

# How Scientific Papers are Structured

(Modified from a Handout by Jean Heitz)

## I. How do scientific papers differ from “popular press” articles?

Information about scientific discoveries can be presented in many different writing styles and formats. The style and format most familiar to nonscientists is called "popular press" and can be found in magazines or newspapers like *Discover*, *National Geographic*, *Newsweek*, and *The New York Times*. These articles are designed to inform the public of new and sometimes controversial issues arising as a result of scientific investigation.

"Popular press" authors often compete with each other to sell their articles to magazines. The more interesting or controversial the topic the more likely the article will be accepted and the more likely the sales of the magazine will increase. As a result, there is considerable pressure to appeal to "*What the reader wants*".

In "popular press" articles, the writing style and format of the article are designed to hold the reader's interest. The articles often contain pictures and illustrative drawings. The author may refer to specific scientists by name. However, the articles generally contain no references to the specific source(s) of information used. That is, no reference list is provided.

The scenario is not the same when scientists write to communicate their discoveries to other scientists. Like “popular press” articles, scientific articles are designed to inform others of new and sometimes controversial issues in scientific investigation. However, the style and format of scientific journal articles are much more prescribed and are dictated by long-standing rules or standards.

Scientific writing follows fairly standard rules. At its best, scientific writing is clear and concise. As such, it borrows heavily from Joe Friday in *Dragnet*, i.e. "*Just the facts.*" Many articles are written in the third person, passive voice. Others are written in the first person, active voice. The voice chosen may be left to the author's discretion, or it may be dictated by the journal in which s/he hopes to publish. Verb tense may be either past or present, but must be consistent throughout the paper. Illustrations and tables are presented only to support the textual information that is presented. All information obtained from others' studies is referenced and all references are listed at the end of the paper.

The authors of scientific journal articles must provide enough information to allow others to duplicate their study as exactly as possible. This means that the specific species name(s) of any organism(s) must be provided along with age, sex, diet, and maintenance methods. Manipulations performed and equipment used must be specified. This includes specifying equipment manufacturer and model number. Composition and dose levels of all chemicals and/or drugs must

be provided. Results must be clearly stated. This includes stating what hypotheses remain possible and what hypotheses can be eliminated.

Not all papers submitted to journals are accepted for publication. Scientific papers must be approved by a board of recognized experts in the field, the journal's editorial board, before they are accepted for publication. The editorial board is made up of other scientists working in the same area. The decision to publish is based on the recommendations of these reviewers. If an article is accepted, the author is not paid for the article, but rather, is expected to pay the journal from \$50 to several hundred dollars per page to help defray publishing costs.

At first glance, such restrictions on style and format may appear to be incompatible with or even contrary to independent thought and expression. Some might even consider them a capricious or "picky" exercise of power by the editorial boards of journals. In reality, however, these rules have been instituted for very good reasons. Thousands of new scientific articles are published every month in over 9000 life science journals from more than 100 countries. With a set or standard format, a scientist can open any journal article and know where to find results, discussion, methods, etc. With dialogue limited to "just the facts", s/he can similarly get through an article with a minimum of reading time and at a minimum cost of publication.

## II. What are the rules for writing experimental research papers?

### General Rules for Publication

Experimental papers will generally contain the following information.

Author(s)' Name(s)  
Course Title  
Lab day/time/instructor  
Date submitted

#### TITLE

ABSTRACT  
INTRODUCTION  
METHODS  
RESULTS  
DISCUSSION  
REFERENCES  
TABLES AND FIGURES

How each section should be formatted and what each should contain are described below. This description is set up in the form of a scientific paper.

#### **TITLE**

The title should be centered on the page. It should be specific, descriptive and concise. In other words, the title should provide a very brief description of the rationale for and results of the experiment. Key words pertaining to the experimental organism and experimental objective(s) should be found in the title.

Researchers often search titles to decide which articles pertain most to their own areas of interest. Read the following titles. Which give you a good idea of the content of the articles and which do not?

- 1a) Hypocotyl Growth of Rapid Cycling Brassica
- 1b) Auxin Induced Effects on the Gravitropic Response of Rapid Cycling Brassica Hypocotyls
  
- 2a) The Upstream Struggle of the Salmon
- 2b) Imprinting to Chemical Cues: The Basis for Home Stream Selection in Salmon

## ABSTRACT

Note, that with the exception of the title, each major section of the paper is identified by an appropriate section heading, e.g. ABSTRACT, INTRODUCTION, etc.

The abstract is like the "*Cliff or Spark Notes*" for the paper. As such it:

- 1) begins with a general statement which introduces the reader to the purpose, objective or importance of the study.
- 2) briefly discusses methods to allow the reader to understand how results were obtained.
- 3) presents the major results.
- 4) presents the major conclusions.

Scientists often decide whether or not to read a paper based on the information provided in the abstract.

Even though it appears at the beginning of the paper, the abstract is THE LAST THING WRITTEN! Most publications place limits on the number of words per abstract. In this course, abstracts should be between 150 and 300 words in length.

## INTRODUCTION

### What did you do and why did you do it?

The introduction states the purpose or reason for undertaking the study. It also provides the reader with the rationale for the study. The introduction begins with the general background information that sets the stage for the research (rationale) and then narrows to the specific goals or objectives of the research (purpose).

When writing papers on laboratory experiments, write as if the experiment was your own idea (not an assignment). For example, you could begin a paper as follows.

This paper reports the results of a series of experiments designed to determine . . . (Here provide specifics, i.e. what did you hope to determine. For example -- This paper reports the results of a series of experiments designed to determine the effects of pH on the ADP/ATP translocase in the inner membrane of the mitochondrion.)

As noted above, be sure to include the rationale for doing the work. This is often in the form of observations and/or background information, including references to pertinent literature. Use the references to support your study and make a clear statement of the hypothesis to be tested. For example, after explaining what other studies found (and referencing these appropriately) you could state your hypothesis as follows.

*Based on results from previous studies, we expect the ADP/ATP translocase will have its greatest activity in a relatively small range of pH, with an optimum activity in the middle of this range. That range of pH is likely to coincide with the (intracellular/blood) pH of (specify the organism from which the enzyme was extracted).*

Following this, you should state directly, "The purpose of this experiment is..." or "This experiment is designed to...". For example: *The primary purpose of this experiment is to determine the optimum pH range for the activity of ADP/ATP translocase.* Follow this with a statement about why this study is of biological importance.

## **METHODS**

### **How did you do the study? How were data obtained?**

In this section, you should provide an account of how the experiment was run. In doing this, describe the techniques, materials, chemicals and equipment used. You should provide enough information for the reader to be able to repeat your procedure. For example:

*Six month old Sprague Dawley male rats were anaesthetized using ketamine (1 mg/kg body weight) injected into the tail vein. A midline incision was used to expose the abdominal cavity. Pancreatic tissue was removed and placed in ice cold unbuffered saline (0.9%). Mitochondria were then isolated and the ADP/ATP translocase was purified as described previously (Smith, 1981).*

Note that procedures which are fully described elsewhere in the literature are usually given a brief explanation followed by a reference of the literature source. For example: *Mitochondria were then isolated and the ADP/ATP translocase was purified as described previously (Smith, 1981).*

Do not write the M&M section as a story (e.g. First I did, then I did, then I did, etc.). Instead, organize this section conceptually. If your procedure required a number of different operations, it may be better to subdivide your methods section similarly, e.g. you can organize methods by type of operation with each in a separate subsection with a separate subheading.

### **Example:**

## **METHODS**

### Tissue Extraction

Describe all operations involved in tissue extraction under this subheading.

### Enzyme Purification

Describe all operations involved in purification here. Etc.

### pH optimization test

Describe the method used to test for optimal pH for the enzyme activity.

Do not include a separate listing of all materials, chemicals, equipment used. Instead introduce these as needed in your description of the methods.

## **RESULTS**

### **What did you find as a result of the study?**

This section states specifically what was found, that is, it shows the data that were obtained. If the Methods section is subdivided into subsections, the Results section should be similarly subdivided.

Do not write, "*Results are shown in Table 1.*" without providing further explanation in the text. All pertinent information contained in summary tables and figures should be interpreted by the writer and presented in sentence form, i.e. as a narrative, to the reader. In doing this, you should point out trends evident in the data, important differences, similarities, unexpected results. Do not omit important negative results.

It is true that the reader can interpret tables/figures for him or herself. However, the purpose of the Results section is to let the reader know how you, the author, interpret them. What you point out in the Results section, sets the stage for your discussion of what the results mean in the Discussion section.

## **DISCUSSION**

### **What do the results mean relative to the purpose/hypothesis proposed in the Introduction?**

The Discussion section tells the reader what the results mean. In doing this, the Discussion relates the findings or data obtained back to the purpose(s) of the paper as outlined in the Introduction. How the results relate to those of the other studies, mentioned in the Introduction, is also stated. Possible reasons for such relationships are given. For example, if the results disagree with those of another study, reasons why this may be the case are provided. Possible sources of error in the study and proposals for further research are also included in this section.

Keep in mind that disproving the hypothesis is just as valid as proving it. For example, assume you do a study of children in daycare versus home care. Your hypothesis is that children placed in daycare from age 6 weeks to grade school are less healthy and more emotionally insecure than children whose mothers stayed home until they were of school age. You conduct the study and find no significant difference in either health or emotional well being of the children in the two test groups. How would you report the results? Would you decide not to report them because there was no significant difference among the test groups?

Now consider the following. You are the parent of a child who has been in daycare since s/he was 3 months old. Would you like to know that in this study there was no significant difference in health or emotional security of children in daycare versus home care?

## **REFERENCES**

The term "reference" is sometimes confusing because it is used loosely to refer to two different parts of a scientific paper.

1. Throughout the paper, whenever a statement of fact is made, a previously used procedure explained or the results of another study mentioned, it should be followed by a reference. This is also referred to as a "citation" or "citing a reference". References in

the text of a paper are placed in parentheses. **Refer to Section III. References Part A,** for the appropriate format for citing references in the body of a paper.

2. At the end of the paper, a list of all the references cited in the body of the text appears in what is called the “References” section. **The sources of all citations used in the body of the text should be listed in the References section.** Conversely, all references listed in the References section must be cited in the body of the text. Other references you may have read, but did not cite are not included. This is one of the major differences between a reference list and a bibliography.

In the reference list, all articles and/or books referenced in the paper are listed in alphabetical order according to the last name of the first author. If more than one paper from an author exists, they are listed in chronological order with most recent listed first. **Refer to Section III. References Part B, for specifics on how to format the References list.**

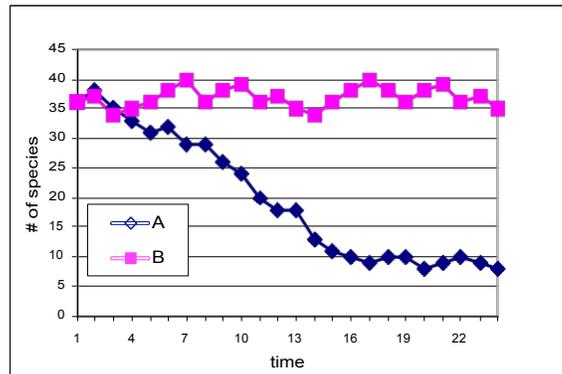
## TABLES AND FIGURES

In the text of the paper, figures and tables must be numbered in order of appearance. For example, the first table mentioned becomes Table 1. The next table mentioned is labeled Table 2 and so on. Similarly, the first figure mentioned in the text is Figure 1; the next is Figure 2 and so on.

Both tables and figures must contain appropriate titles and captions or legends.

1. **Figure titles and legends** are placed below the figure.
2. **Table titles** are placed above the table; legends/footnotes are placed below the table.

Titles and legends for figures and tables should be descriptive enough to allow the reader to interpret the figure/table without reference to the text of the paper. Another way of saying this is that titles and legends should stand on their own. Someone who has not read the paper should be able to understand what the figure is presenting by reading the title and legend alone. Refer to figures and tables in your textbook for examples or see below.



**Figure 1.** Changes in the numbers of animal species on two islands over a 24 month period. On island A, a snake species was removed at time zero. This same species was not removed from island B.

**Table 1.** Numbers of grasshopper deaths per acre per year resulting from the operation of two different agents of mortality in populations of grasshoppers at different density levels.

<b>Grasshopper population density (individuals/acre)</b>	<b>Deaths per year per acre</b>	
	<b>Agent A</b>	<b>Agent B</b>
100	5	0
1,000	50	25
10,000	500	500

When submitting a paper to a journal (or for this course), Tables and Figures must be grouped at the end of the article, just after the References. Tables and Figures should not be incorporated into the article. This allows both the writer and reviewer to determine:

- a. if the text of the paper stands on its own without the tables and figures and
- b. if the tables and figures can be understood without immediate reference to the text.

### III. How should references be cited in the body of the paper and in the reference list?

Each journal adopts a specific referencing format that must be used by anyone who plans to publish in that journal. Articles with references not in the required format are not accepted for publication until the appropriate changes have been made. Just as the data document your interpretations and conclusions, reference citations document statements made about the literature. As a result, you should choose references judiciously and cite them accurately.

Appropriate scientific conduct requires that you read the research paper of the original author. This allows you to interpret the original data for yourself and avoid possible misinterpretations. For example, assume you want to write a paper on melanomas. JD Smith performs an experiment in 1993 which showed the sunscreen additive PABA directly caused an increase in incidence of certain melanomas in rats. He then writes a paper describing his research.

In 1995, SP Adams writes a review article on melanoma and cites the work of JD Smith (1993). You read the article written by SP Adams, but have not read Smith's original paper. If you want to include the statement that PABA has been shown to cause melanoma, which is based on Smith's research, you must find and read Smith's original paper.

If the original paper is in a foreign language or is not available, you can cite Adams' paper. In this case, the citation format would be (Smith, JD as cited in Adams SP, 1995).

#### A. How should we cite references in the body of the paper?

##### *1. Citing a paper or text with a single author*

Citing a single paper or text with a single author may take one of several forms.

For example:

Sorokina (1972) demonstrated that penetration of hydrogen ions across cell membranes in snail neurons occurred very slowly.

In 1972, Sorokina demonstrated . . .

It has been demonstrated that penetration of hydrogen ions across cell membranes in snail neurons occurs very slowly (Sorokina, 1972).

## 2. Citing papers or texts with more than one author

### a. Use one of the following forms when referencing papers or texts with two authors.

In isolated polytene chromosomes (*Chironomus*), Lezzi and Gilbert (1972) reported a loss of puff material at pH 7 of their isolation medium.

In isolated polytene chromosomes (*Chironomus*) a loss of puff material at pH 7 has been reported (Lezzi and Gilbert, 1972).

### b. Use one of the following forms when referencing three or more authors:

Lacko *et al.* (1971) demonstrated that exchange transport of glucose in human erythrocytes was dependent on the pH of the incubation medium. The authors suggest that this implies carrier mediated transport.

Exchange transport of glucose in human erythrocytes is dependent on the pH of the incubation medium (Lacko *et al.*, 1971).

## 3. Citing Several Papers and/or Texts Relating to the Same Topic

A number of papers all relating to the same topic can be referenced as follows.

Numerous authors agree with this observation, while numerous others claim that intracellular pH changes can occur almost simultaneously with incubation in medium of differing pH (see excellent reviews by Wadell and Bates, 1969 and Caldwell, 1956).

## B. What should we include in the reference list at the end of our paper?

All references cited in the body of the text should be listed in the References section at the end of the paper. Conversely, all references listed in the References section must be cited in the body of the text.

The references should be listed alphabetical by the last name of the author (or the last name of the first author of papers or texts with multiple authors). References to journal articles, books, personal communications, and web sites should all be contained in this list.

In this section, you must pay close attention to the placement of commas (,) periods (.) colons (:), spaces, underscoring and the use of upper and lower case letters. Additionally, each journal has its title abbreviated in a specific manner, e.g., the *Journal of Cell Physiology* is commonly abbreviated as *J. Cell Physiol.* In the References section, depending on the requirements of the specific journal you may be required to use full titles or commonly accepted abbreviations.

*Use APA format to develop the reference list for your work in this course.*

## IV. Miscellaneous Instructions: Avoiding Common Mistakes

### A. What if my paper is late or lost?

1. Late papers will not be accepted. Be sure you are working with your team to make progress on the proposal well before the final due date.
2. Always keep a backup copy of your paper on a memory stick. In addition, always keep a copy of the papers you hand in. While it's rare that papers are lost, it can happen.

### B. What basic rules should we follow for all papers?

1. All papers must be typed.
2. You must number the pages of your papers.
3. You must double space between lines of text on the page.
4. Use 1 inch margins on the top, bottom, right and left sides.
5. Use a 12 pt font size. Times New Roman is preferred.
6. Your name(s) and lab # (or lab day and time) must be included on the first page of the paper in the upper right hand corner.
7. The title must be on the first page of the report. Unless instructed otherwise, you do not need a separate title page. Begin your paper following the title.
8. You may write in either the third person or the first person. For both it is best to use active voice. You may use either past or present tense. Whatever you choose, the person, voice and tense must be consistent throughout the paper.
9. Be consistent with your Section Heading Format. For example, all letters in the heading should be CAPITALIZED or **Bold and Underlined** or **Bold**, etc. You can choose whichever format you desire, but be consistent.
10. Begin the References section on a new page, separate from the rest of the paper. All articles cited in the body of the text must appear in the References section. Similarly, all articles listed in the References section must be cited in the body of the text.
11. All Tables and Figures must be grouped at the end of the article, not incorporated into the article. All Tables and Figures must be accompanied by a Table or Figure number, a title and a legend. Some very simple tables may not require a legend.
12. Always check spelling and grammar before finalizing your paper. Use the spell checker on your computer. If a grammar checker is available, use it as well.
13. Do not use plastic report covers. Instead, staple your report in the upper left hand corner.

## C. How can we avoid common mistakes in content?

1. In your Introduction, it is acceptable to state directly, “The purpose of this experiment is...” or “This experiment is designed to...”, etc. You do not need to do this, but you should get to the point quickly.
2. You must include the scientific names of all organisms used in the study. When you first introduce the organism you need to identify both its scientific and common names. For the remainder of the paper, you can use the common name. If the name of an organism appears in the title, the scientific name must also appear (usually in parentheses following the common name).
3. When using scientific species names, the genus name is capitalized but the species describer (or epithet) is not, e.g., *Homo sapiens*. The species name consists of both the genus name and the species describer and must be underlined or italicized. When the genus name is used alone, it is capitalized and italicized.
4. When referencing the information in a whole paragraph to a single article or text, you can start the paragraph by stating, “According to Smith *et al.* (1990) . . . Alternatively, you can put a period at the end of the last sentence in the paragraph, then follow this with the reference. (Smith *et al.*, 1990)
5. You should use metric units of measure in scientific papers. Numbers less than one should be reported in decimals with a zero placed before the decimal point, for example, 0.25. This helps prevent misunderstanding if a decimal point is accidentally left out.
6. The abbreviation, *et al.*, stands for the Latin, *et alia*, which means “and others”. *Et* is a complete word and does not require a period (.); *al.* is the abbreviated form of *alia* and requires a period (.). Because these are foreign words, they also need to be italicized.
7. Similarly, **e.g.** is short for *exemplia gratia* (“for example”) and **i.e.** is short for *id est* (“that is” (to say) or “in other words”). Because these have been in common use for so long they are generally not italicized or underlined.