

## The Research Paper

*I write entirely to find out what I'm thinking,  
what I'm looking at, what I see and what it means.*

Joan Didion

### Overview

A research paper is the currency, the mainstay of scientific information. This is the place where new results and ideas are communicated to other scientists. Most of the facts you learn in a science lecture or textbook are actually interpretations of data that were first described in the form of a research paper.

A research paper is essentially an argument. In a research paper, the authors put together various observations and pieces of data to come to some sort of conclusion. It is written for other scientists, but, because science encompasses many fields, is often written in a way that can be understood by someone educated in science though not necessarily in the field under study.

The format, style, organization, and level of detail of research papers vary depending on where they are published. Some journals, such as *Science* and *Nature*, emphasize short papers without a lot of primary data. Others, such as *Cell*, *Genetics*, and *Genes & Development*, are more complete and thorough. In addition to differences in length, the organization of the papers varies depending on the journal. The format described below is a generic one that is presented as a way to consider each part of a research paper. The particular format you follow will depend on the nature of the assignment you have or the journal to which you are submitting a paper.

As a student, you will often be asked to write a research paper as a way to put together experiments that you did and data you gathered as part of a laboratory exercise or a series of laboratory exercises. Note that this type of assignment is different from the

laboratory notebook. While the laboratory notebook emphasizes careful note taking and observations, the research paper is a chance to make an argument by synthesizing other studies and your own experiments.

## **Specifics**

A research paper has several sections, which are described here:

- **Title**

The title of a research paper should be concise; at the same time, it should contain enough information that a reader can determine the relevance of the paper to their needs without reading the entire paper. In reports of an experimental nature, the specific information given in the title should include the factors being manipulated and the effects of responses being measured. An example of a self-explanatory title is, “Ultraviolet light induces apoptosis via direct activation of Fas/APO-1, independent of CD95L.” Avoid cryptic titles such as “A Research Paper” or “Enzyme Action.” Such titles give little or no information as to the content of the report.

Another way to think about a good title is to put yourself in the position of a researcher who is going to search a database of scientific literature (*e.g.*, PubMed) using key words to find articles of interest.

- **Authors**

When considering authorship on any paper, the contribution of ideas, materials, experimental results, and the work of writing of the paper should all be taken into consideration. In the case of a research paper based on experiments you do as part of a

laboratory exercise for a class, you are the first author by virtue of doing all the writing and a large amount of laboratory work to produce the data. The second author is your laboratory partner. The last author on your paper is your professor, acting as the Principal Investigator. If other students in your class have provided additional data for your paper, they should be included after your lab partner and before your professor, as scientists who have collaborated in your efforts.

- Abstract

This portion of your article should be a summary of your entire paper. Without including specific details or references to figures or other studies, you should provide important background, state the principal objectives of your study, describe the methods used, list your most important results, and state what you can conclude from them. Similar to the research paper itself, the Abstract should ask and answer a question. In addition, it should be able to stand on its own as a summary of the research; if the rest of the paper were missing, the abstract should still be comprehensible to a reader unfamiliar with the study. Although it comes first, the abstract should be the last part of the paper you write. This approach will allow you to extract key points that you have already written in the body of the paper and will ensure that you do not include any information in the abstract that is not in your research article. An abstract is typically between 150 and 500 words in length.

- Introduction

The Introduction should provide a context for the topic under study and give the reader the background necessary to understand the rest of the paper. As a result, the

background will usually be based on previously published material, which must be properly cited. In addition to establishing the context of the problem, the Introduction should provide a concise statement of the problem or goal of the project and a description of the experimental approach(es) used to answer those questions.

Note that the Introduction differs from a Review of a particular topic. While a Review typically covers a topic in detail, the goal of the Introduction is to provide context to understand the question you are asking or the system you are studying. In essence, the Introduction should build to your experimental question. This can be done by describing what is known about a particular topic, to be sure that the reader understands the system, but also considers what is not known or where there is room for additional work.

- **Materials and Methods**

This section describes the specific details of your experiments. As a result, it must provide enough information about the techniques you used to allow the reader to both judge whether the data justify your conclusions and, if desired, replicate your experiments. It is always written in the past tense, as it describes exactly what you did. For example, “The plates were incubated overnight at 37°C.”

This portion of a research paper is usually divided into sections labeled with appropriate subheadings to indicate a specific method (*i.e.*, PCR or Western Blotting). Usually these subheadings are arranged chronologically based on the order of the experimental results presented in the Results section. **DO NOT** present or discuss your results in this portion of the paper. Instead, this section is meant to be a “how to” guide to your experiments.

How much detail is required? You should provide sufficient detail so that a reader could order the materials you used and replicate the experiments. If a published account is already available (for example, bacterial transformation, PCR, sequencing), the technique itself need not be described in detail again, but you must provide enough information about how you performed the experiment so that it can be independently replicated in another laboratory. For example, in a discussion of PCR, you must provide information about the primers and thermal cycling conditions used, but you do not need to describe how PCR is done. In addition, for all experiments, the name and manufacturer of reagents (including enzymes, bacterial strains, kits, columns, *etc.*) and relevant instrumentation/equipment must be provided. This section should also include sample sizes or number of replications, strain and plasmid names, and other factors known to affect the particular experiment (*e.g.*, temperature, pH, *etc.*).

- Results

In this section, you objectively present the results of your work through descriptive text, figures, and tables. In essence, you are reporting what you observed in each experiment. Briefly state what you did in the experiment, leaving out the plethora of details you included in the Materials and Methods section, describe the key result, and indicate the figure or table containing the supporting data. Remember that the essence of good scientific writing lies in its organization and the distillation of critical results. Refer to the figures and tables parenthetically. This will help you avoid bogging down your writing with a lot of extra words and it will help to keep the reader focused on your key points. In addition, you should avoid explaining every detail of every figure. It is far better to direct the reader to a specific portion of the figure that gives the best

demonstration of what you claim is your result. The first one or two sentences of each new paragraph or portion of results should be a transitional statement that explains the logic of why, based on the last experiment, you went on to do the next experiment. Finally, you should avoid drawing conclusions or inferences about the results in this section; save that for the discussion.

- Figures and Tables

Figures and tables provide ways to display primary data, such as an image of a gel or a Southern blot or a list of numerical data. Each figure and table should be accompanied by a legend. A well-written legend provides enough information about the figure or table that the expert reader (for example, a scientist in a related field) could understand the experimental results by simply looking at the figure or table and reading the legend. In other words, figures and tables are independent units that can be understood without reference to the text. Try this out by going to any journal article and “reading” it by simply glancing at the figures and tables. Note that every figure and table should be referenced in the text.

- Discussion

This is the portion of your paper where you interpret the results in the context of what is known in the field. The first paragraph should summarize what you believe to be your most important results and what you believe are the best conclusions based on your findings. Then, you may go on to discuss those conclusions in a broader scientific context (*i.e.*, compare them to what has been reported by others in the same area of biology). Discuss the implications of your data and propose future experiments to address

unanswered questions. It is important to acknowledge deviations in your data, compared to the results you expected, and explain why those deviations may exist.

- **References**

This final section lists all of the references you cited in the research paper. Every paper you cite in the text should have a corresponding reference in the References section and *vice versa*. The specific format of the in-text citations and the references listed in this section of the research paper varies depending on the particular journal or assignment. However, two rules-of-thumb always apply. First, follow whatever format is suggested or required. This ensures that the references are formatted in a consistent fashion throughout your paper. Second, watch the details of the suggested format. If a comma is written after the volume number, this means that a comma is required, not a colon, not a semicolon.

### **Useful On-line References**

Writing guide

<http://classweb.gmu.edu/biologyresources/writingguide/ScientificPaper.htm>

Great article but extensive

<http://www.amstat.org/publications/jcgs/sci.pdf>

Simple guide with book suggestions for extra help

<http://www.columbia.edu/cu/biology/ug/research/paper.html>