ***What is it?***

Google Scholar is a specific search engine made and run by google. It is another perfectly good option for finding references; however, there are differences from Web of Science. The table below outlines benefits of using Google Scholar and benefits using Web of Science.

Benefits of using Google Scholar		Benefits of using Web of Science
Familiarity with interface		Has been the gold standard for many scientists for a long time
Uses different (and often) larger list of potential references		Usually more results from peer-reviewed journals (not books or other grey literature)
Can search anywhere in the article		Different options for what to search
Can tie to "My Library" and "My Citations"		Explicitly tied in to EndNote Online
Free for anyone to use		Many more options for how to look at and analyze your search results

Strengths

One strength of Google Scholar for is the ability to look for a search term within the whole article (see tutorial videos below). Oftentimes, looking at the whole article rather than just the keywords or title can give you many results that are not that helpful. However, if you are doing something like trying to find references that used a specific technique or a method that is going to be buried in the text, Google Scholar is fantastic! Ultimately, it is up to you to figure out what works best for you.

Where do I find it?

https://scholar.google.com/

How do I use it?

Since Google Scholar is free to use, there are many different resources (including YouTube videos) for how to use it. No single video gives a perfect overview of Google Scholar, so many are included.

- This was my favorite video in terms of the practical information, that it seemed to be done by and for a PhD graduate student , and the production aspects: https://www.youtube.com/watch?v=dcvKk205c8
- This is a two part series by a library that seems like might be aimed at a really beginner level: https://www.youtube.com/watch?v=yDbghsm_d6Q https://www.youtube.com/watch?v=aTi7EnN_kRI
- Finally, another library generated video that gave some good tips https://www.youtube.com/watch?v=EHShh5Rb7vI

A quick note, if you are off campus and want to make sure to link Google Scholar to the NDSU Libraries, follow this tutorial: https://library.ndsu.edu/tutorials/setting-your-preferences-google-scholar
Remember, there is a lot more options for finding and storing files as well as resources for learning how to use the ones we've talked about and new ones, so don't be afraid to keep looking and learning, and if you find a source that you think future students would benefit from, let me know!

3. Other online sources

Finding information from other online resources can be dangerous, as noted in the 'Legitimate Sources' section. However, when we exercise caution and use good judgement, we can find some useful information from other locations. Notably, published government reports or university extension materials, when found through verified websites, can be excellent sources for raw data.

* *Web of Science and Google Scholar sections courtesy of Jason Harmon*

WRITING ANNOTATIONS

What is an annotation? What is an annotated bibliography?
An annotation is an explanatory note or comment, and a bibliography is a detailed list of sources. In our scientific writing, an annotated bibliography is a detailed list of the sources we use in our research, with each source accompanied by notes.

Annotated bibliographies are especially useful for i) learning what work has been done on a topic and ii) generating ideas about how our research fits into current literature. They are a way to organize our thoughts while reading to ensure that we remember what is relevant and do not revisit things that are not.

The Purpose

The purpose of an annotated bibliography is to inform the reader of the relevance, accuracy, and quality of the sources cited.

In terms of this assignment (and future research), we can assume that the reader is *us*. The purpose is to create a blurb that we can refer to when determining what information is relevant to our written document. We cannot remember everything that we read during the prewriting stage, especially when we are reading numerous articles with similar information. Creating this reference can be invaluable when we begin composing our written document, as well as during the revision stage as we search for ways to improve our argument.

What should be included?

1. **Summary**

The summary portion should quickly describe i) why the paper was written, ii) what research was done, iii) what the research found, and iv) why those findings are important. Summaries, generally, can stand alone as useful information. In an annotated bibliography, they should be contextualized, to some extent, with the purpose of creating it. Thus, summaries should focus on the aspect of the work that we are most interested in.

Summaries should answer:

- What is the main message?
- What topics are covered?
- What is the purpose of the source?
- What methods did they use?
- What are the findings, and why are they important?

2. **Assessment**

For each source, the assessment portion should address i) if we want to use it and ii) if so, how we could use it.

Assessments should answer:

- Overall, is this a useful source?
- How does this source relate to my topic?
- Is it reputable and reliable?
- What role would this source play in my writing?
- How does this source relate to other sources in my bibliography?

3. Reflection

Reflections in an annotated bibliography typically related to why the source is useful (or not) to your current project. Reflections are a combination of first impressions (e.g., what was surprising? What was unexpected?) and more traditional reflections after longer periods of thought (e.g., this is really important because…). This portion can be highly personalized to remind us of what we were thinking while reading the source.

Reflections should answer:

- Did this source help me understand something?
- What is my first reaction to this source?
- Why would this be useful?
- Did this source change my mind about an argument?

What should it look like?

Since annotated bibliographies are a tool for each of us, they can be personalized to reflect each person's thinking. However, to meet the purpose of an annotated bibliography, it should include the information highlighted above in the 'Summarize, Assess, and Reflect' format. Most often, these three sections are separated to make it easier to refer back to. They may take the form of paragraphs, bullet point, or even look like an outline.

Example – Annotation

This example provides a moderate amount of detail; you might end up doing more or less, depending on what you need. It is written in sentences and fragments in an outline form, but you can write your annotations in regular paragraph form. As always, I start with the citation of the reference.

Eichele-Nelson JL, AF Wick, TM DeSutter, JP Harmon. 2017. The effects of salinity on the herbivorous crop pest *Tetranychus urticae* (Trombidiformes: Tetranychidae) on soybean and corn. Environmental *Entomology* 46:839846.

I. Summary

a. Paper is primarily about how salinity can indirectly affect an herbivore (mite) by altering the plant the mite feeds on.
b. The larger context is that abiotic factors are often important to insects and plant-insect interactions, but little is known about salinity (despite salinity becoming increasingly important).
c. Performed greenhouse experiments with mites on either soybean or corn grown in pots with varying levels of salinity.
    i. In the greenhouse, mites performed better (fecundity and population growth) as salinity increased.
    ii. Results were similar when on soybean and corn.
d. Performed field experiments with mites on soybean and natural variation in salinity.
    i. Results tended to be an increase in mite performance with higher salinity, but not true in all fields.

II. Assessment

a. Can use as an example of soil characteristics influencing insect, especially a pest species.
b. References in introduction give more examples to possibly use for same purpose.

III. Reflection

a. Wonder why there was variation in the field experiment. Were there differences across fields that can influence these results in big ways?

b. They showed that salinity reduced plant performance, but what else does salinity do to insects that might influence my results?

Example courtesy of Jason Harmon

CREATING AN OUTLINE

One of the most common flaws of scientific writing is a lack of organization. As we have seen repeatedly in our academic careers, science, by its nature, is a summative process. Each new piece of information builds on previous knowledge that has been elucidated by countless experiments and observations. Writing about science should be no different. Each piece of information should be a logical progression from the previous, building on those concepts to address the research question.

Ensuring this logical progression of thoughts does not happen on its own, and writing them in the most appropriate order the first time is impossible. Each writer must find their preferred method for organizing their thoughts.

Outlining

Outlines are a common way of organizing thoughts, and they vary widely in their formality and content. Most outlines are especially useful because they both order concepts and stratify them hierarchically. Thus, outlines can be detailed to whichever level of composition is desired.

The general format of an outline is to 1) identify the research question (thesis statement); 2) identify main categories to address the research question; and 3) identify subcategories beneath each category. These tiers are then denoted by different levels of roman numerals and letters. The information included on each line can be either a short phrase or a complete sentence.

Steps for creating an outline

1. Determine the objectives of your writing
2. Identify a thesis statement
3. Brainstorm ideas to develop or support the thesis
4. Group like with like
5. Decide on hierarchy
6. Decide on sequence
7. Create a cohesive structure for your outline
8. Revise, brainstorm, revise, brainstorm

1. Determine the objectives of your writing

For the purposes of this course, your objectives should already be defined. Either the writing accompanies an assignment that has a direct objective, or else the writing is aimed at addressing the research question. In both cases, this step—often one of the most difficult—is already complete.

2. Identify a thesis statement

The thesis statement, whether it be for an entire document or a single paragraph, is a statement of your purpose for writing. It should directly introduce the nature and scope of your argument. Write this statement down as you are brainstorming, and continue to revise it as your ideas shift.

3. Brainstorm

This purpose of this step is to get as many ideas down on paper as possible, even only partially developed ones. Brainstorming should occur without any concerns for order, importance, redundancy, or grammar. This first inundation of ideas is not the last brainstorming session, as you will

4. Group like with like

This step is when the shape of your argument truly begins to form. Grouping related ideas together helps your writing in two crucial ways. First, you can being to identify broad claims in your argument that will

serve as topics for paragraphs or sections. Second, it helps you write better sentences and paragraphs because you are already focused on a single idea.

5. **Decide on hierarchical structure**

Traditionally, outlines are exemplified for how they stratify ideas. This step involves picking which ideas can serve as topic sentences for a section or a paragraph, which should be broad ideas that have several related ideas to support them. Alternatively, many of your ideas may form parts of sentences underneath those broader topics. This step can be closely related to the brainstorming step, as each person thinks differently. Some writers may try to brainstorm some broad ideas first and follow up by creating specific ideas beneath those headings. Other writers may have several specific ideas that they group together and then have to state a broader heading from those ideas. However the process flows, writers should have a series of topics with ideas grouped beneath them at this point.

6. Create a sequence

Your ideas do not exist in a vacuum. If they are all in the same document, they are all related to one another somehow. With this step, you need to determine the order in which you present your ideas. In some cases, this may be chronologically, while in others it can be a shift from abstract to concrete. Some ideas may build off one another, so they should be placed in the appropriate order. Broader ideas should also be grouped like with like.

7. Create a cohesive structure for the outline

This step refers to formatting your ideas in a consistent way, and it may be essentially complete by the time you complete the previous steps. Most outlines use a combination of Roman numerals, Arabic numerals, and letters (both upper and lowercase) to identify the different hierarchies of ideas. Since you have already ordered your ideas, this step is mainly to clarify how the different ideas relate together. For example, all of the Section-scale ideas should share an identifier; all of the Paragraph-scale ideas should share a different identifier, and so on.

8. Revise, brainstorm, revise, brainstorm

As with all writing, once you create an outline, you need to revise it. Continue brainstorming and revising your outline until you are ready to write. Even as you are writing, you may return to your outline and revise ideas, hierarchies, and sequences.

Example template:

Research question/thesis statement

Objectives I.

Supporting claim 1 – Paragraph 1 topic sentence

a. Evidence 1 – sentence 1
b. Evidence 2 – sentence 2
c. Evidence 3 – sentence 3
d. Evidence 4 – sentence 4

…

…

IV. Supporting claim 4 – Paragraph 4 topic sentence

a. Evidence 1 – sentence 1
b. Evidence 2 – sentence 2
c. Evidence 3 – sentence 3
d. Evidence 4 – sentence 4

V. Conclusion

a. Specific conclusions
b. Relevance to broader scale
c. Broad conclusions

EXAMPLE: Outline

This example shows a partial outline (only the introduction section) to a literature review documenting the effects of tillage on the surface energy balance. The outline includes sentence-by-sentence information.

Step 1 and 2. Determine the objectives of your writing; Identify a thesis statement

These two steps are the beginning to any writing task. You must always know *why* you are writing, and you should be able to distill that purpose down to a single sentence (or few sentences). Do not overthink these steps, as they should be as straightforward as possible.

Step 3 and 4. Brainstorm ideas to develop or support the thesis; Group like with like

The brainstorming step is not shown on this outline, but it is critical to creating the outline. In this example, the ideas stem directly from the thesis statement. Each major term, tillage and SEB (paragraphs I, II), is defined, the purpose is stated (paragraph IV), and the objectives are introduced (paragraph V).

Step 5, 6, and 7. Decide on hierarchy; Decide on sequence; Create a structure for your outline

The action of these steps are not shown, as on the result of those decisions are shown in the outline. The decisions were made on the assumption that: 1) tillage is accessible to a wider audience than SEB, so it should begin the document. 2) Some understanding of methodology is crucial when discussing SEB, so it was given its own paragraph. 3) The introduction should include mention of why reviewing this topic is important, so the paragraph IV revisits the purpose.

Step 8. Revise, brainstorm, revise, brainstorm

Objectives

1. Review the current state of knowledge regarding how tillage affects surface energy balance
2. Identify knowledge gaps

Thesis statement

The surface energy balance can be a tool to quantify the effects of tillage in agricultural systems.

INTRODUCTION

I. What is tillage?
   a. What are the goals of tillage
   b. What are the consequences of tillage
   c. What are the different types

II. What is the surface energy balance?
   a. Definition of SEB and its components
   b. Why is it important in agricultural systems?
   c. How does it relate to tillage III. How to measure SEB?
      a. Eddy covariance
      b. Bowen ratio
      c. Others
      d. Individual components

IV. What is the state of the knowledge?
   a. Are there yearly trends for SEB/Tillage research?
   b. Spatial trends?
   c. Specific cropping systems?

V. Scope and objectives
   a. Include only complete SEB studies with identified tillage treatments
   b. Obj 1: Review current literature on how tillage affects SEB
   c. Obj 2: identify knowledge gaps
   d. Implications: further understanding of the impacts of tillage to soil properties

CREATING A REVERSE OUTLINE

One excellent tool when rewriting is the reverse outline. A reverse outline is just what it sounds like. That is, an outline that we write *after* we have written the document it is meant to outline. Whereas the purpose of a traditional outline is to guide the composition process, the purpose of a reverse outline is to guide the revision process.

The principal of a reverse outline is that ***we never write exactly what we set out to write***. Since we are constantly changing our argument, editing sentences, and altering paragraph structure, things can get out of place. A reverse outline is a good way to assess what we have actually written. Then, we can revisit both the content and organization of our arguments at various scales.

The reverse outline is a diagnostic tool for revisions. Producing one can help us identify problem areas, but it will not fix anything. Rather, we need to return to principals identified in previous handouts, especially Sentences and Paragraphs, as well as those problems identified in the Writing Improvement Guide, to fix our problem areas.

****Always begin with restating the objectives and a thesis statement.****

Document scale

1. **Identify the topic of each paragraph in as few words as possible** If you cannot do this, you likely have more than one topic included.

If you identify more than one topic, choose what you want this paragraph to be about and use that topic. You will likely be moving the other sentences to a new paragraph.

The topic of your writing may not actually be what you had planned in your outline, so be sure to read what you wrote and not what you expected to write.

2. **Identify how the topic of each paragraph relates to the overall thesis statement** If a paragraph does not relate to the topic, remove it (but do not delete it entirely).

3. **Assess the progression of paragraph topics**

Do all of the topics build on one another? Are they grouped with related topics? Do some support and some refute the argument?

Often, simply changing the order of paragraphs can greatly improve the structure of the writing and making the argument much clearer.

Paragraph scale

4. **Determine if each sentence in the paragraph relates to the topic**

If a sentence does not relate to the topic, remove it (but do not delete it entirely).

5. **Determine how each sentence in the paragraph relates to the topic**

Even if all of your sentences do relate to the topic, they may not all fit together. For example, some papers may use a paragraph to explain a topic, the next to support that topic, and a third to relate that topic to something else. Thus, any sentences that explain a topic should not be included in the supporting paragraph, and vice versa. Remember that the purpose of a paragraph guides the purpose of each sentence within it.

(Sentence scale)

If some sentences do not relate to the topic, double-check that they are effective sentences (see Sentence handout). Perhaps the information is useful, but the sentence needs to be revised to address the topic.

Revision stage

6. Assess the progression of topics and sentences after first revision.

Does the argument make sense? You have removed or fixed unnecessary and distracting information. Does the argument not make sense? You have removed critical information. That information needs to be reframed to fit the argument better.

7. Determine if the information in the removed material is relevant

Even if the argument still makes sense without it, some material may still be relevant to the topic. In this case, you need to a) create a new paragraph if you have enough related information or b) reframe your removed information to fit under a current topic.

Example – Reverse Outline

Below is an example of completed steps associated with the reverse outline. Annotations are in BLACK, while the example outline is in GREY. The reverse outline is performed for the file attached at the end of the document. The file is a rough first draft, which is a good time to start thinking about revisions.

****Always begin with restating the objectives and thesis statement****

Restating the objectives and thesis statement (even if it is not the final version) is critical to answering "what is the point?" to your writing.

Step 1. Identify the topic of each paragraph in as few words as possible

Each paragraph has been given a 3-5 word title in the outline. Some of the paragraphs have two topics, and they are joined with 'and' below. Further scrutiny is required to determine if they will need to be separated into more than one paragraph.

Objectives

1. Quantify natural degradation of Bakken crude oil in disturbed soils
2. Assess risk of contaminant uptake in vegetation grown on these soils
3. Discuss the findings within the context of cleanup standards

Current thesis statement

Natural degradation of the Bakken crude oil occurred at the same rate across four different soil materials and four different starting concentrations, and this rate suggests that natural attenuation could be a suitable remediation strategy in some instances in the Northern Great Plains.

INTRODUCTION

1. Crude oil contamination inhibits soil function
2. Natural attenuation
3. Aims and objectives
4. Context for regulatory agency

MATERIALS AND METHODS

1. Soil contamination and research plots
2. Soil TPH sampling and analysis
3. Vegetation PAH sampling and analysis
4. Calculations and statistical analysis

RESULTS AND DISCUSSION

1. TPH degradation – statistical differences
2. Reasoning for no depth differences
3. Introduction of GRO vs. DRO
4. Reasoning for no manure differences
5. PAH uptake – findings
6. Reasoning for low PAH values
7. Context for PAH vs TPH

IMPLICATIONS

1. Region/climate specific information
2. Combination of remediation technologies

Step 2. Identify how topic of each paragraph relates to the overall thesis statement

This step does not need to be written out, but you should answer the question to yourself.

For example, the first paragraph of the introduction introduces the relevance of the study on crude oil degradation (i.e., it harms soil function).

Step 3. Assess the progression of paragraph topics

Again, this step does not need to be written out.

For example, the Introduction follows a progression of 1) Why is crude oil in soil relevant?, 2) What is a method for reducing crude oil?, 3) What are the aims of this specific study?, and 4) What is the context for the regulatory agency?

In this section, paragraph 4 does not flow with the other paragraphs. It does relate to the research objectives and the thesis statement, but perhaps it needs to be moved elsewhere in the document.

Another possible 'out-of-place' paragraph could be #7 in the R&D section. Since they are clearly a major part of the **topic** section, we may ask, 'should the differences between TPH and PAH be addressed sooner?' This can be another area for further scrutiny.

Step 4. Determine if each sentence in the paragraph relates to the
Step 5. Determine how each sentence in the paragraph relates to the topic

These two steps happen in concert with one another, and it is important to consider each step for each sentence. First, you need to determine if the sentence is even necessary. Once you make that determination, you can identify its purpose. This example only shows the extension of the INTRODUCTION to the sentence level, but you should always do the entire document.

The topic of the paragraph 1 is 'crude oil contamination inhibits soil function'. However, the sentences do not all reflect that topic, as both the second and third sentences are more related to remediation. In this case, revisiting the aim of the paragraph can lead to changing the topic of the paragraph to something like 'Oil-contaminated soil requires remediation'. In the next draft, these sentences can be reoriented to support that claim.

Paragraph 2 is focused on natural attenuation, but that term is not defined yet in the document. A sentence doing so should be added either in Paragraph 2 or in Paragraph 1.

Paragraph 3 follows a natural thought progression, but then Paragraph 4 still seems entirely out of place. In fact, much of the information seems to repeat Paragraph 2 (e.g., long treatment times of natural attenuation). The purpose of Paragraph 4 appears to be an attempt to convince regulatory agencies of the value of natural attenuation. This information would fit better before the aims and objectives, with some sentences probably combined with Paragraph 2.

Objectives

1. Quantify natural degradation of Bakken crude oil in disturbed soils
2. Assess risk of contaminant uptake in vegetation grown on these soils
3. Discuss the findings within the context of cleanup standards

Current thesis statement

Natural degradation of the Bakken crude oil occurred at the same rate across four different soil materials and four different starting concentrations, and this rate suggests that natural attenuation could be a suitable remediation strategy in some instances in the Northern Great Plains.

INTRODUCTION

1. Crude oil contamination inhibits soil function
    - **a.** Petroleum hydrocarbons (PHCs) risk human and ecosystem health
    - **b.** Many ways to remove PHCs
    - **c.** Natural attenuation least expensive
2. Natural attenuation
    - **a.** Reduces PHC by physical/chemical and biological mechanisms
    - **b.** Dependent on many characteristics
    - **c.** Conditions limit implementation in some areas
    - **d.** Extended treatment time
3. Aims and objectives
    - **a.** This study different because occurs in field conditions
    - **b.** Look at Bakken crude PHCs in Northern Great Plains loams
    - **c.** Degradation rates of PHCs

   d. Risk assessment for vegetation
   e. Context for applications of the findings
4. Context for regulatory agency
   a. Research applicable to remediation practitioners
   b. Natural attenuation may decrease impacts to soil function
   c. Bioremediation is possibly a viable alternative
   d. Long treatment times make it an unappealing strategy – aims to quantify treatment time

Step 6. Assess the progression of topics and sentences after first revision.
Step 7. Determine if the information in the removed material is relevant
Below is the same outline after the first revision, with those revisions annotated in the previous pages. This new outline can then be used when revising the entire document.

Objectives

1. Quantify natural degradation of Bakken crude oil in disturbed soils
2. Assess risk of contaminant uptake in vegetation grown on these soils
3. Discuss the findings within the context of cleanup standards

Current thesis statement

Natural degradation of the Bakken crude oil occurred at the same rate across four different soil materials and four different starting concentrations, and this rate suggests that natural attenuation could be a suitable remediation strategy in some instances in the Northern Great Plains.

INTRODUCTION

1. Contaminated soil requires remediation
   a. Petroleum hydrocarbons (PHCs) risk human and ecosystem health
   b. PHCs inhibit soil function
   c. Many ways to remove PHCs
   d. Natural attenuation least expensive
2. Natural attenuation – what is it
   a. Reduces PHC by physical/chemical and biological mechanisms
   b. Dependent on many characteristics
   c. Conditions limit implementation in some areas
   d. Extended treatment time
3. Natural attenuation – why is it useful
   a. In conjunction with bioremediation, NA is possibly a viable alternative
   b. Natural attenuation may decrease impacts to soil function
   c. Natural attenuation could be much cheaper and environmentally friendly
   d. Need to quantify treatment times to determine its applicability
4. Aims and objectives
   a. This study different because occurs in field conditions
   b. Look at Bakken crude PHCs in Northern Great Plains loams
   c. Degradation rates of PHCs
   d. Risk assessment for vegetation
   e. Context for applications of the findings; e.g., applicable to remediation practitioners

MATERIALS AND METHODS

1. Soil contamination and research plots
2. Soil TPH sampling and analysis
3. Vegetation PAH sampling and analysis
4. Calculations and statistical analysis

RESULTS AND DISCUSSION

1. TPH degradation – statistical differences
2. Reasoning for no depth differences
3. Introduction of GRO vs. DRO

4. Reasoning for no manure differences
5. Context for TPH vs PAH
6. PAH uptake – findings
7. Reasoning for low PAH values

IMPLICATIONS

1. Region/climate specific information
2. Combination of remediation technologies

Reverse outline – Example first draft

Introduction

Crude oil contamination affects millions of hectares across North America, and it releases petroleum hydrocarbons (PHCs) into the environment that can diminish soil function and be a risk to human and ecosystem health. Numerous methods to remediate PHCs are available, including physico-chemical, thermal, biological, and combination techniques, with the best option being site-specific. However, many of these methods are resource intensive, so natural attenuation is often preferred.

Natural attenuation reduces PHC concentrations primarily by i) natural physical and chemical decomposition and ii) bioremediation by the naturally occurring soil biota. These two processes are heavily dependent on site characteristics, especially PHC concentration and composition, climate, and soil properties, which ultimately dictates the efficiency of remediation. Thus, at sites with short growing seasons, cold temperatures, and low precipitation, natural attenuation may be very slow or else avoided altogether. Further, by increasing time to remediation, this decision can also increase the risk of PHC migration, transfer, or plant uptake.

Many studies assess degradation of PHCs in controlled, laboratory conditions. However, quantifying the natural degradation under field conditions is much more meaningful because of the variability in climate conditions. The aim of this study was to examine natural attenuation of PHCs in Northern Great Plains loam soils. The objectives of this study were to i) determine degradation rates of PHCs of mildly contaminated soils, ii) assess risk of contaminant uptake in vegetation, and iii) discuss these findings within the context of PHC cleanup standards. Combining this information in one study should offer crucial information to remediation professionals when they are deciding which techniques to employ, as well as offer some guidance to regulatory officials tasked with identifying cleanup standards.

This information may also be applicable to remediation professionals to guide them in cost-saving projects. Often, removing a significant portion of the contamination may be done at a certain cost, but reaching the regulatory threshold could require an exponential increase in cost for a limited additional amount of PHC removal. In addition to cost, the damage to soil function may also increase exponentially. Thus, utilizing bioremediation at the end of a project could be a viable alternative. However, many practitioners may not want to incorporate this strategy because it increases the length of time they are liable. This study addresses that risk by quantifying the amount of contaminant uptake into plant vegetative structures and grain. **Materials and Methods**

Spill details and research plots

In October 2013, a crude oil pipeline leak released 21000 barrels of Bakken crude oil onto an agricultural field. The entire site was excavated up to 15 m below the soil, and the contaminated soil was stockpiled on-site to be treated by ex situ thermal desorption. In November 2015, research plots (16 m x 17 m x 0.9 m) were constructed using the following materials from the active remediation site: SP: contaminated subsoil material, TD: thermal-desorption treated subsoil material, A: native, non-contaminated topsoil, SPA: mixture (1:1 by volume) of SP and A, and TDA: mixture (1:1 by volume) of SP and A. More information on plot construction and characterization can be found in O'Brien et al. (2017). In half of the plots, a composted-manure bedding amendment was added to the plots (rate) and incorporated with a rototiller (info).

TPH and PAH sampling

Initial soil samples were taken within two weeks of completing plot construction (Dec 2015; 0 months after construction). One soil core was taken from the center of each plot using a Giddings soil probe down to 0.9 m depth, and cores were divided by four depths (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm). The soils were analyzed for gasoline range organic hydrocarbons (GRO; C6-C12) and diesel/motor oil range organic hydrocarbons (DROMO; C12-C36) using EPA method XXXX (Pace Analytical). The same procedure was followed for additional samples after each of two growing seasons, 9 months and 21 months, respectively.

Plots were planted with hard red spring wheat during the 2016 growing season and field pea during the 2017 growing season. After each season, samples of plant biomass and grain were collected by hand. These samples were evaluated for the 16 PAHs regulated by the EPA using EPA method XXXX (Pace Analytical).

Calculations and statistical analysis

One-way analysis of variance (ANOVA) was used to assess statistical differences between TPH concentration based on depth, manure application, and time within each treatment. The rate constant for each treatment was found using linear regression on the three sampling periods. Half-life was calculated by assuming a first-order kinetic reaction and using $[A]_t * [A]_o = e^{-kt}$. **Mixed-effects model? **Results and Discussion**

TPH Degradation

The half-life calculated for the four treatments were not different from one another (Fig. X). Moreover, the half-life was not different among the four depths, nor was it affected by manure application. The most notable finding is that degradation is occurring despite the low temperatures and lack of precipitation, although the half-life is… **Find some other crude oils half-life to compare to

This lack of significance between depths was unexpected in this study. Natural attenuation rates are typically dependent on i) biodegradation, ii) sorption, iii) volatilization, iv) dispersion/dilution, and v) chemical reactions, and these rates of these processes would typically differ based on depth. For example, more biodegradation would be expected near the surface, where more SOM is present. Similarly, volatilization is typically greatest near the surface due to increased surface area exposed to the atmosphere. Differences between depths were not observed in this study likely because of the homogenous mixing of these plots. A Principal Components Analysis of 26 soil variables indicated that these plots were homogenous both spatially and with depth at the time of construction. Since these soil properties dictate the rate of many of these natural attenuation processes, no differences among depths were observed.

One possible exception to the soil properties dictating the rate of contaminant reduction could be volatilization. Volatilization from lower in the soil profile would have to be slower than at the surface, even with completely homogenous soils because the fluid transport of the soil air within the pores will never match that at the soil surface with the atmosphere. However, very little volatilization is probably occurring at these plots, because the material handling likely encouraged the majority of those compounds to volatilize during construction.

Notably, the GRO (C6-C12) fraction composed less than 10% of the TPH for the SP and SPA at initial sampling. After 22 months, only five of 24 SP samples even detected GROs, while none of the SPA samples contained GROs. Thus, the most volatile compounds were not present, so volatilization is likely accounting for a small portion of natural degradation.

The manure application also did not result in changes to the half-life of these contaminants. This is notable because the manure would only have been incorporated in the top 15-20 cm, so its effect would have caused differences in the depth, as well. The lack of response to manure was likely the result of the application rate being relatively low. The rate was chosen as a typical rate for manure application as a general practice in agriculture, rather than for any remediation value. Additionally, any added nutrients in the manure to spur microbial activity would have been outweighed by the application of fertilizer at the beginning of the study. Thus, the limiting factor for natural attenuation was not governed by SOC or nutrient availability.

PAH uptake

The uptake of PAHs in both wheat and field pea biomass and grain were not increased in any of the treatments compared to the native topsoil (Table X). In general, the PAHs in the biomass were similar/less/greater than… The PAHs in grain were similar/less/greater than…These levels may be higher because volatiles from the adjacent remediation site are being taken in through the stomata.

Likely, the concentrations in the soil are too low to make a difference in plant uptake. In one study, increased contaminant uptake did not occur until concentration reached XX.

Further, the comparison of soil TPH to plant uptake of PAHs is not a direct one because the compounds are not the exact same pool. These PAHs were selected because they are regulated by the USEPA, and they are commonly used to assess contaminant uptake, so comparisons can be made across studies. Despite this imperfect metric, the findings of this study, along with trends in the literature, indicate that risk for plant uptake in these soils is very low.

Implications

Despite the low starting points for contaminant concentration in this study, these findings are still applicable in several circumstances. One important finding of this study is that natural degradation is occurring in these soils in this climate. Information about natural attenuation in this region is lacking, but that knowledge is critical for appropriate decision making in this region in the future, as oil production continues to expand. Additionally, this study may be applicable as a demonstration of combination remediation methods.

Semester project - Overview

For each class, the students will choose/be assigned a research topic relevant to course content. Throughout the semester, the student will complete nine exercises as part of a semester project.

The goals of this project will be to:

1. Supplement course content with outside materials
2. Improve reading and comprehension of scientific literature
3. Incorporate more scientific/technical writing in coursework

The exercises will be:

1. Read peer-reviewed article (1), summarize it with 4-5 bullet points **2.** Read peer-reviewed article (2), write:

   a. 1-2 paragraphs summarizing the article
   b. 1-2 paragraph connecting the article to course content **3.** Read peer-reviewed article (3), identify one figure to write:
      a. 2-4 paragraphs interpreting the figure and article,
      b. 1-2 paragraphs connecting the figure to course content

4. Find a peer-reviewed article (4), read it, and identify one table to write about:
   a. 2-4 paragraphs interpreting the table and article,
   b. 1-2 paragraphs connecting the table to course content
5. Find and read three peer-reviewed articles, and write an annotation for each
6. Using the previous articles and exercises, write a ***four page, double-spaced, document to address the research question.***
7. **Create an outline** for the full paper using (primarily) information from the previous exercises.
8. **Create a reverse outline** of the full paper (assisted by guide) to improve revised version.
9. After being assessed by the instructor, ***reduce that the full paper to three pages,*** doublespaced, and address the same research question more succinctly.

Week	Exercise assigned	Associated module/guide
1	Introduce project; Pick research topic	Introduction; Reference for improvement guide
2	Exercise 1 – Bullets points: Article 1	Approaching scientific literature; Sentences
3	Exercise 2 – Paragraphs: Article 2	Writing as a process; Paragraphs
4	Exercise 3 – Figures: Article 3	Interpreting scientific figures
5		
6	Exercise 4 – Tables: Article 4	Interpreting scientific tables; Finding literature
7		
8	Exercise 5 – Annotations	Writing annotations
9	Exercise 6 – Full paper	
10	Exercise 7 – Outline for full paper	Creating an outline
11		
12		
13	Full paper due	
14	Exercise 8 – Reverse outline	Creating a reverse outline
15	Exercise 9 – Revise full paper	
16	Revised version due	
Finals		

Requirements of the instructor

1. Develop a list (3-5?) of **research topics** that can easily be adapted to research questions

Assigned: TBD
Due: TBD
Associated handout:

2. Identify **three articles** that would be relevant to *all* of the possible research questions
3. Provide (cursory) feedback on the five article responses
4. Provide more **thorough feedback** on the first final paper and the revised version

Exercise 1. Reading and summarizing scientific literature (Article 1)

Assigned:
Due:
Associated handouts: Approaching scientific literature; Sentences

The objective of this exercise is to read, understand, and summarize a peer-reviewed article.

To be turned in to the instructor: 4-5 bullet points summarizing the article.

Students will be given a peer-reviewed article relevant to their chosen (or assigned) research question. Students will **read** the entire article and **summarize** its important points in **4-5 bullet points**. Each bullet point will be one complete sentence.

Although this assignment can be completed in many ways, the bullet points should generally include (but are not limited to):

- What is this article discussing (i.e., what is the research question), and why is it important?
- What methods or techniques did the authors use to address the question(s)?
- What were the main findings?
- What are broader implications of these findings?

Students' responses will be assessed by:

1. Are there 4-5 points? Do they make sense? Are they complete sentences?
2. Do the bullet points make it clear that the student has read the entire article?
3. Do the bullet points accurately summarize the article?
4. Do the bullet points include only information critical to the article (as opposed to ancillary information)?

Exercise 2. Connecting scientific literature to course content (Article 2)

Paragraphs

The concepts TBD ***objective of this exercise is to connect information from a peer-reviewed article to*** TBD ***discussed during class periods.***

To be turned in to the instructor: 2-4 paragraphs summarizing the article and relating it to course content.

Students will be given a peer-reviewed article relevant to their chosen (or assigned) research question. Students will **read** the entire article and **summarize** its important points in **one or two paragraphs**. Students will then write **one to two paragraphs** describing how the article relates to a concept discussed during the class periods.

Similar to Exercise 1, this exercise can be completed in numerous different ways. Some useful information to incorporate may be:

- What is this article discussing (i.e., what is the research question), and why is it important?
- What were the main findings, and what are the implications of these findings?
- What concept from class meetings does this article remind you of?
- Does this article corroborate information discussed in class? Does it refute it? Does it address the concept from a different point of view entirely?

Students' responses will be assessed by:

1. Are there 2-4 paragraphs? Do they make sense? Do they use complete sentences?
2. Does the chosen article relate to a concept or content from course meetings?
3. Does the summary of the article make it clear the student has read the entire article?
4. Does the summary accurately describe the important findings of the article?
5. Does the student make appropriate connections between the article and course content?
6. Are the paragraphs written so that they flow together (e.g., use a transition), or are they simply two paragraphs standing next to each other?

Assigned: TBD
Due: TBD

Exercise 3. Interpreting scientific figures (Article 3)

Associated module: Interpreting scientific figures

The objective of this exercise is to interpret a figure from scientific literature and connect that information to concepts discussed during class periods.

To be turned in to the instructor: 3-6 paragraphs interpreting a figure from the article, summarizing the entire article, and relating it to course content.

Students will be given a peer-reviewed article relevant to their chosen (or assigned) research question; ***this article must have a figure that displays data***. Students will **read** the entire article and **choose a figure** from the article to interpret. In **one to two paragraphs**, students will describe what the figure shows and what it means in the broader context of the article. They will summarize the entire article in **one to two paragraphs**. Further, they will then write **one to two paragraphs** describing how the figure relates to a concept discussed during the class periods.

This exercise can be completed in numerous different ways. Some useful information to include may be:

- What type of figure is being described? What data is being displayed?
- What is the main message of the figure, and how does it relate to the context of the article?
- What were the main findings, and what are the implications of these findings?
- What concept from class meetings does this figure relate to?
- Does this figure corroborate information discussed in class? Does it refute it? Does it address the concept from a different point of view entirely?

Students' responses will be assessed by:

1. Are there 3-6 paragraphs? Do they make sense? Do they use complete sentences?
2. Does the student accurately identify the type of figure and the type of data displayed?
3. Does the student identify and summarize the main message of the figure?
4. Does the student make appropriate connections between the figure and course content?
5. Are the paragraphs written so that they flow together (e.g., use a transition), or are they simply individual paragraphs placed next to each other?

Exercise 4. Interpreting scientific tables (Article 4)

Interpreting scientific tables

Assigned: TBD
Due: TBD
Associated handout:

The objective of this exercise is to interpret a table from scientific literature and connect that information to concepts discussed during class periods.

To be turned in to the instructor: 3-6 paragraphs interpreting a table from the article, summarizing the entire article, and relating it to course content.

Students will be given a peer-reviewed article relevant to their chosen (or assigned) research question; ***this article must have a table that displays data***. Students will **read** the entire article and **choose a table** from the article to interpret. In **one to two paragraphs**, students will describe what the table shows and what it means in the broader context of the article. They will summarize the entire article in **one to two paragraphs**. Further, they will then write **one to two paragraphs** describing how the table relates to a concept discussed during the class periods.

This exercise can be completed in numerous different ways. Some useful information to include may be:

- What type of data is shown in the table?
- What is the main message of the table, and how does it relate to the context of the article?
- What concept from class meetings does this table relate to?
- Does this table corroborate information discussed in class? Does it refute it? Does it address the concept from a different point of view entirely?

Students' responses will be assessed by:

1. Are there 3-6 paragraphs? Do they make sense? Do they use complete sentences?
2. Does the student accurately identify the type of data displayed in the table?
3. Does the student identify and summarize the main message of the table?
4. Does the student make appropriate connections between the table and course content?
5. Are the paragraphs written so that they flow together (e.g., use a transition), or are they simply two paragraphs standing alone?

Exercise 5. Writing article annotations

Writing annotations

The objective of this exercise is to produce an annotation that demonstrates students' ability to read, understand, and synthesize information in scientific literature.

Assigned: TBD
Due: TBD
Associated handout:

To be turned in to the instructor: Three (3) annotations from scientific articles. At least one of these articles must be used in the final writing assignment.

Students will find three peer-reviewed articles relevant to their chosen (or assigned) research question. For each article, students will **read** the entire article and **write an annotation**. Since part of the purpose of an annotated bibliography is to distinguish relevant sources from irrelevant ones, not every source needs to be directly relevant to the research question. However, find **at least one article** that will be useful for the final writing assignment.

An annotation is simply a more formalized way of writing about literature than we have used thus far in the project. Each annotation will be slightly different, but they should include these sections:

- **Summary:** ○ What is the article about? What question does it address and what are the main findings?
  - This summary can be either in paragraph form or bullet points.
- **Assessment:** ○ How does this article relate to ***your*** research question?
- **Reflection:**
  - Does this article corroborate information discussed in class? Does it refute it? Does it address the concept from a different point of view entirely?
  - Does this article offer useful information relevant to the coursework?
- **Citation** ○ Can be in any format for this assignment. However, it needs to include the following:
  Title, Authors, Journal Name, Year of publication, Journal Issue, and Page Numbers.

Students' responses will be assessed by:

1. Are all sections included? Do the responses make sense? Do they use complete sentences?
2. Does the student identify and summarize the main message of the article?
3. Does the student make a clear argument for how this article does (or does not) relate to their question?
4. Does the student make appropriate connections between the article and course content?

Exercise 6. Addressing the research question

None

Assigned: TBD
Due: TBD
Associated handout:

The objective of this exercise is to produce a written document that addresses the research question given at the beginning of the semester.

To be turned in to the instructor: a **four-page**, double-spaced **response to the research question**. This response will be primarily driven by *content covered during course meetings*, but the document must also include *references to at least five of the articles* used in the previous exercises.

Students should use as much of their **previous work as possible** to create this document. Thus, much of the work will not be new writing but rather working to create a **cohesive document** out of the paragraphs they have already constructed. *Creating a coherent, continuous argument is critical to successfully completing this assignment.*

Each response should include:

- The research question, and justification of why it is important
- An application of information covered in course meetings
- Reference to each of the articles from previous exercises
- A logical progression of thoughts responding to the research question
- A conclusion based on the arguments from the course content and outside sources

Students' responses will be assessed by:

1. Did the student follow directions (e.g., four pages, include course content, five references?)?
2. Is the research question and its justification included?
3. Is course content applied appropriately to the research question?
4. Are the outside sources applied appropriately to the research question?
5. Does an argument exist that applies throughout the document?
6. Does the document follow a progression of thoughts to a conclusion about the question?
7. Is the document a coherent, or is it a series of discrete paragraphs shoved together (e.g., did the student take time to add transitions, build context, supply relationships between the concepts)?

Exercise 7. Organizing ideas – creating an outline

Creating an outline

The objective of this exercise is to create an outline that addresses the students' research questions and incorporates relevant information from the previous exercises.

Assigned: TBD
Due: TBD
Associated handout:

To be turned in to the instructor: **an outline** for their four-page document, which is meant to be a resource as they continue their writing.

Outlines are an excellent way to visualize a progression of thoughts, so they can be used as a tool for ensuring that the progression is logical. *Creating a coherent, continuous argument is critical to successfully completing this assignment.*

Because you need to write to think and think to write, your outline will be constantly changing as you write. This outline does not need to be your first nor your last, but it does need to include all of the required elements.

Outlines can be employed in various ways, but the outlines required in this exercise will follow a format of:

A. Section
    a. Paragraph
        i. Sentence

For this exercise, students can determine whether they have more than one section, but all students will have numerous paragraphs and sentences to outline. Notably, the first paragraph of each document will include 1) a justification and 2) the research question.

Students' responses will be assessed by:

1. Does the outline include the three tiers in the assignment?
2. Does the outline include the research question?
3. Does the outline follow a progression of thoughts to a conclusion about the question?

Exercise 8. Revising – creating a reverse outline

Creating a reverse outline

The objective of this exercise is to apply the strategy of reverse outlining to the students' responses to their research questions.

To be turned in to the instructor: **a reverse outline** for their four-page document, which is meant to be assist them in revising the document for clarity and concision.

Similar to pre-writing outlines, reverse outlines are an excellent way to visualize a progression of thoughts. In the case of reverse outlines, however, the practice can identify areas where arguments have

Assigned: TBD
Due: TBD
Associated handout:

gotten off-track, repeated, or superfluous information is included. It is another tool to c*reating a coherent, continuous argument.*

Reviewing your own writing is difficult, because you already know what you are trying to say. However, try to step outside your own thoughts and read the words you wrote as an independent document, without any context of your own thoughts.

The basics of the process are:

- Revisit the research question and write it at the top of the page
- For each paragraph, identify the main point or argument (there should only be one)
- Look at the list of topics of each paragraph and identify how they relate to the research question
  - If a paragraph does not relate to the question, it should be modified or removed
- Within each paragraph, identify the topic of each sentence and how it relates to the main goal of the paragraph
  - If a sentence does not relate to that goal, it should be modified or removed

Student should compare their reverse outline to their prewriting outlines to see how different they have become. For this exercise, students do not necessarily need to revise their document. However, revisions will be required in the next assignment.

Students' responses will be assessed by:

1. Does the outline include the three tiers in the assignment (i.e., document, paragraph, sentence)?
2. Did the student complete all steps identified in the handout?
3. Did the student thoroughly assess their own writing?

Exercise 9. Revised response to the research question

None

The objective of this exercise is for students to edit their own written document to produce a more concise and clear product.

To be turned in to the instructor: a revised copy of Exercise 6 that is a **three-page, double-spaced response to the research question**.

Assigned: TBD
Due: TBD
Associated handout:

The aim of the revisions is to ***improve the overall document*** by addressing poorly constructed arguments, awkward wording, or improper application of course content. Further, the students will remove superfluous ancillary information, redundant sentences, or conversational language to ***reduce the overall length*** of the document to three pages.

Again, this exercise is difficult because reading your own writing without the context of your thoughts is a difficult skill to master. However, each student should be able to utilize the assistance of your instructor's comments, your reverse outline, and the writing modules to complete this exercise.

Despite shortening the document, the students should still strive to *create a clear, coherent, and continuous argument.*

Each response will still include:

- The research question, and justification of why it is important
- An application of information covered in course meetings
- Reference to each of the five articles from previous exercises
- A logical progression of thoughts responding to the research question
- A conclusion based on the arguments from the course content and outside sources

Students' responses will be assessed by:

1. Did the student follow directions (e.g., three pages, include course content, use five references)?
2. Did the student improve the clarity of the document in addition to shortening it?
3. Is the research question included, with justification?
4. Is course content applied appropriately to the research question?
5. Are the outside sources applied appropriately to the research question?
6. Does an argument exist that applies throughout the document?
7. Does the document follow a progression of thoughts to a conclusion about the question?
8. Is the document a coherent, or is it a series of discrete paragraphs shoved together (e.g., did the student take time to add transitions, build context, supply relationships between the concepts)?
9. Did the student remove common writing errors identified in the handout?