Two important disclaimers:
1. I am not a physicist; I’m a science writer and technical editor.
2. All my experience as a writer and editor has been in physics and nuclear engineering. I think the basic principles of scientific communications transcend disciplinary boundaries, but your experience may differ.

Learning to write in the style described here will not only make you a better writer, it will also make you a better scientist. 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.

All images used in this talk, unless otherwise identified, have been purchased from istockphoto.com. http://www.istockphoto.com
Two fundamental rules for every writing project:

Rule #1—think first, then write

Rule #2—Never try to write anything without first making an outline

“Stream of conscious” may have worked for James Joyce (although the jury is still out on that one, in my opinion), but it doesn’t work for science writing.

Trying to write anything without an outline is like trying to build a skyscraper without a blueprint, foundation, tape, or level. If you think you can go back and “fix” it later, you probably can, but it’s going to be painful, expensive, and time-consuming. It’s always faster, cheaper, and ultimately easier to plan first.

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.

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

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.

For more of Professor Wilkins’ excellent advice on technical writing, see his “Brief Guide to Writing and Speaking”: http://www.physics.ohio-state.edu/~wilkins/writing/Handouts/brief_writ_speak.html.

“The only demand I make of my reader is that he should devote his whole life to my works.”

—James Joyce

In science, nobody is going to devote his or her whole life to your work.

You heard it here first.
Writers use two kinds of outlines—“topic” and “sentence”

Topic outlines use short phrases
- CO₂ underground storage—motivation
- Advantages of deep saline formations
- Convection could provide “stirring”
- Boycott effect

A topic outline consists of short phrases that are arranged hierarchically.

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.
Writers use two kinds of outlines—“topic” and “sentence”

**Topic outlines use short phrases**
- \( \text{CO}_2 \) underground storage—motivation
- Advantages of deep saline formations
- Convection could provide “stirring”
- Boycott effect

**Sentence outlines use full sentences (duh!)**
- Deep saline aquifers (DSAs) are underground salt-water reservoirs capped by impermeable rocks.
- DSAs offer large storage capacity for carbon capture and sequestration.
- Sequestered \( \text{CO}_2 \) 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.
Writing a sentence outline will help you as a writer in a variety of ways:

- Your writing will be clearer and more direct. It’s unlikely that you’ll write a cogent paragraph until you can write a sentence that plainly articulates the point of that paragraph.

- Your arguments will be stronger. A sentence outline shows you the narrative flow of the paper. Are your ideas arranged in the most logical, persuasive way to lead the reader to the conclusions you want him to reach? It’s much easier to move sentences around as you are planning a paper than it is whole paragraphs.

- Your paper will be more cohesive, because you’ll be more aware of where transitions are needed to move the reader from one idea to the next.

- Your writing will be more concise. A sentence outline will help you spot superfluous material that stands in the way of a straightforward narrative.

- You will get a better idea of the size and scope of your final paper. The length of proposals, journal articles, and conference papers is usually strictly limited. A sentence outline makes it easier to estimate what the final length of your document will be and allows you to make any needed adjustments earlier in the writing process. It’s agonizing to make major cuts after you’ve already gotten something written, and you’ll avoid the temptation of leaving digressions in your paper because of pride of authorship.

- You will ultimately save time. The investment in planning and getting organized now will pay off in an easier-to-write, coherent, clear final document.

- Your colleagues will eagerly look forward to hearing your next talk or reading your next paper. Your reviewers will expedite your publications. Funders will shower you with $$$. (Okay, maybe not #3...).
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?

Devise a method that makes it easier to move sentences around and “see” the overall structure of the paper

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 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.

If you’re not sure what a logic map is and want to read an astonishingly badly written explanation of the concept, see http://www.sun-associates.com/edtechevaluation/forms/creatinglogmap.pdf.

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.
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?

As you are deciding about these points, consider three main 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 document?

3. What are my space/time/page constraints?
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 talk, paper, or proposal.

Each one of these points is going to be a signpost along the journey.
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 NASA Solar Dynamics Observatory (SDO) was launched in 2010 to study the solar corona.

✓ 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 Sun at all seven EUV wavelengths.

... or if you’ve included superfluous material that will derail the logical flow of your story

Check to see if you’ve left anything out, or if you have superfluous statements that lead the reader off the trail that you’d 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 structure on it.

One of the key advantages of this method is its scalability—you can use it for short papers, theses, talks, posters—for any audience.

Do the math:  one topic sentence = one paragraph
               one figure = one paragraph
               four paragraphs = one page

Suppose you’re writing a Phys. Rev. Lett. and you have 21 sentences and three figures. You know right NOW, before you write another word, that you’ve got too much material for one PRL. Make your adjustments now—it’s much less painful than trying to cut later.
Number your sentences...

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

2. The NASA Solar Dynamics Observatory (SDO) was launched in 2010 to study the solar corona.

3. One component of SDO is the Atmospheric Imaging Assembly (AIA), a suite of four telescopes.

4. The AIA is composed of highly reflective multi-layer mirrors.

5. Mirrors image Sun at all seven EUV wavelengths.

It seems silly, but numbering actually helps to keep you on track. Writing is an evolutionary process, and if you have a numbered list of points and check them off as you write, you’ll stick to your plan.

You can also start writing “in the middle” if you want to; as long as you’ve got a check-off list, you won’t forget important points.
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 inevitably to the next topic statement.
Use the formula to create logical, coherent paragraphs.

So let’s go back to our first two topic sentences from Slide 8...

“The Sun is the source of all space weather...”
and
“The Solar Dynamics Observatory was launched by NASA in 2010...”
and run them through the paragraph cranker OUTER...
1. Topic sentence goes first

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

The Solar Dynamics Observatory was launched by NASA in 2010 to study the solar corona.

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, put the topic sentence first in your paragraphs to emphasize your important points and reinforce the logical structure of your 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 it

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 that affect the performance and reliability of space and terrestrial systems and that can endanger life and health.

The Solar Dynamics Observatory was launched by NASA in 2010 to study the solar corona.

In the second sentence(s), explain, expand on, or provide supporting evidence for the ideas conveyed in the topic sentence.
3. Give an example

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 that affect the performance and reliability of space and terrestrial systems and that 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 was launched by NASA in 2010 to study the solar corona.

Your explanation will often include illustrative examples. Put them next.
Finally, add a transitional sentence that sums up this paragraph and leads the reader logically to the next topic sentence.

In this example, the fourth sentence repeats the ideas of “space weather” and “not currently understood” that are introduced in the topic sentence and sets the stage for the next paragraph, which explains what the SDO is, what kind of research it is designed to do, and how it is addressing the problem of space weather. Thus the two paragraphs are linked structurally by the evolution of the ideas and explanations that they present.
Paragraph equation:

\[1 S_t = 1 P,\]  \hfill [1]

where \(S_t\) is a topic sentence, and \(P\) is a paragraph.

Don’t put more than one topic sentence in a paragraph.

Don’t put anything in a paragraph that doesn’t support, explain, exemplify, or summarize the topic sentence.

Write shorter paragraphs (<8 sentences).

Write from an outline!

No superfluous “stuff” in a paragraph. If it is not directly related to the topic sentence, delete it or move it to its own paragraph.

For more practical advice about how to write a paragraph, see http://www.paragraphorganizer.com/inner/how_to_write_paragraph.htm.

To learn more about the Solar Dynamics Observatory (SDO), see http://sdo.gsfc.nasa.gov/.

To learn more about how the SDO’s extreme ultraviolet (EUV) telescopes were constructed, see https://str.llnl.gov/JanFeb11/soufli.html.
These brief rants are designed to address common mistakes in technical writing and to administer instruction in small, palatable doses. They’re all downloadable PDF files. Feedback is welcomed, but you’re probably not going to change Ms. P’s mind.
Writing is hard work. Even as you get more skilled with practice, it’s still hard work. But it’s manageable if you train yourself to keep writing regularly.

If you really hate writing, think of it as any other distasteful chore you have to do—washing the dishes, doing the laundry, cleaning the apartment. It just gets worse if you put it off until you have mountains of dirty plates and glasses, heaps of stinky towels and underwear, and piles of beer cans and pizza boxes. Doing a little every day keeps you from getting overwhelmed with guilt and paralyzed by the impossibility of writing pages and pages all at once.

Resolve to write *something* every day. Fill in your outline; decide on a figure you want to use and write the caption; add to your bibliography. Break your big project into smaller, less-intimidating chunks. Hammer out a first draft. Repeat daily.

**DO NOT** wait to start writing until you “get in the mood.” If you don’t like to write, that mood may never come.

**A cyber essay that can change your life:** John Perry, “Structured Procrastination” (http://www.structuredprocrastination.com/).
Strive for brevity and clarity.

Write short sentences—less than 25 words.

Avoid long strings of nouns used as adjectives—“mean field anisotropic superconducting reverse bias toroid magnet” (or MASRBTM, to its fans)

Follow the “three preposition” rule.* If you have a sentence that contains more than three prepositions, rewrite it before it wanders off to die.

Writing shorter paragraphs will also help your reader follow the logic of your narrative. For more information on how to write strong paragraphs, see http://people.physics.illinois.edu/Celia/Lectures/Paragraphs.pdf.

*With thanks to Stephanie Teich-McGoldrick, who first introduced me to the three-preposition rule.
“Write with nouns and verbs, not adjectives and adverbs. The adjective hasn’t been built yet that can pull a weak or inaccurate noun out of a tight place.”
—Will Strunk, *The Elements of Style*

Instead of worrying about voice, use strong verbs. Proper verb choice is often the difference between crisp, clear text and bloated, clumsy writing.

Replace wimpy verb phrases and “to be” verbs with strong, action verbs.
Weak verb phrases—made a determination → determined
performed a measurement → measured
carried out the analysis → analyzed

Change nouns ending in –tion, –ment, and –ance back into the verbs they are derived from; your writing will be more crisp and concise.

Make adjectives and adverbs quantitative, not qualitative.

For more about active verbs and passive vs. active voice, see http://people.physics.illinois.edu/Celia/Lectures/Verbs.pdf.
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The probability that a first draft will not require revision asymptotically approaches 0.

“Perfection is achieved, not when there is nothing left to add, but when there is nothing left to take away.”—Antoine-Marie-Roger de Saint-Exupery

Brevity is a key goal. Use your revisions to clarify and simplify.

Give yourself adequate time to reflect and rewrite.

Revising should incorporate four distinct elements:
1) clarifying the selection and presentation of ideas.
2) organizing the narrative logically and incrementally.
3) using language precisely and concisely.
4) correcting “mechanical” errors that detract from a professional argument.

Ideally, editing should be done in three passes:
1) reading for content (the science).
2) editing for style (organization and language).
3) proofreading for mechanics (spelling, punctuation, grammar, usage).

Writing well is a learned skill—train yourself to recognize good writing; emulate good examples, and practice, practice, practice.
To recap: Writing well is a learned skill

To write well, read critically
Make a (full-sentence) outline and follow it
Commit to writing incrementally
Get words on paper/screen
Revise, revise, revise, revise, revise, revise, revise...
FINISH!!!*

*Tip: Don’t use too many exclamation points in scientific writing!!
People will think you’re a crackpot!!!!

Writing well requires an extensive, robust vocabulary and a sensitivity to words’ nuances.
Writing well requires practice and iteration.
Writing well requires constructive criticism from experts and peers.
Train yourself to recognize excellence and emulate it.
Seize every opportunity that presents itself to improve your skills; your investment in will affect your future success.
Practice may not make “perfect,” but it definitely makes “better.”

Sources of good advice and further reading:
Celia’s materials on technical writing and editing:
http://physics.illinois.edu/people/profile.asp?cmelliot (and scroll to the bottom of the page).
Ms. Particular’s Micro-Lectures on Style and Usage:
http://people.physics.illinois.edu/Celia/MsP/MsParticular.htm