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Strategies for Critical Reading of Technical Writing: Primary Literature

Technical and scientific text is written in a very specific form and tone, which must be read actively and critically. Critical reading is different from passive reading; an active reader pays close attention to both writing style and content. These steps will help you understand and judge the content of journal articles read for research or to augment laboratory work.

1. **Selecting an Article:** These reading strategies can be used with any technical writing, but when practicing, start with an article that is interesting and relevant to you. Keywords in the title and abstract of an article will help you determine if it is relevant to your field of interest.

2. **Pre-reading:** Skim the article, paying close attention to sections that interest you the most. Note headings and subheadings, as well as graphics and their captions. Knowing the sections of formal scientific writing is essential to reading them. Unlike fiction, scientific writing need not be read in a specific order. The introduction or the conclusion is a good starting place, because it will provide a context and background for the subject. The next section of importance is the abstract, which will give you a synopsis of the major findings of the study. Sometimes, however, the results will be the most relevant to what you are researching. Or, if you are attempting to reproduce a study or experiment, you will pay close attention to the methods section. Focus on what makes sense for you to read, and if the article seems particularly useful, continue to step three.

3. **Re-reading:** Always read an article you are trying to understand at least twice. After skimming as in step two, read it from beginning to end, underlining vocabulary words, and making notes in the margins.
   A. Defining Terms:
   1. If you can understand the text without knowing a word, you may not have to look it up.
   2. You can glean the meanings of some unfamiliar words from their context within the section.
   3. Identify other terms by thinking about the meanings of their suffixes and/or roots.
   4. Some vocabulary you will need to look up. It can be useful to cross reference the article with introductory textbooks within the field; i.e. if the article is on a chemistry experiment, look in a basic chemistry textbook. The first place to look is the glossary of a textbook in the field. You can also try looking up terms in indices, in case the word is defined elsewhere in the text. A comprehensive Webster's Dictionary also has many scientific terms.

   B. Evaluating the Text:
   Question the authority of the text. Is the information accurate? Are the methods well designed? Are the results relevant and reproducible? Are the statistics represented correctly? Are the conclusions inferred from the results logical? Make yourself notes about these questions, either in the margins or on another piece of paper. Do not worry about answering all of these questions now; they can be discussed in seminar or answered as you become more familiar with the field. Focus on making sure you write them down, and do not take the information you are reading for granted.

4. **Collaborative Reading:** Remember that you are learning how to understand this material with many other students. It is likely that you will seminar on articles that you read for your classes, and this can be the best opportunity to gain a full understanding of the text. Come to seminar prepared with questions. If you look up a word and still do not grasp its meaning, ask your fellow students. After discussing the paper, re-read it and compare how you interpreted the text after the first reading to how you understand the content now.

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Strategies for Critical Reading of Scientific Text: Secondary Literature

Technical and scientific text is written in a very specific form and tone, and must be read actively and critically. Critical reading is different from passive reading; an active reader pays close attention to both writing style and content. These steps will help you understand and judge the content of textbooks, seminar books, and other non-fiction books dealing with science.

1. **Pre-reading:** Skim the chapter or section you are about to read. Note headings and subheadings, as well as graphics and their captions. Read the first and last paragraph, as this will give you an idea of the purpose of the chapter. Reading the topic sentence (usually the first sentence) of each paragraph or section can provide you with a loose outline of the topics covered.

2. **Re-reading:** Next you are ready for a deep, critical reading of the text. After skimming, read the chapter or section from beginning to end, underlining vocabulary words and making notes in the margins or on a separate piece of paper.

3. **Defining Terms:**
    1. If you can understand the text without knowing a word, you may not have to look it up.
    2. You can glean the meanings of some unfamiliar words from their context within the section.
    3. Identify other terms by thinking about the meaning of their suffixes and/or roots.
    4. Some vocabulary you will need to look up. The first place to look is the glossary, if the book has one. You can also try looking up terms in the index, to see if the word is defined elsewhere in the text. A comprehensive Webster's Dictionary also has many scientific terms. You may also cross-reference with other textbooks. It can be especially helpful to use introductory textbooks if you are studying an advanced or specialized topic.

4. **Evaluating the Text:** Question the content, motives, and authority of the text. Does the information match what you have learned from lectures and workshops? How is it connected to the information you might find in newspapers, magazines, or on the news regarding current events and policies? What concepts do you have a clear picture of? What are you having difficulty understanding? Is the purpose of the text informational? Is the purpose to persuade you of something? How can you tell? What are they trying to persuade you of? Do you agree or disagree? Make notes about these questions, either in the margins or on another piece of paper. Do not worry about answering all of these questions now; they can be discussed in seminar or answered as you become familiar with the subject. Focus on making sure you write questions down and think about them in terms of what you already know.

5. **Collaborative Reading:** Remember that you are learning how to understand this material with many other students. It is likely that you will seminar on the material that you read for your classes, and this can be the best opportunity to gain a full understanding of the text. Come to seminar prepared with questions. If you look up a word and still do not grasp its meaning, ask your fellow students.

6. **Final Read:** After discussing the text with your peers and faculty, re-read it and compare your initial interpretation with your new understanding of the content. Have your questions been answered? If not, where else could you go to answer them?

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Putting Scientific Work in Context: Introductions

Nearly all journal articles have introductions that contain the information outlined below. However, not all articles are organized thusly. Some will not contain each section, and some will portray it in different order. The outline shown here is a tool you can use to ensure that you include all information necessary to put your study into the broader context of scientific knowledge. Each section will use words and phrases that are indicative of the purpose of the section. Such language is bolded in the example.

I. Topic Sentence

The topic sentence introduces your topic, explaining why it is important.
Purpose: To begin your paper on general terms and engage your reader's interest.
Example: *The **regulation of abundance** remains a **central question** in mammalian population ecology.*

II. Previous Studies

A paragraph or so provides a brief, condensed history of the previous studies that your work challenges or develops. Information in this section should be cited.
Purpose: To show that you are well-versed in the topic and have appropriately studied the literature before performing your experiments. Also to provide a context for your work.
Example: *For highly migratory herbivores, such as caribou (*Rangifer tarandus*) and wildebeest (*Connochaetes taurinus*), **evidence is mounting** that competition for high-quality forage is regulatory (Dublin et al. 1990; Mduma et al. 1999; Messier et al. 1988; Skogland 1985). For these species, migration **appears to represent** an effective strategy to escape predation. Mobile ungulates and their precocial young **may be able to** space themselves from their less mobile predators (Bergerud 1988; Fryxell and Sinclair 1988; Fryxell et al. 1988).*

III. Gap in Existing Knowledge

A few sentences between history and background states the gap in existing knowledge of the topic and relate the context to your work.
Purpose: To smooth the movement of your introduction from the general history to information specific to your study. To connect the context directly to your work.
Example: ***Further associations** between the spatial dynamics and demography of large herbivores **might be anticipated**. For example, because migratory species may experience seasonal limitations in food, the timing of migration might be sensitive to heightened intraspecific competition for resources (Fryxell and Sinclair 1988).**This hypothesis has not been tested**. For long-lived mobile mammals, however, understanding such relationships often requires extensive observations in space and time (Mduma et al. 1999; Stirling et al. 1999). **Despite recent advances** (Bergerud 1996), the dynamics of migratory caribou **remain incompletely understood**. **Long-term studies may help to resolve that shortcoming.***

IV. Introduction and Background of Your Study

Any background information essential to understanding your study should be stated now. Terms unknown to the scientific community are defined here, and information is cited.
Purpose: To help your readers understand and interpret the contents of the paper.
Example: *The Buchans Plateau caribou (*R. t. caribou*) herd (Fig. 1) affords an opportunity for long-term investigation. Migration of the Buchans herd represents a traditional movement of caribou on the*

island of Newfoundland; since the late 1950s it has been intensively studied (Bergerud 1974), along with herd size, population structure, and body size.

V. Hypothesis

The last sentence is nearly always your hypothesis, which is the main objective, prediction, or question you hope to answer. The hypothesis has been underlined in this example for emphasis. There may also be a "mapping" section here, informing the reader of what they will find in the rest of the paper.
Purpose: To pose the question or problem that your study addresses; also to show the reader what to expect in the rest of the paper.
Example: *By augmenting long-term data with more recent observations from radio telemetry and age and sex classifications,* ***we assembled*** *a data set of >40 years on the movements and demography of caribou.* ***We report*** *on long-term trends in population ecology of the herd.* *We anticipated, coincident with a 20-fold numerical increase, that the Buchans herd would exhibit signs of density-dependent feedback in growth, vital rates, body condition, and timing of migration, consistent with migratory caribou elsewhere (Bergerud 1996; Couturier et al. 1990; Messier et al. 1988; Skogland 1985).*

Putting it all together: This is what the example looks like in paragraph form.
The regulation of abundance remains a central question in mammalian population ecology.For highly migratory herbivores, such as caribou (Rangifer tarandus*) and wildebeest* (Connochaetes taurinus*), evidence is mounting that competition for high-quality forage is regulatory (Dublin et al. 1990; Mdumaet al. 1999; Messier et al. 1988; Skogland 1985). For these species, migration appears to represent an effective strategy to escape predation. Mobile ungulates and their precocial young may be able to space themselves from their less mobile predators (Bergerud 1988; Fryxell and Sinclair 1988; Fryxell et al. 1988).*

Further associations between the spatial dynamics and demography of large herbivores might be anticipated. For example, because migratory species may experience seasonal limitations in food, the timing of migration might be sensitive to heightened intraspecific competition for resources (Fryxell and Sinclair 1988).This hypothesis has not been tested. For long-lived mobile mammals, however, understanding such relationships often requires extensive observations in space and time (Mduma et al. 1999; Stirling et al. 1999). Despite recent advances (Bergerud 1996), the dynamics of migratory caribou remain incompletely understood. Long-term studies may help to resolve that shortcoming.

*The Buchans Plateau caribou (*R. t. caribou) *herd (Fig. 1) affords an opportunity for long-term investigation. Migration of the Buchans herd represents a traditional movement of caribou on the island of Newfoundland; since the late 1950s it has been intensively studied (Bergerud 1974), along with herd size, population structure, and body size. By augmenting long-term data with more recent observations from radio telemetry and age and sex classifications, we assembled a data set of >40 years on the movements and demography of caribou. We report on long-term trends in population ecology of the herd. We anticipated, coincident with a 20-fold numerical increase, that the Buchans herd would exhibit signs of density-dependent feedback in growth, vital rates, body condition, and timing of migration, consistent with migratory caribou elsewhere (Bergerud 1996; Couturier et al. 1990; Messier et al. 1988; Skogland 1985).*

This example was taken from Mahoney, Shane P. & Schaefer, James A. 2003. Long-term changes in demography and migration of Newfoundland caribou. *Journal of Mammalogy.* 83(4):957-963.

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Researching a Scientific Topic: Finding and Using Sources

Now that you have your topic, it's time to go to the library and research it. There are two different kinds of information you will find: **primary sources** and **secondary sources**, defined below. Use secondary sources to familiarize yourself with the topic and for general, common knowledge about your subject. Use primary sources to confirm the information found in secondary sources, and to cite specific studies on the information you are using. Remember that secondary sources are like the game Telephone; the farther information travels the more distorted it becomes. Always corroborate your information by looking it up in the primary source.

Kinds of Information

Specific Information: Primary Sources

Primary sources are articles or books written by the researchers who have carried out their own work. These are usually in the form of journal articles, although they can be books. Most primary sources are peer reviewed, meaning the article has been read and approved by a panel of experts in the field.

These sources can be found in:

- The periodicals
- References of secondary sources
- Online Databases, such as Cambridge Science Abstracts

They can be used for:

- Specific data from studies
- Checking the general info
- Supporting the general info

General Information: Secondary Sources

A secondary source is one that obtains its information from primary or other secondary sources and uses that info to inform the general public. Some secondary sources are:

- Non-fiction books
- Encyclopedias
- Popular magazine articles, such as Science News
- Newspaper articles
- Websites

These sources can be found in:

- The library catalog
- The periodicals
- Databases, such as Proquest and Ebscohost
- Internet search engines, such as Google

They can be used for:

- Definition of terms and answers to general questions
- Better understanding of the topic
- Basic facts
- Life history
- Natural history

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Using Your Sources

Use your sources to learn more about your topic and to support subtopics of the outline of your paper.

Plagiarism:

Using another author's ideas or words without proper acknowledgment is plagiarism. Plagiarism is an academic crime. Colleges expel or dock credit from students caught plagiarizing. Whether it is intentional or unintentional, you are plagiarizing if you:

1) use another person's words without putting them in quotation marks,
2) use another person's ideas without citing them as a source,
3) borrow a fact from your source without citing it, or
4) reprint any tables, illustrations, or charts without documenting the source.

You do not need to cite when you:

1) use common knowledge (such as the name of the president or the date of WWI),
2) find the information undocumented in more than four sources, or
3) write your own ideas or experiences.

Avoiding Plagiarism: It will be easy for you to avoid plagiarism if you use the proper precautions. Always, credit your source by using standard citation methods (such as MLA or APA) and practice paraphrasing.

Paraphrasing:

When you use evidence or ideas from a source, but do not directly quote the original, you are paraphrasing. Paraphrasing is important because it forces you to put information and ideas into your own words. The process of paraphrasing demonstrates a deeper understanding of the material because it requires the writer to synthesize the information in the original source.

Example:

Original Source

> Studies of moose-vegetation dynamics in other boreal forest systems indicate that browsing-induced reduction of canopy height and closure by as little as 12% to 50% results in higher light intensity, lower humidity, warmer and drier soils, and lower primary productivity of tree species (Bonan 1992, Kielland and Bryant 1998). Over the long term, soil chemistry can become altered through reductions in litter quality and rate of litter decomposition, causing a buildup of soil carbon that feeds from the bottom up to exacerbate the reduction in ecosystem productivity (Pastor et al. 1993).
>
> --Taken from: Schmitz, O. J., Johnston, K. M., Post, E., Burns, C. E. (2003, December). Ecosystem Responses to Global Climate Change: Moving Beyond Color Mapping. *Bioscience*. 53 (12). 1199-1206.

Paraphrase

> Moose can impact boreal ecosystem productivity even with minimal browsing. When browsing caused a 12% to 50% decrease in canopy height and forest closure, the result was lower reproduction of tree species, drier and warmer soils, greater light intensity, and less humidity (Schmitz et al. 2003). The long term effect is most prevalent in soil quality. Moose cause a reduction in the quality of litter and the rate at which it decomposes, thereby altering soil chemistry and increasing the amount of carbon in the soil. This furthers the reduction in overall productivity of a boreal ecosystem.

Strategies for Paraphrasing: Paraphrasing is putting the source's information into your own words. The following strategies can make the process more comfortable:

1) Imagine you are explaining the idea to a friend.
2) Avoid using the author's sentence structure, wording, or phrases.
3) Resist the desire to look at the original source when paraphrasing.

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Standard Format of Primary Scientific Literature

The Six Parts:
1. Title
2. Abstract
3. Introduction
4. Methodology/Experimental
5. Results/Discussion
6. Conclusion

1. *Title:* The title should be a clear phrase or sentence that provides enough information about the experiment to entice the reader, yet not too much detail. It may address the essential findings or purpose of the experiment.

2. *Abstract:* The abstract is a brief statement of the purpose and important results of the experiment. It should be no more than five sentences and can be written last, after the rest of the paper is clearly formulated.

3. *Introduction:* The introduction gives the experiment a context. It provides a background in the subject matter, including relevant previous studies. All sources used must be cited. The hypothesis is clearly stated here.

4. *Methods/Experimental:* The methods section states specific materials, equipment, and instrumentation used. It describes how lab/field work was carried out, and emphasizes measures taken to reduce possible error, or remove background noise from data. Other scientists in the field should be able to reproduce the experiment using information in this section.

5. *Results/Discussion:* This is a well-written account of the data obtained on lab/field notes. It will include graphics, diagrams and tables to illustrate the most significant data. Graphics should be well-labeled and accompanied by footnotes. Each figure, however, cannot stand alone and its content should be well-described in the text of the results. There should be a subheading for each significant result, or assay, under which the results will be stated and discussed in terms of the experiment. For some less complex experiments, all of the results can be stated under one heading and the discussion will be part of the conclusion.

6. *Conclusion:* The conclusion addresses the overarching implications of the most significant results. It may list possible sources of error to explain why some data deviate or why the experiment was not successful. It should not infer more than the results actually mean. The conclusion responds to the introduction, explaining why the results are important to future work in the field. It may state how the experiment could be re-evaluated so that more conclusive results may be obtained.

References: A bibliography of any works cited in the introduction, conclusion, or throughout the paper. There are several general formats, but the format is usually specific to a field or journal.

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Peer Review Form for Scientific Writing

Student: _____ Reviewer: _____

Questions to answer while reviewing the paper:

1. Is the title useful? What are the keywords?

2. Is the abstract brief? Are the purpose and important results stated? Are there any details that could be removed?

Introduction

3. Does the introduction section 1) put the experiment in context, 2) provide background about the subject and 3) explain why it is a relevant study? If not, what information would make it more clear?

4. What is the hypothesis? Do you know what to expect in the rest of the paper?

Methods

5. Does the methods section clearly state the specific materials, equipment and instrumentation used? What, if anything, is left out?

6. Are there enough details provided for you to effectively reproduce the study? If not, what could be added to make it more useful?

Results and Discussion

7. Does the results section use well-labeled graphs, diagrams, tables or photos to illustrate the most important results? Are the graphics adequately explained in the text?

8. Are there errors inherent to the study? Are the ways to minimize this error addressed?

9. How is the results and discussion section organized? Can you suggest a more effective way to organize it?

Conclusion

10. Does the conclusion section address the implications of the most important results?

11. How are the results related to the context addressed in the introduction?

12. Are improvements and ideas for future studies suggested?

Odds and Ends

13. Is the paper written in the appropriate voice (active or passive, depending on faculty preference)?

14. Are the interpretations of the results sufficiently skeptical and balanced, or do they infer more than logically follows?

15. Is background information and previous studies cited using a formal citation style?

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Title and Abstract: Your Paper in a Nutshell

The title and the abstract always appear at the beginning of an article, but they are usually written last, after the rest of the paper is complete. This is the stage where the paper will be clearly organized, and can be compressed into a few sentences. These sections act like a book jacket, inviting the reader to look further.

I. The Title

The title is a short phrase, rarely a complete sentence. It should be clear, informative, and detailed, but not contain unnecessary details. It should contain the key words that define your topic. It should emphasize subjects or findings that are unique to your study.

Purpose: The title conveys the key points of your study to a reader glancing through a citation index, database, or references page.

Examples of Titles:

Too Vague:
Effects of pH on the growth of bacteria
Revision:
Effects of pH variance on growth of Pseudomonas aeroginosa

Too Detailed:
Effects of pH variance from 4.0 to 9.0 on the growth of prokaryotic Pseudomonas aeroginosa *bacteria (strain142) in minimal media under aerobic conditions*
Revision:
Acidic pH increases growth rate of Pseudomonas aeroginosa

II. The Abstract

The abstract is a condensed version of your paper. An effective abstract will not refer to figures or information in the text, abbreviate unknown terms, or contain too much or too little detail. It will convey the relevance of the topic to the reader, and summarize the approach to answering the question, the major supporting data, and the major conclusions reached by performing the study.

Purpose: Similar to a title, the abstract provides the reader with key points about the study and entices one to read further.

Technique: An abstract can be constructed by taking the topic sentences from each section and rewording them to flow well in one paragraph. However, your abstract should never repeat the sentences from your text.

Please refer to the back of this handout for examples of abstracts.

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Examples of an Abstract:

Too Vague:
Ecdysone, is a major steroid hormone of *Drosophila melanogaster*. Heterozygous flies have a greater life span and resist stress with a greater ability. A mutant is involved in the biosynthesis of ecdysone and doesn't have effects when it eats ecdysone. This shows the importance of ecdysone in regulating life.

Too Detailed:
Ecdysone is the major steroid hormone of the fruit fly *Drosophila melanogaster*. Steroids are well known for their role in development and reproduction in all life forms. The chemical structure of Ecdysone is C10H23N2OSO4. Flies that are heterozygous for mutations of the ecdysone receptor, which is coded on the third chromosome and consists of five proteins (alpha, beta, gamma, sigma, and hepa domains), exhibit increases in life-span and resistance to various stresses, with no apparent deficit in fertility or activity. A mutated fly, also lacking wings and the melanin gene, involved in the biosynthesis of ecdysone displays increased life span and stress resistance without lack of fertility and activity (figure 3). These effects are suppressed by feeding ecdysone droplets, at a concentration of 0.6mM, to the flies. These observations demonstrate the importance of the ecdysone hormonal pathway, a new player in regulating longevity.

Revised:
Ecdysone, the major steroid hormone of *Drosophila melanogaster*, is known for its role in development and reproduction. Flies that are heterozygous for mutations of the ecdysone receptor exhibit increases in life-span and resistance to various stresses, with no apparent deficit in fertility or activity. A mutant involved in the biosynthesis of ecdysone displays similar effects, which are suppressed by feeding ecdysone to the flies. These observations demonstrate the importance of the ecdysone hormonal pathway, a new player in regulating longevity.

This example was taken and adapted from Simon, A. F. et al. 2003. "Steroid Control of Longevity in *Drosophila melanogaster*." *Science* 299(5611): 1407-1410

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Methods: A Recipe for Science

Methods sections (also called materials and methods or experimental) are often difficult to write because of the temptation to include too many details or too few details about the experiment. This handout includes an activity where you can use the information below to effectively critique an example (provided on the back of the handout).

1.) Why Describe the Methods?

Readers use the methods section as a way to ascertain that sufficiently analytical methods were used, making the results meaningful. It can also serve as a historical marker, denoting the technology available at the time. Finally, it provides readers with a way of testing your results; they should be able to reproduce the results you obtained by following your methods.

2.) What Should You Include in the Methods?

The methods section should list chemicals, instruments, and special equipment used. It should provide a step-by-step procedure. Sometimes a diagram of an apparatus or a flowchart of the procedure can be used to clarify complicated methods. (See the graphics handout for advice on how to incorporate graphics.) If a procedure was changed or adapted during the experiment, this section can reveal that change. However, it should not waste space with menial mistakes (e.g., "spilled flask so refilled"). Those details stay in your notebook.

3.) Necessary information:

There should be just the right level of detail so that a scientist in the same field could reproduce the experiment or study and obtain the same results.

Names	Measurements	Descriptions
Chemicals	Concentrations	Procedures
Procedures	pH	Statistical analysis
Special equipment	Temperature	Instruments
Equations	Wavelength	Study Sites:
Instruments:	Time intervals	Topography
Model #	Number of samples	Vegetation
Manufacturer	Volumes	Climate
	Weights	Ecology

4.) Unnecessary information:

There should not be unnecessary details that distract the reader and waste space. These include names that are vague, unofficial, or names of typical laboratory equipment (gloves, stirrers, pipettes). Measurements of amounts where concentrations suffice are unnecessary. Descriptions of items or procedures that are common knowledge are also unnecessary.

5.) Activity: Critiquing Methods

Read the example on the back. Make two lists: one of necessary details that have been left out, and one of unnecessary details that can be removed. Think about the level of information in the example. Could you, given the background knowledge and the right equipment, reproduce this experiment?

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Example of a Materials and Methods Section:

Materials and Methods

The hydrolysis of ONPG took place in four pre-prepared solutions: 20mM KCl; 2mM MgSO4; 100 mM B-mercaptoethanol, and a 200mM buffer at five different pH values varying from 4.0 to 9.0. Each solution was added in 0.75ml amounts to 0.3mL ONPG to a concentration of 4mg/ml. These were incubated in shaking water baths for 5 minutes at the selected temperature. When pH was varied, temperature was held constant; when temperature was varied, pH was held constant (tables 1&2). To this mixture was added 0.03ml β-gal at a concentration of 5.5x10^-5 mg/ml. The reaction proceeded for 5.10 minutes, then was terminated by addition of 0.75ml of sodium bicarbonate. Absorbance was read in a blanked Oceanoptics spectrophotometer at a wavelength of 420 nm. Results were reproduced twice. Specific activity was calculated with the provided equation (figure 1).

In the second part of the lab, ONPG concentration was varied between 2 and 0.1 mM. This variation was achieved by adding ONPG in decreasing amounts and water in proportionally increasing amounts. The same procedure was followed as above. Temperature was held at 37 degrees Celsius, and pH was a constant 7.5. Two reproducible results were obtained for each variance. Then, 0.3ml of lactose were added to the reaction, with each varied amount of ONPG. The standard assay was repeated twice.

This example is taken from an anonymous student paper in Molecule to Organism.

Necessary:	Unnecessary:

Could you reproduce this experiment? Why not? What would you improve to make this Methods section work?

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Results and Discussion

The results and discussion sections of your research article present the major results of the study and a direct, logical interpretation of these results. The results section is usually accompanied by graphics. Note that the purpose and contents of the results and discussion are the same for both formats.

I. Results

a.) Text:

The text does not merely repeat the data already expressed in tables and figures. Rather, it highlights unexpected findings and major results. It should, however, describe the findings expressed in the graphics, so that one can understand them independent of the figures.

Purpose: The text describes, in paragraph form, the major results of your study. This space does not serve as interpretation. Phrases such as "this means" and "shows that" should not appear here.

b.) Graphics:

Graphics may be in the form of drawings, diagrams, photographs, tables, and graphs. They should be large enough to read easily but not so big as to waste space. All graphics should be accompanied by detailed captions describing their contents. They should be labeled in order of appearance in text (i.e. figure 1, table 1, etc.) The symbols should be clear and a legend, if necessary, should be simple and easy to interpret.

Purpose: Illustrations support, clarify, and emphasize the information in the text. They help speed the reader's understanding and provide visual evidence of the results, which is easier to believe than text.

II. Discussion:

The discussion will state how well the experiment answered the question or proved the hypothesis. If the anticipated results do not match the actual results, explain why not. You should describe the meaning of individual results without yet relating them to the broader context of the work; that is done in the conclusion. (See the reverse side of this handout—"Putting the Results into Context: Conclusions.")

Purpose: The function of this section is to provide a specific interpretation of the major results stated in the result section.

III. Formats

1. Use with small-scale experiments where the results are few and very connected

Results: Text of the results section goes here, in paragraph form. Graphics are printed nearby.

Discussion: Text of the discussion is here. Sometimes the discussion is part of the conclusion, and the conclusion goes from narrow to general.

2. Use with complex results that are difficult to find relationships between

Results/Discussion

First major result: Text of one result is here in paragraph form, and transitions directly to discussion with no separate heading.

Second major result: Text of the next result is here, transitioning into its discussion. After all the results, there is a separate conclusion.

See the back of the handout for an example of each format discussed here.

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Putting the Results into Context: Conclusions

The conclusion follows a less strict outline than the introduction, but is ordered nonetheless. It will put the findings of your study, rather than the study itself, into context. In many journals and fields, passive voice is disposed of for this section and first person is used.

I. General Statement

The first sentence or two puts the results into context by providing a general, umbrella truth relevant to the topic.

Purpose: A statement introduces the conclusion by reminding your readers of the generalities put forth in the introduction. This will set up the context for you to discuss the conclusions specific to your experiment.

Example: *In sea urchin embryos, different stressors (heat shock, Zn, EGTA, TPA) induce different stress responses and not all induce a thermotolerant response.*

II. Major Conclusions

The next paragraph describes the major finding of this specific study. If there are several important results, this section may be several paragraphs long.

Purpose: This section relates each major conclusion of your work to the context introduced above. This is not a place to be a megalomaniac about the significance of your results; the tone should remain skeptical and humble. However, it should give an informative interpretation of what each result means to your field of study; i.e., what knowledge gaps your work has filled.

Example: *In this study, we demonstrate that a particular hyperosmotic stress, a NaCl concentration that is twice that of seawater (Casano et al. 1998), induces a thermotolerant response probably by activating a phosphorylation signaling cascade, such as the TPA treatment (Roccheri et al. 1995). We suggest that p38SAPk is the effector of this pathway because we found that SB203580 treatment inhibits the regeneration of the cilia, causes malformations, and does not give rise to acquired thermotolerance.*

III. Future Work

Most experiments will leave researchers with more questions than answers. This section states the future research that may be done to answer these questions.

Purpose: This section will let your readers know that even if you do not have significant results, the work was valuable because it gave you an idea of where to go next. It will let people new to the field know what work remains to be done in that field.

Example: *We now plan to ascertain whether the p38 activation is a specific deciliation response or whether it is also induced by other stressors such as heat shock or EGTA, which also induces thermotolerance.*

All above examples are from Casano, C., et al. 2003. “Sea urchin deciliation induces thermoresistance and activates the p38 mitogen-activated protein kinase pathway.” *Cell Stress and Chaperones* 8 (1): 70-75.