How to Get Started if You Hate to Write

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The opinions expressed are solely my own and are not necessarily shared by the Department of Physics, The Grainger College of Engineering, or the University of Illinois. But they should be.

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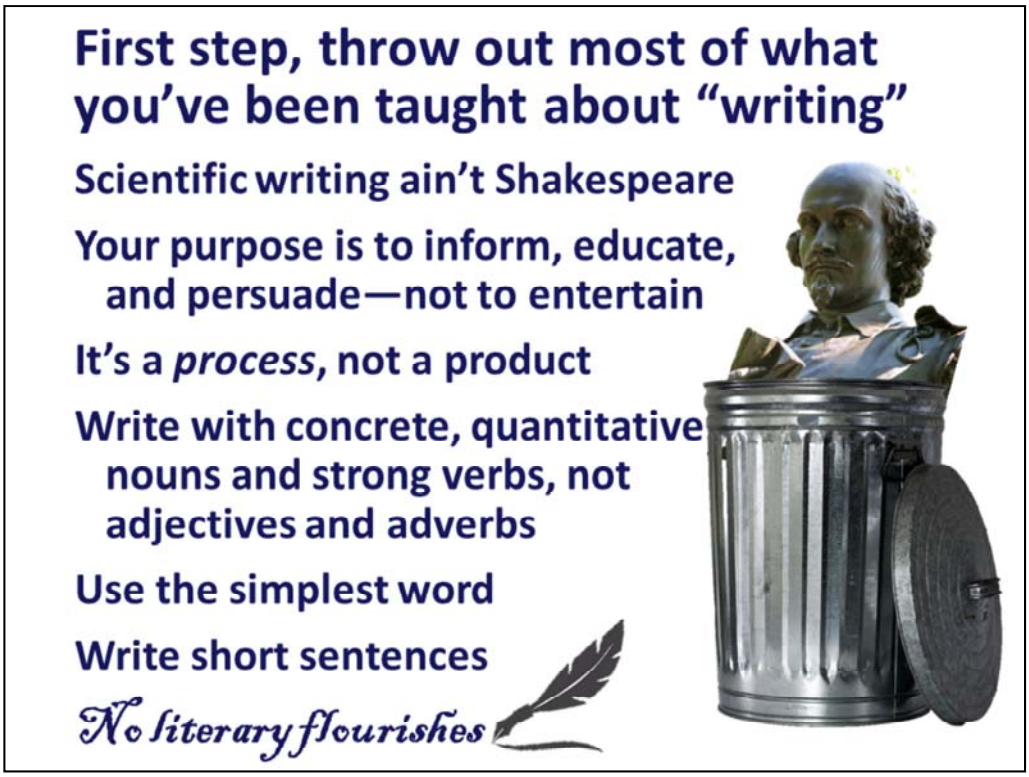
One thing I've learned in physics, you have to satisfy both the theorists and the experimentalists…

…so this talk has two parts:

I. a theory of technical writing

II. the nuts and bolts of first putting together a scientific paper



Scientific writing is fundamentally different from other kinds of writing—in tone, in style, in content, in organization.

Good scientific writing is concise, direct, concrete, and unambiguous.

The harder the concepts you're writing about, the simpler and more transparent the writing should be.

Learning to write in the style described here will not only make you a better writer, it will also make you a better scientist or engineer. It will force you to see holes in your thinking, areas where you've made assumptions, places where you should add references, or data, or further analysis.

Technical writing is a *craft*, not an art

Like any other craft, you have to learn the techniques

You have to get feed-back from experts

You have to practice—a lot!

The same skills that make you a good scientist or engineer will make you a good technical writer—logic, precision, pattern recognition, the ability to sort out what's important

Successful science writing is

Written with the *reader* in mind

Logically constructed—think "linear"

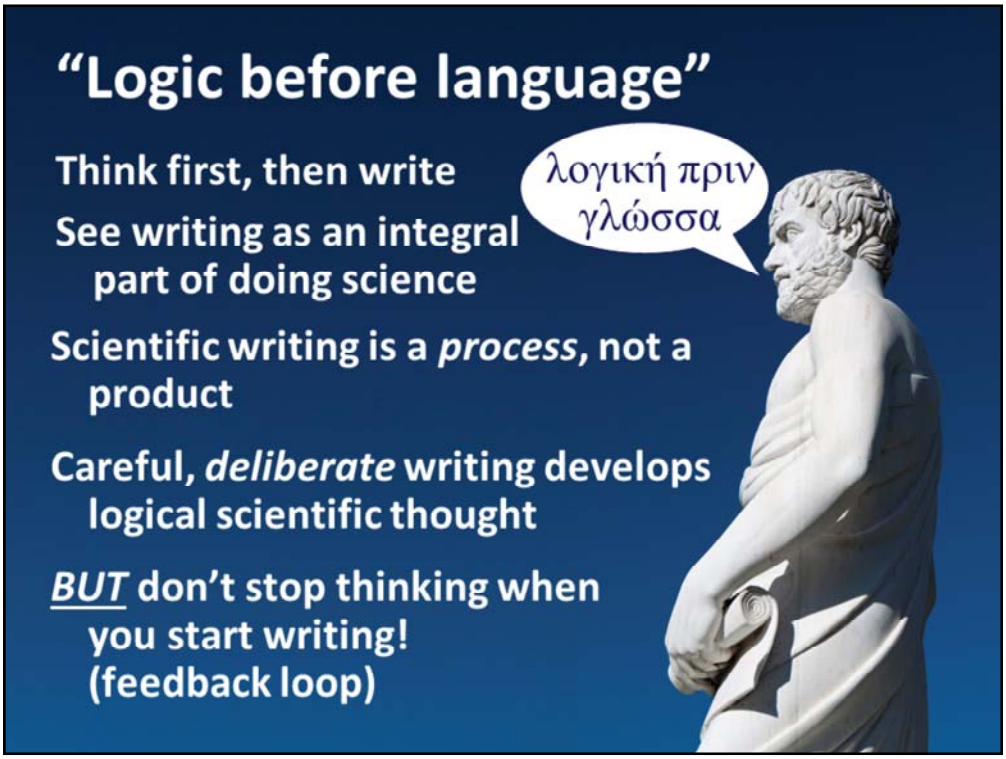
Hypothesis → Point A → Point B → Conclusions

Clearly and succinctly expressed

Precisely and simply worded

Written to inform and persuade the reader

The first step in *any* writing project should be an analysis of the audience for whom the document is intended.



logikḯ prin gló̱ssa (loyeekee prin glōssuh)

Too often, scientists and engineers think of doing research and writing as discrete tasks that have little to do with one another. Today, I'd like you to think of them as a feedback loop, where progress in one informs and drives progress in the other.

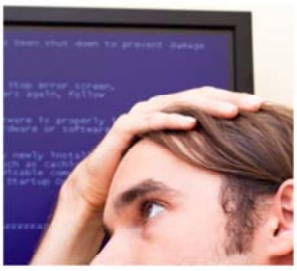
From Peter Woodford: "Somehow the discipline of crystallizing a thought into a grammatical sentence with a beginning, a middle, and an end clarifies, sharpens, and delimits the thought.

As you first start thinking about your paper, answer four questions:

1. **What is my *purpose* in writing this document? What's my ultimate goal?**
2. **Who is going to read it? What do they already know, and what am I going to have to explain? What do *they* want to get out of this paper?**
3. **What *one thing* do I want the reader to remember? What's the "take-away" message?**
4. **What are my space/time/page constraints?**

At this stage of your writing project, think about what you want to convey to your audience. What are the important points that you want them to understand and remember?

Novice writers use the "core dump" method —inefficient and produces poor results



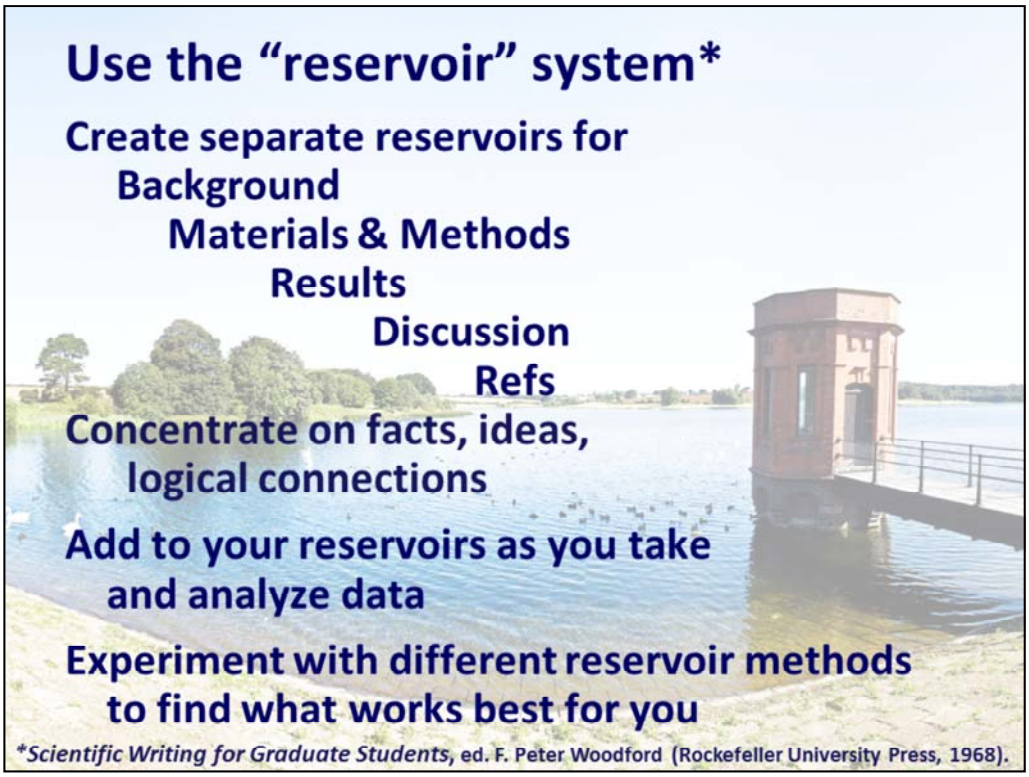
Always start from a plan—always!

1. Promotes thinking
2. Easiest way to get started if you don't like to write
3. Gives you control over length and focus
4. Increases the logical persuasiveness* and coherence of your final paper (or talk)

*"Persuasion in Technical Communications," http://people.physics.illinois.edu/Celia/Persuasion.pdf

An outline is a tool that enables you to look systematically at how a paper or presentation is organized. Learning to write from an outline is one of the easiest ways to (1) get started and (2) improve the content and coherence of your scientific writing.

Next, we'll look at how to use outlines to get started on any writing project.

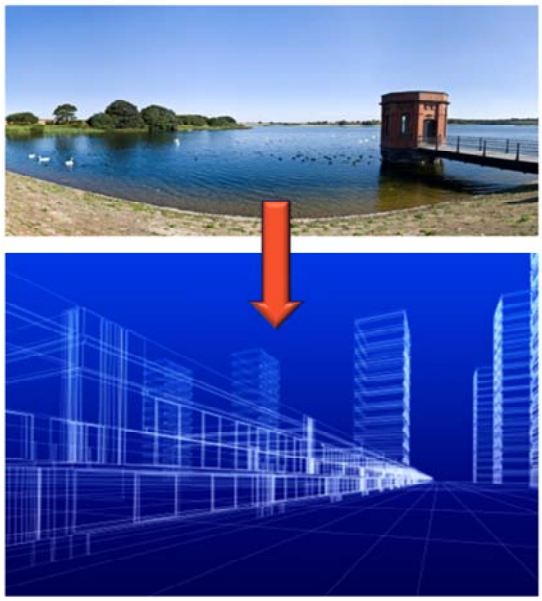


The idea of creating separate holding pens for various parts of a technical document was first articulated, as far as I know, by F. Peter Woodford in *Scientific Writing for Graduate Students: A CBE Manual* (Rockefeller University Press, New York, 1968). Although targeted to graduate students in the life sciences and dated in language (not ***all*** scientists are men!), the fundamentals of Woodford's approach are practical and useful for all scientists and engineers.

Your reservoirs can take many forms—color-coded index cards, color-coded sheets of paper, separate word processing files. Experiment and find a method that works for you.

Now you're ready to start building a coherent narrative

In the next steps, we'll take the **content** of our reservoirs and make a **plan** to guide the building of our paper



Close your eyes and picture in your mind your favorite childhood storybook

What made it so attractive to you?

I'm going to guess that book had

- Words you understood
- Interesting, engaging pictures
- A simple, direct storyline
- Clear connections and transitions
- A satisfying ending
- Ideas that captured your imagination and expanded your horizons

Guess what!
Nothing has really changed since you were 5.

Think about what made a good story when you were 5 years old. The same elements that attracted you as a child still work—interesting pictures, words you understand, simple, direct storyline, a logical structure, analogy, an enthusiastic narrator, something that stimulates your imagination and makes you think.

RULE #1: Never write *anything* without first analyzing your audience

Who is going to read my paper?

What do they already know?
(words, concepts, methods)

What *don't* they know that
I will have to explain?

Where might they become confused?

Where can I send them for more information?

What is most important for them to understand?

Think carefully about who you want to read your paper, and craft your message to engage that reader.

RULE #2: Tell a good story

- Orient the reader with a solid introduction
- Emphasize what is new
- Use language that is understandable and meaningful for your reader
- Arrange the narrative so the logic is clear—use transitional statements to guide your reader
- Provide clear, visually interesting, memorable figures
- Provide a strong summary; don't just trail off at the end

If the first rule of writing a successful paper is to know your audience, the second rule is ***tell a good story***, in language that your reader will understand.

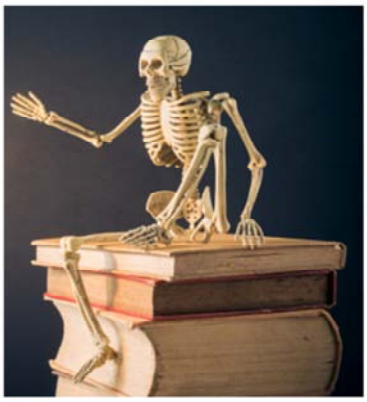
RULE #3: Never write *anything* without first writing a synopsis and an outline!

"If you don't know where you are going, you might wind up someplace else."

—Yogi Berra

Start out with a five-sentence synopsis

1. What was the goal?
2. How does it fit into the context of prior work?
3. What method(s) did you use?
4. What were your results?
5. What do they mean? What have you contributed?



Answer each question in one coherent sentence

The synopsis is the "skeleton" for your paper

Writing a synopsis is a good way to get started because it defines the content and scope of your paper.

Think of the synopsis as the skeleton—it gives the whole paper its shape and supports your evidence and arguments.

Next, make an outline to avoid an amateur's mistakes

- Using chronological instead of analytical order
- Devoting the most ink to the parts that took the longest to do
- Including superfluous or discursive information
- Omitting discussion of assumptions
- Failing to provide logical transitions
- Each sentence in your synopsis becomes a section of your outline

Some beginning authors think that if they spent 90 percent of their time on some aspect of the experiment, they should devote 90 percent of the paper to that topic., or they should present a chronological history of the experiment.

Readers don't want to know all the things that went wrong, all the components that failed, all the adjustments that had to be made to get the data. They want to know what worked, how it worked, what the results are, and what you think they mean.

Remember, a journal is an archive of your results and how you got them so others can reproduce them, not a cemetery where you bury all your mistakes.

Your outline should accommodate the standard model of science papers

I. Background and Introduction

II. Methods/Procedure

III. Results

IV. Discussion

V. Conclusions

VI. Acknowledgments

VII. References

Make outlines for §I. through §V.

Formal scientific papers are ***always*** presented in this order, but they're not written in this order.

No experienced researcher that I know starts with the title and writes a paper sequentially. Nobody.

Most scientists and engineers usually write papers in the following order:

1. Methods
2. Results
3. Discussion
4. Conclusions
5. Background and Introduction
6. References
7. Acknowledgments
8. Abstract & Final Title

You ***must*** have an outline to keep a coherent narrative flow as you write the separate sections of a paper.

Writers use two kinds of outlines—"topic" and "sentence"

Topic outlines use short phrases

- CO_2 underground storage—motivation
- Advantages of deep saline formations
- Convection could provide "stirring"
- Boycott effect

A topic outline is a good way to get started, but it may not be detailed enough for science writing

A topic outline consists of short phrases. Here's an example of a topic outline for a paper on carbon sequestration in deep saline formations.

A topic outline may be best for organizing a number of issues or ideas that could be presented in a several different ways, where the order of presentation is not important. Unfortunately, that is not typically the case for science papers.

While they might not be detailed enough, topic outlines are fast and easy to write. You might find it helpful to sketch out a topic outline first, and then expand it into a full-sentence outline.

Writers use two kinds of outlines—"topic" and "sentence"

Topic outlines use short phrases

- CO_2 underground storage—motivation
- Advantages of deep saline formations
- Convection could provide "stirring"
- Boycott effect

Use "sentence" outlines for science writing

- **Deep saline aquifers (DSAs) are underground salt-water reservoirs capped by impermeable rocks.**
- **DSAs offer large storage capacity for carbon capture and sequestration.**
- **Sequestered CO_2 would rise and form a separate layer that restricts dissolution.**

Today we'll look at the sentence outline, which is better suited for papers (and talks) that require complex information to be presented in strict logical order.

Many of the ideas about full-sentence outlining are taken from a course given by Ohio Eminent Scholar and Professor of Physics at The Ohio State University, John W. Wilkins (who is also a Physics Illinois alumnus). His trenchant thinking and incisive writing on communicating in physics are gratefully acknowledged.

Tips for writing a sentence outline

Make your sentences as specific and quantitative as possible.

If you have two closely related sentences, combine, differentiate, or eliminate one.

Make a logic map of your sentences; can you show a linear progression of your ideas?

This slide is an example of a "sentence" outline

Make your sentences as specific as possible. The purpose of the sentence outline is to help you spot missing or superfluous material. If your sentences are vague and generalized, you'll lose the main advantage of sentence outlining.

If you have two sentences that say about the same thing, eliminate one of them, combine them, or further differentiate them.

Ideally in science writing, the narrative should flow logically and incrementally from Point A to Point B to Point C to the conclusions. If your outline does not reveal a logical progression of ideas, move things around until it does.

Devise a method that makes it easy to move sentences around and "see" the overall structure of your paper

Hint: a word processing document that shows you only one screen at a time is not an ideal method

A word processing document that displays only part of your outline at a time may not be the best way to get an overall look at your paper. Experiment with other methods—index cards dealt out on a big table, Post-It notes stuck on a wall—use your imagination.

Some physicists I know start out with a visual "outline"; they decide first on the figures they want to present and build from there.

Today, we're going to write the introduction for a paper about the special mirrors built for NASA's Solar Dynamics Observatory

Courtesy NASA

First, write down main points you want to make in the introduction section

- The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
- Mirrors image the sun at all seven euv wavelengths.
- The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
- One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.
- The sun is the source of all space weather, but its physical processes are poorly understood.

*Write a complete sentence for each point, in any order now—we'll arrange the points logically in the next step

Start by writing down the main points you want to make in the paper. Don't worry about details now—just concentrate on the main ideas.

Next, arrange the points so they provide a logical narrative arc*

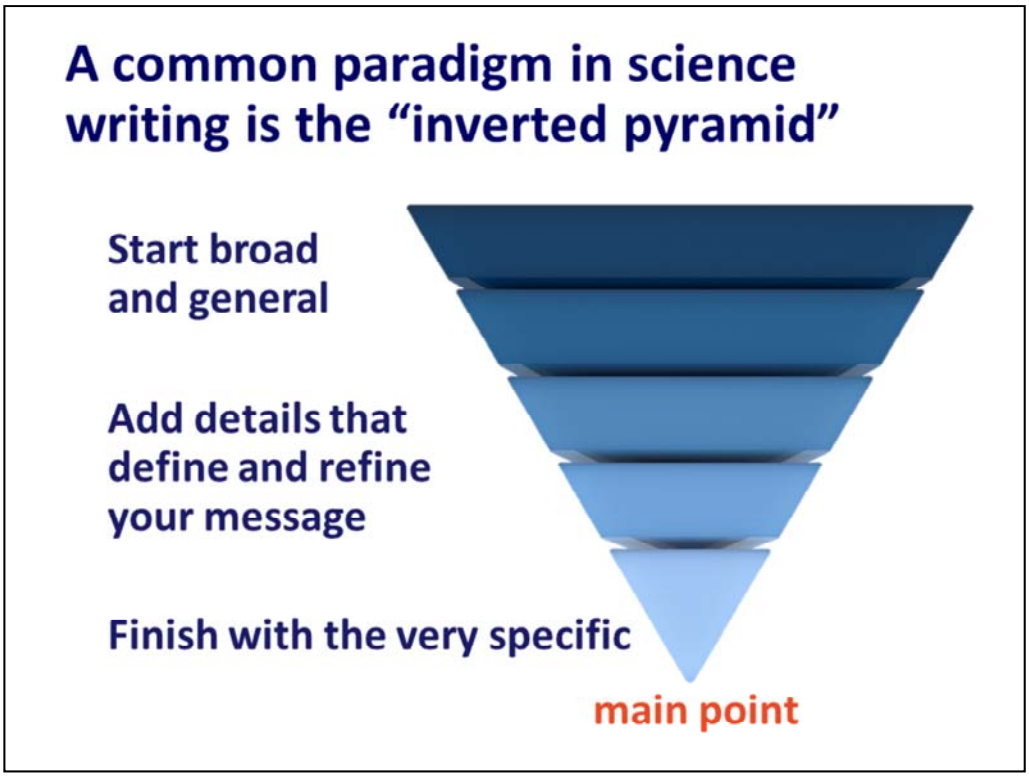
*Show a linear progression from premise to conclusions

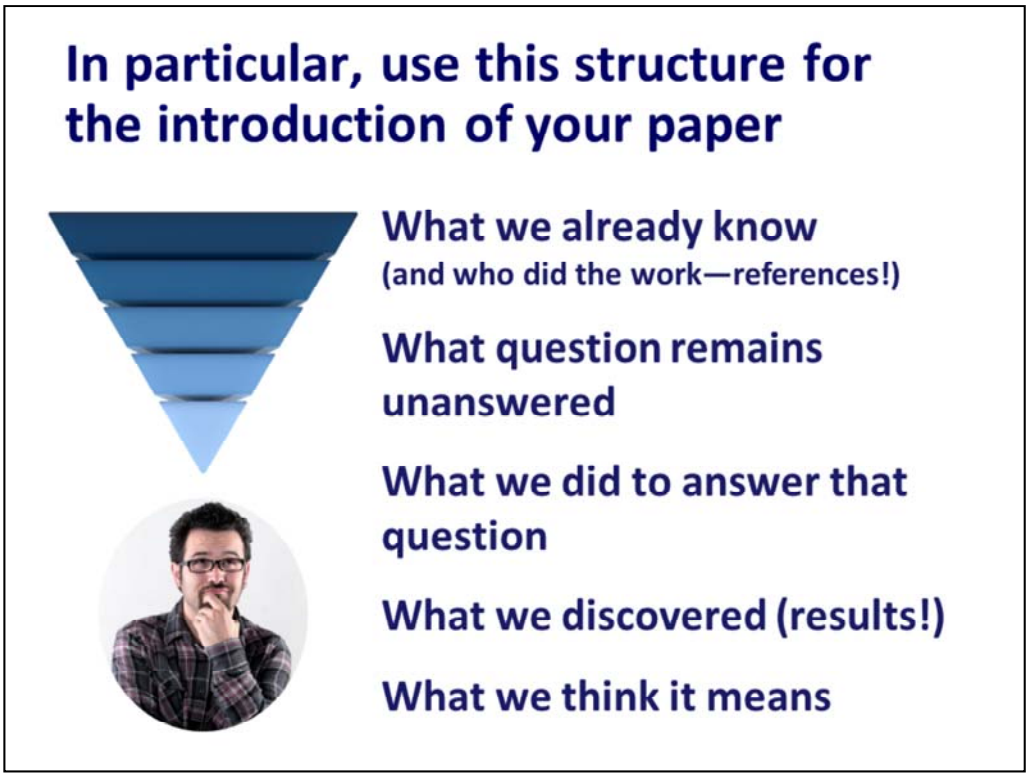
*No digressions or discursive material

Next, arrange the points in a logical order so they provide a coherent storyline.

Think of this step as creating a map to guide your reader through your paper, proposal, or talk.

Each one of these points is going to be a signpost along the journey.





A good introduction uses the following structure:

What we already know (and who did the work—references!)
What question remains unanswered.
What we did to answer that question.
What we discovered (results!)
What we think it means

Next, arrange the points in a logical narrative

- The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
- Mirrors image the sun at all seven euv wavelengths.
- The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
- One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.
- The sun is the source of all space weather, but its physical processes are poorly understood.

Using the inverted-pyramid structure as a guide, we next arrange the points we want to make into a coherent, logical order.

Next, arrange the points in a logical narrative

- The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
- Mirrors image the sun at all seven euv wavelengths.
- The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
- One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.

1. The sun is the source of all space weather, but its physical processes are poorly understood.

Start with the “big picture” statement.

What do we already know, and what remains to be answered?

Next, arrange the points in a logical narrative

- The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
- Mirrors image the sun at all seven euv wavelengths.

2. The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

- One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.

1. The sun is the source of all space weather, but its physical processes are poorly understood.

What we did to solve the problem.

Next, arrange the points in a logical narrative

- The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
- Mirrors image the sun at all seven euv wavelengths.

2. The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
3. One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.
1. The sun is the source of all space weather, but its physical processes are poorly understood.

How we went about it.

Next, arrange the points in a logical narrative

4. The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.

- Mirrors image the sun at all seven euv wavelengths.

2. The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

3. One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.

1. The sun is the source of all space weather, but its physical processes are poorly understood.

Next, arrange the points in a logical narrative

4. The atmospheric imaging assembly (AIA) is composed of highly reflective multi-layer mirrors.
5. Mirrors image the sun at all seven euv wavelengths.
2. The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
3. One component of SDO is the atmospheric imaging assembly (AIA) , a suite of four telescopes.
1. The sun is the source of all space weather, but its physical processes are poorly understood.

Check to see if you've left anything out…

- ✓ The sun is the source of all space weather, but its physical processes are poorly understood.
- ✓ The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.
- ✓ One component of SDO is the atmospheric imaging assembly (AIA), a suite of four telescopes.
- ✓ The AIA is composed of highly reflective multi-layer mirrors.
- ✓ Mirrors image the sun at all seven euv wavelengths.

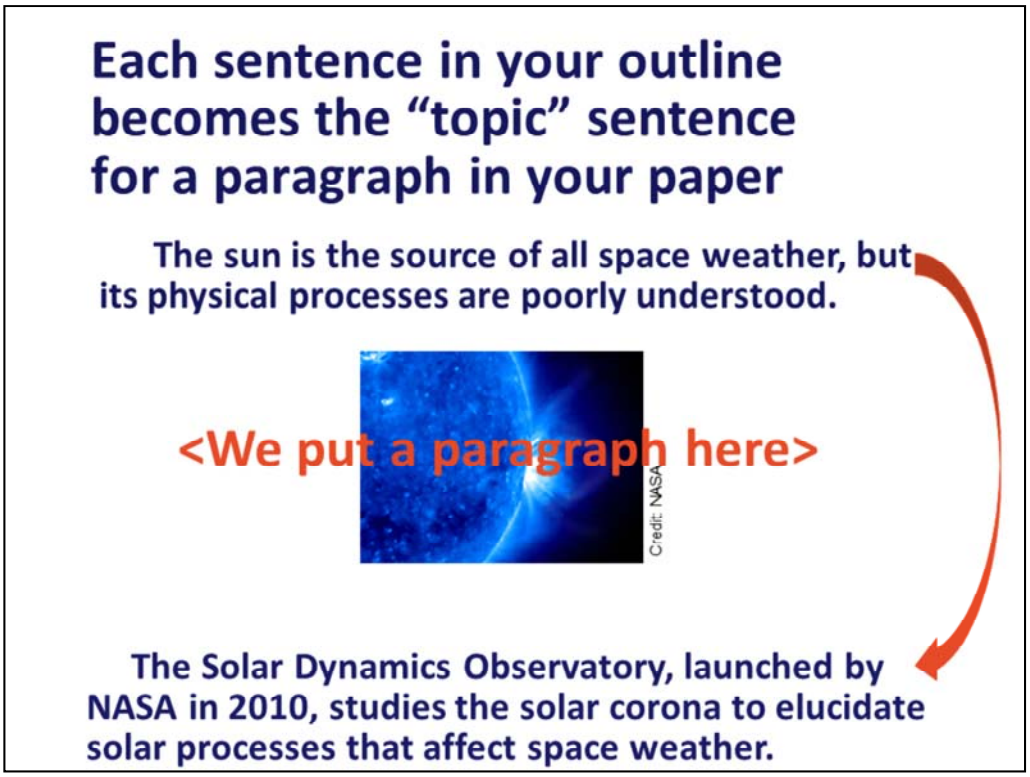
…or included discursive material

Check to see if you've left anything out, or if you have superfluous statements that lead the reader off the trail that you've laid out for him or her to follow.

Make adjustments (additions or deletions) now. It's much easier to write from a structure than to try to go back after you've already written something and try to impose a logical order on it.

It's also much less painful to cut things now than after you've struggled to get them written and are tempted to leave in superfluous information out of pride of authorship.

NOW **(and only now) you're ready to start writing…**



Your main points—your topic sentences—provide a framework for your narrative.

The purpose of ***every additional word*** that you put in a paragraph should be to support and explain the topic statement and move the reader logically and incrementally to the next topic statement.

Celia's foolproof, four-step SEES* method to crank out science writing:

1. State the topic sentence first
2. Explain it
3. Give an example, expand, or present evidence
4. Summarize it in a way that leads logically to the next topic sentence

*State ➔ Explain ➔ Exemplify ➔ Summarize

Tip: Use the same construction paradigm for paragraphs, subsections, and sections of your paper

Use the formula to create logical, coherent paragraphs.

1. Topic sentence goes first (state)

The sun is the source of all space weather, but its physical processes are poorly understood.

The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

In science writing, the topic sentence is almost always the first sentence of the paragraph. While literary writing might put the topic sentence last, to build suspense, or in the middle, to redirect a reader's attention, we put the topic sentence first in scientific writing to emphasize the important points and reinforce the logical structure of the arguments.

Readers pay the most attention at the beginning of chunks of text. Exploit this natural human tendency by putting your topic sentences in the places where people are most likely to recognize and remember them—as the first sentence of each new paragraph.

2. Explain the topic sentence

The sun is the source of all space weather, but its physical processes are poorly understood.
Space weather refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere of the earth. Space weather affects the performance and reliability of space and terrestrial systems and can endanger life and health.

The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

Next, provide additional explanatory details about the topic sentence. Define any unfamiliar words or explain unfamiliar concepts.

3. Give examples or evidence

The sun is the source of all space weather, but its physical processes are poorly understood. Space weather refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere of the earth. Space weather affects the performance and reliability of space and terrestrial systems and can endanger life and health. **For example, a coronal mass ejection, the solar equivalent of a hurricane, can disrupt telecommunications systems on earth.**

The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

Then give examples to further explain or illustrate the concepts contained in the topic sentence. You can also expand on the idea(s) presented in the topic sentence or add evidence for it here.

4. Summarize and transition

The Sun is the source of all space weather, but its physical processes are poorly understood. Space weather refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere of the Earth. Space weather affects the performance and reliability of space and terrestrial systems and can endanger life and health. For example, a coronal mass ejection, the solar equivalent of a hurricane, can disrupt telecommunications systems on Earth. **Solar research is needed to understand solar processes and predict space weather.**

The Solar Dynamics Observatory, launched by NASA in 2010, studies the solar corona to elucidate solar processes that affect space weather.

Finally, summarize the foregoing material and provide a transition to the topic sentence in the next paragraph.

In this example, the last sentence points back to the topic sentence (the sun's physical processes are poorly understood) and anticipates the next topic sentence (the SDO was launched to elucidate solar processes). By repeating the idea that solar processes are poorly understood and require additional study, the last sentence sets the stage for the next paragraph.

Thus, the two paragraphs are logically linked by the idea they share.

Commit to writing incrementally

Think "feedback loop"

Writing is a *process*

1. Construct a preliminary outline, based on your initial goals for the project
2. Write portions of the "results" and "discussion" sections while you're taking and analyzing data
3. Add to your references as you go
4. Make your figures and tables early

Advantages:

- More complete, persuasive paper
- Finished result faster, giving you more time to edit and polish

Commit to writing incrementally; writing should be an integral part of your research work—remember "feedback loop."

Advantages of the incremental method:

1. You may discover additional data that are needed while the equipment is still set up and the project ongoing.
2. You get a finished paper faster, with more time to revise and edit.

Highly recommended: H.B. Michaelson, How to Write and Publish Engineering Reports and Papers (Oryx Press, Phoenix, 1990). Yes, it's old, but it's really good.

Plan for time to reflect and revise

You should allow as much time for revision as you do for writing your paper in the first place

Ideally, revising occurs in three steps:

1. **Checking and improving the content and logical structure**
2. **Evaluating the use of language (emphasis, tone, vocabulary)**
3. **Proofreading for mechanical errors**

Rewriting often takes more time that writing. As you are planning your timeline for completing your paper, build in sufficient time for getting feedback from others and revising the manuscript.

The probability that a first-draft paper, ripped off the printer 30 ns before the deadline, will be acceptable work asymptotically approaches 0.

Allow time for careful proofreading!

VOLUME 76, NUMBER 17 PHYSICAL REVIEW LETTERS 22 APRIL 1996

Effect of Filamentation of Brillouin Scattering in Large Underdense Plasmas Irradiated by Incoherent Laser Light
[Phys. Rev. Lett. 75, 4413 (1995)]

T. Afshar-rad, L. A. Gizzi, M. Dessleberger, and O. Willi

We regret that in the printed version of the manuscript, Figs. 2(a)–2(c) were interchanged with Figs. 3(a)–3(c). In addition, the published Fig. 3(d) was incorrect. As the principal conclusion of the article was based upon a comparison of Figs. 2(a) and 2(b) to Figs. 3(a) and 3(b), this error may have prevented many readers from comprehending the Letter. We are therefore reprinting it correctly below.

You do not want to be these authors. Trust me.

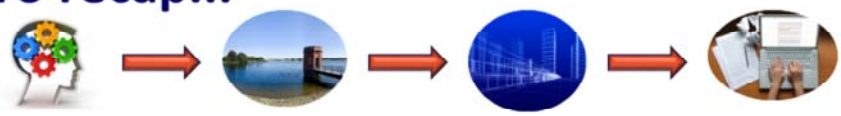
In particular, leave time for careful proofreading.

Old copy editor's tip: Instead of reading from the top left corner, across and down, as you would read anything else, start in the lower right corner and read backwards, bottom of the page, one line at a time, to the top. Doing so ***forces*** you to look at each letter and each word individually.

Other good proofreading tactics are to read the text aloud (reading slows you down and you look at each word) or underline the line of text with your finger as you are reading (also slows you down).

Finally, proofread ***everything***—titles, section headings, data in tables, labels in figures.

To recap...



1. Heed Aristotle—logic before language.
2. Start filling your reservoirs while the project is still underway. Write incrementally.
3. Write from an outline. Always! And use a full-sentence outline for best results.
4. Use the SEES paragraph method to create a tightly written, coherent logical narrative.
5. Proofread!

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NOTES: