Writing Scientifically (taken from David R. Caprette (caprette@rice.edu), Rice University)

Copy from one, it's plagiarism; copy from two, it's research. --- Wilson Mizner (1876 - 1933)

Common Errors in Student Research Papers

This is not an exhaustive list. With every new lab protocol, you folks come up with the darndest ways of messing up a perfectly good paper. However, if you heed the comments here your reports stand a much better chance of being mistaken for professionally written research papers.

Quotes

When you write a paper related to literature, history, current events, and many other fields, direct quotes are essential to fully discuss the subject. In science, there is **very rarely** any call for a direct quote. On student papers, there is no reason at all to include direct quotes, except in the case when the student doesn't understand the concept and uses the quote to avoid having to explain it his- or herself. Obviously, this doesn't go over too well with the grader. As a rule, **do not** use direct quotes **ever** in a scholarly technical paper. **Your** ideas must be expressed, not those of someone else.

Verb tense

Use proper tense when writing portions of a paper. Use of the wrong tense, at best, is irritating to read and reflects poorly on the student's writing skills. At worst, the reader can be confused as to what facts are already known and what was newly discovered in the actual study that is the subject of the paper. As a rule, use **past** tense to describe events that have **happened**. Such events include procedures that you have conducted and results that you observed. Use present tense only to describe generally accepted facts. Examples:

We **sought** to determine if mating behavior in Xiphophorus helleri was related to male tail length by placing combinations of two male fish with different length tails in the same tank with a female fish.

We **found** that protein synthesis in sea urchin embryos treated with actinomycin D **was** considerably less than in untreated embryos. This finding agrees with the model stating that protein synthesis in 24 hour sea urchin embryos **is** dependent on synthesis of new messenger RNA.

Reference to results of a specific study should also be in past tense.

Abercrombie and Fitch **reported** that 30% of the public is allergic to wool.

Mixing tenses is even worse - this sort of thing hurts my ears. Unfortunately, the people who read the news in television and radio broadcasts are frequently unaware of this.

Two guys **rob** a liquor store downtown. The robbery **occured** at midnight last night.

Proofread!

Incomplete sentences, redundant phrases, obvious misspellings, and other symptoms of a hurredly-written paper can cost you. Please start your work early enough so that you can proofread it. Check spelling of scientific names, names of people, names of compounds, etc. Spelling and grammatical errors can be embarassing. Since many very different terms have similar names, a spelling error can result in a completely incorrect statement.

When you print off your report, please make sure that tables are not split over more than one page, that headings are not "orphaned," pages submitted out of sequence, etc. Remember, someone has to read this thing1

Irrelevant information

Anecdotal information

Sometimes you may feel the need to justify a statement or procedure by stating that 'the instructor told us to do this instead of that.' You might think it appropriate to state that 'we used Cricket Graph III to produce a graph of x versus y.' Such information is anecdotal and is considered to be superfluous. In some cases omission of anecdotal information is unfortunate. Papers in the older literature tend to be a lot more exciting and often more informative for those not 'in the know,' because the researcher could report how a conclusion was reached, including the reasoning and various sidetracks that led him/her to conclusions. The writer could actually tell the story of the investigation process. Modern papers omit such information because the volume of literature is so great, most of us doing a literature search don't have time to wade through the extra information, and publication costs are too high to permit printing of superfluous information.

Unnecessary background

If you state facts or describe mechanisms, do so in order to make a point or to help interpret results, and do refer to the present study. If you find yourself writing everything you know about the subject, you are wasting your time. Stick to the appropriate point, and include a reference to your source of background information if you feel that it is important.

Subjectivity and use of superlatives

Technical writing differs from the writing of fiction, opinion pieces, scholarly English papers, etc. in many ways. One way is in the use of superlatives and subjective statements in order to emphasize a point. We simply do not use such writing styles in science. Objectivity is absolutely essential.

Subjectivity refers to feelings, opinions, etc. For example, in your discussion you might write, "We felt that the fixative was bad, because we had difficulty finding flagella on our Chlamydomonas." Another researcher is unlikely to risk time and resources on the basis of your "feeling." On the other hand, you might write, "The percentage of cells with flagella was inversely proportional to the time they spent in fixative, suggesting that the fixative was causing cells to shed flagella." This is something another scientist can use.

Superlatives include adjectives such as "huge," "incredible," "wonderful," "exciting," etc. For example, the mitochondria showed an incredibly large increase in oxygen consumption when we added uncoupling agent." Your definition of incredible might be different from that of someone else - perhaps a five fold increase is incredible to you, but not for the next person. It is much better to use an objective expression, such as "Oxygen consumption was five fold greater in the presence of uncoupler, which is a greater change than we saw with the addition of any other reagent."

Similarly, we don't write that we believe something. We present the evidence, and perhaps suggest strong support for a position, but beliefs don't come into play. In particular, we do not "expect" a particular set of results, or "wire" a hypothesis so that it appears that we correctly predicted the results. Objectivity is essential.

Proof

See my essay on fact, hypothesis, and theory. The requirements for scientific proof are extremely rigorous. It is highly doubtful that any single experiment can be so well controlled that its conclusions can be regarded as proof. In fact, for any result to be accepted it must be confirmed independently. In fact, we can never know if a model as we describe it presents an accurate picture of any natural process. We can never look at the original blueprint to check our conclusions. So... your data may strongly support a position, or they may allow you to reject a hypothesis, but they aren't likely to provide anything close to proof.

Grammar and spelling

Please avoid obvious grammatical errors. Granted, you aren't writing an English paper (heck, an English teacher would tear my own writing style to shreds). However, clear written communication requires proper sentence structure and use of words. Make sure that your sentences are complete, that singluar and plural terms are matched, and that they make sense when you **proofread**.

Spelling errors in a paper make you look amateurish. For example, *absorbance* is read from a *spectrophotometer*. You don't read *absorbancy* from a *spectrometer*. Worse, they can change the entire meaning of your writing. One letter changes the chemical compound you describe. I know the action of *cycloheximide* in eukaryotic cells, but I do not know the action of *cyclohexamide*.

Wrong word or phrase

Changing temperature had the following *affect* on the subject.

'Affect' is a verb. 'Effect' is a noun. What happened to the subject was an effect. The temperature change affected the subject. Please learn the difference.

The data lead to the *assumption* that x has no relationship to y.

If you base a conclusion on data, then your conclusion is a deduction, not an assumption. In fact, in experimental science assumptions are usually avoided. A purpose of controls is to eliminate the need to assume anything.

Our inability to ensure that all cells in the population were in the same stage of development *skewed* our data.

This statement doesn't reveal very much. The writer intended to say that the data points were more scattered, that is, the nonuniformity of the population resulted in unacceptably high experimental error. The word 'skew' means 'having an oblique position; turned or twisted to one side; slanting; sloping.' It can be used as an adverb or noun as well. In statistics, the word refers to an asymmetric distribution of data. Nowhere in the definition is there any reference to the state of being incorrect or more scattered. Thus, not only is the word overused, it is also mis-used.

We *rationalized* the finding that blocking the sodium pump had no affect on uptake of glucose by suggesting that the symport mechanism depends solely on the sodium gradient, which persists long after the pump is shut down.

A definition of 'rationalize' is 'to explain or justify.' Another is 'to attribute logical or creditable motives to actions that result from other, perhaps unrecognized, motives.' In short, to make excuses. As I learned in English class a long time ago, the term's principle usage is in situations when an attempt is made to make a justification on dubious grounds. For example, 'he rationalized his poor behavior by saying that he had just broken up with his girlfriend and was distraught.' The definition does not include anything about the explanation being valid, therefore another word would be preferable. Try

A likely explanation for the finding...*is that...*

The word 'data' is plural. However since investigators usually refer to sets of data, there is a tendency to use the word as though it was singular. Hence a writer will state, 'the data *was* affected by the phase of the moon,' or 'the data *suggests* that phase of the moon has no effect on mood.' As awkward as it may seem to you, the proper phrases are, 'the data *were* affected...,' and 'the data *suggest*...' By the way, the singular form is 'datum.'

Oversimplification

We used a spectrophotometer to determine protein concentrations for each of our samples. We used an oscilloscope to measure resting potentials in crayfish muscle.

The spectrophotometer or oscilloscope may be a novel, mysterious, and versatile device to you, but I suspect that if I gave you a protein sample or crayfish and provided you only with a spectophotometer or oscilloscope you would have a hard time getting any data. The former statement leaves out the dye reagent, standards, pipettors, etc. that are required to perform the assay. The latter omits any reference to the micropipets or the specialized electronic instrumentation that is required in order to measure transmembrane potentials. Both statements represent an attempt by the student to either avoid the effort of writing a complete description, or to save space. Rather than oversimplify, it is better to omit description of the method at all, although in most papers a complete summary of the method should be included.

Superficiality

The purpose of a discussion is to interpret the results, not to simply state them in a different way. In most cases a superficial discussion ignores mechanisms or fails to explain them completely. It should be clear to the reader why a specific result came to pass. The statement, "The result agreed with the known theoretical value," tells us nothing about the mechanism(s) behind the result. Explanations may not be easy and your explanation may not be correct, but you will get most or all of the available credit for posing a reasonable explanation, even if it is not quite right. Superficial explanations, on the other hand, will cost you.

Anthromorphism

Sometimes you cannot easily find the right wording in order to explain a concept, or you may not understand the concept well enough in order to write an explanation. Anthropomorphism is a type of oversimplification that helps the writer avoid a real explanation of a mechanism. A couple of examples should make the point for you.

Sodium wants to move down the chemical gradient toward the compartment with the lower concentration.

The thought behind the statement is correct, but the statement does not represent the correct mechanism. Sodium has no free will. It tends to move toward the compartment with lower concentration because the probability of a sodium ion moving through a channel on the more concentrated side of the membrane exceeds the probability that an ion will move through a channel on the less concentrated side. If you don't want to explain the principle behind osmosis, you can simply state that osmotic pressure tends to drive sodium from the more highly to less highly concentrated side of a membrane.

The ETS works furiously in a vain attempt to restore the chemiosmotic gradient

Wow. Well, the adverb "furiously" normally applies to a deliberate action, and we know that the ETS is a set of carrier complexes embedded in a membrane, which cannot be capable of a deliberate action. Something that cannot act deliberately cannot think, either. This type of statement results from a misconception. The ETS did work faster - why? There is a phyisical explanation that does not require attributing a free will to the ETS.

Common mistakes in reporting results

Converted data are data that have been analyzed, usually summarized, and presented in such a way that only the information pertinent to the objectives of the study is presented. *Raw data* refers to results of individual replicate trials, individual observations, chart records, and other information that comes directly from the laboratory.

Once you have presented converted data, do not present the samedata in a different way. For example, if the data are plotted, then don't include a table of data as well. Present a figure (such as a graph) if appropriate. If the data are better represented by a table, then use a table. The caption with any figure or table should include all pertinent information. One should not have to go into the body of the paper to find out the results of statistical tests on the data, or the rationale behind a curve fit.

Raw data should never be included in your results. Raw data include lists of observations, meaurements taken in order to obtain a final result (e.g., absorbance, relative mobility, tick marks on a microscope reticule).

Use an appropriate number of decimal places (if you need decimal places at all) to report means and other measured or calculated values. The number of decimal places and/or significant figures must reflect the degree of precision of the original measurement. Example:

The apparent molecular weight (MW) of a polypeptide is proportional to the logarithm of the relative mobility of the corresponding band on an SDS gel. If you can measure relative mobility to the nearest 0.5 mm, and 0.5 mm represents 10,000 daltons on that part of the gel, then any estimate of MW should be rounded to the nearest 10,000 daltons. You will be marked down for reporting an apparent MW of 25,768.46 daltons, for example. By the way, since the number of significant figures reflects the level of precision, there is never any need to qualify a measurement or calculation as 'about' or 'approximate.'

Graphs and other pictures that represent data are called figures, and are numbered consecutively. Tables are distinguished from figures, and are numbered consecutively as well. For example, a paper with two graphs, a reproduction of a segment of chart record and two tables will have figures 1, 2, and 3, and tables 1 and 2. Do note that I distinguished graphs from chart records. Not everything with gridlines is a graph. Graphs are analytical tools. Chart records are raw data (which may be presented in results as an example, if appropriate).

Do not draw conclusions in the results section. Reserve data interpretation for the discussion.

The significance of 'significance'

A statistically significant difference is one in which the probability that the groups of data are identical with respect to the characteristic under investigation is so low that the investigator can confidently conclude that the difference exists. **If sufficient data are collected**, and statistical significance is not achieved, the investigator can conclude that the null hypothesis is not supported - there is no significant difference.

That does **not** mean that the 'result is insignificant.' A finding, for example, that there are no intrinsic differences in fundamental mathematical ability among racial groups would be a very significant finding. Significance in this study refers to the importance of the result. 'It is significant that we found no significant differences among the groups studied' is a valid, though perhaps confusing, statement.

There is a tendency among students to reject a study as 'inconclusive' just because no statistically significant differences were found. Don't you dare do that! You can conclude something from even the most poorly designed experiments. In fact, most well-designed experiments result in support for the null hypothesis. Be prepared to interpret whatever you find, regardless of what you think you should find. The purpose of experimental science is to discover the truth - not to make the data conform to one's own expectations.