CORNING SCHOOL OF OCEAN STUDIES
GUIDELINES FOR WRITING SCIENTIFIC PAPERS

The Purpose of Writing in Science

The most important consideration in writing science literature is to remember that it is a *creative process*. Many readers and writers of science misunderstand this, and falsely believe that science writing must be a dull, boring and clinical endeavor. While there are certain rules that must be followed when writing in science, its main purpose is to communicate creative and often original research to an audience. Conducting research in science without presenting the new-found information to others is without purpose.

When you look at the structure of a scientific paper, also called a *journal article*, a *manuscript*, or *primary literature*, you will see that it follows a strict format. There is a very good reason for this. Readers of scientific papers want to know exactly where to look in a document for specific information. By adhering to a common format, writers of science know where to include appropriate information and readers know where to find it. We will below the nine sections commonly found in scientific papers and what information belongs in each. The sections include:

- Title
- Abstract
- Introduction
- Methods
- Results
- Discussion
- Acknowledgements
- References
- Tables and Figures

Shorter communications in scientific writing may combine sections (e.g. "Results and Discussion") or omit sections (e.g. some short publications do not have abstracts or acknowledgements). It is also possible to find papers that do not have tables or figures. This guide will describe each of the sections listed above. You will receive specific instructions whenever you are asked to write a paper for a course (or for publication in a scientific journal!) as to what you must include.

You can find hundreds, if not thousands, of guides describing how to write scientific literature. Some guides are in the form of textbooks, some guides are in the form of handouts in class, some guides are in the form of internet sites. It is important to remember that, while the details might vary, the “skeleton” remains the same. If you ever find yourself receiving conflicting advice from your professors, or your peers, or even in “Instructions to Authors” in peer-reviewed journals (and you probably will), it is **your job** to ask for clarification. The devil is in the details. Your faculty in the Corning School of Ocean Studies are all “on the same page” with the format of how to write a scientific paper for your courses, but we will probably vary somewhat on smaller details. If you are ever confused, it is your responsibility to ask for an explanation. This is good preparation for your future as a scientist, for you will find throughout your career that different reviewers and editors will require different things from your writing.

Title

For many writers, constructing a title can be one of the hardest parts of a paper to write. The title must convey sufficient detail that the reader knows what the paper is about, but must not be a paragraph in length! Writers must avoid the temptation to be cute or witty, but must also not be so dull as to discourage the reader from reading the information. A title such as "*Feeding in damselfishes*" does not tell the reader much beyond the fact that the paper is about damselfishes and probably concerns what they eat and how they eat it. A title such as "*The bite rate, mouth size, diet type and quality and diel variation in feeding in the herbivorous pomacentrid damselfishes* Stegastes dorsopunicans, *the dusky damselfish, and* S. planifrons, *the threespot damselfish (Teleostei: Perciformes, Pomacentridae) in the San Blas Archipelago of Panama in the Caribbean*" tells the reader more than what is necessary and has probably frightened a prospective reader from reading the paper.

The title should be the last (or perhaps next to last) part of the paper to be written. One good way for writing a title is to make a list of key words from the paper: question/hypothesis tested, species name (if applicable), location of study, equipment used, major concepts, etc. From the list, select several of the key words and play around with different titles. Read your title and see if it conveys the major ideas of your paper, without having to make the reader guess too much. An appropriate title for the damselfish research above might be "*Dietary preferences of two herbivorous damselfishes,* Stegastes dorsopunicans *and* S. planifrons, *from Panama*". There are better titles than this, but this one is on the right path.

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	**Maximum Points**	**Points Earned**
Title		
descriptive of study, not overly wordy, or vague	2	

Abstract

The Abstract of your paper is an important section. It is the last section you will write, even if it appears at the beginning of your paper. The role of the Abstract is to summarize your paper in such a way that a reader can judge whether or not s/he wants to read your entire paper. One good way to write an Abstract is to start with a one-sentence summary of each of your paper's main sections: Introduction, Methods, Results, Discussion. Put those sentences into a paragraph and then edit so that sentence flows into the next. It is an excellent idea to read the abstracts of several papers that interest you to see how they were assembled.

Abstract

Animals have behavior patterns that are instinctive, but may change with experience. I tested whether the length of time a hermit crab was held out of water affected the amount of time it took it to emerge from its shell once I put it back in the water. A hermit crab was held out of water for varying time intervals and then placed back into the water. The recovery time was relatively constant, however the crab became more aggressive. I concluded that the amount of time that the hermit crab spent out of the water did not influence how long it took it to emerge from its shell.

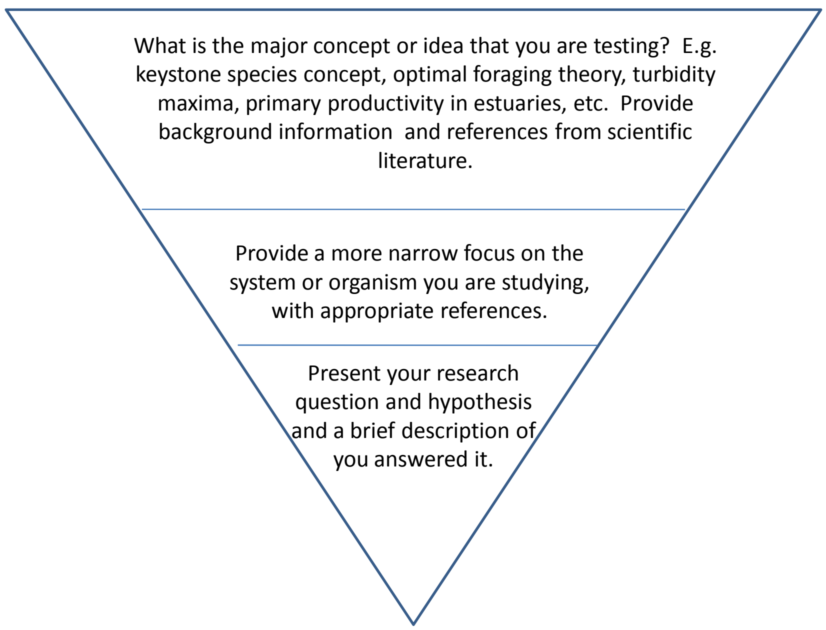
GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	**Maximum Points**	**Points Earned**
Abstract		
includes summary of Introduction, Methods, Results,	8	

Introduction

The Introduction of your paper provides background information about the concept or idea you are investigating and will outline the specific system, organism, etc you are studying. An Introduction will also present your research question and your hypotheses and briefly inform your reader how you set about finding your answers.

In its simplest form, you can think of the Introduction as having three parts. In a short paper for a field or laboratory exercise, your Introduction may only comprise three paragraphs. In a more developed research project for an upper-level course or your senior research project, your Introduction may run to five or more pages but it will still have three essential parts. You can view your Introduction as an inverted triangle.



You will develop your ability to write introductions through practice. Your instructor will provide specific instructions for what you must include in your Introduction, how and where to find appropriate references, and how to organize your “triangle”.

Sample Introduction from a Bi101 Paper

It is a general assumption that stress often modifies an organism’s behavior (need reference here). These modifications can be useful or they can be detrimental to the organism. If stress makes the animal more alert, it can be beneficial because the animal is ready to react. If stress causes changes in the body that affect the heart rate or metabolism that cost energy, it can be bad.

Subjecting an animal to a condition it is not used to may modify its behavior. Some hermit crabs are intertidal animals that only move around when they are covered by water (need reference here). When they are in air, it may be stressful for them and they retreat inside their shells. They do not come out again until they are covered with water.

I hypothesized that the amount of time a hermit crab spent out of water would affect how long it would take the crab to emerge from the shell once it was returned to water. The longer a crab was held out of water, the longer I expected it to take to come out of its shell once it was back in water. I called this time interval the recovery time; I expected that recovery time was correlated with exposure time.

Sample Portion of an Introduction from an Os400 Paper

Protein and energy are two of the main things that animals need in order to metabolize and grow. Proteins can be burned into energy to make about one-half of the 21 amino acids used in metabolism and growth (Bowen, et al, 1995). There have been many studies that have suggested that higher protein level diets increase the growth rates of fish.

One of the many studies that supported the idea that an increase in protein causes an increase in growth rates was done by Millikin (1982) with striped bass (age 0), Morone saxatilis. In the wild juvenile striped bass eat insect and fish larvae. He found that increasing the protein concentration in the fish's diet had a significant effect in the weight gain of the fish (1982). Lee and Putnam (1973) found that rainbow trout, Oncorhynchus mykiss, use dietary protein for energy. These fish are omnivores, and their main diet consists primarily of insects. Rainbow trout can grow sufficiently if there is a high protein/calorie diet because it gives them a lot of energy (Lee and Putman,1973; Boujard and Medale, 1994). Winfree and Stickney (1981) also did a study on how different diets of protein and energy effects on the growth rates of Tilapia aurea. Tilapia aurea normally feed on plankton. Winfree and Stickney (1981) found that when the right protein to energy ratio was shown, that was when the fish size had increased the most and the fastest.

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	Maximum Points	Points Earned
Introduction		
comprehensive background information provided describing the problem addressed in the paper; at least one literature citation included to provide background	7	
in middle third of Introduction, a more focused description of your problem/area of interest in paper; more focused literature included	7	
experimental question(s) and hypotheses clearly defined	3	
well- written and well organized; flows from general information to specific problem	3	

Methods

The Method section of your paper concisely describes how you performed your research. A reader will look to this section to obtain guidelines on how to conduct their own research, and to evaluate how you conducted your work to obtain the result and interpretations you did. It is not a "how to" guide and is not written as a list of steps to be performed. It does not look like a recipe from a cookbook nor a list of instructions for a laboratory exercise. You write the Methods section in past tense as a narrative of what you did.

A Methods section may be subdivided to help the reader follow along. There may be separate sections for describing a field site, collection and care techniques for organisms held in the laboratory or the statistical methods used to analyze your data.

It is important to include a certain level of detail, but you must use caution not to get carried away. Brands and types of major equipment are noted (e.g., an Orion Model 210 pH meter). Minor equipment is also noted, although brands are not generally specified (e.g., a plastic weighing dish). If you are in doubt as to include a detail, include it. Omissions of information are more serious than excessive inclusions. Use common sense as much as possible. For example, if you place samples temporarily in a bucket, it is unlikely you need to note the color or volume of the bucket. Properties of the equipment that could influence the experiment should however be noted. For example water held in a metal bucket over time will be enriched in trace metals; if metals factor in the experiment, the bucket composition must be noted.

Consider the following examples:

> *We carried a white bucket and a small dipnet to the tide pool. We placed the dipnet into the tide pool and collected every small fish we could over a 10 minute time period. We then carried the bucket and dipnet back to our red Jeep and drove back to Castine. We placed the fish in the seawater table with running seawater.*
>
> *We dipnetted fish from the tide pool for a 10 minute interval. The fish were placed in a bucket and returned to the laboratory where they were placed in a seawater table with running water.*

Notice how the second example is much shorter and eliminates some extraneous detail. You will have to use your judgment in deciding what level of detail to use. In this example, the color and make of the vehicle used to transport the fish probably will not influence the outcome of the research. However, if you feel that it might, you should include that detail.

You must also take into account the level of expertise of your reader. Consider the following examples:

> *Fieldwork was conducted aboard a launch at two stations near Castine Harbor, ME on Sept. 2, 2008 from 9:50 to 11:35 h. Three charted landmarks (US Chart 13309) were sited at each station. Groups of three students took a magnetic bearing for each landmark using either an illuminated Weems and Plath or a Davis hand bearing compass. A bottom sounding was also taken at each station by one student team using a "lead line", which consisted of a window weight attached to a marked line. The lead line was tied to the stern, then thrown overboard; the distance between the window weight and the sea surface was measured in meters when the line was taught. Taking the bearings and bottom sounding required about fifteen minutes at the first station and ten at the second, with about five minutes of transit time between the two stations.*

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In the first example, it is clear that students worked in teams in order to collect data; and the author also described how a lead line is used. In the second example, it is not specified who made the observations, and the author assumes that the reader knows how to deploy a lead line. When you are writing, you must consider who your reader is and whether or not, for example, s/he would know how to employ a lead line.

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	Maximum Points	Points Earned
Methods		
sufficient detail to evaluate, repeat experiment not too much detail, correct tense throughout	10	

Alternate Methods Section Grading Rubric

This section:	✓
Focuses clearly on methods (excessive introductory material and results are not included)	
Is formal; contractions, slang, opinions, and non-relevant material (e.g. "we had fun") are avoided	
Is without directives[1] and the use of "you"	
Includes concise descriptions of all procedures	
Includes concise descriptions of all materials (if not commercially available)	
Specifies the make and model of major instrumentation	
Describes procedures in the sequence performed	
Notes the study site (latitude and longitude)[2]	
Uses SI units throughout	
Mentions appropriate precautions (e.g. to avoid contamination, stressing organisms, etc.)	
Provides enough information that a reader could repeat the study, given access to the same equipment and study site	

[1] Methods sections never take the form of recipes or directives. "Now you weigh the sample" and "Weigh the sample next" are *not* used; "The sample is then weighed" *could* be used.

[2] Specifying N for latitude and W for longitude are sufficient, e.g., 44^{o}22.501' N and 68^{o}46.385' W is adequate.

Results

The Results section of your paper presents and organizes experimental data or field results in a way that does not overwhelm the reader. Most commonly, the Result section includes both written text and figures or tables. It does *not* discuss the meaning of the data; that is saved for the Discussion section.

The *written text* of the Results section helps to organize data for the reader. Results sections point out trends in your data and often group data into ranges and averages, especially in cases where many data were collected. Consider these examples:

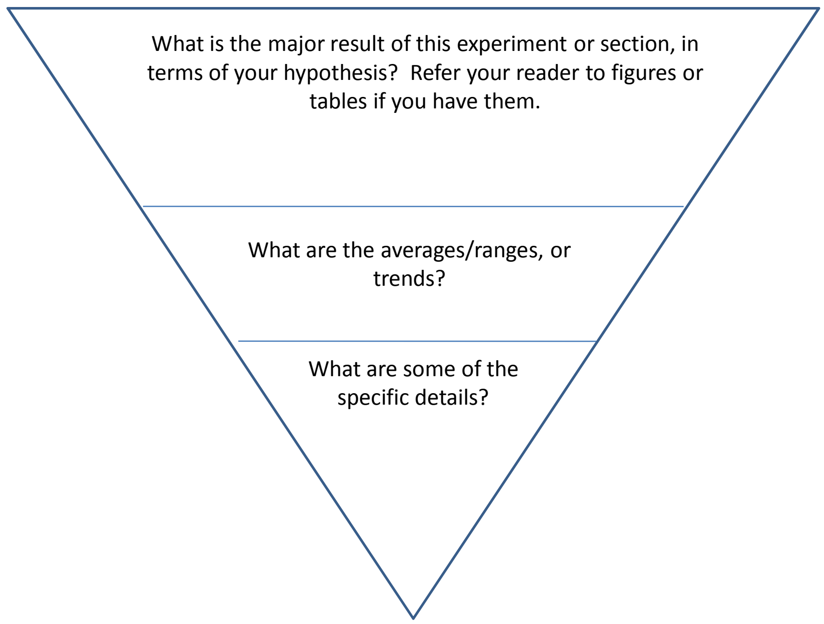
> *Salinities in the estuary ranged from 12-33 ppt; the average salinity was 21 ppt (Figure 1).*
>
> *The metabolic rate of crabs in cold water was half that of crabs in room temperature water (Figure 1).*

In both of these examples, the author summarized the trend for the reader in an easily accessible way by stating a range and average, or suggesting that one value was half of another. These are results that are easily grasped. The author refers the reader to the figures to get the precise numerical details that would be too much to assimilate if written in the text.

For the crab experiment for example, you would not want to read

> *"The metabolic rate for the ten crabs in cold water was 12.2 mg O_2/L, 16.4 mg O_2/L, 16.5 mg O_2/L, 12.7 mg O_2/L, 11.8 mg O_2/L, 13.4 mg O_2/L, 14.2 mg O_2/L, 9.7 mg O_2/L, 10.6 mg O_2/L, and 13.2 mg O_2/L and the metabolic rate for the ten crabs in room temperature water was 24.6 mg O_2/L, 32.0 mg O_2/L, 33.0 mg O_2/L, 24.9 mg O_2/L, 23.6 mg O_2/L, 26.8 mg O_2/L, 28.4 mg O_2/L, 20.0mg O_2/L, 22.6 mg O_2/L, and 26.4 mg O_2/L."* and then have to figure out the pattern for yourself.

Just as you imagined the Introduction as an inverted triangle, you can review the Results section in a similar way. A Results section may include subsections for different experiments or portions of the study, and you can envision a "triangle" for each result you wish to convey.



This would be a typical Results section:

> *There was a significant difference in the level of primary productivity in samples from the estuary and the bay (Figure 1). Productivity in the estuary was twice that (30 g C/m^2) of the open bay (15 g C/m^2).*

Figures and Tables for your Results Section

The role of the *text* in your Results section is to convey the general trends, as discussed above. The role of figures and tables in your Results section is to present your data in more detail for readers. While you (almost) never present "raw" data in your written text, nor in your figures and tables, you often present means accompanied with standard deviation, standard error, and/or variance. The picture truly is worth a thousand words.

Figures

A figure is most often in the form of a "graph", although we call them figures in scientific writing. A figure can also be a map, an illustration, or a photograph, but these are less commonly used. All figures have the following components:

- A figure caption appears *underneath* the figure
- Figures are always numbered in order of appearance in the text of the paper
- The independent variable is plotted on the x-axis (the horizontal axis)
- The dependent variable is plotted on the y-axis (the vertical axis)
- All axes are labeled, and the units of measure are included where appropriate
- All axes are numerically labeled if appropriate
- A figure legend may be present, depending on the figure
- All figures make appropriate use of space (little empty space seen)
- All shading and gridlines are generally removed

Tables

A table is an excellent means of presenting complicated data that are not easily graphed and difficult to summarize in the written text of a Results section. All tables have the following:

- A table caption appears *above* the table (note that this is as different location than the figure caption)
- Tables are always numbered in order of appearance; their numbering is independent of the figure numbering
- All tables include units (when appropriate) in column headings and not in the main body of the table

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Results		
results clearly stated at the beginning of each paragraph	8	
information flows well within and between paragraphs	1	
refers reader to any accompanying figures and/or tables	1	
Figures/Tables		
figure or table caption included and descriptive of contents	10	
axes properly labeled	5	

Alternate Results Section Grading Rubric

This section:	✓
Focuses clearly on results, not on methods or interpretation	
Is organized so as not to overwhelm the reader with details	
Summarizes all experimental and field data numerically (data may be grouped by averages and ranges)	
Outlines or calls attention to similarities and differences in the data (e.g. between different experiments, procedures, or field locations)	

Tables in this section:	✓
Are mentioned in the text of the Results section	
Have headings (e.g. “Table 1. Results for Stations 1, 2, and 3.”)	
Include units of all measurements	

Figures in this section:	✓
Are mentioned in the text of the Results section	
Have legends (e.g. “Figure 1. Salinity versus depth at Station 3.”)	
Include axis labels, and labels include units	
Have formats consistent with the homework’s specifications (e.g. white background, no gridlines or labels)	

Discussion

In the Discussion section you should evaluate and interpret the meaning of your results in terms of the original question or hypothesis, explain their significance, and discuss any weaknesses of the experimental design. From the reader's point of view, this is the most important section of your paper. As you might expect, it is a difficult section to write.

You should complete the Introduction and Results sections before you begin writing the Discussion. Consider the "story" you want to tell and what sequence you wish to lay it out for the reader. You can outline the contents of the Discussion by taking the following steps.

1. Write down your hypothesis again. Look at the tables and/or figures you constructed for the Results section, evaluate any statistical test of your data and determine whether you should accept or reject your hypothesis. In writing this section you should explain the logic that allows you to accept or reject your hypothesis.

2. Check the prediction you wrote in the Introduction section. Do your results confirm your predictions or not?

3. Write down the specific data (using the actual numbers) that led to your conclusion about your hypothesis. If you received additional results from other lab teams working on a similar problem, list that information also.

4. Write down what you know about the science involved in your investigation. How do your results fit what you already know? Be sure to identify the sources of this information.

5. List any weaknesses you have identified in your experimental design. You must tell the reader how these weaknesses may have affected your results. Since your laboratory experiments are subject to limitations of time and facilities, you will not be able to do a "perfect" experiment. It is important for you to understand and to acknowledge in your report how limitations may affect the validity of your conclusions.

6. List any problems that arose during the experiment itself. Unforeseen difficulties with the procedures may have affected the data and should be described for the reader's consideration.

7. Review your experimental design and procedure. Consider how you might be able to get more specific or more reliable results by changing the experiment. You should be able to suggest future experiments or investigations that might clarify areas of doubt in your results.

Once you have considered those items, and organized them in a convincing manner, you can then begin to write your Discussion. Begin by reiterating your major conclusion/discovery in light of what you set out to do. Consider the following example:

> *All three anemone fractions (whole animal, animal alone, zooxanthellae) were significantly enriched in ^{15}N and ^{13}C relative to controls; our data provide the first direct evidence of ^{15}N and ^{13}C transfer from resident anemonefishes to host anemones and their intracellular zooxanthellae both in the laboratory and in situ.*

These authors indicate the result (significant enrichment) and hypothesis (anemonefish provide nutrients to anemones) of their experiment in the first sentence of their Discussion to remind the reader of the purpose of the paper, and to provide the "lead in" for their discussion of their results.

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	Maximum Points	Points Earned
Discussion		
experimental question restated and whether or not supported by results	5	
discuss current results relative to published literature on the subject	5	
why or why not (of above) fully discussed	5	
proposes appropriate future experiments/studies	5	

Acknowledgements

This section allows you to thank those individuals who helped you with your research or with the writing and editing of your paper, as well as any sources of funding you may have received. If you received special permits to collect organisms, or special permission to access someone's property to conduct your field studies, you can also thank them in this section.

You may not be required to include this section in the scientific writing you do in regular coursework but this section is appropriate for your senior research project.

References (or Literature Cited)

You must give credit where credit is due. Any information you provide in your paper that is the result of someone else's work and instruction must be acknowledged. If you do not provide literature citations in your text, and also at the end of your paper, you are guilty of plagiarism. You will be given more instruction on how to avoid plagiarism in your work. When you are first learning to write scientific papers, you should always err on the side of caution and cite too much rather than too little.

There are subtle differences in the way literature citations are written; your instructor will give you details for each assignment. For example, two different formats are illustrated below.

The first set of citations follow the "Instructions to Authors for the Journal of Experimental Marine Biology and Ecology (JEMBE)"

The second set of citations follow the "Instructions to Authors for Limnology and Oceanography(L&O)".

It does not matter which format you choose, *but you must be consistent in the application of one format*.

JEMBE

Citation in text
"The research spans many disciplines (Thompson 1999) and results are often contradictory (Becker and Seligman 2001). However, Hixon (2003) integrated the results in a way to resolve the conflicts. This integration has facilitated much new work (Abbott 2007, Barakat et al. 2004, Kelso and Smith 2004, Medvec et al. 2006).
Note that when an author (or authors) appears as a subject of a sentence, only the year of the publication is in parentheses

Journal article
Barneche DR, Floeter SR, Ceccarelli DM, Frensel DMB, Dinslaken DF, Mario HFS, Ferreira CEL (2009) Feeding macroecology of territorial damselfishes (Perciformes: Pomacentridae). Mar Biol 156:289-299

Fenchel T (1986) Protozoan filter feeding. Prog Protistol 1:65-113

Article by DOI (Digital Object Identifier)

Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med.doi 10.1007/s001090000086

De Pol-Holz R, Ulloa O, Dezileau L, Kaiser J, Lamy F, Hebbeln D. (2006) Melting of the Patagonian ice sheet and deglacial perturbations of the nitrogen cycle in the eastern South Pacific. Geophys Res Lett 33:L04704, doi:10.1029/2005GL024477
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Book
South J, Blass B (2001) The future of modern genomics. Blackwell, London

Book chapter
Brown B, Aaron M (2001) The politics of nature. In Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230-257

Online document
Doe J (1999) Title of subordinate document. In: the dictionary of substances and their effects. Royal Society of Chemistry. Available via DIALOG. http://www.dose/title of subordinate document. Accessed 15 Jan 1999

Dissertation
Trent JW (1975) Experimental acute renal failure. Dissertation, University of California

L&O

Citation in text
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Online document
Doe, J. 1999 Title of subordinate document. *In*: the dictionary of substances and their effects. Royal Society of Chemistry. Available via DIALOG. http://www.dose/title of subordinate document. Accessed 15 Jan 1999

Dissertation
Trent, J.W. 1975. Experimental acute renal failure. Ph.D. thesis, Univ. of California.

GRADING CRITERIA AND POINT VALUES FOR LABORATORY RESEARCH PAPER

Paper Component	Maximum Points	Points Earned
Literature Cited		
relevance and quality of literature used in paper (1-3 references from literature expected)	8	
proper and consistent format (in text and lit cit section), minimum of punctuation errors	2	