Format for Research Papers

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A scientific research report is a form of communication in which the investigator succinctly presents and interprets data collected in an investigation. Writing such reports is similar to the writing in other scientific disciplines except that the format will differ as will the criteria for grading.

Writing the Report

The questions and hypotheses that initiate an investigation, the resultant data gathered, and the background information obtained by reading the literature will lead to conclusions. Your research report presents these conclusions and the appropriate evidence (data and relevant literature).

Before writing the report, construct an outline that logically presents the information to support your conclusions. Organize the data into tables and figures to present the evidence in a logical order. Many authors prefer to construct a draft by rapidly putting down ideas with little regard to sentence structure, and to make corrections later. Others prefer to make revisions as they proceed. Write the report with a target audience of other students with experience in biology equivalent to that of the class for which the report is written.

Proper use of English is considered paramount in grading. Your major responsibility is to make the reader understand exactly what you mean by using words with precision, clarity, and economy. Every sentence should be exact and say something of importance (no "padding"). Economy and accuracy require using straightforward English sentences (subject, verb, and object). Follow a consistent pattern of tenses. Write in the active voice unless you have good reason to use the passive voice. The active is the natural voice, the one in which people commonly speak and write.

Quotations are to be avoided. All sentences should be based on your understanding of source material that you then write as your own original sentences. When discussing the works of others, do not include extraneous information, such as first names or scientific affiliations. In scientific writing, the major idea of a paragraph (or sentence) is placed first. Evidence for the idea, modifications, exceptions, etc., then follow. This allows readers to quickly skim research reports by reading the first sentence in each paragraph.

After finishing a draft, review it to see if the paragraphs and sentences follow a logical sequence. Examine the arrangement of paragraphs within a section; some may belong in another section. Make sure that the transitions from one idea to another are clear. Study each sentence to see if it can be clarified, shortened, or omitted. Rewrite as necessary to achieve clarity. This type of review and rewriting is best done after not looking at the manuscript for a few days. Then, you should be able to approach the manuscript with renewed objectivity. Knowledgeable friends and classmates can also help with this review process.

Type your report using double spacing, 12 point font, left margin justified, and one inch margins. Number pages with the Introduction on the page following the title page. Do not use running heads; your name should only appear on the title page. Proofread and spell-check your paper to correct errors.

Report Format

Scientific research report format is based on the scientific method and is organized to enable the reader to quickly comprehend the main points of the investigation. The format required in all biology classes consists of a **Title Page, Abstract, Introduction, Methods, Results, Discussion,** and **Literature Cited** sections.

Section headings (Abstract, Introduction, Results, etc.) are always capitalized, centered, and placed with the body of each section immediately following. The end of one section is immediately followed by the next section on the same page. There should be no table of contents.

The title should be placed on the title page along with your name (or names if multi-authored) and any other information required in the class. The title must be descriptive of the work carried out. The name(s) of the author(s) should only appear on the title page. The reader should be able to tell, just by reading the title, what has been done without having to read the paper. With a title such as

A Biology Lab Report

the reader has no idea whether the work involved an animal, plant, or microorganism, or what was measured or tested. The following is a self explanatory title:

The Effects of Light and Temperature on the Growth of the Bacterium *Escherichia coli*

Here the title specifically states three things: the environmental factors that were manipulated (light and temperature); the response of the organism that was measured (growth); and the specific organism that was used (*Escherichia coli)*. Notice that scientific names of organisms are italicized in printed material. Only the genus begins with an uppercase letter.

If several variables were used, you do not need to state all the specific factors that were manipulated. For example, if several chemicals were used the following title would be acceptable:

Effects of Various Chemicals on the Growth of *Escherichia coli*

In cases such as these, the title would be too long if it included every variable that was used.

Abstract

The abstract is a short summary of the purpose of the study, the basic findings of the research, and the conclusions that can be drawn based on these findings. The abstract should be no more than 4-5 sentences, and only longer if you have many separate results.

Introduction

The Introduction concisely describes the purpose of the investigation and should tell the reader why this work was done. You should briefly review past research on the problem with enough background information to orient the reader (this is usually accomplished by a literature search of **published** materials). The background information included must be appropriately referenced (see the section on how to cite references). You might first discuss the general problem or theory pertaining to the problem you are studying, and then discuss the topic more specifically to the group, species, or specific area you are researching.

You should conclude the Introduction with a statement of the problem (the hypothesis) you have investigated. State the specific question(s) you are attempting to answer, the general method used, and how your investigation will help clarify or expand the knowledge in the general area. One function of the Introduction is to briefly tell the reader what to expect in the paper. Therefore, it may be easier to write the Introduction after completing the rest of the paper.

Methods

In this section, you explain the type of data gathered or the experiment in sufficient detail so that it can be duplicated. Avoid unnecessary details and include only information that is necessary to complete the experiment or gather the data. The experimental design, apparatus, procedures of gathering and analyzing data, types of control, etc., should be described. If standard procedures are used, cite the reference and describe only the modifications made (if any).

When experiments are conducted outdoors, you should describe the factors that may influence the results of the investigation such as location of the study site, the weather, etc. If any specimens were collected for the investigation, you should state how, where and when that material was collected. Photographs, maps, and diagrams (all presented as figures) can be used as an aid in describing the experimental procedures.

Write the Methods section in the past tense. It should not be written as if it were

directions in a laboratory manual; therefore, do **not** make a list of materials and do **not** give instructions on how to do something. For example, do **not** write:

For this experiment you will need the following equipment: six petri plates, one liter of agar, and one inoculating loop. First pour agar into the six petri plates, then inoculate the plates with a fungus using the inoculating loop. Then you put the plates into the incubator.

It sounds as though you are leading the reader by the hand, telling him how to do the experiment. You should succinctly describe either in the first person or in passive voice how the experiment was done. Mention the materials that were used in the research in the narrative as the experimental procedure is explained in detail. The reader should be able to make a list of necessary materials while reading the section. An acceptable manner to convey the same idea as the above is:

Six petri plates were prepared with agar, inoculated with an inoculating loop, and placed in the incubator for ten hours at 37°C.

Results

In this section, you present the data in a straightforward manner with no analysis of the reasons the results occurred or the biological meaning of the data (these comments are reserved for the Discussion). However, you should interpret the data (preferably statistically), highlight significant data and point out patterns, correlations, and generalizations that emerge. Also write this section using the past tense.

Data are generally organized into tables and/or figures (graphs). Tables and figures **must** be accompanied by a caption and be referred to in the text. A Results section that includes only a table or a figure and no text is **not acceptable**. Unreduced, unsummarized, or "raw" data should not be included. The text describes the results presented in tables and figures and calls attention to significant data discussed later in the report. Do not repeat what is already clear to the reader from reviewing the tables and figures, which, if well constructed, will show both the results and experimental design. A portion of the results text might read as follows.

The number of bacterial colonies increased up to 40ºC, but decreased at higher temperatures (Figure 1). The greatest amount of growth occurred between 35° and 40°C.

In this example, Figure 1 refers to the graph in which the data are presented. In the same sentence, the author says something about the data and refers the reader to the appropriate figure. The figure (graph) may contain numerous data points (e.g., number of bacterial colonies at 1º C intervals from 0º to 60º C), but the author did not bore the reader with a description of each. Rather, generalizations are made concerning the relationships shown by the data, which the figure illustrates ("a picture is worth a thousand words").

Use of Tables and Figures

Summarize data in a form that allows the reader to easily see any correlations, relationships, or patterns that are important. Typical forms for doing this are tables and figures. Tables are made when it is important that specific values are shown (i.e. means, standard deviations, etc.). Figures are made when it is more important to shown trends or relationships of data. Certain requirements, however, must be met:

1) Refer to the tables as Tables; refer to all other items (graphs, pictures, drawings, maps, etc.) as figures.

2) When you include a table and/or figure, you must refer to it in the text. For example, consider the following sentence.

   The results of the temperature experiment are somewhat confusing (Figure 1).

   This sentence tells the reader that all the pertinent data are to be found in Figure 1 (a graph, perhaps) and to refer to the figure while reading.

3) Independently number tables and figures. For example, in a paper containing two tables and two figures, you would number the tables Table 1 and Table 2, and the figures as Figure 1 and Figure 2.

4) Assign tables and figures their respective numbers on the basis of the order in which you first mention them in the text. The first table you mentioned is Table 1, the second is Table 2, etc. The same applies for the figures.

5) Tables and figures can either follow as closely as possible the actual page on which the table or figure is mentioned in the text or be included on individual pages following Literature Cited. Ask your instructor for their preference.

6) All tables and figures **must** have self explanatory captions. The rules for composing the captions are the same as for composing the title of the paper. The reader should be able to look at a table or figure and by reading the caption know exactly what was done in that part of the experiment without having to read the text for an explanation.

7) All tables and figures should include the units of measurement used (grams, meters, seconds, etc.). Otherwise the data are meaningless. All columns in a table and both axes (X axis and Y axis) of a graph must be independently labeled including units.

8) Headers for tables are always placed **above** the table, and captions for figures are always placed **below** the figure.

Discussion

In this section, you attempt to explain the meaning of the results, giving particular attention to the problem or hypothesis posed in the Introduction. You should address physical, chemical, and biological factors that may have affected the results. The way the results came out may be advantageous or disadvantageous to the biological system being considered (*e.g.*, cell, organism) and you should discuss this. To do this competently, you should be familiar with appropriate literature including books and journal articles (the background information mentioned in the Introduction). Compare the results to the back-ground information and, in doing so, construct explanations why the results occurred. You should also explain differences from or similarities to any related experiments completed by other workers.

In constructing explanations, you reach conclusions that explain the outcome, support those conclusions with well reasoned arguments, and documentation from the scientific literature. In effect, you are presenting and defending a point of view in the discussion section.

Literature Cited

Citing Literature in the Text of the Paper

Whenever you mention information that is not common knowledge or was not obtained personally (through experiments or observations), you must include a reference to indicate the source of that information. Failure to cite the work of others not only does not give proper credit to the researchers, but is considered plagiarism. There are several ways that references can be cited in a scientific paper. You must follow the format described here. Scientific papers usually do not use footnotes (so don't).

When referencing information, place the name(s) of the author(s) at the end of the sentence in parentheses with the year of publication. For example,

Some birds are primarily insectivorous and probably obtain all the water they need from the body fluids of the insects they eat (Jones and Smith 1963).

If readers want to see the publication in which this information appeared, they can turn to the Literature Cited section, find the reference, and look it up. Alternatively, place the name(s) of the author(s) of the information in the statement. The name(s) should be followed by the year of the publication (in parentheses) in which that information appeared. For example,

Most of the information in this guide on how to write a scientific research report originally appeared in Gubanich (1985).

However, use this way of reference sparingly as the information is the most important part of the sentence, not the authors.

If reference to more than one publication is required in the same sentence, place the citations in the appropriate parts of that sentence.

Although not all birds have to drink water (Jones and Smith 1963), there are numerous exceptions (Taylor 1964, Smith and Smith 1968, Altert et al. 1969). The metabolic rate of the species seems to play a role (Harrigan 1965) as well as the food source (Montgomery and Landers 1966).

If three or more authors wrote a single reference (such as Oksche, Farner, Serventy, Wolff and Nichols 1963), the citation is abbreviated as follows:

The zebra finch was found to differ in these respects from the species observed in this study (Oksche et al. 1963).

In this case only the name of the first author is used, followed by the abbreviation et al. Both are Latin; et means "and" and al. is the abbreviation of alnon, which means "others" (hence, "and others"). When this reference is listed in Literature Cited, however, all the authors must be included.

The Literature Cited Section

The Literature Cited lists, in alphabetical order by the last name of the first author, all published information that was referred to in the paper. This section provides the reader with the information needed to access the original sources. Note that the Literature Cited includes only those references that were actually cited. Any other information that you may have read concerning the problem but did not mention (cite) in the paper is not included. This is why the section is called Literature Cited, instead of References or Bibliography. Literature Cited is always the last section. The proper order of the citation is: author(s), year of publication, title of article, and source (name of journal or book in which the article appears). The first author is listed last name first followed by the initials; other authors are listed with initials before the last name. The last author is separated from the preceding authors by the word "and." No quotation marks (or underlining) are used in the citation, not even around the titles of articles. Only proper nouns are capitalized in the title of the article. However, the first letters of book titles or journals are capitalized. If the source is a journal, the name of the journal is followed by the volume number and the page numbers (*e.g.*, Ecology 49:212-214).

If the information comes from a book in which the chapters are credited to different authors, the reference in Literature Cited is credited to the author of the chapter and the title of the article is the chapter title. In this case the page numbers, editor(s) of the book and book title are given as the source. If the information comes from a book in which chapters are not credited to different authors, the title of the article is the book title. When citing a book, the name of the publisher and the city are always given.

Sample Citations

Follow these examples when listing citations in the Literature Cited Section.

Articles from journals

Smith, P. T., S. Kambhampati, and K. A. Armstrong. 2003. Phylogenetic relationships among *Bactrocera* species (Diptera: Tephritidae) inferred from mitochondrial DNA sequences. Molecular Phylogenetics and Evolution 26:8-17.

Hoetker, G. M., and K. W. Gobalet. 1999. A fossil razorback sucker (Pisces: Catostomidae, *Xyrauchen texanus*) from Southern California. Copeia 1999:755-599.

McBride, T. A., B. W. Stockert, F. A. Gorin, and R. C. Carlsen. 2000. Stretch-activated ion channels contribute to membrane depolarization after eccentric exercise. Journal of Applied Physiology 88:91-101.

Books

Bury, R. B., and D. J. Germano. 1994. Biology of North American Tortoises. United States Department of the Interior, National Biological Survey, Wildlife Research No. 13. Washington, D.C.

Gubanich, A.A. 1985. Writing a Scientific Paper: How to Survive the Laboratory Research Report. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Chapter in a book

Davis, S. D., K. J. Kolb, and K. P. Barton. 1998. Ecophysiological processes and demographic patterns in the structuring of California chaparral. Pages 297-310 *in:* Landscape Disturbance and Biodiversity in Mediterranean-type Ecosystems. Ecological Studies Volume 136. Rundel, P., W. G. Montenegro, and F. Jaksic, editors. Springer Verlag, Berlin.

Citation with an unknown author

Anonymous. 2000. Animal research: celebrities wanted. Science 287:1719.

Internet Sources

Online sources may **not** be cited unless they are online peer-reviewed literature (e-journals) or are government publications. If the article found online can be found in paper form in a library, simply cite as for a regular article (no internet source needed). If the article can only be found on the internet, cite the reference as follows.

Kloock, C. 2005. Aerial insects avoid fluorescing scorpions. Euscorpius 21:1-7. Accessed online at http://www.science.marshall.edu/fet/euscorpius/.

U.S. Fish and Wildlife Service. 2001. The Endangered Species Act of 1973. Accessed online at http://endangered.fws.gov/esa.html.

Tables

Tables should be constructed as shown below with only three rules (horizontal lines); no vertical lines. Table descriptions should be detailed and placed above the body of the table.

Table 1. Fish remains identified from archaeological site CA-IMP-791 on the Colorado River.

Taxon	Element Count
Catostomidae	186
Razorback sucker	102
Cyprinidae	1
Gila sp.	167
Bonytail	9
Roundtail chub	2
Colorado pikeminnow	8

Table 2. The number of items (% of total items, % frequency of scats) found in scats of *Gambelia sila* from the Kern Front Oil Field and the Lokern Natural Area, Kern Co. and the Elkhorn Plain Natural Area, San Luis Obispo Co., California. Bolded entries are the total for the order. The n value denotes the number of scats collected per area.

Taxon	Kern Front (n=42)	Elkhorn (n=19)	Lokern (n=10)	Combined (n = 69)
Coleoptera	**4 (8%, 9.5%)**	**38 (69.0%, 94.7%)**	**30 (83.3%, 90.0%)**	**72 (51.1%, 43.7%)**
Carabidae		6 (10.9%, 21%)	9 (25%, 33%)	15 (10.6%, 9.9%)
Cucurlionidae			4 (11.1%, 10%)	4 (2.8%, 1.4%)
Scarabidae		5 (9.1%, 15.8%)		5 (3.7%, 4.3%)
Tenebrionidae		13 (23.6%, 15.8%)		13 (9.6%, 4.3%)
Unidentified	4 (8%, 9.5%)	14 (25.5%, 42.1%)	17 (47.2%, 50%)	35 (24.8%, 23.9%)
Diptera	**1 (2%, 2.4%)**		**2 (5.6%, 20%)**	**3 (2.1%, 4.2%)**
Muscidae	1 (2%, 2.4%)			1 (0.7%, 1.4%)
Unidentified			2 (6.5%, 25%)	2 (1.4%, 2.9%)
Hymenoptera	**2 (4%, 4.8%)**	**9 (16.4%, 26.3%)**		**11 (7.8%, 9.9%)**
Formicidae	1 (2%, 2.4%)	6 (10.9%, 10.5%)		7 (5.0%, 4.2%)
Vespidae		2 (3.6%, 10.5%)		2 (1.4%, 2.8%)
Unidentified	1 (2%, 2.4%)	1 (1.8%, 5.3%)		2 (1.4%, 2.8%)
Orthoptera	**43 (86%, 95.2%)**	**7 (12.7%, 36.8%)**	**4 (11.1%, 40%)**	**54 (38.3%, 71.8%)**
Acrididae	30 (60%, 66.7%)	1 (1.8%, 5.3%)	3 (8.3%, 33%)	34 (24.1%, 45.1%)
Unidentified	13 (26%, 28.6%)	6 (10.9%, 31.6%)	1 (2.8%, 10.0%)	20 (14.2%, 26.8%)
Total Items	50	55	36	141

Figures

Figures encompass anything that is not data in a table. A figure could be a graph, a map, a line drawing of a piece of an organism, a picture of an unusual piece of equipment used in the study, etc. Descriptive captions for figures are placed below a figure.

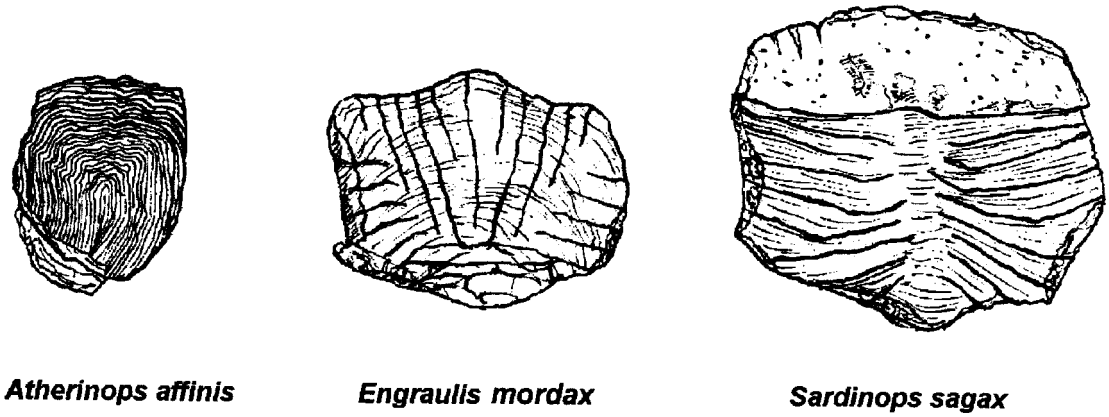

Figure 2. Typical scales of topsmelt (*Atherinops affinis*), northern anchovy (*Engraulis mordax)*, and Pacific sardine (*Sardinops sagax*).

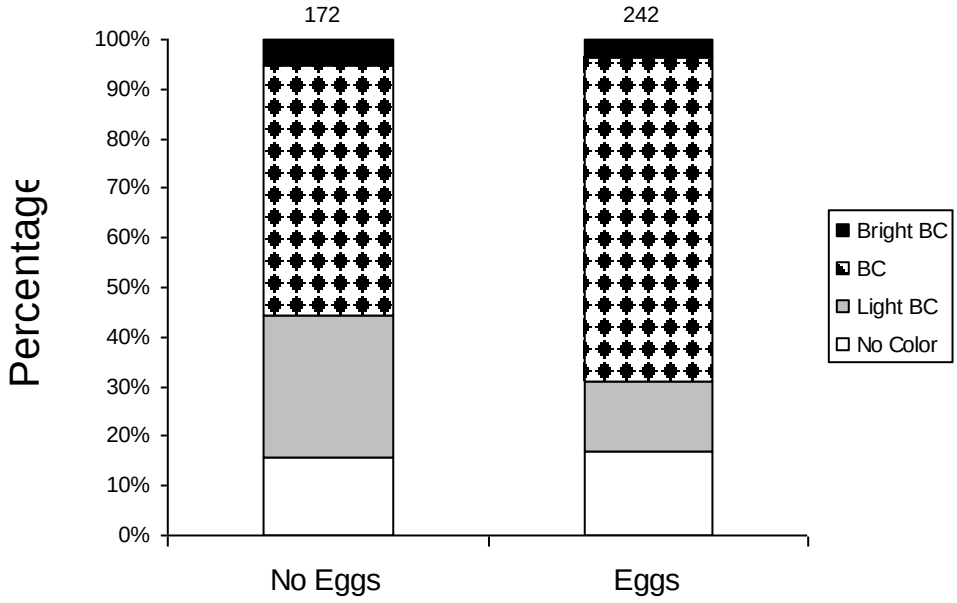

Figure 4. Percentage of gravid and non-gravid female *Gambelia sila* on the Elkhorn Plain, California displaying breeding colors (BC) from 1992-1994. Numbers at the top of each bar are sample sizes