Writing Scientific Manuscripts

a guide for undergraduates

Written and produced by the

Journal of Young Investigators

Peer-reviewed, undergraduate science journal.

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Introduction

Welcome to JYI's Guide to Reporting Scientific Research! This is a free guidebook, written and distributed by the Journal of Young Investigators, an international science research journal run entirely by undergraduates, for undergraduates.

This guide is designed as a resource for undergraduate science researchers who are getting ready to write up their research for a journal. As an undergraduate, you probably haven't had the chance to write many professional papers. That will change – quickly. Grad students and practicing scientists spend much of their time writing scientific manuscripts, abstracts, and grant proposals.

This guide is laid out to give you an introduction to the publication process, peer review, and writing scientific manuscripts. Peer review and publication are hot topics in the scientific community. So much of the community lives under the constant pressure of "Publish or Perish" that it *must* be a hot topic. Tenures are granted, funding awarded, and professional reputations made based on how often – and how well – a scientist publishes. As far as the scientific community is concerned, even the most brilliant piece of research is useless unless reported – and reported well.

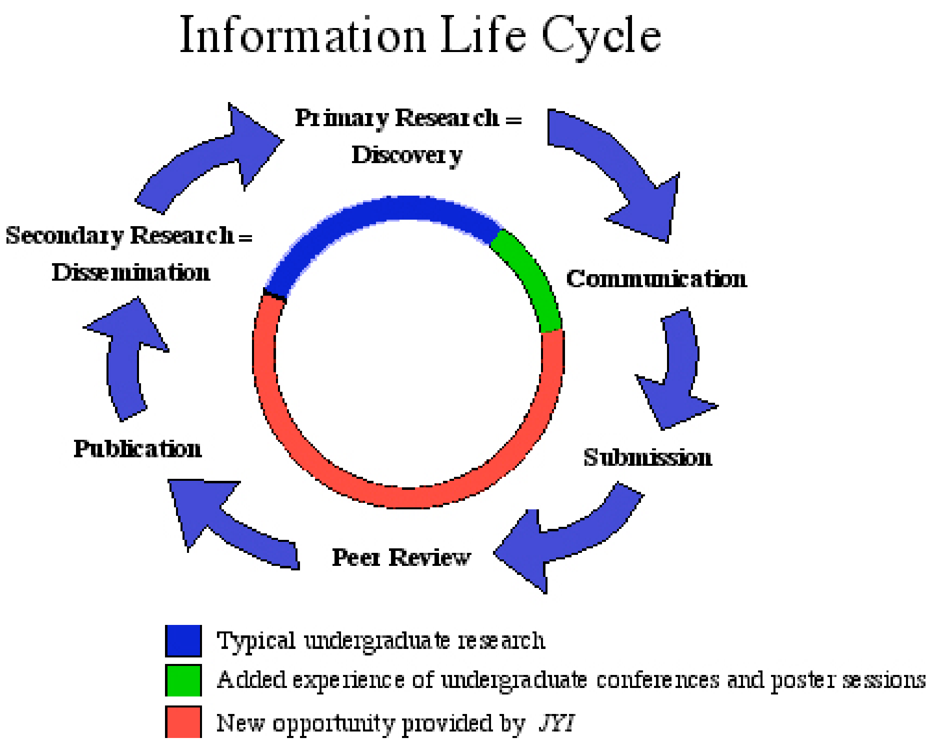
This guide is written for undergraduates, by undergraduates. Somewhere out there, in that sea of opinions on publishing, are people who disagree with us on the process, style, and content of research reports. We know that. This is not the be-all and end-all bible on writing scientific manuscripts. It's a guide for undergrads. Listen to your advisor, read other manuscripts, and, above all, practice writing your own. Come grad school, you'll be glad you did.

What is JYI?

A quick digression, for those of you who were wondering . . .

The Journal of Young Investigators (JYI) is an international scientific research journal run entirely by undergraduates, and publishing only undergraduate science research. JYI is committed to filling a major gap in undergraduate science education: peer review and publication.

Today, students have abundant opportunities to conduct scientific research; however, they have precious few opportunities to communicate that research to their peers in the scientific community. JYI and other undergraduate journals grant students the chance to communicate their research, improve their technical and scientific writing, and learn about this final and critical piece of the scientific process.



However, JYI goes one step further than other undergraduate journals. At JYI, undergraduates direct, manage, and participate in every step of the publication process. Undergraduates write the research papers, staff the editorial positions, review the manuscripts, produce the general-audience articles, direct the publications, formulate the business plans, write the grants, issue the press releases, and direct every other part of the entire corporation, working with fellow students as close as their home university and as far as the other side of the world. As a result, JYI staff members learn—not only how to write and review scientific manuscripts—but how a scientific journal works . . . and how to *make* one work!

Since undergraduates do not have all the scientific knowledge necessary to review manuscripts, JYI employs professional scientists who work with JYI Associate Editors to review Research manuscripts. These advisors play a crucial role in JYI, both by improving the quality of reviews and in guiding JYI's Associate Editors.

JYI is always hiring. Any undergraduate, from any university or country, may apply. For information on what positions are currently available, please visit www.jyi.org.

Part I: Publication & Peer Review

When you are embroiled in publishing a paper, it can seem like the process is complicated, difficult, and drawn-out. But the basics of any publication process are the same: decide to publish, write, submit, wait, revise, publish.

Deciding to Publish

No scientist publishes the results of every single study she does. Some studies just aren't worth it. As an undergraduate, you will rely on your mentor to help you decide when is the right time to publish. Usually, you'll only publish when you have something important to say: an interesting new result or conclusion to report to the community.

Once you've decided to publish, you need to choose your forum. Some studies really only warrant an abstract at a conference or a brief note to a journal. Some studies warrant full-out reports. Again, as an undergraduate, you'll work with your advisor to decide what forum is best for your particular study.

If you decide to publish in a journal, the next question is: which journal? Undergraduates rarely participate in writing reports for top-tier journals like *Science,* or even field-specific top-tier journals like the *Journal of Geophysical Review*. Most undergraduates publish in small, highly specialized journals. Again, you'll work with your advisor to decide which journal is the right one for your work.

(**Shameless plug**: all undergraduates, from any university or country, are welcome to submit their research to the *Journal of Young Investigators*. At JYI, the undergraduate is the lead author and works with the editors and reviewers through every stage of the publication process. When publishing in most journals, the undergraduate rarely gets a chance to participate in every level of publication. End of plug.)

Submitting Your Paper

Once you've decided upon the journal, visit its website and thumb through old issues to get a sense for its style and formatting. Usually, journals have special pages for authors describing exactly what their submission policies are. Follow those guidelines.

After Submission

Every journal deals with submission slightly differently, but they all follow the same general format:

1. Author submits manuscript and figures to journal

2. Journal assigns the manuscript to an editor

3. Editor modifies to manuscript to remove any identifying information, then sends it to several reviewers. Usually, the editor will send it to two or more reviewers; however, some journals send their manuscripts to an entire review board that reviews the papers together.

4. Some journals allow reviewers to accept or decline a review. Reviewers can take months to decide if they will take on a review.

5. Reviewers review the paper. Usually, reviewers work alone, and they don't know who the other reviewers are. They can take a long time reviewing the manuscripts, since they must be very thorough – and are usually very busy themselves.

6. Reviewers return reviews, comments, and a recommendation to the editor. Usually, the recommendation is something like: Accept, Accept With Revisions, or Reject. The editor reads the reviews, considers the recommendations (and the reasons behind those recommendations), and decides whether or not to accept the paper.

7. If the paper is accepted, the editor will send the reviews and comments to the author, usually asking for a revised edition of the paper.

8. The author revises the paper, and sends it back to the editor.

9. If the editor thinks the paper needs a second review, he/she may send it out for another round. Otherwise, he/she sends it off to be published.

10. Publication. The whole process might have taken 6 months to a year!

Overview of Peer Review

Every year, hundreds of thousands of scientists conduct experiments, obtain results, and draw conclusions. Most – if not all – of these conclusions contradict conclusions drawn by other scientists. Which of these experiments are "good" science and which are poor? How do we even begin to evaluate them all?

The scientific community relies on a process called peer review, or "refereeing", to decide which work is worthy of the community's attention. Peer review is exactly what it sounds like – researchers submit their work to a group of their peers, usually well-respected and accomplished scientists who can be trusted to judge what is "good" science and what is not. The group delivers a verdict, usually along with substantial comments and recommendations.

The scientific community uses peer review in just about every facet of its work. Committees of scientists peer review grant proposals before allocating funding. Groups of faculty and doctors review their colleague's work when considering them for tenure. And, most famously, scientists review each other's research reports before publication.

This guide will focus on peer review and publication.

Purpose of Peer Review

In the scientific community, peer review serves two major purposes:

- **To filter what is published as "science".** The most obvious purpose of peer review is to determine which papers report "good" science that a journal can be proud to publish. No journal wants to publish unimportant, poorly executed, flawed studies – and no scientist wants to read them.

- **To provide researchers with perspective.** Even the most gifted researchers can't catch all the flaws in a study. One function of peer review is to allow a researcher's colleagues to comment on the quality of her work before it is published.

How It Works

An author writes a manuscript reporting his/her study (see Part II), and submits it to a scientific journal. The manuscript is assigned to an editor to see it through the peer review process, and the editor sends the manuscript (with names removed) to several referees who will do the review. At most journals (including JYI), these referees are called associate editors.

The referees review the manuscript, critiquing it and making comments, then return their reviews to the editor. They also return recommendations for publication: should our journal publish this paper? Usually, the recommendations are along the lines of: 1) Accept unconditionally, 2) Accept after the author has made some revisions, 3) Reject but ask the author to resubmit a revised version for additional review, or 4) Reject outright.

The editor compiles the referees' comments and sends them to the author, anonymously.

One of the key features of this system is that it is anonymous. The referees do not know who the author is and the author does not know who the referees are. The referees do not act as a group, and no referee knows who the other referees will be or what they will say. This design is to encourage candid feedback that is not influenced by anything but the work itself.

Some journals are changing this system slightly, and informing the author of the referee's identities. This is to establish some degree of accountability for the referees. JYI does not reveal the identities of our reviewers.

The Role of Editor

The editor is the intermediary in the peer review process, but also the ultimate judge. Referees make recommendations to the editor; however, the editor is under no obligation to take their advice. When referees disagree on whether a manuscript should be published, the editor can send the manuscript out for additional review, or can decide then and there. The editor alone decides which manuscripts are published and which are not.

The referee's job, then, is not only to offer constructive criticism for the author, but also to guide the editor to making the right decision about a manuscript. A referee must substantiate his/her recommendations and provide enough reasoning and evidence for the editor.

Limitations and Issues

"Editors and scientists portray peer review as a quasi-sacred process that helps to make science our most objective truth teller. But we know that the system of peer review is biased, unjust, unaccountable, incomplete, easily fixed, often insulting, usually ignorant, occasionally foolish, and frequently wrong."

-- Richard Horton, editor of The Lancet*,*
a prominent British peer-reviewed
science journal

The peer review system is far from perfect. Within the scientific community, it is denounced more often than praised – but, as with democracy, it beat the alternative.

Some of the most common complaints about the peer review process are:

- **It's slow.** Getting a paper peer reviewed can take months – sometimes even years. It takes a long time to write the paper, to submit it, for the referees to review it, for the editor to decide, for the author to make the revisions, for it to be re-reviewed and re-revised . . .

- **Conflicting views.** Say an author sends out a paper that opposes a certain theory, and the paper is reviewed by an advocate of that theory. It might be very good science, and the referee might have very good objections, but it is outside of the scope of the journal to decide which is right. The editor is then in a difficult situation, trying to decide whether this is "good" science or not.

This happens quite often, especially when editors bring their personal views of science to bear on publication decisions.

- **Personal views.** Some people argue, perhaps legitimately, that the peer review process is far too open to personal issues – jealousy, vendettas, grudges, pet theories. Referees can be particularly critical of conclusions or assumptions that contradict their own views of a subject. An editor must be very careful in judging which opinions are based on objective evaluation and which may be based on personal views unrelated to science.

- **Fraud.** Editors and referees assume that a paper is honestly written – that is, that none of the results have been faked or evidence manipulated. When scientific fraud has occurred, peer review often does not catch it. One of the most famous cases of scientific fraud that went undetected by peer review was the Schon scandel of 2001-2002. Jan Hendrik Schon was a German physicist working at Bell Labs, who published 15 papers in *Science* and *Nature* – both top-tier journals with rigorous peer review. The 15 papers reported work he had done producing a transistor on the molecular scale – truly revolutionary science - however, he had falsified results for all 15. The papers were subsequently withdrawn after independent groups discovered the fraud.

It's important to remember that a paper accepted in peer review can still be poorly written, poorly researched, and just plain wrong. Some of the most influential manuscripts of the 20^{th} century were never peer reviewed, including Watson and Crick's famous 1951 paper that announced the discovery of DNA.

That said, you still have to know how to research and write well.

Part II: Writing a Scientific Manuscript

The Scientific Manuscript

This is a basic overview of a scientific manuscript. In the sections to follow, we will break down each section in detail.

Structure of an Article

The structure of a research article usually depends on the journal to which the article is being submitted. Many journals have page limits, figure limits, or specific article divisions to which authors must adhere. **Before you begin writing, check the journal you will submit to for formatting instructions.**

JYI has few restrictions; however, there are a set of basic guidelines which any JYI research article must follow. These are the basic structure guidelines that most journals have:

Abstract
Just about every journal out there requires an abstract. An abstract is a **single** paragraph of about 500 words or less. In the abstract, the author must summarize *why* the research was conducted, *how* it was conducted, and what the major results and conclusions were. References are typically not cited in the Abstract, since the reader expects a more full discussion in the body of the article.

Introduction
Every scientific report needs an introduction, though it is sometimes broken down into different components. The length of an introduction depends on the journal and the paper; however, the structure and content should be similar. In the introduction, the author must present the problem his or her research will address, why this problem is significant, and how it applies to the larger field of research. The author must clearly state his or her hypothesis, and quickly summarize the methods used to investigate that hypothesis. The author should address relevant studies by other researchers; however, a full history of the topic is not needed.

The introduction should contain all the background information a reader needs to understand the rest of the author's paper. This means that all important concepts should be explained and all important terms defined. The author needs to know who will be reading this paper, and make sure that all the concepts in the paper are accessible to them.

JYI caters to an audience of professionals *and* undergraduates. In a paper submitted to JYI, background information should be extensive enough for an undergraduate science major to understand, but not so detailed as to bog down a professional reader. For example, an author need not define an "electron"; however, a "Cooper paired electron" does require a definition.

Body of Article

After the introduction, articles may vary in their structure. Some authors will find it best to progress directly into a “Methods and Materials” section; however, others may find a different breakdown more appropriate. At JYI, the structure of the body of the article is left to the author’s discretion. However, you should always check with the particular journal you will be submitting to before writing the body of the article.

Whichever journal you’re submitting to, several key points do need to be addressed in the body of the article. You should thoroughly describe the methods you used to investigate the problem, and should briefly describe why these methods were used. Any materials used should be documented, and any computer programs used should be discussed.

The body of the article should address the experiments, models, or theories devised. It should contain little to no background information, since this information should be placed in the introduction. Also, the body of the article should contain no results, conclusions, or interpretations.

Results

Most journals – including JYI - require a results section. In this section, the author should thoroughly detail the results of the experiments, models, or theories developed in the body of the article. The results should be supplemented by figures and tables, and the figures and tables should be briefly explained. *No interpretations or conclusions should be drawn*. All interpretation and discussion of the results should be saved for the Discussion and Conclusions section.

Discussion and Conclusions

Most journals – including JYI – require a discussion and/or conclusions section. In some cases, when the author has many points to discuss, he or she may split this into two sections; however, one section is usually sufficient.

In this section, the author should restate the problem he or she was attempting to address, and summarize how the results have addressed it. The author should discuss the significance of all the results, and interpret their meaning. Potential sources of error should be discussed, and anomalies analyzed. Finally, the author should tie his or her conclusions into the “big picture” by suggesting the impact and applications this research might have. This can be accomplished by discussing how the results of this paper will affect the author’s field, what future experiments could be carried out based on this research, or what affect the conclusions could have on industry.

Acknowledgments

An acknowledgements section is not usually required; however, most papers include a paragraph of acknowledgements and thanks for help received on the research or the paper. In journals where the reviewer’s names are revealed, it is considered polite for the author to acknowledge the help of the reviewers.

References

Every article must have references – usually many. References should come primarily from papers published in professional journals. A small number of abstracts or textbook-type references may be permitted; however, these should not make up the bulk of an author's references. Personal communication references are permitted, but, again should be kept to a minimum.

Figures and Tables

Most articles include tables and figures. These should be of high image quality, with minimal pixelization. All figures and tables should be referenced within the text of the article, usually in the results section. The figures and tables should be thoroughly described within the text, and their meaning discussed within the discussion section.

Writing Style

The basic rules of writing apply to any paper; however, they are especially important to a professional document being submitted for publication. Before submitting a paper to a journal, make sure that it:

♦ Contains no misspellings.

♦ Is grammatically correct.

♦ Meets the formatting guidelines of the journal

♦ Avoids the first person.

♦ Does not contain personal anecdotes or stories

♦ Is not trying to be clever—research manuscripts are no place for story telling, only reporting of facts

Audience

Every journal addresses a specific audience, and an author must write his or her paper with that audience in mind. For example, JYI addresses an audience of professional scientists working in various fields, as well as undergraduate science majors. This means that every research article published by JYI must be accessible to both professionals and undergraduates. For example, a physics-related paper should be accessible to anyone working in the field of physics, whether an undergraduate, graduate student, or professional.

Before submitting a paper to a journal, the author should think about which concepts need to be defined and described for that particular audience.

A Note on Scientific Misconduct

Scientific misconduct is grounds to reject a manuscript. Misconduct can range from inappropriate treatment of test subjects to outright fraud.

Types of misconduct include:

- **Gift Authorship:** This is when a researcher who had nothing to do with the research is listed as a co-author. Every author on a paper must have been involved with the research.

- **Redundant publication:** Authors cannot publish the same material in different places. A new paper may discuss the ideas and results of a previous paper, but every paper must contain new information, interpretations, or results. (This is not true for abstracts – a scientist *may* submit an abstract for a conference, then publish that information in a scientific journal. Redundant publication refers only to peer-reviewed publications).

Types of fraud:

- **Plagiarism:** Copying data, ideas, or work by other authors, without giving them credit. Discussing another researcher's idea is not plagiarism, unless the author tries to pass it off as his/her own idea. Again, it is difficult for referees to catch plagiarism, unless they know what they are looking for.

- **Fabrication:** Inventing or faking results. It is almost impossible for peer review to catch this kind of fraud. It is usually discovered when other researchers try to reproduce the author's results. Fabrication of results is never done innocently, and it leaves a permanent mark on the scientists' career – if it doesn't destroy it completely.

- **Falsification:** "Tweaking" or manipulating results. It is difficult for reviewers to catch this kind of fraud, and it is usually tough for other researchers too.

- **Conflict of interest:** If an author stands to make a significant financial profit from the results of a study – *and does not state that explicitly* – this constitutes a type of fraud. For example, if an author who owns stock in a pharmaceuticals company publishes a study indicating that a new drug by that company is simply fantastic, he *must* indicate that he owns stock in the company. Though seldom an issue for undergrads, you should still know about it.

Word Choice

We can hear what you're thinking: a whole section on word choice?

Yes, that's right, a whole section on word choice. It's that important.

Verbs are important for science, and undergraduates (and a lot of professionals!) often mix them up. For example, what is the difference between "examine" and "analyze"? In the first, the author is describing an activity to gain knowledge, in the second, the author is describing the analysis of that knowledge. One examines a scene to find facts – then analyzes those facts to draw conclusions.

This is particularly important when stating the thesis or hypothesis of a paper. Is the purpose of the paper to "examine" the relationship between two variables or to "analyze" it? Those are two fundamentally different activities. Word choice is not the difference between an acceptable and a unacceptable paper – but it can be the difference between a good and a great paper.

Below, we outline something known as the Bloom's Taxonomy, which categorizes actions and abstractions particularly relevant to discussing science. Bloom's Taxonomy has several levels: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation.

Knowledge: This is pure recitation of fact. Words that indicate knowledge include: define, describe, identify, know, label, list, match, outline, recall, recognize, state, tell, locate, find.

In a scientific manuscript, these words might be used appropriately in the following ways:

> This study **found** that strawberries are red.
>
> Researchers have **identified** green strawberries in Portugal.
>
> Smith et al. (1999) **labeled** these strawberries G-Berries.

These are usually inappropriate words to use when analyzing anything. For example, an author should not write: "The purpose of this experiment is to look at these green strawberries." That's 4th-grade book-report material. The purpose of a scientific experiment must be to analyze, draw conclusions, or evaluate.

These words should be used most often in the Methods & Materials section and Results section.

Comprehension: These are words to describe meaning, interpolation, or state a problem. For example: Comprehend, explain, interpret, outline, discuss, distinguish, predict, restate, translate, compare, describe.

These words are used to interpret facts, infer causes, and give examples. They should be used in the Introduction and Discussion sections, but probably not in the Methods & Materials and Results sections.

Application: These are used to apply concepts to other situations or ideas. For example: solve, show, use, illustrate, construct, examine, classify.

These words should be used when applying old information to solve new problems. They should be used in the Introduction and Discussion sections. They should not be used in the Methods & Materials section or the Results section.

Analysis: The separation of material into components so the material's organization can be understood. For example: analyze, distinguish, examine, compare, contrast, investigate, categorize, identify, explain, separate.

These words should be used when explaining patterns and meaning. They should be used in the Discussion section.

Synthesis: The building of a structure or pattern from different parts. For example: create, invent, compose, predict, plan, construct, design, propose, devise, formulate.

These words should be used when discussing possibilities, making predictions, and drawing conclusions. In research articles, they should show up in the Introduction and Discussion sections. In literature reviews, they should show up any time the author begins to argue a point or apply his/her thesis to evidence.

Evaluation: Make judgments about the value of ideas or material. For example: evaluate, judge, select, decide, justify, debate, verify, argue, recommend, assess, rate, determine.

These words should be used when making recommendations, drawing conclusions, assessing values, or critiquing ideas. In research articles, they should show up in the Introduction and Discussion sections. In literature reviews, they should show up any time the author begins to argue a point or apply his/her thesis to evidence.

The Abstract

What is an Abstract

An Abstract summarizes the major aspects of a paper. It is usually one paragraph long, and should succinctly summarize the purpose of the paper, the methods used, the major results, and the author's interpretations and conclusions.

Readers use the Abstract to decide whether they want to read the rest of a paper. It must contain enough information for them to understand the work, and for them to decide whether it applies to their project or not.

Usually, an Abstract is 200 - 300 words, and should follow this format:

Idea 1: The problem to be investigated. This should be 1-2 sentences that sum up why this study was conducted.

For example: "Several studies have suggested that rampart craters on Mars form in regions with high soil volatile contents - namely, water ice."

Idea 2: The purpose of the study. This should be 1 - 2 sentences that explicitly state what this study investigated and how it differs from similar studies.

For example: "This study is the first to use data from Mars Odyssey's Gamma Ray Spectrometer to correlate the distributions of water ice and rampart impact craters on Mars. We hypothesized that if rampart craters form due to high volatile content in the soil, then regions with more sub-surface water should show a higher percentage of rampart impact craters."

Idea 3: The methods. This should be 1 - 2 sentences that summarize the important methods used to investigate the problem.

For example: "We plotted the distribution of rampart impact craters on Mars and the water ice concentrations obtained by the Mars Odyssey's Gamma Ray Spectrometer, then used statistical tests to determine if there was a correlation."

Idea 4: The major results. This should be 1 - 2 sentences that summarize the major results - not *all* of the results - just the important ones.

For example: "We found that regions with high sub-surface water ice concentrations had a higher percentage of rampart impact craters than regions with low sub-surface water ice concentrations. For example, 87% of impact craters in Acidalia Planitia, a very water rich area, were designated rampart craters; however, only 23% of craters in water-poor Syrtis Major were designated rampart."

Idea 5: The interpretations. This should be 1 - 2 sentences that summarize the author's interpretations of the results.

For example: "These results lend support to the idea that the fluidized ejecta morphology that characterizes rampart craters is caused by a high water ice concentration in the sub-surface."

Idea 6: The implications. This should be 1 sentence that summarizes the meaning of these interpretations, i.e., why do we care about this.

For example: "Understanding the factors that influence crater formation and morphology will allow us to better age-date the Martian surface, and mapping the distribution of ancient rampart craters may help us estimate sub-surface volatile concentrations from the Martian past."

In this example, the resulting Abstract is about 230 words:

"Several studies have suggested that rampart craters on Mars form in regions with high soil volatile contents - namely, water ice. This study is the first to use data from Mars Odyssey's Gamma Ray Spectrometer to correlate the distributions of water ice and rampart impact craters on Mars. We hypothesized that if rampart craters form due to high volatile content in the soil, then regions with more sub-surface water should show a higher percentage of rampart impact craters. We plotted the distribution of rampart impact craters on Mars and the water ice concentrations obtained by the Mars Odyssey's Gamma Ray Spectrometer, then used statistical tests to determine if there was a correlation. We found that regions with high sub-surface water ice concentrations had a higher percentage of rampart impact craters than regions with low sub-surface water ice concentrations. For example, 87% of impact craters in Acidalia Planitia, a very water rich area, were designated rampart craters; however, only 23% of craters in water-poor Syrtis Major were designated rampart. These results lend support to the idea that the fluidized ejecta morphology that characterizes rampart craters is caused by a high water ice concentration in the sub-surface. Understanding the factors that influence crater formation and morphology will allow us to better age-date the Martian surface, and mapping the distribution of ancient rampart craters may help us estimate sub-surface volatile concentrations from the Martian past."

In Abstracts, bluntness is best. Phrases like "In this study, we examined…", "We hypothesized…", or "We found…" are not poetic, but they are clear and succinct. The reader should be left with no doubt about what the purpose of the study was, what methods were used, what the major results were, and why those results are important. The rest of the paper will fill in the details.

The Abstract should NOT contain:

- Lengthy background information - that belongs in the Introduction

- Lengthy methods discussion - that belongs in the Methods section

- References to other literature

- Abbreviations or acronyms

- Figures, images, or references to them

Abstract Standards for Review

At JYI, we use the following criteria to judge Abstracts. Different journals use different standards, but these cover the basics:

Content:

___ Author states *why* the research was conducted

___ Author states *how* the research was conducted

___ Author states what the major *results* were

___ Author states what his/her *conclusions* were

Structure

___ The Abstract Follows the “Problem - Purpose of This Study - Method - Results - Conclusions” Structure

Abstract Section Overall:

___ Succinct: not verbose

___ Clear: easy to read and understand

___ Balanced: all the major topics are covered

___ Focused: no superfluous information is included

Common Mistakes in an Abstract

For such a short section, the Abstract is easy to get wrong. At JYI, we see undergraduates make the same mistakes over and over again. Here are some of the major ones to watch out for in your own writing:

1. **No Abstract.** Every paper needs an abstract. Your is no exception!

2. Abstract Really an Introduction. An Abstract is not an Introduction - it is a summary of the *whole* paper. Often, authors will write an Abstract that is ten sentences of background information, with no reference to the results or conclusions of the study. Don't panic about including enough background – if a reader wants details, she goes to your introduction.

3. Missing Information. Authors frequently forget to include information like: What was the purpose of this study? What were the methods used? What were the major results? What do these results mean? Be sure than your Abstract answers all those questions.

4. Too Much Information. Some authors include way too much information on the background, the problem, the methods, or the implications of a study. Usually, 1 - 2 sentences for each of the major sections (Introduction - Methods - Results - Conclusions) is enough. The Abstract should be short, snappy, and succinct. When readers want details, they'll read the actual paper.

The Introduction

What is an Introduction

An Introduction must provide the reader with all the information he/she will need to understand the rest of the paper. The author must summarize the problem to be addressed, give background on the subject, discuss previous research done on the topic, and explain in no uncertain terms exactly what this paper will address, why, and how.

An Introduction is usually 300 to 500 words, but may be more, depending on the journal and the topic. Some Introductions (especially for psychology papers) are several pages long. They usually follow this general format:

Idea 1: The broad topic: problem and background. The author should take an entire paragraph to state the problem to be investigated, and to give background on that problem. At then end of the first paragraph, the reader should know the broad topic that this paper will address. Later paragraphs will fill in the specifics.

For example: "Over the past decade, there has been heightened interest in the availability of mineral resources and in how quickly the world's expanding population is depleting these reserves. As worldwide consumption and usage of materials increases (Wagner LA 2002), the question arises as to whether adequate supplies of metals such as copper, silver, and zinc exist to satisfy the rising demand. The Stocks and Flows Project (STAF) at Yale University's Center for Industrial Ecology seeks to track the current and historical reservoirs of technologically significant materials, together with the flows into and out of these reservoirs, through substance flow analysis (SFA) and life cycle assessment (LCA) as defined in Table 1. With these tools of industrial ecology, the environmental impacts and policy implications of world metal production and usage can be examined on national, regional, and global scales."

This paragraph gives the reader:

1. The broad topic: World-wide depletion of mineral resources
2. The problem: Do we have enough copper, silver, and zinc?
3. The background: STAF is tracking this problem using SFA and LCA

Idea 2: Narrower topic: background and problem. Next, the author should zero in on the specific problem his/her paper will address. This should be done as bluntly as possible, i.e.: "This study examines . . ." or "This paper focuses on . . ."

For example: "This paper characterizes the anthropogenic life cycle of silver for 1998 in the Commonwealth of Independent States (CIS) of Central Asia, one of nine world regions designated by the STAF group."

In the next several paragraphs, the author should discuss this narrowed topic and must include the following:

> _ **Clear Statement of Hypothesis**. This is the "If-Then" statement that underlies the author's whole study. **If** rampart craters on Mars form because of groundwater **then** we should see a correlation between groundwater and rampart crater distributions.
>
> Most authors forget this. The author need not write "We hypothesized that…". The hypothesis can be something as simple as an If-Then statement of what they were looking for.
>
> For example: "Previous studies have suggested that the lobate ejecta blankets that characterize rampart craters form because of groundwater or ice in the subsurface. If this is true, then areas with more groundwater or ice should have more rampart impact craters and areas with no groundwater or ice should have no ramparts."
>
> _ **Previous Research**. The author should summarize the results and findings of other studies in this area. What research has been done on this topic? How will this study differ? What other studies on similar topics might influence this study?
>
> The author should provide enough discussion on previous research for the reader to understand the bigger picture, but not too much. This is not a review paper - the author should only discuss those papers that truly are relevant to his/her study. Depending on the topic, the discussion of previous research might run for two paragraphs or two pages.

_ **Explanation of Concepts**. In different journals, this means different things. For example, in a journal that specializes in gene therapy research, an author need not explain basic theories.

The *Journal of Young Investigators* caters to an audience of undergraduate science majors. Authors are expected to explain all concepts that an average undergraduate science major would not be familiar with. For example, the author need not explain how impact craters form, but should explain how multi-ringed impact basins form.

Idea 3: Motivation for Research. The final paragraph of the Introduction should be a summary of "Why should we care?" Why is the research important? Why is this problem important? How will answering this problem advance research in this area, in industry, in policy, or in people's lives?

Introduction Standards for Review

At JYI, we use the following criteria to judge Introductions. Different journals use different standards, but these cover the basics:

Background Information:

___ Enough Information: a non-specialist undergrad could understand this paper

___ Relevant Information: all of the information *needs* to be there

Previous Studies Described:

___ Enough Information: an interested reader could use this as a starting point

___ Relevant Information: all the previous studies are actually relevant to this one

Statement of Problem:

___ Clearly Stated: there is no doubt in the reader's mind of what this paper will study

Motivation for Research:

___ Clearly Stated: there is no doubt in the reader's mind of why this was done

Significance of Research:

___ Clearly Stated: there is no doubt in the reader's mind of why we care

Hypothesis:

___ Clearly Stated: the reader understands the logic behind the author's study

Structure:

___ The Introduction Follows the General Structure: "Broad Topic - Narrow Topic - Hypothesis - Purpose of This Study - Implications/Impact"

Introduction Section Overall:

___ Succinct: not verbose

___ Clear: easy to read and understand

___ Balanced: all the major topics are covered

___ Focused: no superfluous information is included

Common Mistakes in an Introduction

1. Too Much Information. Authors sometimes include far too much information in their Introductions. Only information related to the subject should be included.

For example, this is far too much information: "Benjamin P. Danielson (1954) first described the morphology of multi-ring impact basins on the Moon. He characterized them as large impact basins with multiple terraced levels, central rings, central peaks, and abundant secondary craters. Since then, multi-ring impact basins have been identified on Earth, Mercury, Venus, Mars, and many of the outer satellites."

This whole section could be reduced to: "Danielson (1954) defined multi-ring impact basins as having multiple terraced levels, central rings, central peaks, and abundant secondary craters."

2. Not Enough Information. Another common mistake authors make is to assume that their audience knows more than they do. Authors often do not explain concepts, do not provide enough background information, or do not discuss enough previous studies.

Reading a paper where the author assumes you know thing you don't is incredibly frustrating and pointless. Don't make your readers struggle to understand your paper – make yourself clear.

This is a difficult balance to strike, between superfluous explanations and not enough information. Think carefully about your audience and discuss with your advisor what should be included and what left out. The reviewers will help with this too, providing an outsider perspective.

3. Unclear What Study Is. Often, authors will build a thorough Introduction, but it is unclear what the rest of their paper will cover. The author needs to **bluntly** state what this paper will cover, how, and why. Phrases like "This study examines…" or "In this study…" are valuable.

4. Lists. A common temptation in Introductions is to list material, either in paragraph or bullet format. Sometimes this is unavoidable. Usually it is not. Try to avoid lists and describe your study in prose instead.

5. Confusing Structure. Authors often throw all sorts of information into an Introduction without thinking thru the organization. The result is a confusing read.

Remember to follow the structure outlined above: Big problem – my portion of that big problem – hypothesis (logic underlying my study) – description of my study – why the reader should care about this study.

6. First-Person Anecdotes. Undergraduates sometimes confuse a scientific manuscript with *My Wild Adventures in the Lab*. They might try to open an Introduction with an amusing story to "draw the reader in", thinking that this is an essay for an English class. First-person reporting does not belong in a research manuscript. The author shouldn't even say "I found…" but "It was found…". It's a passive voice, but a standard one for reporting research.

The Methods & Materials Section

What is a Methods & Materials Section

Though papers may vary in the structure in the middle, the standard body of a research manuscript is a Methods & Materials section. Every paper submitted to JYI must have a Methods & Materials section.

The purpose of the section is to make it possible for interested readers to **repeat** the author's experiment and reproduce his/her results. The author must describe, in painful detail, exactly what he/she did: what experiments were run and how they were run, what equipment and materials were used and how they were used, how much, how often, what, where, when, and why.

Some of the information the section must include is:

- Subjects used (animals, plants, humans) and their pre-experiment handling and care (anything that might affect the results must be included)
- Sample preparation techniques
- Origins of samples and materials (e.g., "Twenty-one 18-year-old students from the Psychology 101 class at the University of San Diego in California")
- Description of the field site (if applicable) including physical and biological features, and exact location (include a map, if applicable)
- Protocol for collecting data - how were the procedures carried out?
- Statistical analysis techniques used. If used (for example, in ANOVA tests), the author must report the threshold used to determine statistical significance.
- Information on computer programs used or written (for some computer science or physics articles, the author should include the relevant codes in the appendix)
- Descriptions of equipment set-up and function

If parts of the experiment have been described elsewhere, then the author may reference it. For example: "Samples were prepared using the same process as described by Newton et al. (2000)." Otherwise, the author must describe each piece of the experiment.

The author should use the third person, passive construction throughout, and always use the past tense. For example: "The sample was heated to 90 degrees C for 30 seconds." - NOT: "I heat the sample to 90 degrees C for 30 seconds."

A Note on Details

Hitting just the right level of detail is difficult in these sections. An author must provide enough detail for a reader to be able to reconstruct his/her study, but not so much that the relevant points get buried. When reading your M&M section, ask yourself at each place: "Would I need to know this to reproduce this experiment?" If the detail is not needed, remove it.

For example, this is too much detail: "We poured the Pepsi into a graduated cylinder until the bottom of the meniscus was at the 45 ml line. We poured the Pepsi onto the top of the algar sample, then repeated the procedure 55 times." You're not writing for middle schoolers – another scientist will know how to add 45 ml of Pepsi to a sample. So, you can reduced this to: "We added 45 ml of the Pepsi to each of the 55 samples."

Methods & Materials Section Review Standards

At JYI, we use the following criteria to judge M&Ms. Different journals use different standards, but these cover the basics.

Materials:

___ Enough Detail: all relevant materials used are listed

___ Relevant Information: the materials listed are actually relevant

Methods:

___ Enough Detail: all relevant methods used are listed

___ Relevant Information: the methods listed are actually relevant

Controls:

___ Appropriate Positive Controls Were Used

___ Appropriate Negative Controls Were Used

Experimental Approach:

___ Adequate and Appropriate Tests of Hypothesis

Materials & Methods Section Overall:

___ Succinct: not verbose

___ Clear: easy to read and understand

___ Balanced: all the major topics are covered

___ Focused: no superfluous information is included

Common Mistakes in a Methods & Materials Section

1. Not Enough Information. Oddly, few people include *too much* information - nearly every author includes *too little*.

For example, this is too little information to reproduce a study: "We mosaicked images from the THEMIS instrument."

This should be expanded to: "Using USGS Integrated Software for Imagers and Spectrometers (ISIS), we mosaicked day-time thermal inertia images from the Thermal Emission Imaging Spectrometer (THEMIS) on board Mars Odyssey. The images covered the region 7˚N to 34˚N and 209˚E to 236˚E around the Olympus Mons volcano on Mars, and had a resolution of 100 meters-per-pixel. THEMIS images from October 2002 to July 2004 data releases were used. The max/min light/dark ratios were stretched manually to match individual images."

2. Background/Introduction Material Included. Sometimes an author will include background material or explanations of concepts in the Methods & Materials section. That material belongs in the Introduction. In this section, the author should make no references to outside work, unless referencing a method or material.

For example, this is ok: "Samples were prepared using the method described by Newton et al. (2000)" - but this is not: "This theory was first proposed by Newton et al. (2000)."

3. Verbose Descriptions. In the case of experimental setups, a diagram is worth a thousand words. Some authors - especially in chemistry or physics papers - describe elaborate lab setups with run-on sentences like:

"Main blue-cord A was then connected via 0.25-inch screws to the third quarter-inch mark of lead pipe B, which was taped to wooden crate C with 0.5-inch-wide gray duct tape and . . ." The mind goes blank. Spare your readers. Include a diagram.

4. Results Reported. Sometimes, authors get so carried away describing their experiments that they report results in this section.

For example: "The samples were soaked in linseed oil for 4 hours, turning purple and developing a distinct smell of cabbage." The information about color and smell here should not be included in the Methods & Materials section, but in the Results section.

5. Sources of Error Discussed. Discussion materials do not belong in the Methods & Materials section. The author should not discuss sources of error or possible causes for results - in fact, the author should not discuss results at all.

For example, this kind of sentence does not belong in the Methods & Materials section: "During image stretching, some resolution was lost, possibly interfering with counts of craters less than 5 km in diameter." This should be rephrased to: "During image stretching, some resolution was lost." The interpretation of how this might affect results should be saved for the Discussion section.

The Results Section

What is a Results Section?

With very few exceptions, every journal requires a Results section. **It *cannot* be combined with the Discussion section.**

The purpose of a Results section is to present the *key* results of the experiment without interpreting their meaning. The trick is knowing what to include. The author should **not** include the raw data, but should **summarize** it with text and tables. The author should avoid writing out long lists of numbers - numbers and measurements should all be tabulated.

For example: "Regional age-dating with crater counts from ejecta blanket degradation approximated ages from regular crater counts (Table 1)." The ages for each region from both methods would then appear in Table 1.

The author should state the results of statistical analyses in this section, but should not describe every detail of the analysis. We assume our readers know what a null hypothesis is, a rejection rule, chi-square test, etc.

Important negative results should be reported too - though not interpreted.

Results Section Review Standards

At JYI, we use the following criteria to judge Result sections. Different journals use different standards, but these cover the basics:

Results Exposition:

___ Sufficient Detail: enough to understand the key results of the study

___ Appropriate Detail: no superfluous information

___ Appropriate Presentation: numbers and results are tabulated, not listed

Experimentation/Number of Trials:

___ Sufficient to Test the Hypothesis

Statistical Tests:

___ Performed when Appropriate

Data:

___ Believable: probably not an artifact of poor experimental setup

Results Section Overall:

___ Succinct: not verbose

___ Clear: easy to read and understand

___ Balanced: all the major topics are covered

___ Focused: no superfluous information is included

Common Mistakes in a Results Section

1. Raw Data. Occasionally an author will for some reason include all his/her raw data. This is not just unnecessary - it's mind-numbing. The author should present only the key results, meaning those results that bear on the question or problem being addressed. Generally this means presenting means, percentages, standard deviations, etc.

2. Redundancy. Authors will often present their results in a table, then re-state everything in the text. This is redundant. Text should be used to clarify figures and tables - not rehash them.

3. Discussion and Interpretation. Authors **frequently** combine the Results and Discussion sections or include interpretation in the Results section. Some journals (a very, very few) permit this. JYI does not.

Author cannot include interpretation or discussion in the results section. This includes discussion of possible sources or causes of error.

4. No Figures or Tables. Every Results section should have at least one table. No matter what discipline the author is writing in, he/she should have data to present. A notable exception is some mathematics or computer science papers.

5. Methods/Materials Reported. Often, an author will write something like this is the Results section: "We found that sample A contained pyroxene, so we ground sample B to a powder and ran the experiment again. With sample B, we found pyroxene again." The information "so we ground sample B to a powder and ran the experiment again" is M&M material and does not belong in the Results section. The author must report only results in the Results section – no new methods or materials at all.

The Discussion Section

What is a Discussion Section?

Most journals require a Discussion or Conclusions section. Every paper submitted to JYI must have a Discussion section. It *cannot* be combined with the Results section.

The purpose of a Discussion section is to interpret the results, relating them to previous studies that the author and other authors have done.

The author should begin the Discussion section by re-stating the hypothesis he/she was testing. Then he/she may begin interpreting the results in light of this hypothesis. To interpret the results, the author should address the following questions:

1. Did the results provide answers to the (testable) hypotheses?

2. If so, what does this mean for the hypothesis?

3. If not, do the results suggest an alternative hypothesis? What is it? Why do the results suggest it? What further results might solidify this hypothesis? Have others proposed it before?

4. Do these results agree with what others have shown? If so, do other authors suggest an alternative explanation to explain the results? If not, how does this experiment differ from others? Is there a design flaw in this experiment? In others?

5. How do these results fit in with results from other studies? Do results from related studies affect the way these results are being interpreted?

In addition to simply interpreting the results, the author should discuss the following questions (though the order may vary):

1. What factors or sources of error might have influenced these results?

2. What anomalous data turned up and how can it be explained? Is it explained by the author's theory? Someone else's theory? Error?

3. Was this experiment the most effective way to test this hypothesis? (Obviously the author thought so at the beginning, but does he/she still think so?) How could the experiment be improved to gain further insight?

4. How have the results and conclusions of this study influenced our knowledge or understanding of the problem being examined?

5. What would be the next step in this study?

6. What experiments could be run (or data found) that would lend further support to the author's hypothesis? (Either the original hypothesis, or the new one designed to explain the results). What experiments could be run (or data found) that would disprove the author's hypothesis?

This section should synthesize the whole paper. The author should re-address the major issues he/she discussed in the Introduction, and re-interpret them in light of the results.

A Note on Good Writing

Rules of good writing apply to every section in a scientific paper, but are particularly important for the Discussion section. This is the section where the author draws together the entire paper and dishes out the take-home message. This is the most important part of the paper.

The author should carefully construct it, using topic sentences and watching out for wordy-ness.

Discussion Section Review Standards

At JYI, we use the following criteria to judge Discussion sections. Different journals use different standards, but these cover the basics:

Motivation for Study:

___ Clearly Restated

Interpretation of Results:

___ Sufficient Interpretation of Results: the author leaves to loose threads

___ Logical Interpretation of Results: the author draws justifiable conclusions

Possible Limitations and Sources of Error:

___ Adequate Discussion

___ Acceptable Errors: the sources of error do not lower confidence in the results

Ramifications:

___ Clear and Adequate Discussion

___ Realistic

Discussion Section Overall:

___ Succinct: not verbose

___ Clear: easy to read and understand

___ Balanced: all the major topics are covered

___ Focused: no superfluous information is included

Common Mistakes in a Discussion Section

1. Combined with Results. It's amazing how often authors combine the Results and Discussion sections, even though we specifically tell them not to. The Results and Discussion sections cannot be combined. They have two very different purposes. The Results section is for fact. The Discussion section is for interpretation.

2. New Results. Sometimes an author will include a new result in the Discussion section – one he/she did not report in the Results section. **All** results **must** be reported in the Results section. They can be restated in the Discussion section, but they must appear in the Results.

3. Broad Statements. Sometimes an author will draw sweeping conclusions based on his/her one tiny study. These are only appropriate even for major, ground-breaking papers – the kinds of papers that undergraduates rarely write. For example, it's unlikely that a paper examining valley networks in one small region of Mars is going to shed light on the evolution of the Martian climate through time or the fate of the liquid water that once ran on its surface. The study might provide new clues, but no sweeping, broad statements can be made.

4. The "Inconclusive" Cop-Out. Months of research and pages of words, all leading up to a: "The results are inconclusive." What a waste! Don't waste your reader's time with a statement of "it's inconclusive". The author needs to draw what conclusions he/she can, then suggest how the experiment should be changed to properly test the hypothesis.

5. Ambiguous Data Sources. Often, an author will get so wound up in his/her Discussion, that it's hard to tell when he/she is talking about the results of *this* study and when he/she is talking about the results of *other* studies. Don't let authors get away with that kind of ambiguity – *whose* study is being discussed is vital information.

6. Missing Information. Authors often leave out critical information from the Discussion section. For example, they might forget to re-state their hypothesis and motivation, might not tie their work into the larger field of research, might not compare their work to other's, might not discuss sources of error . . . in short, they might not answer all the questions outlined in the "What is a Discussion Section" above. Be sure to discuss everything.

Figures, Tables, Equations, and References

Figures & Tables

Terminology

A table presents lists of numbers or text in columns, and should be used to illustrate differences, but not to represent relationships.

A figure is any visual presentation of results or illustration of concepts/methods, including: graphs, images, diagrams of set-ups, drawings, maps, etc.

Sometimes authors get clever and label different figures Diagram 1, Illustration 2, Graph 3, Image 4, Map 5, etc. Some journals allow this. At JYI, we only use Tables and Figures.

Referencing Figures & Tables

At JYI, we ask authors to reference figures and tables like this:

"The results clearly indicate a positive trend (Figure 1)."

Authors should avoid sentences that only direct the reader to a figure or table. For example: "Figure 1 illustrates the positive trend."

All Figures and Tables are numbered sequentially: Figure 1, Figure 2, Figure 3, Table 1, Table 2, Table 3. The author should number them in the order they are called, so, for example, Figure 9 should never be referenced before Figure 1.

Good Figures and Tables

A Figure or Table should be able to stand alone, separate from the text of the article, and be understood. That means they **must**:

• **Be High Resolution.** Pixilated images, fuzzy graphs, and illegible tables are the bane of a good paper.

• **Have Neat, Legible Labels.** On graphs, each curve should be clearly and legibly labeled. On images, the relevant parts should be clearly and legibly labeled. On tables, the columns should be clearly and legibly labeled. There should be zero ambiguity about what the figure or table is illustrating.

• **Be Simple.** Figures and tables that cram too much information into a small space obscure their meanings and defeat their own purpose.

• **Be Clearly Formatted.** Tables should have lines clearly separating it from other pieces of the manuscript. Graphs should have appropriate axes, and images should have appropriate boxes.

• **Indicate Error.** All tables should have Standard Deviation information; all graphs should have error bars.

• **Have Detailed Captions.** This is the most important point, which brings us to our next section . . .

Captions

Captions are one of the most important elements of a good manuscript. Often, a reader will flip through a paper, read the captions, and decide if it is worth the read.

A caption should be clear and succinct, yet detailed. It should convey all the information needed for a reader to understand the figure, without reading the whole manuscript. For example, a good caption of a graph would tell the reader what the graph illustrates, what samples were used, if any (not just "Sample B-12", but "Sample B-12, the potassium-rich feldspar"), and the relationship displayed.

This last one is very important – a caption should tell the reader the meaning of the figure or table. Does the table illustrate a trend that the reader should be noting? Does this figure illustrate the sample site, and, if so, what are the features of note at this site?

Captions have a lot of information to relay, so they **must** be longer than one or two sentences. They shouldn't be longer than about 10 sentences.

Equations

Equations are some of the most thoroughly abused elements of a scientific manuscript. Some authors for some reason derive everything – they rarely need to. Also, equations are often simply *typed* in to the manuscript, ensuring that the symbols and formatting will be utterly distorted upon publishing.

Equations must be written in Word's Equation Editor function, or saved as jpeg or gif files and imported into the document. They should be numbered sequentially, and referred to in the text as "Equation 1", "Equation 2", etc.

Derivations should only be done if they are relevant to the work. Many mathematics papers do require lengthy derivations. If the derivation has been presented in some other work, it is usually best to just write: "As derived in Jones et al. (1999)."

References

Types of References

Scientific manuscripts may reference peer-reviewed journal articles, abstracts, books, and personal communications. They should not reference textbooks, and they should reference as few non-peer-reviewed works (e.g., abstracts and personal communications) as possible. The majority of a manuscript's references should be from peer-reviewed sources.

Also, authors should not reference themselves too often. For undergraduates, this means not referencing the advisor too often. A reference section that is 50% the authors does not carry much weight.

Formatting

Before submitting your manuscript to a journal, check what their referencing style is. It is thoroughly unprofessional to submit an unformatted article to a journal. Be professional. Do your homework.

At JYI, we use the following in-text formatting style:

"Recent evidence suggests that the most recent volcanism at Olympus Mons may have been 30 million years ago (Head 2003; Albertson et al. 2004, 2005; Xu and Charleston 2005)."

"Xu and Charleston (2005) found evidence of recent volcanism on Olympus Mons dating to around 30 million years ago."

The end-of-text referencing style is:

"Jones, HP (2001) Behavior of fruit flies. Fruit Fly Journal 81: 982- 988."

"Jones, HP and TJ Smith (2001) Behavior of fruit flies. Fruit Fly Journal 81: 982- 988."

"Jones, HP et al. (2001) Behavior of fruit flies. Fruit Fly Journal 81: 982- 988."

Review Standards for These Elements

At JYI, we use the following criteria to judge these elements. Different journals use different standards, but these cover the basics:

Figures & Tables:

___ Figures & Tables Are Properly Constructed as JPEG Images (i.e., they are not constructed in Word, they are not saved as Powerpoint files, they are saved as regular JPEG image files).

___ Figures & Tables Are Properly Numbered (iFigure 1, Figure 2, Table 1, Table 2)

___ Visually and Textually Clear: Figures and Graphs Are Clearly Labeled

___ Choice of Figures Enhances Understanding of the Text

___ The Captions Are Detailed and Thorough

___ The Figures and Tables Can Stand Alone Without the Rest of the Article

Equations:

___ The Equations Are Written in Equation Editor or Imported as JPEGs/GIFs

___ Choice of Equations Enhances Understanding of the Text

___ The Equations Make Sense

___ All Variables Are Clearly Defined

References:

___ Correctly Formatted Within the Text: "(Jones 1999; Jones et al. 2000; Jones and Smith 2001)."

___ Correctly Formatted in the References Section: "Jones, HP and TJ Smith (2001) Behavior of fruit flies. Fruit Fly Journal 81: 982- 988."

___ Adequate Use of Citations

___ Appropriate Citations (e.g., none from popular size magazines or introductory textbooks)

Common Mistakes in Figures & Tables

1. Inappropriate Format. How does your journal want figures and tables submitted? Within the text? As separate files? Jpeg? Bitmap? Make sure you submit them that way.

2. Redundant Information. Authors will often include the same information in many places: the text, figures, and tables. If an author includes information in figures, he/she should not include the same information in tables – and vice versa. Also, if a table or figure gives specific results, the author should not re-list those results in the text of the paper.

3. Ugly. The most common problems with figures and tables is that they are blurry, unclear, unlabeled, pixilated, and, in a word: ugly. Figures and tables are some of the most important pieces of a paper. The author should invest time and effort into making clear, succinct, visually pleasing figures and tables. This doesn't mean they need to be *pretty* – just clear, concise, and professionally laid out.

Common Mistakes in Captions

1. No Caption. No more need be said. Don't do it.

2. One-Liner. One sentence is never, ever, enough for a caption. Give the reader more information.

3. Regurgitates Figure/Table. A caption that re-states exactly what the table/figure says is no good – the caption must explain *what it means* and *why it is important.*

Common Mistakes in Equations

1. Superfluous Derivations. Most papers don't need derivations of every equations used. Use your best judgment and, with every equations, ask: "Does this really need to be here?"

2. Format. All Figures and Tables should be included as separate JPEG or GIF files – *not* inserted into the text. When they are inserted into the text, the quality degrades

Common Mistakes in References

1. Formatting. The most common mistake in references is their formatting. No matter how many times we tell people how to format their references, they still use brackets, numbers, footnotes, or any number of other methods. Be professional. Do your homework before submitting.

2. Type of Reference. Some papers will cite 5 references, all of them textbooks. This is unacceptable. A scientific manuscript should cite several – meaning at least a dozen – papers from peer-reviewed journals or books. If a paper cites less, then the author probably has not included enough background information and discussion of relevant research.

Part III: Writing a Literature Review

What is a Literature Review?

A literature review addresses a specific topic by evaluating research that **others** have done on it. As an author, you will weave your review article around a certain thesis or problem you wish to address, evaluate the quality and the meaning of the studies done before, and arrives at a conclusion about the problem based on the studies evaluated.

A literature review is not a summary, and it is not a list. The author cannot simply cite the studies that have been done and the results that have been obtained. If you describe past research without evaluating it, then your "review" is little more than a book report. A literature review must be a ***synthesis*** of the results of your search, organized around your chosen theme.

The article should be your **evaluation** of the literature and of the issue at stake. This is a challenging piece of work. You must:

1. Organize information and relate it to your thesis or research question
2. Synthesize results into a summary of what is and isn't known
3. Identify contradictions, inconsistencies, and gaps in the research
4. Identify and analyze controversy when it appears in the literature
5. Develop questions for further research
6. Draw conclusions based on your evaluation of the studies presented

Literature Review vs. Research Article

A literature review surveys research done by others in a particular area. You will read and evaluate studies done by others, instead of conducting a new study yourself.

Research articles, on the other hand, present research that you have conducted yourself. A research article should contain enough background information and literature evaluation to shed light on the your study, but the ultimate purpose of the paper is to report research done by you.

Writing a Literature Review: Preliminary Research

Writing a literature review starts weeks to months before you ever begin the article. Before writing, you must:

1. **Select a topic**. This can be challenging. Unless you are already very well-read in your area, you probably will not be able to just dream up a topic that is both interesting and narrow enough. Pick a general field, then start reading through the literature until you find a controversy or topic that is interesting. The topic should be:

    a. **In a well-studied field**. An area of science that is well-studied will give you more topics to choose from (e.g., more series of studies on the same problem). It will also have many more authors, perspectives, theories, and controversies than a field that only a few people study.

    b. **Of current interest**. You should pick a topic that is currently being researched, not an issue that no one has touched in thirty years. Though many of your sources may be old, you should be able to find research being done on this topic today.

    c. **Of interest to *you***. Don't just pick a topic because it's a hot field of study. Pick one that you are personally interested or involved in.

    d. **Narrow**. Estimate how long of a review you want to produce. Are you aiming for 10 pages? For 20? If you pick a topic that is too broad (e.g., "Impact craters"), then you will find literally thousands of studies and your review will flounder.

    e. **Controversial or diverse (opinion-wise)**. Make sure you have something to evaluate. If everyone agrees about a topic, then there's not much to evaluate (unless you disagree!). You should pick a topic that has at least two completing hypothesis to explain/test it. Then you will be able to compare, contrast, and analyze.

You might consider picking several topics, reading several articles on each of them, and selecting the topic that you think will make the best review.

2. **Search for articles.** If you have chosen too broad a topic, this can be a nightmare. Even with a narrow topic, finding relevant articles can be tough. Here are some tips:

    a. Try online searches using resources like PubMed. These allow you to search by keyword or author, and they often have the article available in an electronic format.

    b. Ask your professors who specialize in the area. They'll be able to point you to the "classic" papers on this topic. Otherwise, you might find yourself bogged down in detail papers.

c. When you find a relevant article, scan its references. Usually, you will find several more relevant articles cited.

d. Look for older review articles on similar topics. Review articles written five or ten years ago can fill you in on the history of the topic and point you in the direction of later research.

3. **Select the relevant studies and relevant information**. Not all of the studies you have found will be relevant to your thesis. Also, only certain portions of each study might be relevant to you. Don't bog your reader down with too much – sift out the relevant studies and information.

4. **Write an outline**. As you read about your topic and gather your information, draft an outline of what your review will cover and in what order. Ideally, you should go through several drafts as you read more about your topic. Annotate your outline with which studies you will discuss where, when, why, and how. This will help you when you start to structure the actual paper.

The next step is to analyze the studies you have chosen.

Writing a Literature Review: Analyzing the Literature

One of the hardest parts of a literature review is analyzing studies done by others. You must be able to evaluate the techniques used, results obtained, conclusions drawn, and errors present in each study, then apply your evaluation to your topic. Below are some questions to help you start thinking about each study.

For each research study you read, ask yourself:

1. Has the author formulated a thesis? What is the problem or issue being addressed? Is this problem relevant to my review?

2. Is the problem clearly stated? Is the significance of the problem discussed? (I.e., why should the reader care about this study?)

3. What are the strengths and limitations of the way the author has formulated the problem? Could the problem be approached more effectively from another perspective?

4. Is this paper primarily theoretical, experimental, interpretive, clinical? A combination? Could the study have been better if conducted in a different framework? (I.e., could a theoretical study have been strengthened by actual experiment? Was a clinical study crippled by a lack of theoretical work?)

5. What is the author's theoretical framework (e.g., psychoanalytic, developmental, feminist)? For example, in the field of Mars geology, many authors build their papers on the idea that Mars was once a warm, wet planet, instead of the cold, dry planet we see today. Others start with the assumption that Mars has always been cold and dry. The theories to which the authors subscribe manifest themselves through their assumptions, interpretations, and conclusions. What assumptions have your authors made? And how do those assumptions affect the conclusions they draw?

6. Has the author evaluated the literature relevant to the problem/issue? Does the author discuss studies that contradict his/her thesis as well as those that support it?

7. How effective is the study's design? Is the method for investigating the problem appropriate? What errors does the method introduce? How accurate and valid are the measurements?

8. Is the analysis of the data accurate and relevant to the research question? Are the conclusions validly based upon the data and analysis?

9. Has the author objectively carried out the study, or only "proved" what he already believes?

10. Does this study contribute to our understanding of the problem? How is it useful to us?

11. How does this study fit into my review? How does its problem relate to the problem I will address? How will I use its conclusions, methods, or imitations to illustrate the point I am trying to make?

12. Does this study support my thesis or not? Do I need to re-evaluate my thesis?

Writing a Literature Review: Structure & Writing

Your whole article should revolve around your thesis. We cannot emphasize this enough: **thesis, thesis, thesis!**

Since no two theses are alike, no two review articles will be structured exactly alike; however, there is a general format that review articles should follow:

1. **Abstract.** A brief summary of your thesis, the major studies investigated, and conclusions drawn.

2. **Introduction.** This section should introduce the topic and your thesis, and should discuss why this topic is significant. It should clearly define

exactly what this article will discuss, outline the order in which you will discuss it, and give the reader any background information needed to understand the coming sections.

3. **Body:** The body of your article depends on your topic. For example, if your topic discusses and evaluates three different methodologies, you might divide the body of the article into three sections, each discussing one of the methods. In these sections, be sure to describe and evaluate the studies in detail, comparing them and discussing their implications.

4. **Discussion and Conclusions:** You should conclude your review by re-stating your thesis and the purpose of the article, then discussing the conclusions you have drawn. You should also discuss the implications of your study and where you think research in this field should go from here.

5. **References:** Literature reviews published in professional journals usually cite 50 to 100 studies. A short literature review usually requires 20 or more.

6. **Length:** A short literature review is usually 7 to 10 pages long (single spaced). Most reviews, however, need to be longer to address all the material that needs to be discussed. Writing a good review is not about quantity, though – it's about quality. Weed out the unimportant and make your writing and logic tight.

In evaluating studies, describe them briefly, then discuss the relevant areas (e.g., research assumptions, theories tested, hypotheses stated, methodology, variables examined, results, interpretations, speculations, etc.) All studies have strengths and weaknesses. Identify them and discuss how they are relevant to your thesis. Be sure to compare the study with others that you have discussed.

Questions to Ask Yourself About Your Review

As you are writing your review, keep the following questions in mind. When you have finished, go through and make sure you answer each of these questions for yourself:

1. Do I present a specific thesis, problem, or research question? (Make sure you're not just **summarizing** a field of study!)

2. Who is my audience? Will readers find my literature review relevant and useful?

3. What is the scope of my review? What types of publications did I use (journals, books, popular media, government documents, person communication?)?

4. What am I reviewing? Is my issue addressing theory, methodology, policy, quantitative research, or qualitative research? A combination? Make sure this is clear in your review!

5. Has my search for studies been broad enough to contain all the relevant studies?

6. Has my search been narrow enough to exclude irrelevant studies?

7. Have I included enough sources? (Usually, anything less than a dozen sources is far too few for a literature review.)

8. Is the literature I've chosen actually relevant to my thesis? Does every study I've chosen to include shed some light on the problem my article is addressing?

9. Have I **critically analyzed** the studies or do I just summarize the articles? Have I discussed the strengths and weaknesses of the studies?

10. Have I cited and discussed studies that contradict my perspective?

11. Is my review more than just a descriptive summary? Is it organized into useful, informative sections that present different ideas revolving around my thesis?