

Four important disclaimers:

1. I am not a physicist; I'm a science writer and technical editor. No questions about the quantum Hall effect in topological insulators, please!
2. All my experience as a writer and editor has been in physics and nuclear engineering. I think the basic principles of scientific communication transcend disciplinary boundaries, but your experience may differ.
3. All my experience has been at universities.
4. The opinions expressed are solely my own and are not necessarily shared by the University of Illinois. But they should be.

Audience questions:

1. Who hates to write?
2. Who is convinced that logical, analytical, methodical left-brainers become scientists, and creative, artistic right-brainers become writers?
3. Who finds writing difficult?
4. Who thinks writing is a distasteful chore that has to be done, but that interferes with your research?
5. Who thinks you already write fine and you're just here because your adviser told you to come?

All images used in this talk, unless otherwise identified, are royalty-free and have been purchased from istockphoto.com. <http://www.istockphoto.com>

“Logic before language”

Two-way relationship
between thinking and
writing—feedback loop

λογική πριν
γλώσσα

Careful, *deliberate* writing assists in
developing logical scientific thought

Scientific writing is a *process*;
good writing evolves as your
thinking matures

BUT don’t stop thinking when
you start writing!

logikí prin glóssa (loyeekee prin glössuh)

Too often, scientists 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.

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.

Use the “reservoir” system*

Create separate reservoirs for

- Background**
- Materials & Methods**
- Results**
- Discussion**
- Refs**

Concentrate on facts, ideas, logical connections

Add to your reservoirs as you take and analyze data

Experiment with different reservoir methods to find what works best for you

*Scientific Writing for Graduate Students, ed. F. Peter Woodford (Rockefeller University Press, 1968).

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 remain sound.

Fill your reservoirs thoughtfully

Is the item really necessary?

To what reservoir does it logically belong?

Content for reservoirs:

Facts, observations, data

Figures and captions

Tables

Analogies

Ideas and speculations

Unanswered questions

Key words

Felicitous phrases



At this stage, don't worry too much about niceties of language—concentrate on getting things sorted into the right categories.

Vernon Booth, a major god in my pantheon (*Communicating in Science: Writing a scientific paper and speaking at scientific meetings*, 2nd ed. [Cambridge University Press, Cambridge, 1993]) also recommends the use of writing reservoirs.

Before you start writing, answer four questions:

Am I ready to publish?

**What question has been asked,
and what are the conclusions?**

**What is the most suitable journal?
(Who's my audience?)**

**How are my findings related to the existing
body of knowledge?**



Question 1: self-explanatory

Question 2: Do *not* ask “what was the purpose of the research?” Doing so leads to “investigating x process” or “measuring y phenomena,” which do nothing to explain what hypothesis was tested.

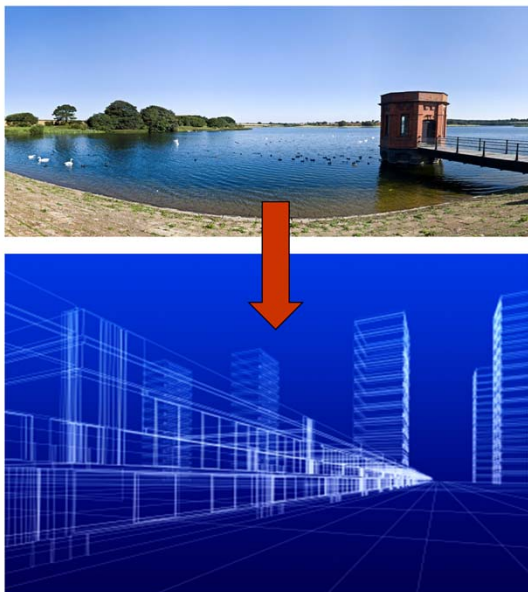
Question 3: Why choose one journal over another?

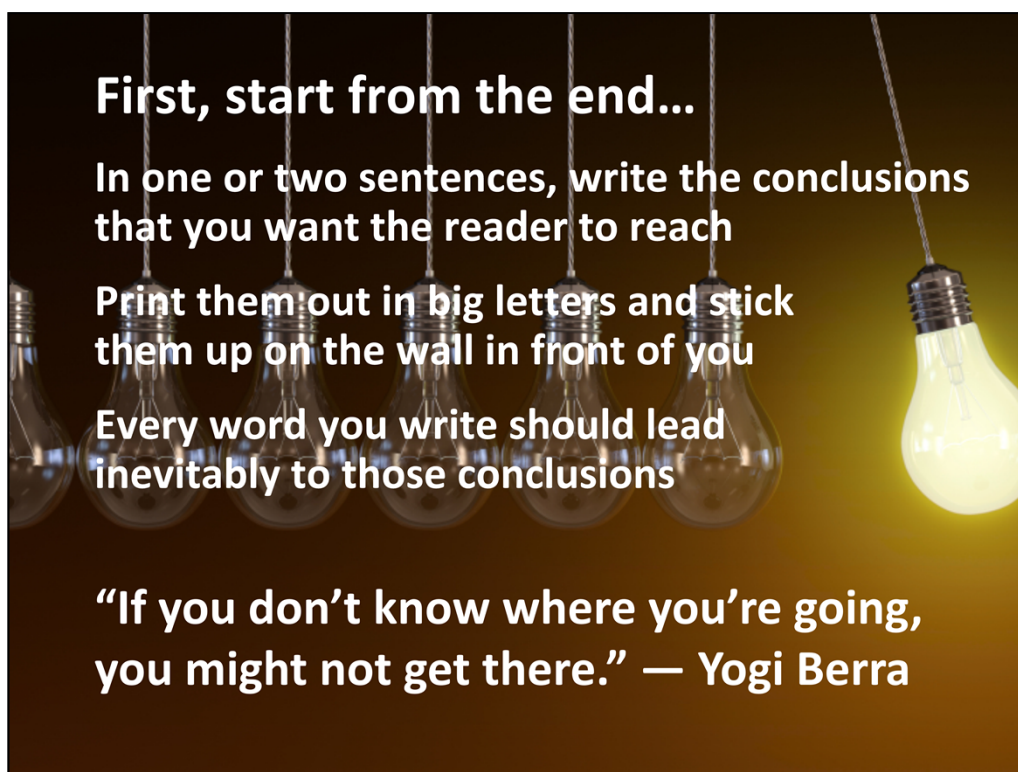
- General quality and prestige.
- Size of the audience.
- Type of audience.
- Speed of publication.
- Availability of supplemental materials.

Question 4: specifies exact area where advance was made, where the work of others stopped short, and what future work must be done. Eliminates irrelevant material and prepares for the introduction and discussion sections.

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





It’s a truism that in order to get someplace, you’ve got to know where you’re going.

Before you start writing, decide where you want the reader to end up.

**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://courses.physics.illinois.edu/PHYS496/Lectures/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.

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.

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 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

- **CO₂ 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 CO₂ 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.

Practice full-sentence outlining

Improved clarity
Improved logical argument
Improved cohesiveness; better transitions
Improved conciseness
Improved control of length
Improved writing efficiency
Improved reader experience



This slide is an example of a “topic” outline—the order that the points are presented in doesn’t really matter

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.

This slide is an example of a “sentence” outline—use it for writing projects (papers, proposals, talks) where it’s important to show a logical progression of your ideas

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.

Start by writing down the main points you want to make

- 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.
- Mirrors image Sun at all seven EUV wavelengths.
- The Sun is the source of all space weather, but its physical processes are poorly understood.
- The AIA is composed of highly reflective multi-layer mirrors.


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

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? And where do you want them to end up? (Hint: at your predefined conclusions!)

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 so they provide a logical narrative

- 
- **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.**
 - **Mirrors image Sun at all seven EUV wavelengths.**
 - **The Sun is the source of all space weather, but its physical processes are poorly understood.**
 - **The AIA is composed of highly reflective multi-layer mirrors.**

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 to the conclusions that you want him or her to reach.

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.

Note how the sentences are arranged in a logical order and “zoom in” from general to very specific—a standard paradigm for science writing.

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 paper for *Physical Review Letters* 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 paper. 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.**

Now you're ready to start writing...

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.

Each sentence in your outline becomes the “topic” sentence for a paragraph in your paper

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

<We put a paragraph here>



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

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. Put the topic sentence first**
- 2. Explain it**
- 3. Give an example of it**
- 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.

So let's go back to our first two topic sentences from Slide 16...

"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 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 next sentence(s), explain, expand on, or provide supporting evidence for the ideas conveyed in the topic sentence.

In the SEES method, this first *E* can stand for three things: explanation, expansion, evidence.

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.

Note that the writer has used an example from terrestrial weather, a hurricane, to explain space weather. Neat!

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 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.

Solar research is needed to understand solar processes and predict space weather.

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



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:

$$1 S_t = 1 \P, \quad [1]$$

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.

In fact, no superfluous stuff anywhere!
(q.v. <http://people.physics.illinois.edu/Celia/Lectures/Fluff.pdf>)

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>.

You can use the same method for talks, too!

Put your topic sentence at the top of the slide

Use the rest of the slide for

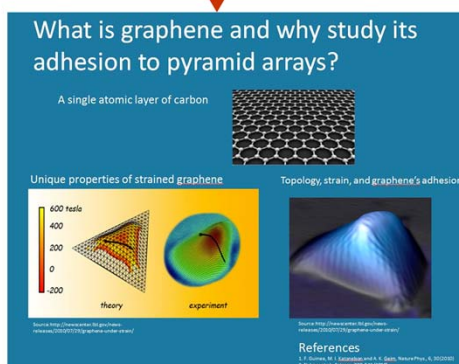


illustrative figures

data

examples

clarifying details



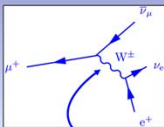
Courtesy Stephen Gill, Mason Group, University of Illinois

Take advantage of the way people's attention naturally ebbs and flows. People typically pay attention at the beginning, drift off in the middle, and then snap back to attention when something changes (the indentation of a new paragraph or the change of a slide).

Use that natural human tendency to position your important points where your reader or your audience is paying the most attention—at the beginning of a paragraph or the top of a slide.

Replace the content-less PPT “title” with a motivating topic sentence

Background

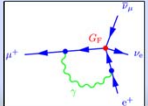


The V-A theory factorizes into a pure **weak** contribution, and **non-weak** corrections, essentially uncontaminated by hadronic uncertainties.

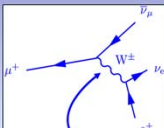
$$\frac{1}{\tau_{\mu^+}} = \frac{G_F^2 m_\mu^5}{192\pi^3} (1 + q)$$

The muon decays only via the weak interaction

All relevant weak interaction physics confined to one parameter with a simple experimental interpretation.



Muon decay gives us unique access to the electroweak scale

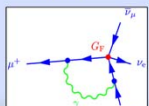


The V-A theory factorizes into a pure **weak** contribution, and **non-weak** corrections, essentially uncontaminated by hadronic uncertainties.

$$\frac{1}{\tau_{\mu^+}} = \frac{G_F^2 m_\mu^5}{192\pi^3} (1 + q)$$

The muon decays only via the weak interaction

All relevant weak interaction physics confined to one parameter with a simple experimental interpretation.



Courtesy David W. Hertzog

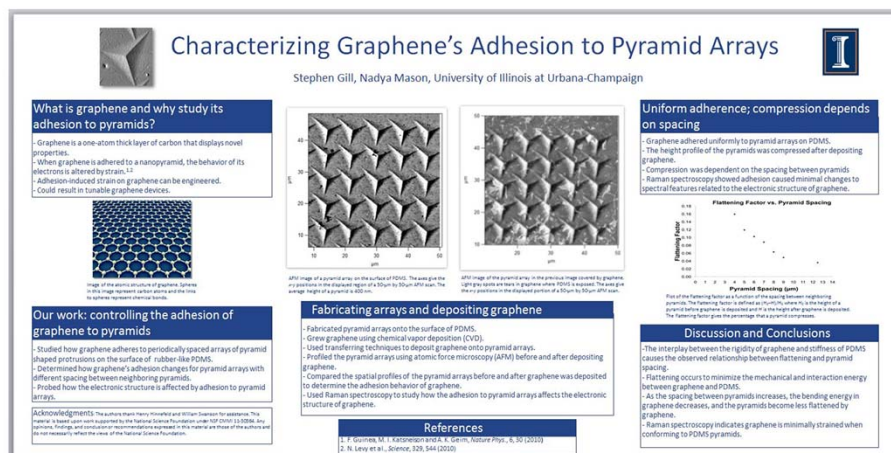
***Tip: Write the statement as a sentence and left-justify it**

Instead of a few-word, contentless “title,” put a sentence at the top of the slide, which the audience will read first, that explains and unifies the rest of the information presented on that slide.

When you’ve nearly finished your presentation, copy the title statements of each slide into a separate document and read them as a narrative. Does your “story” hang together? Are there obvious gaps? Is any part of the story hard to follow?

And even for posters!

Put your topic sentence at the top of each section to attract attention and immediately orient the viewer



Courtesy Stephen Gill, Mason Group, University of Illinois

Think of the section headings of your poster as your topic sentences. Use the rest of the space to explain, exemplify, and summarize.

Tip: Start filling your reservoirs and crafting your outline early

Start writing while you're still taking data

Conventional approach is finish the project and then write it up—bad idea

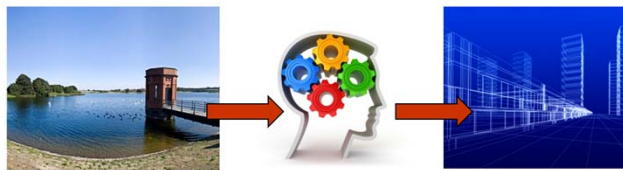
Making the outline will make you see where the holes are and where more (different) data are needed

Much easier to fill in those holes while the project is on-going



Commit to writing incrementally; writing should be an integral part of your research work—think “feedback loop.”

To recap...



1. Heed Aristotle—logic before language
2. Start filling your reservoirs while the project is still underway
3. Write from an outline. Always!
4. Use the SEES paragraph method to create a tightly written, coherent logical narrative

cmelliot@illinois.edu

NOTES: