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Subject
Working method and terminology 1

II. Drafting (Writing) a scientific report

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Guidelines for writing a Scientific Report

What is a scientific report?

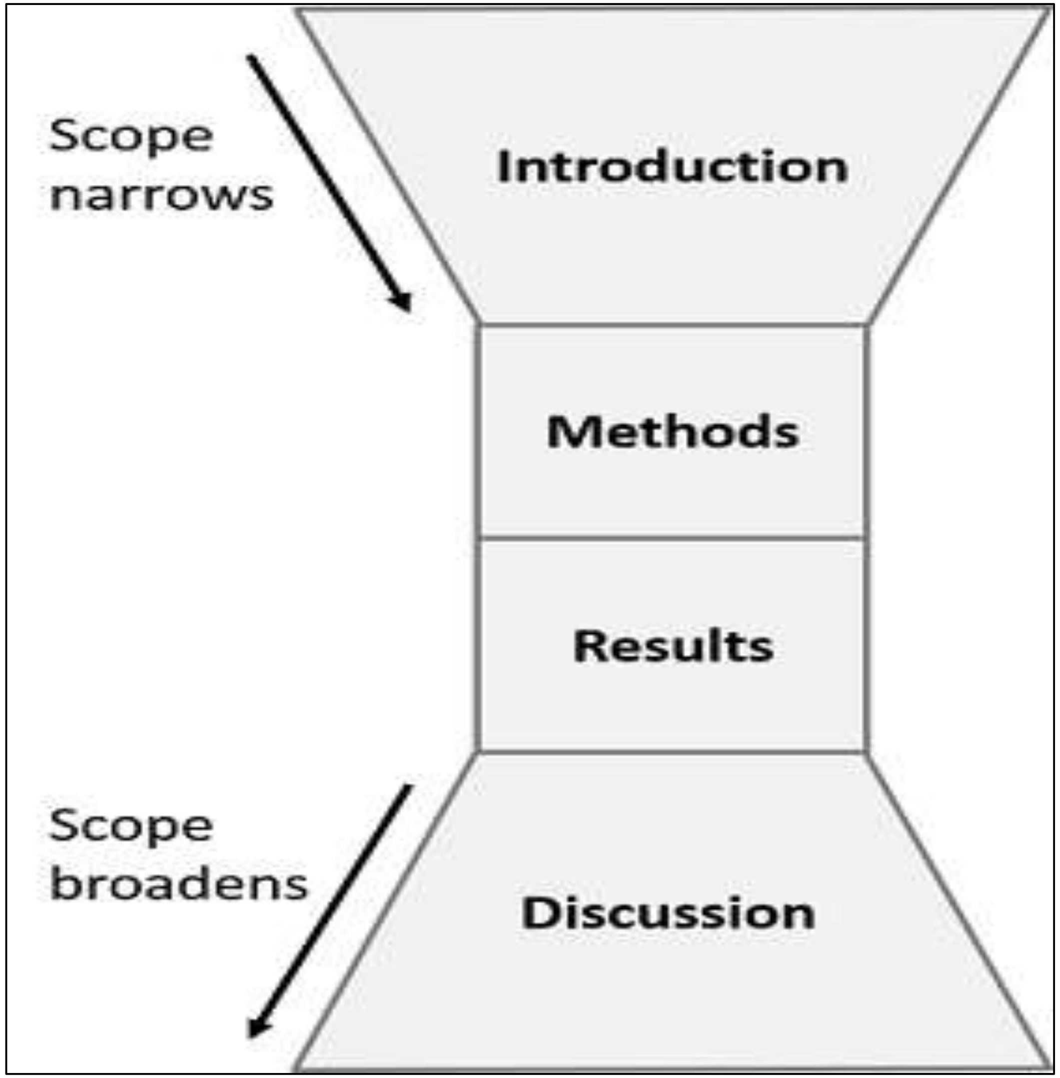
A scientific report is a written document that presents an experimental or research study's findings, conclusions, and recommendations.

Writing a scientific report can be a challenging task, but it is a crucial aspect of scientific research. A well-written scientific report enables researchers to communicate their findings effectively to other scientists and stakeholders, ultimately advancing their field of study. In this article, we will outline the main steps and important parts of writing a scientific report.

What does a scientific report include?

Research findings are typically presented in journals and other professional reports in the **IMRaD** format (**I**ntroduction, **M**ethods, **R**esults and **D**iscussion). The purpose of each of these sections is to answer the following questions:

- **Introduction - Why** did you do your experiments?
- **Methods - Which** experiments did you do and how did you do them?
- **Results - What** happened when you did them?
- **Discussion - What** do the results mean?



IMRAD method

There are also the following additional sections:

- A specific title
- An abstract or summary
- Acknowledgments (to thank those who assisted with your work)
- A reference list
- Appendices (optional)

The structure of a scientific report

The normal scientific report has a standard structure (parts in parentheses are optional):

1. Title
2. Abstract / Summary
3. **I**ntroduction
4. **M**ethods
5. ***R***esults
6. ***D***iscussion
7. (Acknowledgements)
8. Literature cited
9. (Appendix)

Title

Purpose: To sum up your work in a single phrase or sentence. It needs to be clear, specific and brief; its meaning should be obvious to most readers.

- **Clear:** Technical terms and abbreviations should only be used if they will be familiar to the readers of your report.
- **Specific**: Give enough information to enable the reader to know if the research is likely to be of interest to their own fields.
- **Brief**: Avoid obvious phrases, like ‘The role of’, ‘Studies of’, ‘An examination of”, ‘An investigation into’, ‘Research into’, and ‘An experiment on’. Titles with these words are often too long or not descriptive enough. This is also your first shot at grabbing the reader’s attention.

EXAMPLE

- **Less descriptive title**: Migrating Whales and Electromagnetic Fields
- **Preferred title**: The Effect of Electromagnetic Fields on Migrating Whales

The title is phrased in a similar way to the research question, also known as the operational question. Clearly identify the independent variable (IV) and dependent variable (DV).

Recall that the independent variable (IV) is the part of the experiment that you are changing and the dependent variable (DV) is what is being measured as a result of that change.

HINT: Use this formula to create a scientific title.

The Effect of _______ **[IV]** on ______ **[DV]**

For example: The Effect of Exercise on Heart Rate

Example 1 - **"Photosynthesis" This doesn't tell the reader much about the paper.** Instead "The effect of differing light wavelengths on the rate of photosynthesis on the common garden pea plant (Pisum sativum)" This tells the reader what is in the paper.

Example 2 - "**Studies on a snake**", again too brief. What snake, where, what kinds of studies? Instead "The Thermal Ecology of a Population of the Common Death Adder (*Acanthophis antarcticus*), in Sippy Downs, Queensland"

Introduction

The principal job of an introduction is to guide the **reader** from the **broad area** of **your discipline to the particular topic you will be discussing**. From a larger perspective on the problem, the introduction typically proceeds through several transitional sentences, leading the reader logically **to the specific question you hope to answer with your experiment** or topic you intend to discuss in your research paper.

The following is a list of 3 elements that are needed in the introduction.

1. Orient the person reading your report to the subject using a concise review of relevant background information. **Research** the available scientific information regarding the selected experimental topic.

· The literature cited may be from a variety of sources, i.e. your class text book, other text books, research articles, articles from the internet, etc.

· Information must be **unmistakably relevant** to the specific content of the laboratory.

· Be selective. When extracting information from other sources, identify 3 or 4 main points. Summarize each point in 1 sentence.

2. Include the purpose of your report. Allow the person reading your paper to understand **why** you are performing your experiment.

3. Indicate your expectations of the outcomes of the experiment and what alternatives you might expect. This proposed explanation of the outcomes/ phenomenon is known as the **hypothesis**.

HINT: Use this formula to write your hypothesis:
If ______________________[IV] is ________________________ [describe how it was changed], then _______________ [DV] will _____________________ [describe the expected effect].

For example: "If the **antibiotic cleaning agent** is placed on a bacterial colony, then **growth of the colony** will be **inhibited**."

Materials and Method

Students often start with this section as it is straight-forward. In writing a materials and methods section, you need to describe what you **did** in such a way that a fellow scientist can follow and duplicate your experiment.

The following is a list of 5 elements that are needed in the introduction.

1. Use the third person and past tense.

HINT: Use this formula to write your methods.

Change this sentence from the book.

- Add 5 drops of 0.1 M copper (II) sulphate solution into one of the test tubes and shake it so that the solution covers the zinc surface.

To past tense with you doing the action.

- I add**ed** 5 drops of 0.1 M copper (II) sulphate solution into one of the test tubes and **shook** so that the solution cover**ed** the zinc surface.

Remove all I, We, Me and replace with the equipment used.

- Five drops of 0.1 M copper (II) sulphate solution was added into one of the test

2. When following a procedure from a lab manual or published paper, simply describe how you conducted your experiments (there should be enough detail such that the reader could easily duplicate your experiments – no lists!, write as a paragraph). Common practices like gel electrophoresis do not need to be explained in detail.

3. Keep in mind what information is important to the results obtained and for reproducing the experiment. This includes details such as concentrations, temperatures, measurements, units, timing, calculations, etc. Irrelevant details like "A wax pencil was used to label the test tube," can be left out!!

4. In field studies it is important include the locations and times that data were collected.

5. Explain who you summarized the data (means, standard deviation) and the calculations and statistical analysis you did.

Incorrect Example:

"We measured the samples' hardness. Then we put the pieces of metal in the furnace and then waited for one hour. Then we removed them and put them in the hardness tester again. Joe was listening to his IPod while we did this lab..”

Correct Example

"Samples of different hardness were prepared by annealing them in a furnace for various lengths of time and at different temperatures. The hardness was measured before and after annealing, using a Rockwell hardness tester set up for the B scale.”

Results

The Results section describes, in words, your observations (qualitative data) and the measured experimental data (quantitative data). It also includes the data displayed in tables and/or in graphs. **Results describe only what was found or observed, just the facts. Interpretation and explanation of results is discussed in the discussion section.**

Figures

Figures include **graphs**, **maps**, **photos** and **technical diagrams**. Presentation of data in graphs is generally more desirable than tables because they aid the reader in visualizing trends in the data. There are many different types of graphs, but the most common graphs used in scientific writing are line graphs, used for continuous data such as time and temperature (Fig. 1), and vertical bar graphs used for discrete data such as apples vs oranges OR boys vs girls (Fig. 2). Regardless of the type of graph you use, all contain similar elements.

(1) **Axes.** A graph consists of a horizontal axis and a vertical axis. The independent variable (what's changed)are plotted on the horizontal axis (bottom line) and values of the dependent variable (the effect or the outcome you measured) are plotted on the vertical axis (up and down line)

(2) **Labels.** Both axes should be clearly labelled and include units of measure.

(3) **Figure Caption.** There should be a figure caption **below** the graph that briefly describes the information in the figure. It should be clear, concise, and informative. The figure caption should be understandable without reference to the text and answer, if appropriate, the questions "what", "where", "when" and "why". Figures are numbered in order they appear in the text.

Discussion

The main purposes of the discussion are to:

- discuss the relationships between your results,
- discuss how the results relate to your initial objectives and hypotheses,
- describe the shortcomings of your work,
- describe the implications of your work,
- provide major conclusions supported with evidence,
- and suggest future applications of your research findings.

• Start with a summary paragraph, reiterating your question and main findings. This may be all someone reads!

• It is important to discuss your initial hypotheses in terms of whether your results provide adequate support for them.

• Include anomalies or negative results – try to explain them based on the theories you have learnt.

- Discuss how your results are similar or different from published findings, and attempt to explain any differences, with support from references.
- If it is impossible to find a good explanation for your results – simply admit it. It is better to admit uncertainty, rather than create poor, unsubstantiated excuses.
- State all of your conclusions, and build on them by providing evidence from your data and from the literature.
- End with a concluding paragraph to summarise the key findings and their implications.
- Most of the discussion should be written in the present tense. When you discuss your data, write in the past tense, and when you discuss future implications of your work, write in the future tense.

Discussion Layout Example

The results are not consistent with the research hypothesis. In addition, the results differ from those of my classmates **[describe what difference was, were your values higher or lower, different color, failure to grow, etc.].**

One explanation for this difference is that ____________________ **[explain what was done differently, or what may have happened, or where your procedures varied].**

This would have caused ________________ **[explain how the difference in your procedures may have altered the results].**

CONCLUSIONS

- Provide a very brief summary of the Results and Discussion.
- Emphasize the implications of the findings, explaining how the work is significant and providing the key message(s) the author wishes to convey.
- Provide the most general claims that can be supported by the evidence.
- Provide a future perspective on the work.
- Avoid: repeating the abstract; repeating background information from the Introduction; introducing new evidence or new arguments not found in the Results and Discussion; repeating the arguments made in the Results and Discussion; failing to address all of the research questions set out in the Introduction.

Literature cited / References

In this section you should provide a complete listing of all, and only, references cited in the text of the report. There are three things to consider here

- What to cite
- How to cite it in the text
- How to construct a reference list

- What to cite

You should cite appropriate references wherever you make a point of substance (fact, or opinion) that is not your own or may not be regarded as common knowledge. e.g.

Several species in the genus Calopteryx perform a complex 'wing floating' display as part of the courtship behaviour (Malmquist 1956) **[Fact]**

This behaviour is generally considered to be a display of male quality (Fredenholm 1978, Agassiz and Moore 1980, Summers 1991). **[Opinion of others]**

- Styles of citation

If writing a manuscript for publication in a scientific journal, obviously use the style of the journal in question (exactly - including punctuation). If you are writing any other type of report, you can choose your own style, but if in doubt the easiest approach is probably to follow the style of a major journal in the appropriate subject area. There are two main styles you will encounter:

The most common (and most straightforward) cites references in the text using names and dates, and lists all references alphabetically in the reference list.

In the text,

e.g. Wide fluctuations in temperature reduce egg viability **(Smith 1987).**
or... **Smith (1987)** found that wide variations in temperature reduced egg viability.

In list

Smith, A. J. (1987). The effect of temperature on egg development and survival in the damselfly Calopteryx virgo. J. Zool. (Lond.) 47: 231-243.

Note that the necessary information about the journal is the journal title, the volume number (47) and the pages of the article (231-243). Journals often also have a part number, e.g. volume 47(2). In general you do not need this in the citation, the page numbers should be sufficient.

The list should be in alphabetical order by first author. If there is more than one reference by the same author then order them by date. If there are papers with the same first author but different second/third authors then these come after the single author papers by the first author, and in alphabetical order by second.. third etc.. authors, e.g

Smith A J (1987) ....
Smith A J (1989) ....
Smith A J, Girton S and Mackay R H (1984) ....
Smith A J and Wallis K C (1983) ....
Smith A J and Wallis K C (1985) ....

If you have several citations by the same author in the same year in your list, then denote them with letters e.g.

In the text: Smith (1987a), Smith (1987b)

In the list:

Smith, A. J. (1987a). The effect of temperature on egg development and survival in the damselfly Calopteryx virgo. J. Zool. (Lond.) 47: 231-243.
Smith, A. J. (1987b). The oviposition behaviour of Calopteryx virgo (Odonata: Zygoptera). Anim. Behav. 27: 197-209

The other main style is to use numerical superscripts (or equivalent) in the text, numbering the references in the order in which they are mentioned in the text, and ordering the final reference list in the same way, e.g.

In the text:

Wide fluctuations in temperature reduce egg viability[23].

Smith[23] found that wide variations in temperature reduced egg viability.

In the reference list:

22. Wilcove H (1978) Mating strategies in a calopterygid damselfly. Anim. Behav. 16: 21-30
23. Smith A J (1987) The effect of temperature on egg development and survival in the damselfly Calopteryx virgo. J. Zool. (Lond.) 47: 231-243
24. Morris L L (1991) A model of territory switching behaviour. Am. Nat. 230: 390 -395

In many journals using this system, the titles of the references in the list are also omitted e.g.

23. Smith A J (1987). J. Zool. (Lond.) 47: 231-243.

This is done to save space, but unless you are specifically asked to do this it is best to include the complete reference. Although such numerical systems usually require the reference list to be ordered by number, it is possible (and much more convenient) to use an alphabetical listing even if numbers are used in the text (alphabetically ordered references are numbered in order and then the numbers used in the text instead of names). The advantage to a numbering system is that is saves space in the text, the disadvantage is that the numbers don't tell you which paper is being referred to as you read - you need to keep looking them up in the list. Some final points to bear in mind about references and their citation:

• Every reference cited in the text must appear in the reference list, and every reference in the list must appear in the text.

- Don't cite things you have not read or seen the relevant part of. If you need to cite something you have seen discussed or cited somewhere else, but haven't seen, and cannot get hold of, you should make it clear that you are citing someone else's interpretation of the original reference, e.g.

In the text: Jones (1928 - cited in Smith 1987)

In the list you should then give the citation for Smith (1987) not for Jones (1928).

- There are standard abbreviations for journal names. These are often given in the journal itself, and are available on a list in the Library, or can be found by looking up the journal on Biological Abstracts. If you don't know what the standard abbreviation is, and it is not obvious, them use the full name rather than making up your own abbreviation.

Books

In the end reference, separate information about author(s), date, title, edition, and publication by periods. The basic format is as follows:

Author(s). Date. Title. Edition. Place of publication: publisher. Extent. Notes.

For books with 2 authors, names are separated by a comma in the end reference but by "and" in the in-text reference (Leboffe and Pierce 2010)

Leboffe MJ, Pierce BE. 2010. Microbiology: laboratory theory and application. Englewood (CO): Morton Publishing Company.

For books with 3 to 10 authors, list all authors in the end reference; in the in-text reference, list only the first, followed by "et al." (Ferrozzi et al. 2000)

Ferrozzi F, Garlaschi G, Bova D. 2000. CT of metastases. New York (NY): Springer.

For books with more than 10 authors, list the first 10 in the end reference, followed by "et al." (Wenger et al. 1995)

Wenger NK, Sivarajan Froelicher E, Smith LK, Ades PA, Berra K, Blumenthal JA, Certo CME, Dattilo AM, Davis D, DeBusk RF, et al. 1995. Cardiac rehabilitation. Rockville (MD): Agency for Health Care Policy and Research (US).

Organization as author

[ALSG] Advanced Life Support Group. 2001. Acute medical emergencies: the practical approach. London (England): BMJ Books. (ALSG 2001)

Author(s) plus editor(s) or translator(s)

Klarsfeld A, Revah F. 2003. The biology of death: origins of mortality. Brady L, translator. Ithaca (NY): Cornell University Press. In the text: (Klarsfeld and Revah 2003)

Luzikov VN. 1985. Mitochondrial biogenesis and breakdown. Galkin AV, translator; Roodyn DB, editor. New York (NY): Consultants Bureau.

In the text: (Luzikov 1985)

Chapter or other part of a book, same author(s)

Gawande A. 2010. The checklist manifesto: how to get things right. New York (NY): Metropolitan Books. Chapter 3, The end of the master builder; p. 48–71.

In the text: (Gawande 2010)

Chapter or other part of a book, different authors

Rapley R. 2010. Recombinant DNA and genetic analysis. In: Wilson K, Walker J, editors. Principles and techniques of biochemistry and molecular biology. 7th ed. New York (NY): Cambridge University Press. p. 195–262. In the text:(Rapley 2010)

Journals

For the end reference, list authors in the order in which they appear in the original text. The year of publication follows the author list. Use periods to separate each element, including author(s), date of publication, article and journal title, and volume or issue information. Location (usually the page range for the article) is preceded by a colon.

Author(s). Date. Article title. Journal title. Volume(issue):location.

Journal titles are generally abbreviated according to the List of Title Word Abbreviations maintained by the ISSN International Centre.

For the in-text reference, use parentheses and list author(s) by surname followed by year of publication.

(Author(s) Year)

For articles with 2 authors, names are separated by a comma in the end reference but by "and" in the in-text reference. (Mazan and Hoffman 2001)

Mazan MR, Hoffman AM. 2001. Effects of aerosolized albuterol on physiologic responses to exercise in standardbreds. Am J Vet Res.

For articles with 3 to 10 authors, list all authors in the end reference; in the in-text reference, list only the first, followed by “et al.” (Smart et al. 2003)

Smart N, Fang ZY, Marwick TH. 2003. A practical guide to exercise training for heart failure patients. J Card Fail. 9(1):49–58.

For articles with more than 10 authors, list the first 10 in the end reference, followed by “et al.” (Pizzi et al. 2002)

Pizzi C, Caraglia M, Cianciulli M, Fabbrocini A, Libroia A, Matano E, Contegiacomo A, Del Prete S, Abbruzzese A, Martignetti A, et al. 2002. Low-dose recombinant IL-2 induces psychological changes: monitoring by Minnesota Multiphasic Personality Inventory (MMPI). Anticancer Res. 22(2A):727–732.

Volume with no issue or other subdivision

Laskowski DA. 2002. Physical and chemical properties of pyrethroids. Rev Environ Contam Toxicol. 174:49–170. In the text: (Laskowski 2002)

Volume with issue and supplement

Gardos G, Cole JO, Haskell D, Marby D, Paine SS, Moore P. 1988. The natural history of tardive dyskinesia. J Clin Pharmacol. 8(4 Suppl):31S–37S.

In the text: (Gardos et al. 1988)

Volume with supplement but no issue

Heemskerk J, Tobin AJ, Ravina B. 2002. From chemical to drug: neurodegeneration drug screening and the ethics of clinical trials. Nat Neurosci. 5 Suppl:1027–1029. In the text: (Heemskerk et al. 2002)

Multiple issue numbers

Ramstrom O, Bunyapaiboonsri T, Lohmann S, Lehn JM. 2002. Chemical biology of dynamic combinatorial libraries. Biochim Biophys Acta. 1572(2–3):178–186.

In the text: (Ramstrom et al. 2002)

Issue with no volume

Sabatier R. 1995. Reorienting health and social services. AIDS STD

Dissertations and Theses

Lutz M. 1989. 1903: American nervousness and the economy of cultural change [dissertation]. [Stanford (CA)]: Stanford University. In the text: (Lutz 1989)

Patents

Blanco EE, Meade JC, Richards WD, inventors; Ophthalmic Ventures, assignee. 1990 Nov 13. Surgical stapling system. United States patent US 4,969,591.

In the text: (Blanco et al. 1990).

Newspapers

Weiss R. 2003 Apr 11. Study shows problems in cloning people: researchers find replicating primates will be harder than other mammals. Washington Post (Home Ed.). Sect. A:12 (col. 1). In the text: (Weiss 2003)

DVDs

Indicate a copyright date with a lowercase “c”.

Johnson D, editor. c2002. Surgical techniques in orthopaedics: anterior cruciate ligament reconstruction [DVD]. Rosemont (IL): American Academy of Orthopaedic Surgeons. 1 DVD. In the text: (Johnson c2002)

Websites and Other Online Formats

References to websites and other online formats follow the same general principles as for printed references, with the addition of a date of update/revision (if available) along with an access date and a URL.

Website

Format for end reference:

Title of Homepage. Date of publication. Edition. Place of publication: publisher; [date updated; date accessed]. Notes.

If no date of publication can be determined, use a copyright date (if available), preceded by "c". Include the URL in the notes.

APSnet: plant pathology online. c1994–2005. St Paul (MN): American Phytopathological Association; [accessed 2005 Jun 20]. http://www.apsnet.org/.

For the in-text reference, include only the first word or two of the title (enough to distinguish it from other titles in the reference list), followed by an ellipsis. In the text: (APSnet . . . c1994–2005).

Appendices

Use appendices (if you must) for large amounts of raw data, long species lists, detailed mathematical or laboratory working, of a non-standard method, or (short) program listings, but only where the inclusion of such information markedly enhances the usefulness of the paper. Normally such appendices are not required - avoid using them just because you want to show how much data you collected!

Acknowledgements

This is the place to acknowledge persons or organizations who have made significant contributions to the execution of the work. For example: funding bodies, people who have contributed ideas or assisted with some of the actual work, landowners giving access to sites, specialists who have made identifications and people who have read and commented on the manuscript. Don't get carried away. You may not really need to thank all your friends, relations and loved ones for general help through life's little crises.

Abstract

The abstract appears after the title. The abstract gives a general overview summarizing the purpose, methods, major findings and conclusions. Use concise sentences reflecting the major points from the laboratory.

The following is a list of 5 elements that are needed in the abstract. Write each element in one or two sentences.

1. State the purpose. What was the purpose of the laboratory? That is, why was the experiment done?

2. State the predicted outcome. Was the prediction based on a scientific theory or law? If yes, identify the relevant theory or law. Then, state the researched hypothesis or hypotheses.

3. Summarize the methods, including only the major methods used. If a well known technique is used (e.g., gel electrophoresis), just state the name of the technique. The details about the technique will follow in the materials and method section of the laboratory report.

4. In one or two sentences, highlight the major results. Start with a sentence beginning, “The major findings from this laboratory were…”

- Only the key results are included in the abstract. Generally, this means reporting the final results from the calculations.
- If an average of the data was calculated, report only the average not individual data points.
- If class data are used for comparison, state the average or make a general statement about how they compare to your individual data points.

The other data will be discussed in the results and conclusion sections of the report.

5. Summarize your major conclusions. Start with a sentence such as, “From the data, it can be concluded that…”

Example

Examination of the ability of vegetative propagules (small buds and branched fragments) of the green alga Codium fragile ssp. tomentosoides to attach and grow on natural substrata was conducted in laboratory and field experiments. In the laboratory, the probability of attachment (on coralline algae, mussel shell, smooth and rough rock) was greater for buds than cut branches (both ~4 cm long) over 10 weeks. Probability of attachment also differed among substrata with attachment to coralline algae being the greatest. In the field experiment, buds were transplanted to three tide pools at different tidal heights on the rocky shore. After eight months the proportion that attached did not differ significantly among pools. These findings indicate that vegetative propagation may contribute to the invasive success of Codium fragile.

Scientific Report Checklist

TITLE	- Is it brief? - Is it specific? - Does it contain key words such as the independent and dependent variable?
ABSTRACT Summary	- Does it state the hypothesis? - Are the procedures briefly explained? - Does it include the main results and conclusions?
INTRODUCTION **Why was the study undertaken?** **What question was studied?**	- Does it state the problem/issue? - Does it mention relevant literature and what is already known about the problem? - Have you cited this literature? - Does it include the purpose of the experiment? - Does it state what your expectations of the outcomes are and what alternatives you might expect**? (HYPOTHESIS)**

MATERIALS & METHODS **How was the problem studied?**	- Is it in 3rd person, past tense? - Have you stated equipment, facilities, chemicals used? - Have you given enough information for someone to repeat your study? - Have you included the statistics; calculations done to the data?
RESULTS **What were the findings?**	- Are ALL of the relevant results included? - Have you included data in the form of tables, graphs etc? - Do the tables and graphs have an explanatory caption?
DISCUSSION **What do these findings mean?**	- Have you commented on how the results met with your expectations? - Have you interpreted the results i.e. Trends, cause and effect? - Have you explained your interpretation with researched scientific articles? - Have you cited this literature to support your results? - Do your own results or the results of others support your interpretation? - Are there errors in your results? - What effect do these errors have on your data? - Have you stated real world applications of your experimental conclusion?

Title is informative.

The Effects of the Fungus *Phytophthora infestans* on Bean, Pea, and Corn Plants

Write author's name first followed by lab partners' names.

Lynne Waldman, Partner One, Partner Two

Label sections of lab report clearly.

Provide background information.

Do not cite sources in Abstract.

State purpose of current experiment.

Briefly describe methods.

Describe results. Do not refer to any figures.

Briefly explain the results or state your conclusions.

Limit Abstract to a maximum of 250 words.

Abstract

Phytophthora infestans is a fast-spreading, parasitic fungus that caused the infamous potato blight by devastating Ireland's crops in the 1840s *P. infestans* also causes late blight in tomato plants, a relative of the potato. In this experiment, the effects of *P. infestans* on *Phaseolus* variety long bush bean, *Zea mays* (corn), and *Pisum sativum* (pea) were studied. The soil surrounding the roots of 18-day old plants was injected with *P. infestans* cultured in an L-broth medium. Plant height, number of leaves, and leaf angle were measured for each plant during the next 8 days. Chlorophyll assays were performed prior to exposure, and on the eighth day after exposure to the fungus. The plants were also examined for black or brown leaf spots characteristic of late blight infections. The results showed that *P. infestans* had no apparent effect on the bean, corn, and pea plants. One reason for this may be that there were no fungus zoospores in the L-broth medium. More probably, however, *P. infestans* may be a species-specific pathogen that cannot infect bean, corn, or pea plants.

Italicize Latin names.

Provide background information.

Introduction

Originating in Peruvian-Bolivian Andes, the potato *(Solanum tuberosum)* is one of the world's four most important food crops (along with wheat, rice, and corn). Cultivation of potatoes began in South America over 1,800 years ago, and through the Spanish conquistadors, the tuber was introduced into Europe in the second half of the 1600s. By the beginning of the 18^{th} century, the potato was widely grown in Ireland, and the country's economy heavily relied on the potato crop. In the middle of the 19^{th} century, Ireland's potato crop suffered widespread late blight disease caused by *Phytophthora infestans*, a species of pathogenic plant fungus. Failure of the potato crop because of late blight resulted in the Irish potato famine. The famine led to widespread starvation and the death of about a million Irish.

The potato continues to be one of the world's main food crops. However, *P. infestans* has reemerged in a chemical-resistant form in the United States, Canada, Mexico, and Europe (McElreath, 1994). Late blight caused by the new strains is costing growers worldwide about $3 billion annually. The need to apply chemical fungicides eight to ten times a season further increases the cost to the grower (Stanley, 1994 and Stanley, 1997). *P. infestans* is thus an economically important pathogen.

P. infestans, which can destroy a potato crop in the field or in storage, thrives in warm, damp weather. The parasitic fungus causes black or purple lesions on a potato plant's stem and leaves. As a result of infection by this fungus, the plant is unable to photosynthesize, develops a slimy rot, and dies. *P. infestans* similarly infects the tomato plant (*Lycopersicon esculentum*) (Brave New Potato, 1994).

The purpose of the present experiment was to determine the effects of *P. infestans* on plant height, number of leaves, leaf angle, and chlorophyll content of three agriculturally important plants: *Phaseolus* variety long bush beans, *Zea mays* (corn), and *Pisum sativum* (peas). Symptoms of fungal infection were assumed to be similar to that in potatoes.

Use proper citation format (e.g., Name-Year system).

Do not use direct quotations. Paraphrase source text and cite the source in parentheses.

Use an abbreviated title when no author is given.

State purpose of experiment clearly.

Materials and Methods

Phaseolus variety long bush bean, *Zea mays* (corn) and *Pisum sativum* (pea) seeds were soaked overnight in tap water. Fifteen randomly chosen seeds of each species were planted 1 cm beneath the surface in three separate trays containing 10 cm of potting soil. Another set of trays, which was to be the control group, was prepared in the same fashion. All the experimental plants were placed in one fume hood, and all the control plants were placed in relative positions in another fume hood in the same room. The plants were exposed to the ambient light intensity in the hood (153 fc) and air current 24 hrs a day, and were watered lightly daily. The plants were allowed to germinate and grow for 18 days.

Write M&M in past tense.

Provide sufficient detail to allow the reader to repeat the experiment.

Phytophthora infestans on potato dextrose agar was obtained from Carolina Biological Supply House. At day 10 of the plant growth regime, pieces of agar on which the fungus was growing were transferred to L-broth. L-broth consisted of 5 g yeast extract, 10 g tryptone, 1 g dextrose, and 10 g NaCl dissolved in distilled water, and adjusted to pH 7.1, to make 1 L of medium. The medium was sterilized before adding the fungal culture. After 4 days in L-broth, 6 mL of the fungal culture was injected into the soil around the roots of each 18-day old plant. 6 mL of L-broth without *P. infestans* was injected into the soil of the control plants. All plants were then allowed to grow for another 8 days.

Include figures in M&M section if they help clarify the methodology.

Figure 1 Leaf angle as measured in bean, corn, and pea plants

determine if *P. infestans* causes wilting in the three plant species. In addition, the plant was examined visually for the presence of any leaf spots.

Chlorophyll assays were performed on one plant from each tray prior to injection and on the eighth day after injection. For each chlorophyll assay, the leaves of the plant were removed from the stem. For each 0.1 g of leaves, 6.0 mL of 100% methanol were used. The leaves were thoroughly ground in half of the methanol with a pestle in a mortar. The leaves were ground again after the rest of the methanol was added. Extraction of the chlorophyll was allowed to proceed for 45 min at room temperature. Then the suspension was gravity filtered through filter paper to remove the leaf parts. The absorbance of the filtrate was measured with a Spectronic 20 spectrophotometer at 652 nm and 665.2 nm. The absorbance values were converted to relative chlorophyll units using the following equation derived by Porra and colleagues (1989):

Total chlorophyll (a and b) = Dilution factor × $[22.12\ A_{652\ nm} + 2.71\ A_{665.2\ nm}$ (mg/L)] × Volume of solvent (L) / Weight of leaves (mg)

Make proper subscripts.

Results

P. infestans-treated plants and the control plants had similar growth patterns (Figure 2). Both the experimental and control pea and corn plants grew at a

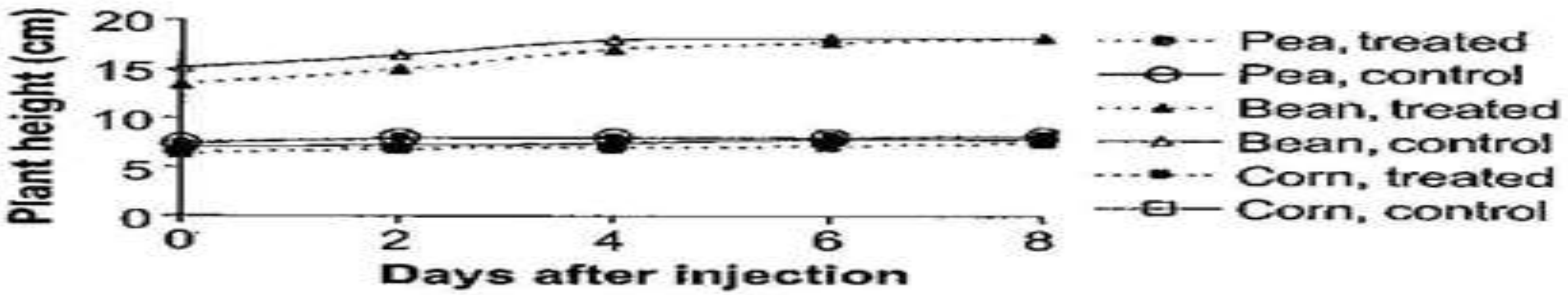


Figure 2 Average height of control and experimental plants in the period after injection with *P. infestans*

Include a text in the Results section. Describe the important results shown in each figure and table.

Refer to each figure and table in parentheses.

Make text in legend and in axis titles large enough to read easily.

Make sure intervals on axes have correct spacing.

Make points and lines black and background white for best contrast.

In the axis titles, write the variable followed by the units in parentheses (where applicable).

Position the figure caption below the figure.

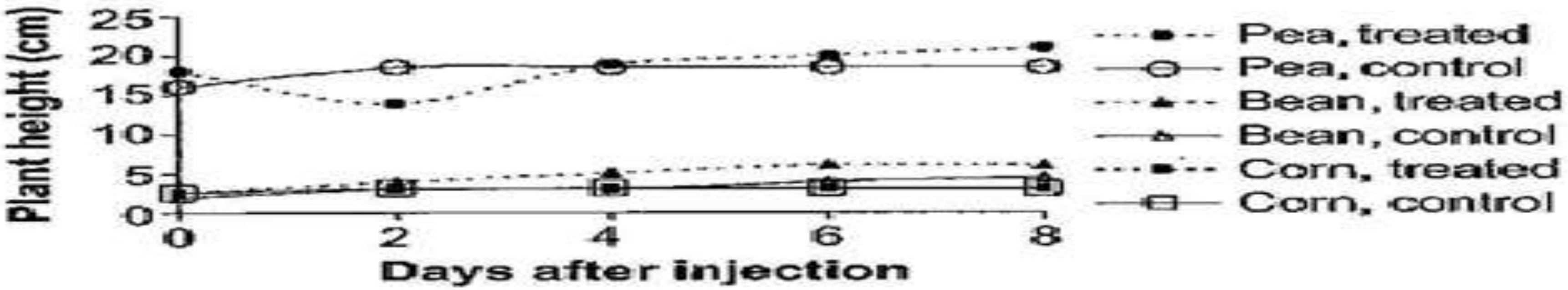


Figure 3 Average number of leaves of control and experimental plants in the period after injection with *P. infestans*

Make the figure title descriptive. Do not use "*y*-axis title vs. *x*-axis title."

Check that figures are numbered in sequence.

Describe the figures in order.

Insert symbols such as ° using word processing software.

constant, but very slow rate over the eight day test period. The control bean plants were taller on average than the experimental bean plants throughout most of the experiment. Both groups showed the same growth pattern, however, with rapid growth occurring from day 18 to 24 (0 to 4 days after injection), followed by slower growth to the end of the experiment.

As plant height increased, the average number of leaves on all of the plants also increased over the measurement period (Figure 3). There is an uncharacteristic decrease in the number of leaves of pea plants treated with *P. infestans* from day 18 to 20 (0 to 2 days after injection), but this is probably due to counting error.

There was a general decline in average leaf angle of all the plants over the first four days after injection with *P. infestans* (Figure 4). The plants did not follow this pattern over the second half of the experiment, however. The leaf angle of the experimental bean group increased by 28°, while that of the control bean group only increased by about 3°. The leaf angle of the control pea plants increased significantly (33°), while that of the experimental pea plants decreased 4°. The leaf angle of the corn control group decreased 0.5°, while that of the corn experimental group showed a much sharper decline of 24°.

There was also no difference between the experimental and control groups with regard to chloro-

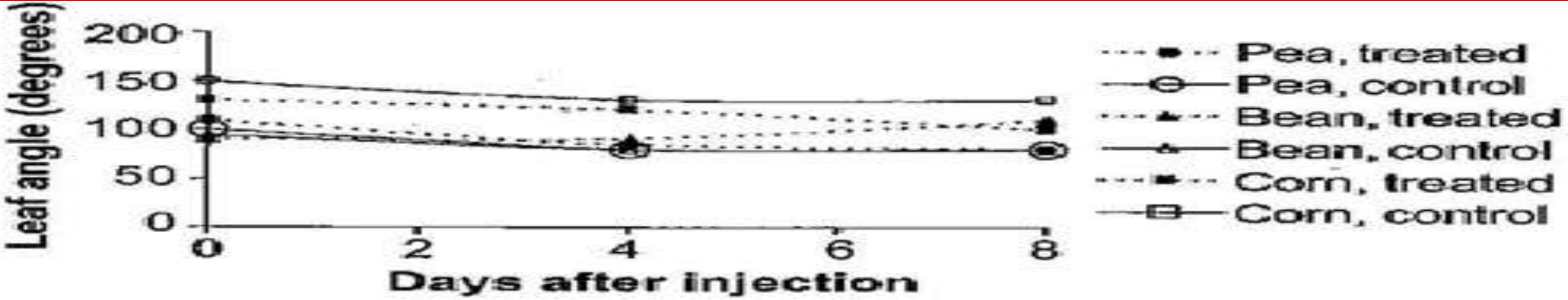


Figure 4 Average leaf angle of control and experimental plants in the period after injection with *P. infestans*

phyll content. There was a slight increase in chlorophyll content from day 18 to 26 (0 to 8 days after injection) in the corn plants (Table 1). For the bean group, there was a large decrease in chlorophyll content, 0.1 relative chlorophyll units, which did not seem to agree with the general appearance of the plants. There may have been some error when this assay was carried out. There was little change in chlorophyll content for the pea group.

Finally, there was no evidence of any brown or black leaf spots symptomatic of *P. infestans* infection.

Number tables independently of figures.

Table 1 Chlorophyll content of corn, bean, and pea plants prior to infection and 8 days after infection

Plant	Relative chlorophyll units		Change in chlorophyll content (relative units)
Plant	Day 0	Day 8	
Corn, treated	9.036×10^{-4}	9.383×10^{-4}	$+3.45 \times 10^{-5}$
Corn, control	9.270×10^{-4}	8.963×10^{-4}	$+3.34 \times 10^{-5}$
Bean, treated	1.034×10^{-1}	1.2×10^{-3}	-1.022×10^{-1}
Bean, control	1.7×10^{-3}	1.6×10^{-3}	-1×10^{-4}
Pea, treated	1.3×10^{-3}	1.7×10^{-3}	$+4 \times 10^{-4}$
Pea, control	1.2×10^{-3}	1.2×10^{-3}	0.0000

Position the table caption above the table.

Use scientific notation correctly.

Do not split small tables across two pages.

Briefly restate the results in the Discussion section.

Give possible explanations for the results.

Support explanations with references to published sources.

Offer possible ways to test whether explanation is valid.

Discussion

P. infestans did not affect the plant height, leaf angle, number of leaves, and chlorophyll content of *Zea mays, Pisum sativum,* or *Phaseolus.* Symptoms of infection are the presence of brown or black spots (areas of dead tissue) on leaves and stems, and, as the infection spreads, the entire plant becomes covered with a cottony film (Stanley, 1994). None of the experimental plants exhibited these symptoms.

There may be several reasons why *P. infestans* did not affect the plants in this study. One reason is that the L-broth culture of *P. infestans* may not have contained zoospores of the fungus. Zoospores are motile spores that can penetrate the host plant through the leaves and soft shoots, or through the roots (Stanley, 1994). Zoospores are usually produced in wet, warm weather conditions (Ingold and Hudson, 1993). If the L-broth culture did not contain any zoospores, or if the soil around the plants was not sufficiently saturated to stimulate production of zoospores, then these conditions may have prevented *P. infestans* from attacking the roots and shoots of the plants.

In order to determine if the problem was lack of zoospores, first the L-broth culture could be examined microscopically for presence of zoospores. Second, the *P. infestans* plants could be watered with different quantities of water to determine if the fungus requires wetter soil for zoospore production and motility.

Whenever possible, use primary references (journal articles, conference proceedings, collections of primary articles in a book). Avoid textbooks (secondary references) and websites (may be unreliable).

Another reason why *P. infestans* may not have affected the plants is that this species of fungus may be specific to potato *(Solanum tuberosum)* and tomato *(Lycopersicon esculentum)* plants (Stanley, 1994), which both belong to the nightshade family (Solanaceae). In contrast, corn belongs to the grass family (Gramineae), and peas and beans are legumes (Leguminosae). It may be that these plant families are not susceptible to *P. infestans*, which has a very limited host range (Stanley, 1994). Non-susceptible plants have been shown to have defense mechanisms that prevent *P. infestans* from infecting them (Gallegly, 1995).

Further research is required to determine if *P. infestans* really cannot infect corn, pea, and bean plants. Goth and Keane (1997) developed a test to measure resistance of potato and tomato varieties to original and new strains of *P. infestans*. Their experiments involved exposing the experimental plants' leaves directly to the fungus, and this method could perhaps be tested on corn, pea, and bean leaves as well.

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In Name-Year end reference format, list authors alphabetically by first author's last name.

Substitute the title when no author is given.

Use mostly primary journal articles or articles in a book.

List all authors (up to 10; then list first 10 followed by "*et al.*" or "and others.")

See the tabbed pages in Chapter 4 for examples of how to reference printed and electronic sources.

Give inclusive page numbers, not just the page(s) you extracted information from.

Make sure all in-text citations have a corresponding end reference.

Make sure all end references have a corresponding in-text citation.