SCIENTIFIC WRITING BOOKLET

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GENERAL GUIDELINES

A scientific paper is a written report describing original research results. The format of a scientific paper has been defined by centuries of developing tradition, editorial practice, scientific ethics and the interplay with printing and publishing services. A scientific paper should have, in proper order, a Title, Abstract, Introduction, Materials and Methods, Results, and Discussion.

Title

A title should be the fewest possible words that accurately describe the content of the paper. Omit all waste words such as "A study of ...", "Investigations of ...", "Observations on ...", etc. Indexing and abstracting services depend on the accuracy of the title, extracting from it keywords useful in cross-referencing and computer searching. An improperly titled paper may never reach the audience for which it was intended, so be specific. If the study is of a particular species, name it in the title. If the inferences made in the paper are limited to a particular region, then name the region in the title.

Abstract

A well prepared abstract should enable the reader to identify the basic content of a document quickly and accurately, to determine its relevance to the reader's interests, and thus to decide whether to read the document in its entirety. The abstract should succinctly state the principal objectives and scope of the investigation where these are not obvious from the title. More importantly, the abstract should concisely summarize the results and principal conclusions. The abstract should not include details of the methods employed unless the study is methodological, i.e. primarily concerned with methods. The abstract must be brief, not exceeding 250 words or as otherwise defined by the journal. If the essential details of the paper can be conveyed in 100 words, do not use 200. Do not repeat information contained in the title. The abstract, together with the title, must be self-contained as it is often published separately from the paper in abstracting services. Omit all references to the literature and to tables or figures, and omit obscure abbreviations and acronyms even though they may be defined in main body of the paper.

Rules for Scientific Writing

- Interest, inform, and persuade the reader
- Write for your reader and write clearly
- Eliminate unnecessary redundancy
- Avoid digressions
- Don't over explain and avoid overstatement
- Avoid unnecessary qualifiers
- Use consistent tenses
- Use the precise word
- Simpler words are preferred over complex words and use concrete words and examples
- Simpler sentences are preferred over more complicated sentences
- Use the active voice (except generally in methods)
- Make sure the subject and verb agree
- Use affirmative rather than negative constructions
- Avoid use of the indefinite "this"
- Use transitions
- Cite sources as well as findings
- Proofread your paper carefully; spell check does not catch everything; "there" is spelled correctly but not if you meant "their"

In general, the best writing is simple and direct. Writing that is simple and direct is most easily understood. It also tends to be the most forceful and memorable. Use no more words than necessary — and never use a complicated word if a simpler one will do just as well. Many people seem to feel that writing in a complicated way makes one sound serious, scholarly and authoritative. While this type of writing may sound serious, it is no more authoritative than writing that is simple and direct. Certainly, it is more difficult to understand. Often, it sounds pompous and overbearing. If your purpose is to be understood in a way that is both forceful and memorable, adopt a style that is simple and direct.

USING AN OUTLINE TO PREPARE YOUR PAPER

Description of an outline

An outline is:

- A logical, general description
- A schematic summary
- An organizational pattern
- A visual and conceptual design of your writing

An outline reflects logical thinking and clear classification.

Value of the Outline

- Aids in the process of writing
- Helps you organize your ideas
- Provides a snapshot of each section of the paper will flow
- Presents your material in a logical form
- Shows the relationships among ideas in your writing
- Constructs an ordered overview of your writing
- Defines boundaries and groups

Developing the Outline

Before you begin:

- Determine the purpose of your paper
- Determine the audience you are writing for
- Develop the thesis of your paper

Then:

- Brainstorm: List all the ideas that you want to include in your paper
- Summarize the question(s)/problem(s)
- List the key points/elements pertaining to the question(s)/problem(s)
- Organize: Group related ideas together; place each key point/element in a separate file
- Order: Arrange material in subsections from general to specific or from abstract to concrete
- Make sure the organizing scheme is clear and well-structured
- Identify the important details that contribute to each key point/element
- Label: Create main and sub headings
- Note the sources pertaining to each detail

WORD USAGE IN SCIENTIFIC WRITING

Any glossary of word usage assumes that what is acceptable for some uses may not be for others. Some terms and expressions are worn-out clichés and have outlived their usefulness; other expressions and terms, though not incorrect, are not precise. In reporting and recording research, try to be as accurate and precise in describing it as in doing it. Avoid the ambiguous and "faddish."

- Use a US-English spelling checker.
- Make sure you use words according to the precise meaning understood by the average person.
- Ideally, you would check whether every word could be deleted or replaced by a better one.
- Aim for economy:
    - *because* instead of ~~*based on the fact that*~~;
    - *for* or *to* instead of ~~*for the purpose of*~~.
    - ~~*there were*~~ *several subjects* ~~*who*~~ *completed*…;
    - ~~*it is suggested that*~~ *a relationship may exist…;*
    - ~~*both*~~ *alike;* ~~*one and*~~ *the same;*
    - ~~*a total of*~~ *n subjects;*
    - *four* ~~*different*~~ *groups;*
    - ~~*absolutely*~~ *essential;*
    - *found* ~~*previously*~~*;*
    - *small* ~~*in size*~~*;*
    - *in* ~~*close*~~ *proximity;*
    - ~~*very*~~ *close to zero;*
    - ~~*much*~~ *better;*
    - ~~*period of*~~ *time;*
    - *summarize* ~~*briefly*~~*;*
    - *the reason is* ~~*because*~~*;*
    - ~~*also*~~ *included;*
    - *except* ~~*for.*~~
- Aim for precision:
    - *patient* or *gymnast* instead of ~~*subject*~~;
    - *concentration* or *frequency* instead of ~~*level*~~.
- Don't generalize unnecessarily. For example, don't say *some* if you know of only one instance.
- *This* on its own is an *ambiguous antecedent.* Use instead *this test* or *this problem*.
- Avoid hype (hyperbole). Words like *very* and *extremely* are usually unnecessary.
- Note these singular and plural forms: criterion, criteria; datum, data; medium, media; phenomenon, phenomena.
- Don't use *however* or its synonyms twice in one paragraph, because changing the direction of an argument twice in one paragraph may annoy readers.
- Don't use *however* more than once every 10 paragraphs. Try a thesaurus for synonyms.
- Avoid the so-called *non-human agent.* For example, use *the authors concluded that…* rather than ~~*the study concluded that*~~….
- Avoid colloquialisms, such as ~~*steer clear of*~~.
- Avoid ~~*as such*~~. Poor: ~~*The SCAT is a reliable test of state anxiety. As such, it is suitable for experimental studies*~~. Better: *The SCAT is a reliable test of state anxiety; it is therefore suitable for experimental studies.*
- Avoid ~~*her*~~*,* ~~*his*~~ and any other sexist language, even if the subjects are clearly of one gender.

Above ("the above method," "mentioned above," etc.) -- Often, you are referring to something preceding, but not necessarily *above*; a loose reference, convenient for writers, but not for readers. Be specific. You know exactly what and where, but your readers may have to search (sometimes through much preceding material).

Affect, effect -- Affect is a verb and means to *influence.* Effect, as a verb, means to *bring about*; as a noun, effect means *result.*

All of, both of -- Just "all" or "both" will serve in most instances.

Alternate, alternative -- Be sure which you mean.

And (to begin a sentence) -- Quite proper. You have been told not to do this in grade school. But teacher's purpose was to keep you from using fragmentary sentences; either "and" or "but" may be used to begin complete sentences. And both are useful transitional words between related or contrasting statements.

Apparently (apparent) -- means *obviously, clearly, plainly evident*, but also means *seemingly* or *ostensibly* as well as *observably.* You know the meaning that you intend, but readers may not. Ambiguity results. Use *obvious(ly), clear(ly), seeming(ly), evident(ly), observable* or *observably,* to remove doubt.

Appear, appears -- Seem(s)? "He always *appears* on the scene, but never *seems* to know what to do." "Marley's ghost *appeared* but *seemed* harmless."

As -- Dialectal when used in place of *that* or *whether*; do **not** use *as* to mean *because* or *inasmuch as.*

At the present time, at this point in time -- Say "at present" or "now" if necessary at all.

Below -- See comment about *above.*

But (to begin a sentence) -- Go right ahead (see "And" and "However").

By means of -- Most often, just "by" will serve and save words.

Case -- Can be ambiguous, misleading, or ludicrous because of different connotations; e.g., "In the case of Scotch whiskey,...." *Case* also is a frequent offender in padded, drawn-out sentences. For "in this case," try "in this instance."

Compare with, compare to -- Compare *with* means to examine differences and similarities; compare *to* means to represent as similar. One may conclude that the music of Brahms compares *to* that of Beethoven, but to do that, one must first compare the music of Brahms *with* that of Beethoven.

Comprise -- Before misuse, comprise meant to contain, include, or encompass (not to constitute or compose) and still does, despite two now opposite meanings. Use and meanings now are so confused and mixed that "comprise" is best avoided altogether.

Correlated with, correlated to -- Although things may be *related to* one another, things are *correlated with* one another.

Different from, different than -- Different from! Also, one thing *differs from* another, although you may *differ with* your colleagues.

Due to -- Make sure that you don't mean *because of*. Due is an adjective modifier and must be directly related to a noun, **not** to a concept or series of ideas gleaned from the rest of a statement. "Due to the fact that..." is an attempt to weasel out.

During the course of, in the course of -- Just use "during" or "in."

Either....or, neither...nor -- Apply to no more than two items or categories. Similarly, *former* and *latter* refer only to the first and second of only two items or categories.

Experience(d) -- To experience something is sensory; inanimate, unsensing things (lakes, soils, enzymes, streambeds, farm fields, etc.) do not experience anything.

Following -- "After" is more precise if "after" is the meaning intended. "After [not *following*] the procession, the leader announced that the ceremony was over."

High(er), low(er) -- Much too often used, frequently ambiguously or imprecisely, for other words such as *greater, lesser, larger, smaller, more, fewer*; e.g., "Occurrences of higher concentrations were lower at higher levels of effluent outflow." One interpretation is that greater concentrations were fewer or less frequent as effluent volume(s) increased, but others also are possible.

However -- Place it more often within a sentence or major element rather than at the beginning or end. "But" serves better at the beginning.

Hyphening of compound or unit modifiers -- Often needed to clarify what is modifying what; e.g., a small-grain harvest (harvest of small grain) is different from a small grain harvest (small harvest of *all* grain), a fast *acting* dean isn't necessarily as effective as a fast-acting dean, a batch of (say, 20) 10-liter containers is different from a batch of 10 [1-] liter containers, *and a man eating fish is very different from a man-eating fish!* Grammatically, adjectives are noun modifiers, and the problem is when adjectives and nouns are used to modify other adjectives and nouns. **Adverbs** (usually with "ly" endings), however, **are** adjective modifiers.

In order to -- For brevity, just use "to".

Irregardless -- No, *regardless*. But *irrespective* might do.

It should be mentioned, noted, pointed out, emphasized, etc. -- Such preambles often add nothing but words. Just go ahead and say what is to be said.

It was found, determined, decided, felt, etc. -- Are you being evasive? Why not put it frankly and directly? (And how about that subjective "felt"?)

Less(er), few(er) -- "Less" refers to quantity; "fewer" to number.

Majority, vast majority -- See if *most* will do as well or better. Look up "vast."

Myself -- Not a substitute for me. "This paper has been reviewed by Dr. Smith and myself" and "The report enclosed was prepared by Dr. Jones and myself" are incorrect as is "Don't hesitate to call Dr. Doe or myself"; *me* would have been correct in all instances. (Use of *I* also would have been wrong in those examples.) Some **correct** uses of *myself*: I found the error myself. I myself saw it happen. I am not myself today. I cannot convince myself. I locked myself out of the car.

Partially, partly -- Compare the meanings (see also *impartially*). *Partly* is the better, simpler, and more precise word when partly is meant.

Percent, percentage -- Not the same; use percent only with a number.

Predominate, predominant -- *Predominate* is a verb. *Predominant* is the adjective; as an adverb, *predominantly* (not "predominately").

Prefixes -- (mid, non, pre, pro, re, semi, un, etc.) -- Usually not hyphened in U.S. usage except before a proper name (pro-Iowa) or numerals (mid-60s) or when lack of a hyphen makes a word ambiguous or awkward. *Recover* a fumble, but perhaps *re-cover* a sofa. *Preengineered* is better hyphened as *pre-engineered*, one of the few exceptions so hyphened. Breaking pairs such as *predoctoral* and *postdoctoral* into *pre- and post-doctoral* "forces" hyphening of both otherwise unhyphened words.

Principle, principal -- They're different; make sure which you mean.

Prior to, previous to -- Use *before, preceding*, or *ahead of*. There are *prior* and *subsequent* events that occur before or after something else, but *prior to* is the same kind of atrocious use that attempts to substitute "subsequent to" for "after."

Proven -- Although a *proven* adjective, stick to *proved* for the past participle. "A *proven* guilty person must first have been *proved* guilty in court."

Provided, providing -- *Provided* (usually followed by "that") = conjunction; *providing* = participle.

Reason why -- Omit *why* if reason is used as a noun. The reason is...; or, the reason is that...

Since -- has a time connotation; use "because" or "inasmuch as" when either is the intended meaning.

Small in size, rectangular in shape, blue in color, tenuous in nature, etc. -- Redundant.

That and which -- Two words that can help, when needed, to make intended meanings and relationships unmistakable, which is important in reporting scientific information. If the clause can be omitted without leaving the modified noun incomplete, use which and enclose the clause within commas or parentheses; otherwise, use *that*. Example: "The lawn mower, *which is* broken, is in the garage." But, "The lawn mower *that is* broken is in the garage; so is the lawn mower *that* works."...*That is broken* specifies the particular mower being discussed, whereas *which is broken* merely adds additional information to the sentence.

To be -- Frequently unnecessary. "The differences were [found] [to be] significant."

Varying -- Be careful to distinguish from *various* or *differing*. In saying that you used varying amounts or varying conditions, you are implying **individually changing** amounts or conditions rather than a selection of various or different ones.

Where -- Use when you mean *where*, but not for "in which," "for which," etc.

Which is, that were, who are, etc. -- Often not needed. For example, "the data that were related to age were analyzed first" means that the *data related to age* were analyzed first. Similarly, for "the site, which is located near Ames," try "the site, located near Ames" or "the site, near Ames." Rather than "all persons who were present voted," just say that "all persons present voted." Rephrasing sometimes can help. Instead of "a survey, which was conducted in 1974" or "a survey conducted in 1974," try "a 1974 survey."

While -- Preferably not if, *while* writing, you mean *and, but, although,* or *whereas*.

Remember that a research report should communicate and record information as accurately and concisely as possible. The purpose is to report, not to impress with elegance. Excess wordage, tortuous construction, unnecessary detail, duplication, repetition, third-person passive pseudo-objectivism, etc., obstruct rather than facilitate communication. It's the message that is important, not sheer numbers of words. Use precise words and expressions of unmistakable meaning; avoid the clouded, ambiguous, vague, and needlessly complex.

GRAMMAR

- Make sure you write well-formed sentences, and keep their structure simple.
- Use the first person (*I* or *we tested six runners*) rather than the passive voice (~~*Six runners were tested)*~~. Similarly, say *Smith reported* instead of ~~*reported by Smith*~~.
- With comparatives (*more than*, *less than*), the *than* may need to be *than that of* or *than with* or *than by* etc. to clarify the meaning. Similarly, *similar to* may need to be *similar to that of.* Examples: *The measure was more valid than that of Smith et al. (1994). We experienced fewer problems with the revised instrument than with the published version. The method was similar to that of an earlier study.*
- Don't use a long string of qualifiers in front of a noun: *a modified test of cognitive function* is better than ~~*a modified cognitive function test*~~.
- Avoid grammatically questionable formal cliches, such as: ~~*Based on these results, it is concluded that* and *The results showed that*~~
- Use the past tense to report results (yours or others'). Use the present tense to discuss them. *We have found that…; Smith (1989) reported a similar result. A simple explanation of these findings is that…*
- Avoid so-called *misplaced modifiers*: ~~*Wh[illegible]ein supplementation resulted in… Athletes were consulted when designing… If necessary, subjects were tested… Based on these results, we conclude…*~~ The next two examples are marginal: *Using stable tracers, it is possible to measure… Given the importance of body mass, there has been little study of its effects…* Note that *a noun was verbed to verb something* (e.g. *an experiment was performed to test this hypothesis*) is also technically incorrect but is used so widely that it has to be accepted. *A noun was verbed (by) verbing…* is also acceptable. The active voice would avoid these awkward expressions.
- Put *only*, *partly* and *mainly* next to the word they modify: *The test consists only of new items.*
- The following rules are broken so frequently that I doubt whether they can be considered rules any more.
    - *Which* or *that*? Simple rule: *Which* always follows a comma (and a pause), but *that* never does. *This study, which cost $10,000, was a success. The study that cost $10,000 was a success.*
    - *Owing to* or *due to*? Simple rule: *Owing to* always has a comma, *due to* never does. *The data were lost, owing to computer malfunction. The loss of data was due to computer malfunction.*
- An adverb is placed usually after the verb. Placing it before the verb creates a *split infinitive* (*to boldly go…* is acceptable if emphasizing *go;* if the emphasis is on *boldly*, *to go boldly* is better).

ACTIVE VERSUS PASSIVE VOICE IN WRITING

In the active voice, the grammatical subject is the doer of the action, and the sentence tells, “who’s doing what.” The passive voice tells what is done to the subject of the sentence. The person or thing doing the action may or may not be mentioned but is always implied.

Verbs are also said to be either active (The executive committee approved the new policy) or passive (The new policy was approved by the executive committee) in voice. In the active voice, the subject and verb relationship is straightforward: the grammatical subject is the doer of the action, and the sentence tells, “who’s doing what”. The verb 'actively' moves the sentence along.

The passive voice tells what is done to the subject of the sentence. The subject of the sentence is acted upon by some other agent or by something unnamed (The new policy was approved). Computerized grammar checkers can pick out a passive voice construction from miles away and ask you to revise it to a more active construction. There is nothing inherently wrong with the passive voice, but if you can say the same thing in the active mode, do so (see exceptions below). Your text will have more pizzazz as a result, since passive verb constructions tend to lie about in their pajamas and avoid actual work.

We find an overabundance of the passive voice in sentences created by self-protective business interests, magniloquent educators, and bombastic military writers (who must get weary of this accusation), who use the passive voice to avoid responsibility for actions taken. Thus "Cigarette ads were designed to appeal especially to children" places the burden on the ads — as opposed to "We designed the cigarette ads to appeal especially to children," in which "we" accepts responsibility. At a White House press briefing we might hear that "The President was advised that certain members of Congress were being audited" rather than "The Head of the Internal Revenue service advised the President that her agency was auditing certain members of Congress" because the passive construction avoids responsibility for advising and for auditing.

One further caution about the passive voice: we should not mix active and passive constructions in the same sentence: "The executive committee approved the new policy, and the calendar for next year's meetings was revised" should be recast as "The executive committee approved the new policy and revised the calendar for next year's meeting."

When to use Active Voice

In general, writing should be composed in the active voice because of the sense of immediacy and conciseness conveyed when the subject of the sentence carries out the action. In addition, fewer words are usually required for the active voice, it is more efficient, and it takes the reader from point A to point B in a “straight line.”

When to use Passive Voice

The passive voice does exist for a reason, however, and its presence is not always to be despised. The passive is particularly useful (even recommended) in two situations:

> When it is more important to draw our attention to the person or thing acted upon: The unidentified victim was apparently struck during the early morning hours.
>
> When the actor in the situation is not important: The aurora borealis can be observed in the early morning hours.

In scientific writing, overuse of passive voice or use of passive voice in long and complicated sentences can cause readers to lose interest or to become confused. Sentences in active voice are generally--though not always-- clearer and more direct than those in passive voice.

That being said, the passive voice is especially helpful (and even regarded as mandatory) in scientific or technical writing or lab reports, where the actor is not really important but the process or principle being described is of ultimate importance. Instead of writing "I poured 20 cc of acid into the beaker," we would write "Twenty cc of acid is/was poured into the beaker." The passive voice is also useful when describing, say, a mechanical process in which the details of process are much more important than anyone's taking responsibility for the action: "The first coat of primer paint is applied immediately after the acid rinse." Thus in scientific writing, the passive voice is often preferred to indicate objective procedures. Scientists and engineers are interested in analyzing data and in performing studies that other researchers can replicate. The individual doing the experiment is therefore relatively unimportant and usually is not the subject of the sentence.

You can recognize passive-voice expressions because the verb phrase will always include a form of be, such as am, is, was, were, are, or been. The presence of a be-verb, however, does not necessarily mean that the sentence is in passive voice. Another way to recognize passive-voice sentences is that they may include a "by the..." phrase after the verb; the agent performing the action, if named, is the object of the preposition in this phrase.

You can see examples of all the verb tenses in passive voice at
http://owl.english.purdue.edu/handouts/grammar/g_tenses2.html

The active voice enhances the authority of the writer, while the passive voice can obscure it. Passive voice: It is understood by students that good writing is essential in college. Active voice: Students understand that good writing is essential in college.

Consider these pairs of sentences:

The report was read by Betty.
Betty read the report.

A decision was made to stop the project.
We decided to stop the project.

The passive voice should be avoided.
Avoid the passive voice.

Scientists conduct experiments to test hypotheses.
Experiments are conducted by scientists to test hypotheses.

Watching a reaction boil over through shielding reminds me to be careful.
I am reminded to be careful by watching a reaction boil over through shielding.

Now, ask yourself: which of the two sentences in each set sounds better to you — and why? In general, the active voice (the second sentence in each pair) is preferable to the passive voice (the first sentence in each pair) because the active voice tends to be simpler, clearer and more direct. The active voice also makes for more forceful and interesting writing. Thus, we say: Avoid the passive. Favor the active.

Useful resource: http://owl.english.purdue.edu/handouts/print/grammar/g_actpass.html.

Active-Passive Exercise:

Rewrite the following sentences so that passive constructions are changed to active verbs. Some of these sentences do not use passive verbs or are better off left in the passive, so this exercise will also engage your attention in recognizing passive constructions and in using them when appropriate.

1. Before the semester was over, the new nursing program had been approved by the Curriculum Committee and the Board of Trustees.

2. With five seconds left in the game, an illegal time-out was called by one of the players.

3. The major points of the lesson were quickly learned by the class, but they were also quickly forgotten by them.

4. For several years, Chauncey was raised by his elderly grandmother.

5. An unexpected tornado smashed several homes and uprooted trees in a suburb of Knoxville.

6. I was surprised by the teacher's lack of sympathy.

7. Tall buildings and mountain roads were avoided by Raoul because he had such a fear of heights.

(answers appear on page 24)

WRITING THE INTRODUCTION

The first step will be to meet with your research director to discuss the content of the Introduction. This should be very explicit to the specific research you will be doing. Much of your time before writing must be spent in reading appropriate papers that are the background to the work you will be doing. Your research director can help you identify these papers. As you spend additional time working on the project, you should continue to read appropriate papers from the literature that will help you understand your work better. You should take responsibility for learning from your research director, or someone else whom is designated, the papers that are most appropriate for you to read in the future. Additionally you should acquire skills in conducting literature searches on your own for relevant papers in the most current literature as they appear by checking the most appropriate journals on a regular basis. You should ask your research director to also identify papers that include the methods you will be using in your study.

The Introduction should begin by introducing the reader to the pertinent literature. A common mistake is introducing authors and their areas of study in general terms without mentioning their major findings. For example:

"Parmenter (1976) and Chessman (1978) studied the diet of Chelodina longicollis at various latitudes and Legler (1978) and Chessman (1983) conducted a similar study on Chelodina expansa"

compares poorly with:

"Within the confines of carnivory, Chelodina expansa is a selective and specialized predator feeding upon highly motile prey such as decapod crustaceans, aquatic bugs and small fish (Legler, 1978; Chessman, 1984), whereas C. longicollis is reported to have a diverse and opportunistic diet (Parmenter, 1976; Chessman, 1984)".

The latter is a far more informative lead-in to the literature, but more importantly it enables the reader to clearly place the current work in the context of what is already known. An important function of the Introduction is to establish the significance of the current work: Why was there a need to conduct the study?

Having introduced the pertinent literature and demonstrated the need for the current study, you should state clearly the scope and objectives. Avoid a series of point-wise statements -- use prose. The Introduction can finish with the statement of objectives or, as some people prefer, with a brief statement of the principal findings. Either way, the reader must have an idea of where the paper is heading in order to follow the development of the evidence.

Questions to address:	**How to address them:**
What is the problem?	• **Describe** the problem investigated. • **Summarize** relevant research to provide context, key terms, and concepts so your reader can understand the experiment.
Why is it important?	• **Review** relevant research to provide rationale. (What conflict or unanswered question, untested population, untried method in existing research does your experiment address? What findings of others are you challenging or extending?)
What solution (or step toward a solution) do you propose?	• Briefly **describe** your *experiment*: *hypothesis*(es), *research question*(s); general experimental *design* or *method*; *justification of method* if alternatives exist.

Additional Tips:

1. Move from general to specific: problem in real world/research literature ⇒ your experiment.
2. Engage your reader: answer the questions, "What did you do?" "Why should I care?"
3. Make clear the links between problem and solution, question asked and research design, prior research and your experiment.

Be selective, not exhaustive, in choosing studies to cite and amount of detail to include. (In general, the more relevant an article is to your study, the more space it deserves and the later in the Introduction it appears.)

WRITING THE METHODS

The main purpose of the Materials and Methods section is to provide enough detail for a competent worker to repeat your study and reproduce the results. The scientific method requires that your results be reproducible, and you must provide a basis for repetition of the study by others.

Often in field-based studies, there is a need to describe the study area in greater detail than is possible in the Introduction. Usually authors will describe the study region in general terms in the Introduction and then describe the study site and climate in detail in the Materials and Methods section. The sub-headings "Study Site", "General Methods" and "Analysis" may be useful, in that order.

Equipment and materials available off the shelf should be described exactly (Licor underwater quantum sensor, Model LI 192SB) and sources of materials should be given if there is variation in quality among supplies. Modifications to equipment or equipment constructed specifically for the study should be carefully described in detail. The method used to prepare reagents, fixatives, and stains should be stated exactly, though often reference to standard recipes in other works will suffice.

The usual order of presentation of methods is chronological, however related methods may need to be described together and strict chronological order cannot always be followed. If your methods are new (unpublished), you must provide all of the detail required to repeat the methods. However, if a method has been previously published in a standard journal, only the name of the method and a literature reference need be given.

Be precise in describing measurements and include errors of measurement. Ordinary statistical methods should be used without comment; advanced or unusual methods may require a literature citation.
Show your materials and methods section to a colleague. Ask if they would have difficulty in repeating your study.

The table below offers guidelines for effective methods sections in scientific reports.

Questions to address:	How to address them:
How did you study the problem?	• Briefly explain the general type of scientific procedure you used.
What did you use? (May be subheaded as Materials)	• Describe what materials, subjects, and equipment (chemicals, experimental animals, apparatus, etc.) you used. (These may be subheaded Animals, Reagents, etc.)
How did you proceed? (May be subheaded as Methods or Procedures)	• Explain the steps you took in your experiment. (These may be subheaded by experiment, types of assay, etc.)

Additional Tips:

1. Provide enough detail for replication. For a journal article, include, for example, genus, species, strain of organisms; their source, living conditions, and care; and sources (manufacturer, location) of chemicals and apparatus.

2. Order procedures chronologically or by type of procedure (subheaded) and chronologically within type.

3. Use past tense to describe what you did.

4. Quantify when possible: concentrations, measurements, amounts (all metric); times (24-hour clock); temperatures (centigrade).

What to avoid:

1. Don't include details of common statistical procedures.

2. Don't mix results with procedures.

WRITING THE RESULTS AND DISCUSSION

Results Section

In the Results section you present your findings. Present the data, digested and condensed, with important trends extracted and described. Because the results comprise the new knowledge that you are contributing to the world, it is important that your findings be clearly and simply stated. The Results should be short and sweet, without excessive verbiage.

Do not say:
"It is clearly evident from Fig. 1 that bird species richness increased with habitat complexity".

Say instead
"Bird species richness increased with habitat complexity (Fig. 1)".

However, do not be too concise. The readers cannot be expected to extract important trends from the data unaided. Few will bother. Combine the use of text, tables, figures to condense data and highlight trends. In doing so be sure to refer to the guidelines for preparing tables and figures below.

Numbers and Statistics

- Use symbol ~ to mean *approximately equal to.*
- Numbers beginning a sentence must be spelled. It is usually better to rewrite a sentence so you don't start it with numbers greater than ninety-nine.
- Note: one, two, three… nine, 10, 11, 12… Exceptions: a 2-m tape measure; 3 million.
- Put a space between numbers and units: for example, 75 kg. Exception: 75%.
- Note: 0.32 is correct, NOT .32.
- Note: write numbers as follows: 143 2,461 or 2461 21,278 1,409,000
- When you quote numbers, make sure you use the minimum number of significant digits or decimal places. For example, 23 ± 7 years is appropriate but not 23.4 ± 6.6 years; the loss of accuracy is not important because the measurement is not significant to the first decimal place. However 23.4 ± 0.6 is correct because this measurement is accurate to the first decimal place
- Use the appropriate number of digits: two significant digits for standard deviations (one digit if the standard deviation is for a descriptive statistic like height or weight, or if precision is not important); two decimal places for correlations, two significant digits for percentages. Examples: 73 ± 5; r = 0.45; r = 0.08; 16%; 1.3%; 0.013%.
- If it is more convenient to show p values than confidence limits, show the exact p value to one significant digit (for $p < 0.1$) or two decimal places (for $p > 0.10$). Rather than using $p < 0.05$ or $p > 0.05$ it might be better to use the following examples: $p = 0.03$; $p = 0.007$; $p = 0.09$; $p = 0.74$ when the exact p value is important for anyone using your data to calculate confidence limits or using your data in a meta-analysis. If you have a table or figure with a large number of comparisons it may be simpler to use the $p <$ notation to refer to a group of observations.
- Make sure the significant digits of the mean and standard deviation are consistent. Examples: 20 ± 13; 0.020 ± 0.013; 156 ± 7; 1.56 ± 0.07; 15600 ± 700 NOT 1.6 ± 0.07 or 20 ± 13.1
- Use the standard deviation as a measure of spread. Do not use the standard error of the mean.
- Show 95% confidence intervals for effect statistics like a correlation coefficient or the difference between means.
- Interpret the magnitudes of outcomes in a qualitative way, using both your experience of the magnitudes that matter in this area of human endeavor and also any published scales of magnitudes. You must interpret the observed effects and the confidence limits. For example, you might have to say that you observed a moderate effect, but that the true value of the effect could be anything between trivial and very strong. If an effect does not achieve statistical significance, then it is improper to say the value is greater or smaller than control. You can indicate a trend or a tendency in qualitative terms but one cannot absolutely say the values differ.

Tables

Guidelines for effective results sections in scientific reports.

Question to address:	**How to address it::**

What did you observe?	For **each** experiment or procedure:
	• **Briefly describe experiment** without detail of Methods section (a sentence or two).
	• **Report main result(s)**, supported by selected data:
	  o **Representative:** most common
	  o **Best Case:** best example of ideal or exception

Additional tips:

1. **Order** multiple results logically:
   - o from most to least important
   - o from simple to complex
   - o organ by organ; chemical class by chemical class

2. **Use past tense** to describe *what happened.*

3. **What to avoid:**
   - o **Don't** simply repeat table data; **select.**
   - o **Don't** interpret results.
   - o **Avoid** extra words:
     "It is shown in Table 1 that X induced Y" **-->** "X induced Y (Table 1)."

- Create tables with the Table pull-down in Word. Do not use tabs.
- Examples of a simple and complex table are shown below.

Example of a simple table

Table 1**.** Effect of ciliary neurotrophic factor (CNTF) on protein content and lysosomal latency in proximally denervated soleus.

Injection	Protein (mg/muscle)	Lysosomal latency (%)
Vehicle	8.8 ± 0.9	43 ± 4
CNTF	8.0 ±0.8*	33 ± 3*

Proximally denervated muscles were injected (4 µl/muscle/100g body weight) daily, beginning immediately after denervation, with vehicle only (PBS with 0.1% bovine serum albumin) or CNTF (5 µg/ml PBS). At 3 days after denervation, protein content (Biuret method) and lysosomal latency were determined as described in Materials and Methods.

*Significantly different from vehicle only ($P<0.02$).

Example of a complex table

Table 2. Final muscle weights, total protein concentration, GLUT-4 protein, and hexokinase and citrate synthase activities in skeletal muscle following 3-day or 7-day hindlimb suspension (HS).

Group	Final Muscle Weight (g/100 g BW)	Total Protein Concentration (mg/g)	Total GLUT-4 (% of control)	Total Hexokinase (nmol/mg/min)	Citrate Synthase
Soleus					
Weight-bearing	40.0 ± 0.8	149 ± 3	100 ± 9	1.5 ± 0.2	107 ± 5
3-day HS	33.6 ± 1.3*	133 ± 2*	132 ± 16	2.1 ± 0.1*	122 ± 6
7-day H	21.8 ± 1.0*	130 ± 7*	162 ± 10*	2.9 ± 0.2*	143 ± 6*
EDL					
Weight-bearing	42.7 ± 0.7	158 ± 3	100 ± 7	1.9 ± 0.1	64 ± 3
3-day HS	45.9 ± 0.8	156 ± 5	87 ± 7	2.0 ± 0.2	69 ± 7
7-day H	42.4 ± 2.4	146 ± 8	112 ± 8	2.9 ± 0.1*	57 ± 7

Values are means ± SE for 8-17 animals in the pooled weight-bearing group and 6-18 animals in the respective HS groups. * $P<0.05$ vs. weight-bearing control group.

Figures

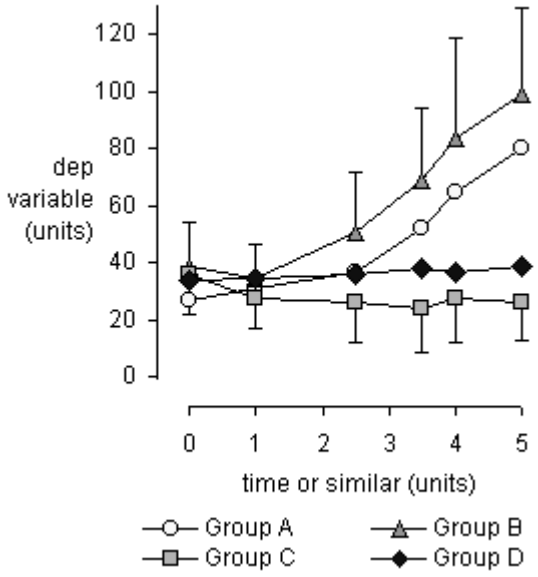
Note these rules for choice of figure format:

- line diagrams or scattergrams if independent and dependent variables are numeric;
- bar graphs if only the dependent variable is numeric;
- bar graphs or pie charts for proportions.

- Do not use scanned images of graphs or diagrams, because the lines and symbols become too "pixelly." Draw the figures directly in a computer, using preferably PowerPoint, Excel, or the drawing window of Microsoft Word.
- Make sure the fonts and any symbols are big enough.
- Do not make figures any wider than ~14 cm, because they need to be viewable in a Web-browser window without the reader having to scroll sideways.
- When using Word, paste each figure directly into the text using Paste Special…, unselect Float Over Text, and paste them in as bitmaps or drawings. Also, make sure the figure is displayed at 100% size and that it looks OK when the document is displayed at 100%.
- Put the figure into the cell of a table, as shown. Place the title and any footnotes for the figure in cells above and below the figure. The style for this text is 11-pt Arial.
- Place each figure or table immediately after the paragraph that first refers to it.
- See the examples (Figures 1-3).

See the examples (Figures 1-4).

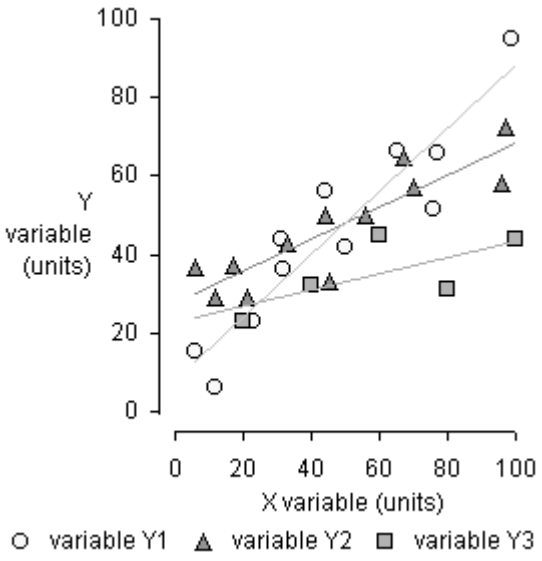
Figure 1: Informative title for a time series[a].



Data are means. Bars are standard deviations (shown only for Groups B and C).

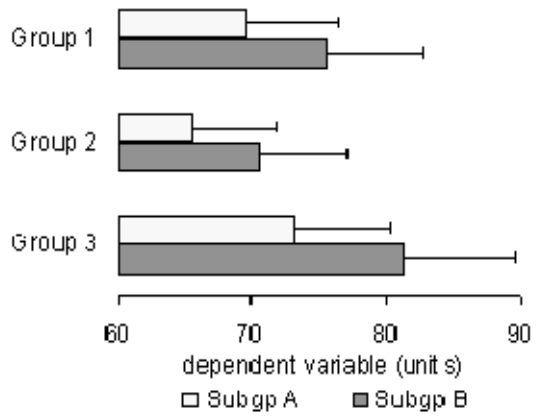
[a]Use letters to label footnotes, if necessary.

Figure 2: Informative title for a scattergram



Least-squares lines are shown for each variable.

Figure 3: Informative title for a bar graph.



Data are means. Bars are standard deviations.

Discussion Section

In the Discussion section you should discuss the results. What biological principles have been established or reinforced? What generalizations can be drawn? How do your findings compare to the findings of others or to expectations based on previous work? Are there any theoretical/practical implications of your work? When you address these questions, it is crucial that your discussion rests firmly on the evidence presented in the Results section. Continually refer to your results (but do not repeat them). Most importantly, do not extend your conclusions beyond those which are directly supported by your results. Speculation has its place, but should not form the bulk of the Discussion section. Be sure to address the objectives of the study in the Discussion section and to discuss the significance of the results. Don't leave the reader thinking "So what?". End the Discussion section with a short summary or conclusion regarding the significance of the work.

Guidelines for effective discussion sections in scientific reports.

Questions to address:	**How to address them:**
What do your observations mean?	• **Summarize** the most important findings at the beginning.
What conclusions can you draw?	For **each** major result: • **Describe** the patterns, principles, relationships results show. • **Explain** how your results relate to expectations and to literature cited in your Introduction. Do they agree, contradict, or are they exceptions to the rule? • **Explain** plausibly any agreements, contradictions, or exceptions. • **Describe** what additional research might resolve contradictions or explain exceptions.
How do your results fit into a broader context?	• **Suggest** the theoretical implications of your results. • **Suggest** practical applications of your results? • **Extend** your findings to other situations or other species. • **Give** the big picture: do your findings help us understand a broader topic?

Additional tips:

1. **Move from specific to general:** your finding(s) **-->** literature, theory, practice.

2. **Don't ignore or bury the major issue.** Did the study achieve the goal (resolve the problem, answer the question, support the hypothesis) presented in the Introduction?

3. **Make explanations complete.**
    - Give evidence for each conclusion.
    - Discuss possible reasons for expected and unexpected findings.

4. **What to avoid:**
    - **Don't** overgeneralize.
    - **Don't** ignore deviations in your data.
    - **Avoid** speculation that cannot be tested in the foreseeable future.

PREPARING THE REFERENCE SECTION

There are a variety of styles used by journals for referencing information. Citations in the text may be referred to by number or by author name. In the reference section the citations are then arranged numerically or alphabetically. Some journals have the submitters first alphabetize the authors and then number each. This is a complicated system and one which we will not use. You may choose to either number in sequence each new reference as it is cited or may alphabetize the first authors of each reference. While the choice is yours, the easiest system is the former because as you add a new reference to the text it is provided with a number. This saves you from interpreting the nuances of how to order the alphabetized authors in the latter system - it may seem trivial but, for instance, how do you alphabetize when the list of authors for two papers is identical and in the same year! When reading references provided to you by your mentor, you should look at how each journal handles its references as well as articles published by your mentor.

Examples of Citation Formats

Numbering system

Second, the sHSP-associated proteins could be released from the Hsp16.6 immunoprecipitate by the ATP-dependent activity of the chaperones DnaK, DnaJ, and GrpE, as has been observed for sHSP-bound substrates *in vitro* (8–10, 31).

Although we found that the plasma concentration of fructose was only about 1/500 of that of glucose as a free monosaccharide, we expected that fructose might be comparable to glucose in terms of mediating pathology through nonenzymatic reactions and downstream processes, because it has been reported that fructose is much more reactive in glycation than glucose.[1,7]

Alphabetical system

The existence of crystallization inhibitors was first observed in the 1960s. (Bliznakov, 1965)

Because we demonstrated that this molecule exhibited a potent capacity as crystallization inhibitor of calcium salts in urine (Grases et al., 1996; Grases et al., 1998a and Grases et al., 1998b).

Previous work had established a direct relationship between plaque weight and precipitation of hydroxyapatite (Cooper and Sallis, 1993 and Demadis et al., 2001).

Whichever system you utilize, the reference itself must include the following:

- ✓ all of the authors listed on the publication (or on the chapter if citing a book)
- ✓ the title of the paper (or chapter if citing a book)
- ✓ the name of the journal (or book)
- ✓ editors if a book is cited
- ✓ volume number
- ✓ complete pagination (first and last page of the work cited)
- ✓ year of publication

Examples of reference formats from select journals

American Journal of Physiology

Journal Articles:

Villalobos AR, Parmelee JT, and Renfro JL. Choline uptake across the ventricular membrane of neonate rat choroid plexus. Am J Physiol Cell Physiol 276: C1288-C1296, 1999.

Book References:

Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA, and Struhl K. Current Protocols in Molecular Biology. New York: Wiley, 1995, p. 25-26.

Pollock DM. Endothelin receptor subtypes and tissue distribution. In: Endothelin Molecular Biology, Physiology, and Pathology, edited by Highsmith RF. Totowa, NJ: Humana, 1998.

Articles Published on the Web:

Dudoit S, Yang YH, Callow MJ, and Speed TJ. Statistical methods for identifying differentially expressed genes in replicated cDNA microarray experiments [Online]. Dept. of Statistics, Univ. of California at Berkeley. http://www.stat.berkeley.edu/users/terry/zarray/Html/matt.html [3 Sept. 2000].

Friedman N, Linial M, Nachman I, and Pe'er D. Using Bayesian networks to analyze expression data [Online]. Stanford University. http://robotics.stanford.edu/people/nir/Abstracts/FLNP1Full.html [2000].

Note that the date may be general or specific to the day.

Journal of Cell Biology

Journal Articles:

Yalow, R.S., and S.A. Berson. 1960. Immunoassay of endogenous plasma insulin in man. J. Clin. Invest. 39:1157-1175.

Benditt, E.P., N. Ericksen, and R.H. Hanson. 1979. Amyloid protein SAA is an apoprotein of mouse plasma high density lipoprotein. Proc. Natl. Acad. Sci. USA. 76:4092-4096.

Brown, W., and A. Nelson. 1983. Phosphorus content of lipids. J. Lipid Res. In press.

Online Peer-Reviewed Articles:

Lopez-Soler, R.I., R.D. Moir, T.P. Spann, R. Stick, and R.D. Goldman. 2001. A role for nuclear lamins in nuclear envelope assembly. (July 9, 2001) J. Cell Biol. 10.1083/jcb.200101025.

Complete Books:

Myant, N.B. 1981. The Biology of Cholesterol and Related Steroids. Heinemann Medical Books, London. 882 pp.

Articles in Books:

Innerarity, T.L., D.Y. Hui, and R.W. Mahley. 1982. Hepatic apoprotein E (remnant) receptor. In Lipoproteins and Coronary Atherosclerosis. G. Noseda, C. Fragiacomo, R. Fumagalli, and R. Paoletti, editors. Elsevier/North Holland, Amsterdam. 173-181.

Pharmacology

Journal Articles:

Sun J, Koto H, Chung KF: Interaction of ozone and allergen challenges on bronchial responsiveness and inflammation in sensitised guinea pigs. Int Arch Allergy Immunol 1997;112:191–195

Articles in Books:

Parren PWHI, Burton DR: Antibodies against HIV-1 from phage display libraries: Mapping of an immune response and progress towards antiviral immunotherapy; in Capra JD (ed): Antibody Engineering. Chem Immunol. Basel, Karger, 1997, vol 65, pp 18–56.

Immunology

Journal Articles:

Shingu M, Hurd ER. Sera from patients with systemic lupus, erythematosus reactive with human endothelial cells. J Rheumatol 1981; 8:581-6.

Zavazava M, Halene M, Westphal E et al. Expression of MHC class I and II molecules by cadaver retinal; pigment cells: optimization of post-mortem HLA typing. Clin Exp Immunol 1991; 84: 163-6

Articles in Books:

Kearse KP, Kaplan AM, Cohen DA. Role of cell surface glycoproteins in the formation of T-cell: APC conjugates In: Schook LB, Tew JG, eds. Antigen presenting cells: diversity, differentiation, and regulation. New York: Alan R. Liss, 1988:221-34.

Virella G, Goust JM, Fudenberg HH. Introduction to medical immunology, 2nd Edn. New York: Marcel Dekker, 1990

ANSWERS TO ACTIVE-PASSIVE EXERCISE

1. Before the semester was over, the Curriculum Committee and the Board of Trustees approved the new nursing program.

2. With five seconds left in the game, one of the players called an illegal time-out.

3. The class quickly learned, but then quickly forgot, the lesson's major points.

4. Chauncey's elderly grandmother raised him for several years.
(NOTE: In the original version the emphasis was more on Chauncey and there is nothing really wrong with that.)

5. An unexpected tornado smashed several homes and uprooted trees in a suburb of Knoxville.
(NOTE: The original was already active.)

6. The teacher's lack of sympathy surprised me.
(NOTE: If the intent is to emphasize your surprise rather than the source then the original version is fine.)

7. Raoul avoided tall buildings and mountain roads because he had such a fear of heights.

SOURCES FOR FURTHER INFORMATION

Websites

http://www.organicworldwide.net/writing.html
http://www.ag.iastate.edu/aginfo/checklist.html - *Word Usage In Scientific Writing*
http://www.sportsci.org/jour/9901/wghstyle.html - *Guidelines On Style For Scientific Writing*
http://www.mang.canterbury.ac.nz/courseinfo/AcademicWriting/Scientific.htm
The Science of Scientific Writing; George D. Gopen and Judith A. Swan
American Scientist, Volume 78
http://mason.gmu.edu/~arichar6/logic.htm -
Logical Fallacies In Scientific Writing; A. Stephen Richardson
http://www.stark.kent.edu/writing/outline.htm - *outlines*
http://bio.winona.edu/delong/EcoLab/21%20Suggestions.html -
Twenty-One Suggestions for Writing Good Scientific Papers:
http://www.mco.edu/lib/instr/libinsta.html - *Instructions to Authors in the Health Sciences*
(a plethora of journals)

Book sources

American Medical Association Manual of Style: a Guide for Authors and Editors, 9th ed.; Williams & Wilkins: Baltimore, 1998.

Atlas, Michel C. Author's Handbook of Styles for Life Science Journals; Iverson, Cheryl, Ed.; CRC Press: Boca Raton, 1996.

Byrne, Daniel W. Publishing your Medical Research Paper: What They Don't Teach You in Medical School; Williams & Wilkins: Baltimore, 1998.

Gehlbach, Stephen H. Interpreting the Medical Literature, 4th ed.; McGraw Hill Medical Publishing Division: New York, 2002.

Matthews, Janice R.; Bowen, John M.; Matthews, Robert W. Successful Scientific Writing: a Step-by-step Guide for Biomedical Scientists, 2nd ed; Cambridge University Press: New York, 2000.

McMillan, Vicky. Writing Papers in the Biological Sciences, 3rd ed.; Bedford Books: Boston, 2001.

Pechenik, Jan A. A Short Guide to Writing about Biology, 4th ed.; Longman: New York, 2001.

Zeiger, Mimi. Essentials of Writing Biomedical Research Papers, 2nd ed.; McGraw-Hill, Health Professions Division: New York, 2000.