

HOW TO WRITE A SCIENTIFIC PAPER IN FIFTEEN STEPS

John M. Drake

September 30, 2010

1. **What is the main point of your study.** Write it as a short declarative sentence. This is the working title. This is the thesis of the paper. Every paragraph must illuminate this thesis. Don't start writing until you know the main point. Until you know the main point you have nothing to say.
2. **Determine what the story is.** Articulate the *narrative arc*. Answer such questions as: What did we want to learn? Why did we need to learn this? What did we do? What do we know now? Sketch it out as flow chart. The arc is defined with respect to *turning points* between dichotomies: question/answer, what/why, theory/evidence, data/interpretation. The centerpiece of the narrative should consist of two parts. If it contains only one part it is too simple to be interesting (or publishable). If it contains three or more parts it is too complicated to remember. Ergo, the narrative should consist of two parts. Parts are typically one of the following: experiment, model, observational study, meta-analysis. Example *two-part-schemes* include the following. With relatively little imagination this list can be extended considerably. This is just a start.

<u>Part 1</u>	<u>Part 2</u>
Experiment 1	Experiment 2
Simple model	Complicated model
Experiment	Model to explain experimental observations
Model to generate hypothesis	Experiment to test hypothesis
Observations underlying a hypothesis	Experiment to test hypothesis
Experiment to test hypothesis	Observational study generalizing experimental results
Pattern in observations	Model to explain pattern

3. **What did you do?** Write a numbered list of methods. e.g., "rarefaction was performed on all samples for which species had been identified". You will be tempted to begin writing in paragraphs. Resist the temptation! There will be time for that later (in step 15, to be specific).
4. **Why did you do what you did?** For each item in (3), declare the rationale with an *infinitive clause* (a "to-clause") as in, "To estimate species richness...", "To measure N flux N", "To...". Combine with the lists from (3) ("To estimate species richness, rarefaction was performed on all samples for which species had been identified"). Each linked pair is a method. Group these methods. These groups will grow up to be paragraphs.
5. **What were the results of what you did?** Results are the atoms of which new knowledge is built. Results come from doing things, so every result must have a counterpart in step 3 and every method must lead to a result. Write a numbered list of results. Every observation, measurement, statistic, etc. should be on a separate line. Group results. These groups will also grow up to be paragraphs.

6. **Outline introduction according to Swales's CARS model.** CARS stands for "Create A Research Space". The CARS model consists of three steps:

- a. Identify a territory
- b. Create a niche
- c. Occupy the niche.

Write down the territory, niche, and strategy for occupation. For a classification of the ways to do this and some formulaic phrases that might be useful, see *Academic Writing for Graduate Students* and chapter 7 of *Genre Analysis* by John Swales.

7. **Draft a list of findings.** Findings must pertain to the problems outlined in the introduction. Findings are the results of step 5 placed in a larger context. The relation of results to findings does not need to be one to one. In fact, many times a finding will build on several results considered together. However, there cannot be findings unsupported by results or results that do not lead to findings. One device for checking this is to place the lists of results and findings next to each other and then draw a line for each connection between result and finding. Any result or finding left unconnected must be examined to determine if it is (i) irrelevant (in which case delete it) (ii) requires a new item to be added to the opposite list (in which case add it), or (iii) may be connected to an existing item in the opposite list. Group findings. This is the outline of the *first half of the discussion*.
8. **Draft a list of problem items.** These are caveats, inconsistencies, and anticipated objections to one of (working backward) the interpretation of findings, the results themselves, or the rationale that links the methods with the niche created in step 6. Write the problem items as a numbered list.
9. **For each problem item provide a response.** Typically a response is a qualification, answer, or synthesis. Problem items and responses are one-to-one. List the problem items and responses together as ordered pairs. Group these pairs. These are the outline of the *second half of the discussion*.
10. **Determine the thesis of the closing paragraph.** The closing paragraph is important enough that we treat it by itself. Draft a thesis for this paragraph. The thesis may be a new direction from the thesis of the paper, but the connection should be clear. To reiterate: the connection between the thesis of the paper and the thesis of the final paragraph must be spelled out in the final paragraph. A few rules for final paragraphs:
- a. End on a positive note,
 - b. Avoid ending with a caveat or "need for further research".
- Good endings include:
- c. Declaration of main finding or restatement of thesis,
 - d. Statement of a new question,
 - e. Identification of a concrete application.
11. **Find the paragraphs.** The first three paragraphs come from the three steps of the Introduction. The rest follow from the groups of methods, groups of results, findings, problem item-response pairs, and the final paragraph. Write a *purpose statement* (one sentence) articulating the role of each paragraph in the narrative arc advancing the thesis of the article. For instance: "This paragraph explains why we used Cormack-Jolly-Seber models rather than band recovery models to estimate population abundance." These sentences are key. They provide bones and muscle to the narrative arc--bones to hold it in place and give it shape, muscle to move it along. Place these sentences in bold face type before each paragraph. They are not part of the manuscript, but aren't to be deleted until the manuscript is in its final form. These sentences provide reminders of the logical flow and purpose of each paragraph.

12. **Blend figures with the narrative.** First, order figures according to the narrative arc. Does each figure illuminate the thesis? If not, strike it. Next, write a legend for each figure. Legends have a few rules:
- The topic sentence of each legend should also be readable as a figure title.
 - The sequence of legends should be an abbreviation of the narrative, broadly readable without reference to the main text.
 - The sequence of topic sentences of legends should be an abbreviation of the narrative, broadly readable without reference to the main text.
 - Each legend should contain whatever technical information is needed to understand every aspect of the figure (error bars, units, etc.).
13. **Write a topic sentence for each paragraph.** Sometimes these topic sentences may be the same as the purpose statements. Other good devices are
- A question. ("Why is silica limiting to *Cyclotella*?")
 - A turning point. ("Having established the importance of interannual variability in this system, we turn to the problem of coexistence")
 - A complication. ("This argument suggests that species A should be more abundant than species B in dry years but not in wet years, but it fails to account for temporary migration of mobile adults.")
 - A development. ("This idea can be made more concrete with a model.")
- Does each paragraph support the paper's main point? If not, strike it or rewrite it.
14. **Write a concluding sentence for each paragraph.** This sentence should close the theme or problem announced in the topic sentence. If the topic sentence is a declaration, the concluding sentence should be a development, clarification, or summary of the support for the declaration. If the topic sentence is a question, this sentence should be a statement of the answer or a statement of why the answer cannot be provided. If the topic sentence and concluding sentence are not connected or do not support the purpose of the paragraph, one or both should be re-written. The concluding sentence should initiate the segue to the next paragraph, at least in logic if not in syntax. (If the two paragraphs are disconnected, they should be places in separate subsections.)
15. **Write the supporting sentences.** Typically there should be 3-6 supporting sentences per paragraph. Supporting sentences in the paragraph that do not advance the paragraph's purpose should be deleted. This is key. Do not write a sentence that does not advance the paragraph's purpose. If you do, strike it. For the methods, results, and conclusions many of these sentences can be lifted directly from the numbered lists in Steps 4, 5, and 9. Swales provides many examples of supporting sentences in introduction paragraphs.

That's all there is to writing. The rest is editing.