Scientific Papers

Although scientific journals all have their own set of guidelines for contributors, the following suggestions are general enough to be of use in the preparation of your lab write-ups as well as the formulation of scientific reports and papers later in your career.

**Title:** This is one of the most important components of the paper. Whereas the title is typically read by thousands, few people ever read the remainder of the paper. The title should be descriptive, giving an indication of what was studied at (e.g. DNA replication, social relationships) and the target of the study (e.g. an organism, group, material). The wording should be chosen with care to give maximum information with least number of words.

Do
- Be descriptive
- Be accurate

Do not
- Use contractions
- Use abbreviations

Example title:
Preliminary canine and clinical evaluation of a new antitumor agent, streptovitacin

**List of authors:** Authors’ names are usually provided in order of contribution beneath the title on a title page.

**Abstract:** An abstract is a summary of the information in your paper, typically no longer than 250 words. After the title, the abstract is the most frequently read part of a scientific paper. The abstract should contain: i) the principal objectives and scope of the investigation, ii) the methodology used, iii) a summary of the results, and iv) the principal conclusions. Because the abstract summarizes the whole document, it should be written.

**Introduction:** A good introduction has the following: i) nature and scope of the problem, ii) a review of pertinent literature, iii) method of investigation and why the particular methods were used, and iv) the principal hypotheses of the investigation. Each journal has a customary style for the introduction. In some journals, the introduction is less than a page, while in others, it is several pages long. Writing an introduction can be quite challenging, but there are several strategies for writing the introduction:

An effective strategy for writing the introduction is to write it after writing the methods, results, and discussion sections. Writing an introduction for sections that do not yet exist can be challenging.
**Methods and Materials:** Methods sections are written in past tense because they are literally documenting a past event. This section should include enough detail that a competent researcher can repeat the experiment(s). The most important aspect of this goal is to recognize potential sources of variability (e.g., whereas the shape of a container in which water is stored does not generally affect the properties of water, temperature and impurities do). Variability between products and equipment can also affect results; therefore, product vendor information should be supplied when products are mentioned so a researcher can obtain the same chemical or equipment that was used (e.g., Gas-exchange was performed on leaves with an Li-6200 (Li-COR Inc., Lincoln NE, USA)).

Do
- Include potential sources of error or variability

Do not
- Include trivial details (e.g., Jon and I walked across the room.)

Example: The samples were centrifuged in a TI-32 rotor (Beckman, Brea CA, USA). The rotors and inserts were pre-cooled to 4°C for 24 hours to prevent heat damage to the samples during centrifugation.

**Results:** This section is where you present the data. The data is typically presented either (1) directly in the text, (2) in tables, especially when you have repetitive data with interacting factors, or (3) in figures, when data cannot be easily summarized in a table. Statistics are often best included in a table. Negative results may also be worth mentioning. This section should be written with a high degree of clarity. All speculation, conjecture, reference to citations, etc. should be placed in the Discussion section.

Summarize data into tables and figures with the goal of communicating more effectively.

Do
- Place labels above tables
- Place labels below figures
- Give tables and figures descriptive labels
- Refer to figures and tables in text

Do not
- Interpret data

Example table title:
Table 1. Leaf mass and number of leaves for double sunlight treatment group (DSTG) between day 1 and day 14.

Instructors are generally adamant that data should be stated without any “discussion.” There is a valid reason for this policy. Over time our understanding of natural phenomena changes and so does our interpretation of experimental results. Results that are described with a heavy influence from current theories are difficult to re-interpret later as new theories are developed.
**Discussion:** The discussion section is the most difficult section to describe. It often ties back to the hypotheses/questions and background information provided in the introduction. For example, if the initial hypothesis was that plants respond negatively to ultraviolet B radiation, and your major result was that the levels of chlorophyll dropped after exposure, then this should be the subject of the first paragraph(s) of your discussion. Later paragraphs would then discuss other aspects of your results, until all data had been discussed. Most important results are discussed first and lesser results later.

You must discuss your results in the context of the work and studies of others. You should discuss what others have found out about the same system and how their results relate to what you observed. When you reference others' work, you should mention what the relevant finding was—in your own words—as a citation. In general, direct quotes are not used in scientific research papers.

Example use of citation:

Although there are differences in absolute magnitude, the activity profile is similar during the exponential and asymptotic phases, consistent with the observations of Armanovsky and Salander (2008).

**Acknowledgements:** This is a small section, which allows a researcher to acknowledge granting agencies that supported the work financially and other contributions of a non-intellectual nature.

**Citations/References:** Although citation and reference are used interchangeably, they refer to different parts of a paper. Citations are embedded in the document and connect specific information to an entry in the references section. Format for citations varies considerably from one journal/book to another. You should identify the appropriate formatting standards for the situation and be consistent in applying the formatting. Entries in the references section are almost always ordered alphabetically. Although there are differences between style guides, entries included: author(s), year, article title, journal, volume, issue, and pages.
The Discussion Section

Writing the Discussion section can be challenging, but it is also the most exciting component of a scientific report. In the Discussion, the writer has the opportunity to be creative and to show the logic and reasoning behind their conclusions.

General Comments for Writing the Discussion

At its core, the Discussion section is devoted to intellectual exploration of the research topic. The original hypothesis and the results are explored and evaluated, and the conclusions from this exploration are then applied to the topic in general.

Form

There is a certain symmetry between the Introduction and the Discussion. The Introduction section starts from a general perspective then focuses down to a specific question. In contrast, the Discussion starts at the specific question and works outwards, applying the new knowledge to the big picture.

Intellectual Exploration

The intellectual exploration aspect of the discussion section is composed of reasoning and inclusion of pertinent information. Previous experiments, past conclusions, and current theories must be re-interpreted using the new data. This task is accomplished by including references to others’ works (e.g., “The mean relationship between tail length and offspring survival is consistent with Jacobson and Larb’s (2004) observation that greater tail allows individuals to access normally inaccessible resources”).

Acknowledging Limitations

In exploring the new results, the limitations of the experiment must be explored as well. All experiments have limitations, and these limitations must be defined (e.g., Although we have developed a new method for co-purifying protein x and protein y thereby establishing a link between these proteins’ functions, the sequence and nature of their functional relationship cannot be determined from samples prepared using this method.”). Pertinent limitations in others’ results can also be identified as part of the discussion (e.g., “Jacobson and Larb’s (2004) observations were limited to daylight observations, so they were unable to determine if individuals were succumbing to starvation or predation.”).
**Persuasion**
The Discussion section can be thought of as a collection of “arguments” based on the author’s and other people’s results. The length of each argument varies, but for student papers, a paragraph is usually sufficient. Each paragraph should include a topic sentence and a concluding sentence. Each assertion or topic sentence must be supported by what is already known about the subject, as well as by your results.

**Contribution**
The Discussion is where you show what you have contributed. For experiments that are part of a class, your contribution is to confirm and support existing theories or “facts.”

**Language/Word Choice**
A scientist’s language must reflect the scientific method; therefore, words, phrases, and sentences should reflect a rigorous and objective search for information. Differences in meaning can be subtle but are important:

<table>
<thead>
<tr>
<th>Inappropriate</th>
<th>Suitable</th>
</tr>
</thead>
<tbody>
<tr>
<td>proves, proof (absolute language)</td>
<td>supports, evidence, consistent, contradictory</td>
</tr>
<tr>
<td>almost, sort of, kind of (ambiguous language)</td>
<td>similar, dissimilar, possible correlation</td>
</tr>
</tbody>
</table>

Prove, proof—these words have a type of closure that scientists dislike. One can provide evidence in support of a theory.

Preferred: evidence, supporting, consistent, inconsistent, contradicting.

Sort of, almost—Ambiguous language should be avoided. Things can be similar or dissimilar, but they cannot be sort of similar.

Preferred: similar, dissimilar, corresponding, possible correlation.

**Strategy for writing the Discussion**
List all of the points or arguments you want to make in the Discussion, and rank them. This list should include:

1. A definite statement accepting or rejecting the hypothesis, a strong answer to the research question, or an equivocal statement if more study is required.
2. Relevant information for interpreting the new data.
3. Limitations of the new data.
4. How the new information relates to previous experiments (i.e., is it consistent with similar experiments?).
5. A statement of contribution to the body of knowledge.