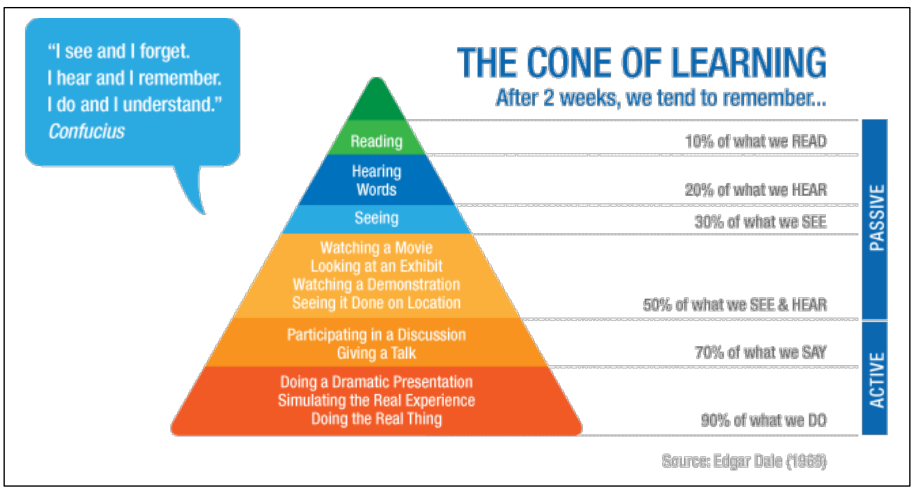
Guidelines on How to Write a Research Manuscript

B. P. Engelward; 2018

This set of advice starts with several general pieces of advice, and then walks through the process of preparing a manuscript.

Please keep in mind that artful concise writing takes time. You need to work on it over the course of many days/weeks. Putting it away and coming back to it generally helps to make your writing better, so try to budget a good amount of time for the writing stage. Don't forget to budget time so that your co-authors have the chance to contribute to the paper. Depending on the complexity of the paper, and depending on how busy the co-authors are, it can take more than two months to refine a paper. You then need to budget about two months to get your reviews. Plus, since you will want to publish in a high impact journal, you also need to budget time for the possibility that it won't be accepted to your first-choice journal. From starting writing to acceptance can take many months, and it can take longer still if the reviewers request additional experiments. But, it is all worth it in the end because few things are as exhilarating as making a substantial contribution to research!



Before you start writing, as you are doing your research, study the literature:
Read a lot and take notes on what you have read. Note that it is well established that the least effective way to learn is to just read. The most effective way to learn is to use what you have learned. Remember Confucius who said "I see and I forget. I hear and I remember. I do and I understand." A fun way to cement learning is to tell your labmates about what you've learned.

When compiling information from the literature, one strategy is to collect key information in a PPT deck where you cut and paste the title/authors and the key data, noting your conclusion from the result. This makes it easier to find the right references later, and it ensures that your thinking is grounded. It is a good idea to put your conclusions about a piece of data into your own words.

Learn Mendeley and consider using Endnote. Mendeley is a great way to organize your papers in PDF format (you can highlight and add notes too). Endnote has some advantages when it comes to putting references into your paper.

Compile your results and discuss your conclusions with your colleagues. Ask them to "poke holes" and make suggestions. Make sure your data is solid before you start writing.

Determine who your audience is. Pick a journal and study the format. Pick several well written papers from the journal of choice and study the way the authors constructed their papers. You will want to emulate *the approach* used by leading authors. Read the instructions to authors, paying special attention to the requirements for figures.

There is a lot of preparation before you actually start writing sentences (see below). **Once you get started writing, resist the temptation to make corrections.** Just get started. Get something down on paper. The first goal is a complete first draft, not a perfect draft. Editing before having a first draft is a waste of time. Making a perfect sentence that later gets deleted is a waste of time.

Manuscript Writing

1) The easiest part is the M&M. Write this part as a way to get going. You can do this way ahead, and work on it when you need a break from the other parts.

2) Do not write the introduction first. This is the hardest part. Write the introduction after you write the results (before or after writing the discussion).

3) Arrange the figures and tables in order, sort of like a talk. Organize your figures in the order of the story. Try to only incorporate finalized figures (with repeats and statistics).

4) Create a PPT slide for each figure, and next to the figure, create a bullet list of what the data show. Double check to make sure you and your colleagues agree that the data supports the conclusions for each figure. Show your figures in a group meeting setting and ask your colleagues to try to find weaknesses in the data and limitations in what you can conclude. It is better to have critical feedback from your lab mates, rather than from others!

> Be extremely careful about how you handle brightness/contrast. If you make adjustments to data by changing brightness/contrast, you *must* make the identical adjustments to all the other parts of the figure.
>
> Be sure to be specific about which samples were run together and which ones were run in separate experiments.
>
> Be sure to describe your statistical approach (number of replicates etc.) in the figure caption.
>
> When it comes time to convert your figure into its publishable format, one approach is to make the figure much bigger than its final form. This is much easier to work with. More importantly, your figure will be large and high resolution, ensuring that the

reduced version retains its quality. There are a lot of technicalities when it comes to making figures. Ask friends for advice.

On a regular basis, do a screen shot of your figure and reduce it to the size you plan to publish. Print the figure and look carefully to see if all the text is legible. There are usually instructions about how small the font can be.

Make your own schematics. Try hard not to copy what others have done, but rather look at many examples, and review the primary literature yourself. You want to make sure the subtleties of how you organize the objects in your schematic are accurate.

5) Once the figures are in place, write the figure captions. The caption describes what is in the figure, but does not interpret the results.

6) The results section is the first section you will write. You will get a much better product if you start by writing a detailed outline. By writing the outline, you will be focused on the content, and not lost in the details of sentence construction. This ensures clear thinking and careful data analysis.

Think first in terms of sub-headers, then put the topic sentence for each paragraph. After this, add bullet points under each topic sentence.

7) You are finally ready to write!! Write the results section first. Get the ideas down first. You don't want to waste time crafting sentences that later get deleted! Avoid rewriting sentences to refine them. Instead, keep going!

As you write the results, when there are things you want to describe that require too many sentences, make a note of those topics in the discussion session, for future reference. In the results section, try to stick closely to describing the data and stating what your conclusion is for each figure.

For references, jot down what you might want to include, but don't get distracted getting references while you are writing. Write first, then finalize the references. You don't want to spend tons of time referencing a paragraph, only to see it deleted from the final draft.

Throughout this process, think about what the reviewer will think when they read your paper. Most importantly, *you need to be sure to state very carefully and conservatively what you can conclude from your data*. If you make too big a conclusion from minimal data, or if what you write is not directly supported by your data, a reviewer will almost certainly turn down your paper (even if everything else in the paper is great).

Try to use simple and concise language. Your goal is not to impress the reader with the complexity of your study, but rather to make it easy for the reader to understand your data and your conclusions. Here are some tips:

• Keep reminding yourself that the goal is to make it easy on the reader.

• Avoid making the reader decode your results.
-Use simple descriptors (instead of V78 cells say "*Aag*-/- cells")

• Generally, it is good to be specific. Avoid saying "this shows", or "it shows". Be specific. Say, "the observation that the cells are viable shows…"

• Avoid saying that something "proves" your hypothesis. Proofs are for math.

• Avoid over-generalizations, such as: "It is always the case that cells are sensitive." Just say "In most studies, it was shown…" Avoid "all", "always", and "never."

Each paragraph of your results should have:

• A topic sentence – usually the first sentence
• Supporting evidence
• At the end of the paragraph, you should have a statement that addresses "what the reader should conclude from reading this paragraph", e.g., the take-home message.
• Your paragraph should "stand alone" and thus not be dependent on the reader having to read the previous paragraph.
• Link paragraphs together with transition text.
For example: "To explore further the observation that cells are less viable, we chose an alternative approach…."

8) Draft the discussion. Start by looking at 3 or 4 well written articles in the journal of your choice. Analyze how other did it. What was the order of their discussion points? Before writing sentences, create an outline and vet it with others. Generally, the discussion looks something like this:

Paragraph 1) Why the reader should care, problem, approach, main results, impact statement
Paragraph 2) Topic 1 - - the major finding
Provide context. What have others seen?
Paragraph 3) Topic 2 – less important but still important topic
Paragraph 4) After main topics are done, move to more tangential results. Describe more minor findings of interest

Second to last paragraph) What are the weaknesses and what more do we want to know? Be careful not to oversell your results. Be objective. Point out the weaknesses.

Last paragraph) Pull it all together. Describe what was shown (or what was overcome) and why is it impactful. Near the end, you can have a short description of possible future research that would extend upon what was done. Generally, it is good to end the paper with a high impact statement.

9) After writing the discussion, turn to the introduction. Make an outline. Use the same approach of reading good papers and emulating their approach to construction of the introduction.

Address the question: “Why was the study done?” Describe relevant background information. *Give the readers enough background to understand what you did and why it is important.*

10). Once you have a complete draft with a logical progression, refine the language. Keep the language simple. It is generally best to start with very simple language and then when refining the language, you can liven it up.

11) Finalize the references. Be sure to give credit to those who came before you. Imagine that leaders of the field are going to read this paper. Whose work will they expect to see referenced? Also, reviewers are often selected from the references.

Don’t rely too heavily on reviews. Of course you need to be thorough about reading the primary literature, especially because you might not agree with the conclusions in a review, once you see the data yourself.

12) Write the abstract last. Do this when the discussion section is fresh in your mind.

13) Now is the time to send your paper to all of the co-authors. You will want their input and advice, so be sure to budget time for feedback. You should generally give your co-authors at least a week to get back to you. It is good if you also take a break at this time. If you put it aside for a week, you will find ways to improve it when you come back to it.

14) While you are still “deep into it”, draft the cover letter. The cover letter should clearly lay out what the problem/knowledge gap was, what the approach was, and what was learned. You need to provide just enough background that someone who is somewhat outside the field appreciates what you have done. It is often good to have bullet points to indicate the major findings. Be sure to end with the significance of the work and its potential impact on the field and/or on real-world problems.

15) Hopefully you selected a journal that you think is appropriate, but that is a bit of a reach. You will never publish in the higher impact journals unless you try! But, be prepared for rejection. Sometimes decisions are relatively arbitrary, so don’t let a rejection get you down too much. Try to bounce back and pick a journal that is a safer bet. Importantly, learn from your reviewers. Their comments took time, and many of them are probably quite helpful. Improve your paper according to the comments of the reviewer before you resubmit. If you don’t do this, you will have a lower quality publication (also, the same reviewer might be picked again!).

16) Be hyper-vigilant about avoiding plagiarism. When you take notes, use your own words and your develop your own strategy for unfolding your story.

Sidebar: My first paper required more than 20 drafts. I wrote as best that I could, and then my advisor read it and gave me feedback. I was astonished at the time that it was so hard to write a paper, and that it took so long! It was also hard not to take it personally when there were criticisms. In the end, I learned that criticisms were a favor, and that I shouldn't take things personally. In the end, it was the best training I could have ever wished for (thank you Leona Samson!).

EFFECTIVE TECHNICAL COMMUNICATION

A Guide for Scientists and Engineers

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OXFORD

UNIVERSITY PRESS

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Principles of Scientific Vocabulary

All big things have little names,
Such as life and death, peace and war,
Or dawn, day, night, love, home.
Learn to use little words in a big way.

—Anonymous

SCIENCE (from the Latin word 'scientia' meaning knowledge) is knowledge arranged methodically or systematized knowledge. Its progress is marked by the emergence of the scientific method, which rests on the rational, accurate, and clear exposition of facts. At its core is a thoroughness of approach that is needed to establish any new finding. For this, the use of appropriate words and sentences is essential.

A sentence is a combination of words, which are the basic units of expression. To communicate effectively with others and to disseminate ideas, views, and observations to a broader community, a scientist or an engineer needs a thorough knowledge of the intricacies of the language. The entire structure of scientific or engineering communication stands on the solid foundation of words. Hence, superficial knowledge of a word and its spelling is of little help. The writer must choose his/her words carefully so as to convey his/her ideas most effectively.

The ability to choose the appropriate words and use these in the appropriate context comes from familiarity with words and their usage. Thus, a writer should avoid using words with which he/she is unfamiliar.

There are eight principles for choosing appropriate words and phrases in scientific and engineering communication. These have been listed below.

- Use short and simple words.
- Use compact substitutes for wordy phrases.
- Avoid redundant words and expressions.
- Avoid the use of mixed metaphors and other figures of speech.
- Avoid hackneyed and stilted phrases.
- Avoid verbosity in the use of common prepositions.
- Avoid the incorrect use of words.
- Exercise care while using technical terms borrowed from traditional English.

Some examples of each of these principles have been given below.

1.1 Use Short and Simple Words

Any communication by scientists and engineers requires the use of short and simple words, which are more forceful than long words. A short word appropriately used, enhances the clarity of expression.

Examples of a few short and simple words that should be used instead of polysyllabic words are provided below:

Avoidable words	*Recommended words*
accomplish	do
terminate	end
conflagration	fire
adjacent to	near
cognizant of	aware of
perform	do
vehicle	car

attempt	try
beverage	drink
envisage	foresee
ameliorate	improve
endeavour	try
perchance	perhaps
abhorrence	hatred
viable	workable
deem	think

1.2 Use Compact Substitutes for Wordy Phrases

The use of simple substitutes greatly improves the clarity of written communication. Some examples are given below.

Avoidable usage	*Recommended usage*
Take into consideration	consider
Avail yourself of	use
In view of the fact that	since
In all instances	always
In a very small number of cases	rarely
In view of the fact that	because
Subsequent to	after
In the near future	soon
In spite of the fact that	although
As a consequence of this fact	consequently
A small number of	a few
Despite the fact that	although
At the present time	now
Prior to	before
For the duration of the study	during the study
During the process of	during
Checked for the presence of	checked for
A series of observations	observations
In order to provide a basis for comparing	to compare

Make an adjustment in	adjust
Give encouragement to	encourage
Is equipped with	has

1.3 Avoid Redundant Words and Expressions

The clarity of the text can be improved by completely removing expressions that do not add value to the text. Every sentence should be trimmed down to its essentials. A number of redundancies can creep into a written communication if it is written carelessly.

Examples of expressions that should be avoided have been given below.

- It has been found that
- It is interesting to note that
- As already stated
- It may be said that
- It is worth mentioning at this point

A list of some expressions, parts of which should be removed due to their redundancy, has been given below. The redundant words have been placed in brackets.

- (absolutely) essential
- (advance) planning
- (advance) warning
- (as) for example
- (at) about, at (about): use any one
- at (the) present (time)
- (brief) moment
- during (the course of)
- merged (together)
- reply (back)
- is (now) pending
- eradicate (completely)
- (current) trend
- never (before)

- (new) innovation
- (mutual) cooperation
- (close) proximity
- (necessary) requisite
- (protrude) out
- revert (back)
- (free) gift

There are a number of instances when the verb is capable of expressing the notion of togetherness. In such instances, the expression 'together' is superfluous. The examples below illustrate this point.

- meet (together)
- unite (together)
- connect (together)
- join (together)
- mix (together)

A little thinking can help a writer avoid such redundancies. Some of these redundancies can be used in special cases for emphasis. However, it is for the scientist or engineer to judge the appropriate context and not use them indiscriminately.

An example of how redundancies can lead to heaviness in the text is:

> The main cause for the failure of the experiment was that adequate precaution was not taken at the time of the experiment for preventing such kind of accidents.

The sentence can be expressed more simply by using fewer words:

> The experiment failed, as adequate precautionary measures were not taken.

Here is another example:

> If the supply of drawing papers already sent falls short of your demands, application has to be made to the Stores Officer for further supply.

This could be shortened to:

> If more drawing paper is needed, apply to the Stores Officer.

In the example below, a 34-word sentence is shortened to an 11-word sentence without any change in the meaning:

> At the present moment our administrative unit has already initiated the procedure of inviting applications from those who are in a position to offer themselves as candidates for the post of Senior Mechanical Engineer.

This could instead be written as:

> Applications have been invited for the post of Senior Mechanical Engineer.

1.4 Avoid the Use of Mixed Metaphors and other Figures of Speech

Sometimes, the use of metaphors can lead to lack of clarity in a text. Usually, the use of metaphors in scientific or engineering text is bad. The use of mixed metaphors is worse.

For example, the following sentence uses mixed metaphors:

> Instead of beating about the bush put your cards on the table.

It uses two different metaphors: 'beating about the bush' and 'putting one's cards on the table'.

The sentence can instead be written simply as:

> Clearly say what you have to state.

There is a general notion that one should avoid words that may be considered vulgar. The origin of this notion may be traced back to the Victorian era when prudishness was at its peak. (A prude is a person who is excessively modest in his/her behaviour, dress, and speech). This has led to the use of euphemisms, that is, words that are less direct. These words are not distasteful and are never vulgar.

Some examples are listed here.

- In the family way: This should be preferred over 'pregnant' (as used in HR policies for industries, for example)
- Sales representatives: This should be preferred over 'salesmen' (as used in titles used in industries, for example)
- Lower income group: This should be preferred over 'the poor' (as used in certain segments addressed by a firm, for example)

Of course, expressions like 'sales representatives' or 'lower income group' are neutral expressions and should, therefore, be given preference.

1.5 Avoid Hackneyed and Stilted Phrases

Engineers and scientists must try to overcome the temptation to use over-worn phrases and expressions. These expressions are used by greenhorns (first-time writers) to embellish their language. They use these phrases in a naive attempt to show their knowledge.

Here are some common examples of such hackneyed expressions:

- filthy lucre
- olive branch
- strain every nerve
- flying colours

1.6 Avoid Verbosity in the Use of Common Prepositions

There is no dearth of appropriate prepositions to suit any context in the English language. However, the tendency amongst writers is to use imposing expressions instead of simple prepositions. This tendency can lead to an avoidable lack of clarity in communication.

Common examples of these expressions are:

As to: In the sentence, 'The director should give a clear indication *as to* the policies he wants to introduce', the simple preposition 'of' could serve the purpose just as well.

In relation to: In the sentence, 'The salaries of the scientists vary *in relation to* their qualifications and experience', the preposition 'with' provides the same meaning.

With regard to: In the sentence, 'The recruitment of only two extra scientists will make little difference *with regard to* the output of work', the preposition 'to' will convey the same meaning.

Since verbose writing obscures the meaning of a sentence and only taxes the readers' time and patience, it should be avoided.

1.7 Avoid the Incorrect Use of Words

Scientists and engineers need to be aware of the specific meanings of the words they use. They have to choose words that can accurately and precisely express their ideas. If a writer uses a word she/he is not absolutely certain about, it can end up creating confusion in the minds of the readers.

Using words accurately is extremely important for scientists and engineers. There are words that are synonymous and are more or less similar in meaning. However, only a writer who is conversant with the different meanings that may be attributed to a word can choose the correct word for the correct context.

Here are some words that describe 'something that happens'. There is a slight difference in the meaning of each word.

Happening: It refers to some unusual or strange incident that has happened.

For example: The employees were afraid of the strange happenings in the vicinity of their company premises.

Incident: It refers to a course of action that may not be very important, yet has the air of something unexpected or unusual that makes one remember it.

For example: I can recall the incident that led to the employee being warned by his supervisor.

Event: It describes a circumstance that is important, because of which it is remembered.

For example: The invention of the integrated circuit was a major event in the history of the electronics industry.

Occurrence: This is a formal word that indicates a happening that is either common or rare.

For example: These days, having an open office is a very common occurrence.

For example: Robbery is a rare occurrence in this small town.

Each of these words has a unique meaning. In scientific or engineering communication, it is important not to use such words interchangeably. Likewise, the word 'keep' is not the same as 'put', as shown in the following example:

The teacher *keeps* the book on the shelf.

The teacher enters the classroom and *puts* the book on the table.

Similarly, 'humid', 'damp', and 'moist', or 'pliable' and 'flexible', or 'permeate' and 'percolate', do *not* express the same meanings.

There are some words that have become so popular that writers use them indiscriminately, ignoring their precise meaning. The word 'blueprint', for example, has become an attractive alternative to 'scheme' or 'plan'. But this term, which comes from engineering technology, actually stands for the *final* stage of paper design.

There are many instances in which ponderous words are misused only because the writer does not know its meaning. Some examples are:

Syndrome: This term, which is gaining popularity, can be easily misused by a writer who is not certain of its meaning. The word 'syndrome' is a medical term. It actually means a group of symptoms, which collectively suggest a particular disease. The syndrome itself is not a disease.

Synergism: The precise meaning of this word is 'the simultaneous collective action which an effect greater than the sum of the individual effects'. It does not mean just collective action, which it is erroneously used to refer to sometimes.

Catalyst: This is a very popular term, which should be used with discretion to avoid incorrect usage. Catalysis is the speeding up of the role of chemical reaction by the addition of some substance, which undergoes no chemical change itself. A catalyst is the agent that brings about this change. This context, which includes 'no change to itself', should be borne in mind before using this word.

There are many other such words, such as conductivity, frequency, anodise, pneumatic, alignment, backlash, impedance, permeability, servo-mechanism, etc., that should be used in proper perspective. The language of science and engineering is never static; it is dynamic. Hence, the scientist or engineer must keep track of these words and their *current* meaning prior to using them.

1.8 Exercise Care while using Technical Terms Borrowed from Traditional English

Common English words are used increasingly to express various scientific and engineering matters. A majority of these words are used in Computer Science and Engineering. A scientist or an engineer writing a document must ensure that these scientific or engineering terms are used appropriately and not confused with their traditional meanings.

Some examples of scientific or engineering terms that have roots in traditional English, have been provided below.

Heap	A temporary data storage area where random access is possible.
Hierarchy	It denotes the method in which data is organized in a step-wise order.
Howler	A buzzer that helps the telephone exchange operator detect whether the telephone user's handset is on the receiver.

Junction box	An electrical unit where it is possible to get a number of electrical wires connected together.
Packet	A group of data bits that can be transmitted together as a group.
Specific	The electrical charge of an elementary particle divided by its mass.
Warm up	When a machine, after being switched on, is in the process of reaching its optimum state.
Idle	A particular state of the engine in which, though running, it does not provide power to move any vehicle or aircraft.
Hang	The particular state when a computer is held in an endless loop and fails to respond.
Footprint	The area covered by any transmitting device such as an antenna or a satellite.
Jump	A term in computer parlance when a programming command is given to direct the processor to a different section of the programme.
Declare	A term used to define a computer programme variable.
Half-life	The time taken for half the atoms in a radioactive isotope to decay.
Inductive	The production of electrical current in a conductor by a change of magnetic field.
Thread	A programme in a computer consisting of many independent smaller sections or heads.
Mouse	A small hand-held input device in a computer. It is used to control the position of the cursor on the computer screen.

To conclude, English written by engineers and scientists must be simple and precise. Long, abstract, fancy, and redundant phrases must be avoided. Short and simple words build the structure, followed by sentences, paragraphs, and ultimately the whole text of the communication. Hence, the choice of words is of great importance. It has to be kept in mind that scientific or engineering writing has a definite objective. Its main purpose is to communicate something. Hence, the words and sentences that are used should be simple, clear, brief, and unambiguous. Without these attributes, communication of any sort is bound to become boring, stilted, and foggy. Words, if used appropriately, go a long way in building the structure of sentences and paragraphs.

A quote from H. W. Fowler reveals the basic rules to be followed in the case of written communication:

Prefer the familiar word to the far-fetched.
Prefer the concrete word to the abstract.
Prefer the single word to the circumlocution.
Prefer the short word to the long.
Prefer the Saxon word to the Romance.

Whitesides' Group: Writing a Paper**

By *George M. Whitesides**

1. What is a Scientific Paper?

A paper is an organized description of hypotheses, data and conclusions, intended to instruct the reader. Papers are a central part of research. If your research does not generate papers, it might just as well not have been done. "Interesting and unpublished" is equivalent to "non-existent".

Realize that your objective in research is to formulate and test hypotheses, to draw conclusions from these tests, and to teach these conclusions to others. Your objective is not to "collect data".

A paper is not just an archival device for storing a completed research program; it is also a structure for *planning* your research in progress. If you clearly understand the purpose and form of a paper, it can be immensely useful to you in *organizing* and conducting your research. A good outline for the paper is also a good plan for the research program. You should write and rewrite these plans/outlines throughout the course of the research. At the beginning, you will have mostly plan; at the end, mostly outline. The continuous effort to understand, analyze, summarize, and reformulate hypotheses on paper will be immensely more efficient for you than a process in which you collect data and only start to organize them when their collection is "complete".

2. Outlines

2.1. The Reason for Outlines

I emphasize the central place of an outline in writing papers, preparing seminars, and planning research. I especially believe that for you, and for me, it is most *efficient* to write papers from outlines. An *outline* is a written plan of the organization of a paper, *including* the data on which it rests. You should, in fact, think of an outline as a carefully organized and presented set of data, with attendant objectives, hypotheses, and conclusions, rather than an outline of text.

An outline itself contains little text. If you and I can agree on the details of the outline (that is, on the data and organization), the supporting text can be assembled fairly easily. If we do *not* agree on the outline, any text is useless. Much of the *time* in writing a paper goes into the text; most of the *thought* goes into the organization of the data and into the analysis. It can be relatively efficient in time to go through several (even many) cycles of an outline before beginning to write text; writing many versions of the full text of a paper is slow.

All writing that I do—papers, reports, proposals (and, of course, slides for seminars)—I do from outlines. I urge you to learn how to use them as well.

2.2. How Should You Construct an Outline?

The classical approach is to start with a blank piece of paper, and write down, in any order, all important ideas that occur to you concerning the paper. Ask yourself the obvious questions: "Why did I do this work?"; "What does it mean?"; "What hypotheses did I mean to test?"; "What ones did I actually test?"; "What were the results? Did the work yield a new method of compound? What?"; "What measurements did I make?"; "What compounds? How were they characterized?". Sketch possible equations, figures, and schemes. It is essential to try to get the major ideas. If you start the research to test one hypothesis, and decide, when you see what you have, that the data really seem to test some other hypothesis better, don't worry. Write them both down, and pick the best combinations of hypotheses, objectives, and data. Often the objectives of a paper when it is finished are different from those used to justify starting the work. Much of good science is opportunistic and revisionist.

When you have written down what you can, start with another piece of paper and try to organize the jumble of the first one. Sort all of your ideas into three major heaps (1–3).

1. Introduction

Why did I do the work? What were the central motivations and hypotheses?

2. Results and Discussion

What were the results? How were compounds made and characterized? What was measured?

3. Conclusions

What does it all mean? What hypotheses were proved or disproved? What did I learn? Why does it make a difference?

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[**] The text is based on a handout created on October 4, 1989.

DOI: 10.1002/adma.200400767

Next, take each of these sections, and organize it on yet finer scale. Concentrate on organizing the *data*. Construct figures, tables, and schemes to present the data as clearly and compactly as possible. This process can be slow—I may sketch a figure five to ten times in different ways trying to decide how it is most clear (and looks best aesthetically).

Finally, put everything—outline of sections, tables, sketches of figures, equations—in good order.

When you are satisfied that you have included *all* the data (or that you know what additional data you intend to collect), and have a plausible organization, give the outline to me. Simply indicate where missing data will go, how you think (hypothesize) they will look, and how you will interpret them if your hypothesis is correct. I will take this outline, add my opinions, suggest changes, and return it to you. It usually takes four to five iterations (often with additional experiments) to agree on an outline. When we *have* agreed, the data are usually in (or close to) final form (that is, the tables, figures, etc., in the outline will be the tables, figures,... in the paper).

You can then start writing, with some assurance that much of your prose will be used.

The key to efficient use of your and my time is that we start exchanging outlines and proposals as early in a project as possible. *Do not, under any circumstances, wait until the collection of data is "complete" before starting to write an outline.* No project is ever complete, and it saves enormous effort and much time to propose a plausible paper and outline as soon as you see the basic structure of a project. Even if we decide to do significant additional work before seriously organizing a paper, the effort of writing an outline will have helped to guide the research.

2.3. The Outline

What an outline should contain:

1. Title

2. Authors

3. Abstract

Do *not* write an abstract. That can be done when the paper is complete.

4. Introduction

The first paragraph or two should be written out completely. Pay particular attention to the opening sentence. Ideally, it should state concisely the objective of the work, and indicate why this objective is important.

In general, the Introduction should have these elements:

- The *objectives* of the work.
- The *justification* for these objectives: Why is the work important?
- *Background*: Who else has done what? How? What have *we* done previously?
- *Guidance to the reader*: What should the reader watch for in the paper? What are the interesting high points? What strategy did we use?
- *Summary/conclusion*: What should the reader expect as conclusion? In advanced versions of the outline, you should also include all the sections that will go in the Experimental section (at the level of paragraph subheadings) and indicate what information will go in the Microfilm section.

5. Results and Discussion

The results and discussion are usually combined. This section should be organized according to major topics. The separate parts should have subheadings in boldface to make this organization clear, and to help the reader scan through the final text to find the parts of interest. The following list includes examples of phrases that might plausibly serve as section headings:

- Synthesis of Alkane Thiols
- Characterization of Monolayers
- Absolute Configuration of the Vicinal Diol Unit
- Hysteresis Correlates with Roughness of the Surface
- Dependence of the Rate Constant on Temperature
- The Rate of Self-Exchange Decreases with the Polarity of the Solvent

Try to make these section headings as specific and information-rich as possible. For example, the phrase "The Rate of Self-Exchange Decreases with The Polarity of The Solvent" is obviously longer than "Measurement of Rates", but much more useful to the reader. In general, try to cover the major common points:

- Synthesis of starting materials
- Characterization of products
- Methods of characterization
- Methods of measurement
- Results (rate constants, contact angles, whatever)

In the outline, do not write any significant amount of text, but get all the data in their proper place: Any text should simply indicate what will go in that section.

- Section Headings
- Figures (*with* captions)
- Schemes (with captions and footnotes)
- Equations
- Tables (correctly formatted)

Remember to think of a paper as a collection of experimental results, summarized as clearly and economically as possible in figures, tables, equations, and schemes. The text in the paper serves just to explain the data, and is secondary. The more information can be compressed into tables, equations, etc., the shorter and more readable the paper will be.

6. Conclusions

In the outline, summarize the conclusions of the paper as a list of short phrases or sentences. Do not repeat what is in the Results section, unless special emphasis is needed. The Conclusions section should be just that, and not a summary. It should add a new, higher level of analysis, and should indicate explicitly the significance of the work.

7. Experimental

Include, in the correct order to correspond to the order in the Results section, all of the paragraph subheadings of the Experimental section.

2.4. In Summary

- Start writing possible outlines for papers *early* in a project. Do not wait until the "end". The end may never come.
- Organize the outline and the paper around easily assimilated data—tables, equations, figures, schemes—rather than around text.
- Organize in order of importance, not in chronological order. An important detail in writing papers concerns the weight to be given to topics. Neophytes often organize a paper in terms of chronology: that is, they give a recitation of their experimental program, starting with their cherished initial failures and leading up to a climactic successful finale. *This approach is completely wrong. Start with the most important results*, and put the secondary results later, if at all. The reader usually does not care how you arrived at your big results, only what they are. Shorter papers are easier to read than longer ones.

3. Some Points of Style

- Do not use nouns as adjectives:

Not:
ATP formation; reaction product
But:
formation of ATP; product of the reaction

- The word "this" must always be followed by a noun, so that its reference is explicit.

Not:
This is a fast reaction; This leads us to conclude
But:
This reaction is fast; This observation leads us to conclude

- Describe experimental results uniformly in the past tense.

Not:
Addition of water *gives* product.
But:
Addition of water *gave* product.

- Use the active voice whenever possible.

Not:
It was observed that the solution turned red.
But:
The solution turned red. *or*
We observed that the solution turned red.

- Complete all comparisons.

Not:
The yield was higher using bromine.
But:
The yield was higher using bromine than chlorine.

- Type all papers double-spaced (not single- or one-and-a-half-spaced), and leave two spaces after colons, and after periods at the end of sentences. Leave generous margins.

Assume that we will write all papers using the style of the American Chemical Society. You can get a good idea of this style from three sources:

- *The journals.* Simply look at articles in the journals and copy the organization you see there.
- *Previous papers from the group.* By looking at previous papers, you can see exactly how a paper should "look". If what you wrote looks different, it probably is not what we want.
- *The ACS Handbook for Authors.* Useful, detailed, especially the section on references, pp. 173–229.

I also suggest you read Strunk and White, *The Elements of Style* (Macmillan: New York, 1979, 3rd ed.) to get a sense for usage. A number of other books on scientific writing are in the group library; these books all contain useful advice, but are not lively reading. There are also several excellent books on the design of graphs and figures.

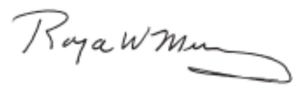
This is an article about “what not to do.”

Skillful writing of an awful research paper

As Editor I have from time to time in this column offered advice to authors on the desirable elements of a good research report. Like contrary children, for some authors such advice seems to vanish like smoke in a wind. So I take here a different approach, based on the idea that some folks have a knack for doing the opposite of what is recommended to them (like contrary children). I present some guidelines for how to prepare a research report that is variously boring, confusing, misleading, or generally uninformative. Whether the author's project is imaginative (or not) and the experiments are done with skill (or not) and the data are scientifically meaningful (or not) is irrelevant. My advice is solely based on principles of presenting the objectives, experiments, results, and conclusion in a fashion that as such no one will finish reading them or, if they do, readers will have little chance of understanding or remembering them. Like any form of skillful writing, following the rules below for awful writing requires practice and a lack of mental concentration.

- Rule 1. Never explain the objectives of the paper in a single sentence or paragraph and in particular never at the beginning of the paper.
- Rule 2. Similarly, never describe the experiment(s) in a single sentence or paragraph and never at the beginning. Instead, to enhance the reader's pleasure of discovery, treat your experiment as a mystery, in which you divulge one essential detail on this page and a hint of one on the next and complete the last details only after a few results have been presented. It's also really fun to divulge the reason that the experiment should successfully provide the information sought only at the very end of the paper, as any good mystery writer would do.
- Rule 3. Diagrams are worth a thousand words, so in the interest of writing a concise paper, omit all words that explain the diagram, including labels. Let the reader use his/her fertile imagination.
- Rule 4. Great writers invent abbreviations for complex topics, which also saves a lot of words. Really short abbreviations should be used for very complex topics, and more complicated ones for simple ideas.
- Rule 5. In referring to the previous literature, be careful to cite only the papers that make claims that would support your own, especially those that contain little evidence for the claim, so that your paper shines in comparison.
- Rule 6. It should be anathema to use any original phrasing or humor in your language, so as to adhere to the principle that scientific writing must be stiff and formal and without personality.
- Rule 7. Your readers are intelligent folks, so don't bother to explain your reasoning in the interpretation of the results. Especially don't bother to point out their impact on or consistency with other authors' results and interpretation, so that your paper can be an island of original thinking.

So these are a few simple rules for poor scientific writing. If you follow them faithfully and your paper is rejected or never cited, irrespective of your native brilliance, you have nonetheless been successful as a poor writer.



Recommendations from Prof. Carr
https://www.youtube.com/watch?v=UY7sVKJPTMA

- W.Strunk and E.B. White., "The Elements of Style".
- ACS Author's Guide.
- R. W. Murray, Anal. Chem. 2011, 83, 633 "Skillful Writing of an Awful Research Paper". Seven Rules to Follow.
- R. Schoenfeld, "The Chemist's English".
- A. Eisenberg, "Effective Technical Communication."
- P. T. O'Connerr "Words Fail Me".
- George M. Whitesides: Whiteside's Group: Writing a Paper (Adv. Mater. 2004, 16, 1375.)

http://mme2017.manucodiata.org/images/download/Miscellaneous/Skillfull_writing_aweful_paper.pdf