

# How to write a research paper

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**NSF HDR Postbaccalaureate Workshop 2023**  
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## PART 1: Cutting Unnecessary Clutter

It is adopted from Dr. Jennifer Huber's "Writing in Science Series"

# Purpose of Science Communication

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- Document your research.
- Transfer knowledge to future employees.
- Inform stakeholders (e.g., supervisors and industry leaders) of scientific achievements so they can make well-founded decisions.
- Advance your career.
- Attract new funding.
- Inspire new scientists.
- Educate the public of scientific achievements that can directly impact the quality of their lives.

The social contract isn't complete until scientific results are communicated, particularly when the research was publicly funded

# “Publish or Perish”

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- The need to “publish or perish” in a research environment can push you to focus on quantity over quality.
- However, performance reviews often include a publication **impact factor** (e.g., h-index from Web of Science).
- If no one reads your work, publishing doesn’t advance science, your career, or your organization.
- Similarly, future employees need to understand technical reports.
  
- **Good writing is more likely to be read, understood, used, and cited.**

# What **NOT** to do - Example 1

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The goal is to communicate clearly and effectively.

**From a journal article in the American Journal of Clinical Oncology:**

“In conclusion, our data suggest that the ABCG2 htSNPs rs2725264 (in the overall group and taxane-platinum combination group) and rs4148149 (gemcitabine-platinum combination group) were associated with OS in unresectable NSCLC patients treated with first-line platinum-based Chemotherapy.”

- Is this sentence easy to understand?
- Is it engaging and interesting to read?

# Good Science Writing

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- Complex ideas don't require **complex language** or **overly-complex sentences**.
- Scientific writing should be **easy and enjoyable to read**.
- Let go of bad writing habits.

# Bad Writing Habits

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## Common bad writing habits for engineers & scientists:

- Using unnecessary jargon and acronyms.
- Using vague words.
- Converting verbs into nouns.
  
- Putting too much distance between the subject noun and verb!
  
- Using passive voice:
  - Passive: “The experiment was done by us.”
  - Active: “We did the experiment.”

## What **NOT** to do - Example 2

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### Original text from an article in Cell:

*“Dysregulation of physiologic microRNA (miR) activity has been shown to play an important role in tumor initiation and progression, including gliomagenesis. Therefore, species that can regulate miR activity on their target RNAs without affecting the expression of relevant mature miRs may play equally relevant roles in cancer.”*



## What **NOT** to do - Example 2

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### Original text from an article in Cell:

*“Dysregulation of physiologic microRNA (**miR**) activity has been shown to play an important role in tumor initiation and progression, including **gliomagenesis**. Therefore, species that can regulate **miR** activity on their target RNAs without affecting the expression of relevant mature **miRs** may play equally relevant roles in cancer.”*

**Note the use of unnecessary jargon and acronyms.**

(e.g., Use standard microRNA or miRNA, not miR)

## What **NOT** to do - Example 2

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*“Dysregulation of physiologic microRNA (miR) activity has been shown to play an important role in tumor initiation and progression, including gliomagenesis. Therefore, species that can regulate miR activity on their target RNAs without affecting the expression of relevant mature miRs may play equally relevant roles in cancer.”*

**Note the use vague words.**

## What **NOT** to do - Example 2

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Original text from an article in Cell:

*“**Dysregulation** of physiologic microRNA (miR) activity has been shown to play an important role in tumor **initiation** and **progression**, including gliomagenesis. Therefore, species that can regulate miR activity on their target RNAs without affecting the **expression** of relevant mature miRs may play equally relevant roles in cancer.”*

**Note the use nouns instead of verbs.**

## What **NOT** to do - Example 2

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*“Dysregulation of physiologic microRNA (miR) activity **has been shown** to play an important role in tumor initiation and progression, including gliomagenesis. Therefore, species that can regulate miR activity on their target RNAs without affecting the expression of relevant mature miRs may play equally relevant roles in cancer.”*

**Note the use of passive voice.**

## What **NOT** to do - Example 2

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Original text from an article in Cell:

*“Dysregulation of physiologic microRNA (miR) activity has been shown to play an important role in tumor initiation and progression, including gliomagenesis. Therefore, **species** that can regulate miR activity on their target RNAs without affecting the expression of relevant mature miRs **may play** equally relevant roles in cancer.”*

**Note the large distance between the main subject and verb in the last sentence**

## What NOT to do - Example 2

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Original text from an article in Cell:

*“Dysregulation of physiologic microRNA (miR) activity has been shown to play an important role in tumor initiation and progression, including gliomagenesis. Therefore, species that can regulate miR activity on their target RNAs without affecting the expression of relevant mature miRs may play equally relevant roles in cancer.”*

### Possible Rewrite:

*Changes in microRNA expression play a role in cancer, including glioma. Therefore, events that disrupt microRNAs from binding to their target RNAs may also promote cancer.*

# Concise Writing

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The **KISS** principle = **K**ep **I**t **S**hort & **S**imple

The Elements of Style by William Strunk:

*“A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all his sentences short, or that he avoid all detail and treat his subjects only in outline, but that he make every word tell.”*

# Concise Writing

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Needless complexity makes scientific writing unclear. Get rid of:

- Needlessly complex words

Example: is capable of à can

- Needlessly complex phrases

Long strings of modifiers in front of nouns. Often a result of overusing jargon.

Example: We employed **factor analysis data mining** tools to identify linkage.

→ We employed factor analysis to mine our data and identify linkage.

- Needlessly complex sentences

Long, convoluted sentences with too many ideas. Delete ideas that aren't important. Break into shorter sentences.



# Concise Writing

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**Needless complexity makes scientific writing unclear. Get rid of:**

- **Needless formality**

Your goal is to inform not impress. You want to sound serious, precise, authoritative, professional, and objective. But you can end up sounding pretentious, vague, and dull.

- **Double negatives**

Example: They didn't believe it was harmful. → They believed it was safe.

- **Redundancy**

Example: new innovations vs. innovations, summarize briefly vs. summarize

# Concise Writing

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## Needless complexity makes scientific writing unclear. Beware of:

- Needless intensifiers such as really, very, quite, extremely

Read sentence without intensifier to see if meaning is weakened or changed.  
Omit intensifier or replace it with word that better conveys your meaning.

Example:           The dogs were very eager to get off their leashes and really run.  
                          The dogs were straining to get off their leashes and run free.

- Expletive constructions such as there is / it is

Example:           There are twenty students who are taking this class.  
                          Twenty students are taking this class. (more energy)

- Which / who clauses

Shortened to a simple adjective, if possible.

Example:           Citizens who knew what was going on voted him out of office.  
                          Knowledgeable citizens voted him out of office.

# Concise Writing - Examples

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## Example 1

Replace the following with a single word:

A large number of	Many
Despite the fact that	Although, despite
Each and every	Each, every, all
Has the opportunity to	Can, could
At this point in time	Now
Compare and contrast	Compare
In a case in which	When, where
Due to the fact that	Since, because
Give rise to	Cause
Have an effect on	Affect

# Concise Writing - Examples

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## Example 2

Identify the unnecessary words in the following sentences:

1. Professor Smith was picked by each and every person on the committee.
2. The student needs to obtain high marks in science in order to study medicine.
3. The manager will, insofar as is possible, make sure that the information is true and accurate.

# Concise Writing - Examples

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## Example 2

Identify the unnecessary words in the following sentences:

1. Professor Smith was picked by each **and every** person on the committee.
2. The student needs **to obtain** high marks in science **in order** to study medicine.
3. The manager will, **insofar as is possible**, make sure that the information is true and accurate.

# Concise Writing - Editing Yourself

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Cutting unnecessary words in your own writing is more difficult.

- Be attentive and ruthless.
- After investing a lot of effort to put words down onto the page, you often don't want to cut them. Don't get too attached to your writing. Cut your 'darlings.'
- Try the sentence without the extra words to see if it conveys the same idea with more power.

# Paper Writing

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- Reporting experiments
- Summarizing findings that contributes new knowledge to a body of knowledge
- Aggregating information about historical work done within a body of knowledge or specific subdomain

# Concise Writing: Individual Exercise

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<https://b.socrative.com/login/student/>

ROOM Code: **KHODA2293**

Take the “Cutting Clutter” Interactive quiz

Discuss as a group at the end.



## PART 2: Scientific paper writing

It is adopted from the Paper writing workshop as part of [CMU Deep Learning \(11-785\)](#) (Jinhyung David Park & Rukayat Sadiq)

# Paper Writing Tools

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- Text Editor
  - MS Word
  - Latex
  
- Reference Tool
  - Mendeley
  - Zotero
  
- Spell Checker

***Knowing your audience helps to know the level of details to include in your research paper***

# Who is your Audience?

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- People with similar background or within similar domain as the author's
- People that can reproduce the work you have done, following your provided appropriate methodology

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- Must have element of novelty (new work)
  - Must be feasible. How would the problem be solved?
  - Must be ethical (approved by a designated ethics board)

# Anatomy of a Research Paper

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- Abstract
- Introduction
- Related Work (Literature review)
- Methodology
  - Model Description
  - Dataset Description
  -
- Experiment, Results, Discussion
- Conclusion
- References

# Abstract

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- The shortest section of a paper about 100 - 150 words
- Executive Summary of Paper
- States the research problem/question
- Researcher's contribution and answer to the research question
- How the answer was tested
- The impact of the research work
- Contains keywords about the research

# Abstract: Example

## Addressing Function Approximation Error in Actor-Critic Methods

Scott Fujimoto<sup>1</sup> Herke van Hoof<sup>2</sup> David Meger<sup>1</sup>

### Abstract

In value-based reinforcement learning methods such as deep Q-learning, function approximation errors are known to lead to overestimated value estimates and suboptimal policies. We show that this problem persists in an actor-critic setting and propose novel mechanisms to minimize its effects on both the actor and the critic. Our algorithm builds on Double Q-learning, by taking the minimum value between a pair of critics to limit overestimation. We draw the connection between target networks and overestimation bias, and suggest delaying policy updates to reduce per-update error and further improve performance. We evaluate our method on the suite of OpenAI gym tasks, outperforming the state of the art in every environment tested.

means using an imprecise estimate within each update will lead to an accumulation of error. Due to overestimation bias, this accumulated error can cause arbitrarily bad states to be estimated as high value, resulting in suboptimal policy updates and divergent behavior.

This paper begins by establishing this overestimation property is also present for deterministic policy gradients (Silver et al., 2014), in the continuous control setting. Furthermore, we find the ubiquitous solution in the discrete action setting, Double DQN (Van Hasselt et al., 2016), to be ineffective in an actor-critic setting. During training, Double DQN estimates the value of the current policy with a separate target value function, allowing actions to be evaluated without maximization bias. Unfortunately, due to the slow-changing policy in an actor-critic setting, the current and target value estimates remain too similar to avoid maximization bias. This can be dealt with by adapting an older variant, Double Q-learning (Van Hasselt, 2010), to an actor-critic format by using a pair of independently trained critics. While this allows for a less biased value estimation, even an unbiased estimate with high variance can still lead to future overestimations in local regions of state space, which in turn can negatively affect the global policy. To address this concern, we propose a clipped Double Q-learning variant which leverages the notion that a value estimate suffering from overestimation bias can be used as an approximate upper-bound to the true value estimate. This favors underestimations, which do not tend to be propagated during learning, as actions with low value estimates are avoided by the policy.

Given the connection of noise to overestimation bias, this paper contains a number of components that address variance reduction. First, we show that target networks, a common approach in deep Q-learning methods, are critical for variance reduction by reducing the accumulation of errors. Second, to address the coupling of value and policy, we propose delaying policy updates until the value estimate has converged. Finally, we introduce a novel regularization strategy, where a SARSA-style update bootstraps similar action estimates to further reduce variance.

Our modifications are applied to the state of the art actor-critic method for continuous control, Deep Deterministic Policy Gradient algorithm (DDPG) (Lillicrap et al., 2015), to form the Twin Delayed Deep Deterministic policy gradient

### 1. Introduction

In reinforcement learning problems with discrete action spaces, the issue of value overestimation as a result of function approximation errors is well-studied. However, similar issues with actor-critic methods in continuous control domains have been largely left untouched. In this paper, we show overestimation bias and the accumulation of error in temporal difference methods are present in an actor-critic setting. Our proposed method addresses these issues, and greatly outperforms the current state of the art.

Overestimation bias is a property of Q-learning in which the maximization of a noisy value estimate induces a consistent overestimation (Thrun & Schwartz, 1993). In a function approximation setting, this noise is unavoidable given the imprecision of the estimator. This inaccuracy is further exaggerated by the nature of temporal difference learning (Sutton, 1988), in which an estimate of the value function is updated using the estimate of a subsequent state. This

<sup>1</sup>McGill University, Montreal, Canada <sup>2</sup>University of Amsterdam, Amsterdam, Netherlands. Correspondence to: Scott Fujimoto <scott.fujimoto@mail.mcgill.ca>.

1. Highlights the Research Problem/Question
2. Highlights specific contribution towards answering research question

Source:

<https://arxiv.org/pdf/1802.09477.pdf>



# Introduction

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- Extended form of the abstract.
- Gives background and sets tone for the research work
- Starts from broad issues to very specific area of research

**Goal: Provides context to research question**

# Writing a Great Introduction

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- Summarize current understanding of research about the subject topic till date
- State the purpose of your research problem
- Highlight set of questions that would be answered by your research
- Briefly explain the methodology & what the study might reveal
- Summarize the structure of the remainder of the paper

# Related Work

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- This covers historical work done on the related research problems and/or related techniques.
- Categorize previous works into themes
- Summarize themes in a coherent format

# Methodology

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- Highly technical and contains technical jargon about the subject matter
- Covers overview of experiments to be done to answer the research question
- Reproducible to get documented results.
- Does not have to be named Methodology - dive straight to its components

# Components of Methodology: Model Description

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- Describe clearly the model architecture
- Cover the key areas about objective of the modelling approach
  - Minimizing a Loss function
  - Maximizing a Reward Function
- Use mathematical expressions to describe the model as needed

# Components of Methodology: Data Description

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- What dataset would be used
  - Type: Speech, Image, Video, 3D point clouds, and so on
  - Data Mode: Single Mode, Multimodal
- How was the dataset was collected?
- Are there preprocessing done - either by you or from the data source
- How do you intend to use the data
- State overall statistics of the dataset e.g. length of dataset, training to validation proportion, etc

# Components of Methodology: Evaluation Metrics

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- What baseline are you selecting?
  - Is this a state-of-the-art, competitive existing baseline
  - Are you implementing a baseline from scratch? Why?
  
- What evaluation metrics would you be using?
  - Clearly define the metrics to be used
  - Demonstrate understanding of how the metrics work
    - Give mathematical formulae if applicable

# Experiments, Results and Discussion

- Experiments section should contain details about hyperparameters, how the dataset was used and how evaluation was performed.
- Standard to report metrics in comparison with other work
  - Make sure to report under similar settings. If necessary/possible, run multiple times and report standard deviations.

method	image size	#param.	FLOPs	throughput (image / s)	ImageNet top-1 acc.
RegNetY-4G [48]	224 <sup>2</sup>	21M	4.0G	1156.7	80.0
RegNetY-8G [48]	224 <sup>2</sup>	39M	8.0G	591.6	81.7
RegNetY-16G [48]	224 <sup>2</sup>	84M	16.0G	334.7	82.9
EffNet-B3 [58]	300 <sup>2</sup>	12M	1.8G	732.1	81.6
EffNet-B4 [58]	380 <sup>2</sup>	19M	4.2G	349.4	82.9
EffNet-B5 [58]	456 <sup>2</sup>	30M	9.9G	169.1	83.6
EffNet-B6 [58]	528 <sup>2</sup>	43M	19.0G	96.9	84.0
EffNet-B7 [58]	600 <sup>2</sup>	66M	37.0G	55.1	84.3
ViT-B/16 [20]	384 <sup>2</sup>	86M	55.4G	85.9	77.9
ViT-L/16 [20]	384 <sup>2</sup>	307M	190.7G	27.3	76.5
DeiT-S [63]	224 <sup>2</sup>	22M	4.6G	940.4	79.8
DeiT-B [63]	224 <sup>2</sup>	86M	17.5G	292.3	81.8
DeiT-B [63]	384 <sup>2</sup>	86M	55.4G	85.9	83.1
Swin-T	224 <sup>2</sup>	29M	4.5G	755.2	81.3
Swin-S	224 <sup>2</sup>	50M	8.7G	436.9	83.0
Swin-B	224 <sup>2</sup>	88M	15.4G	278.1	83.5
Swin-B	384 <sup>2</sup>	88M	47.0G	84.7	84.5

Source:

<https://arxiv.org/pdf/2103.14030v2.pdf>



# Experiments, Results and Discussion

**Ablations** are extremely important.

How much did each proposed component contribute to the final performance?

Sub-Pillar	PE	Tiny-Pillar	DF	SA	Veh.	Ped.	Cyc.	Mean
					60.32	49.22	51.58	53.71
✓					60.13	52.32	54.91	55.79
✓	✓				61.35	53.50	56.58	57.14
		✓			63.11	56.89	61.74	60.58
		✓	✓		67.33	59.24	65.06	63.88
		✓	✓	✓	67.22	59.34	65.82	64.12
✓	✓	✓	✓	✓	67.32	60.49	66.04	64.62

Table 4: Effects of our HS-Pillar with Position Encoding, ST-Pillar with Dense Feature and Sparse Attention. We compare on 20% Waymo validation by per-class and average 3D LEVEL 2 mAPH.

Source:

<https://arxiv.org/pdf/2110.06049v1.pdf>

# Experiments, Results and Discussion

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- Discussion does not need to be its own section.
- However, it should outline the overall takeaways from your work.
- Often, these takeaways are fused in with the results & ablations.

# Conclusion

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- Summary of work done.
- Reiterates the research question and findings from the research work that answers the research question
- Highlights what possible shortcomings of current work if any, areas for improvement, next steps/future work, possible extensions.

# Reference

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Different Referencing styles depending on the type of paper you are writing and the conference/workshop.

**IEEE Reference style** - Most common for engineering papers

Conference Paper, Books, Journals are referenced slightly differently

- Comprehensive guide - [https://owl.purdue.edu/owl/research\\_and\\_citation/ieee\\_style/reference\\_list.html](https://owl.purdue.edu/owl/research_and_citation/ieee_style/reference_list.html) •

**APA** - common for social sciences and Humanities disciplines

**MLA** - common for English & Media Studies paper

**MHRA**

**Harvard**

# Manuscript writing order

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Let's break down a manuscript into different components:

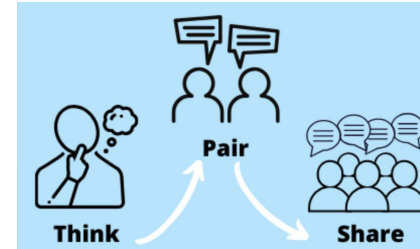
- Abstract
- Introduction
- Methodes
- Results
- Figures and tables
- Discussion
- Acknowledgement
- References

# Think-Pair-Share

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In which order will you write the manuscript?

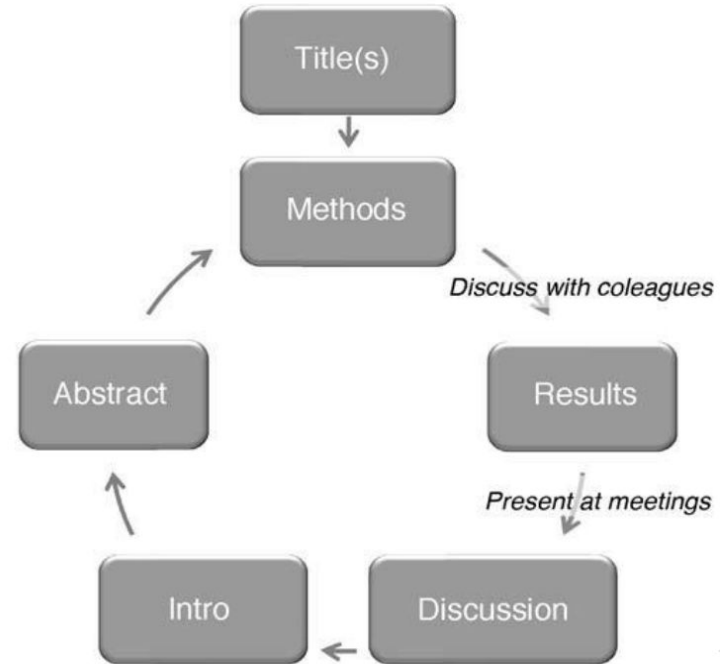
- Abstract
- Introduction
- Methodes
- Results
- Figures and tables
- Discussion
- Acknowledgement
- References



1. Take 2-3 minutes to think
2. Talk to the person next to you and discuss again
3. Share with other participants

# Manuscript writing order

## Order For Writing A Manuscript



Reference

<https://doi.org/10.1111/ans.12036>

Reference

<https://doi.org/10.1016/j.rppn.eu.2011.03.007>

# Submitting to a Journal

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## Choosing a journal

- Consider journal's impact factor, the readership and the journal's reputation for efficiency and fair review

## Review Process

- After submission, your paper will be checked by the journal office for format and completeness.
  - If there is some potential for publication, it will be sent for peer review.
  - Alternatively, the editor might reject the paper immediately. The peer-review process is not perfect and it is best to approach it with a positive and patient attitude



# Guideline for responding the referees

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- Never challenge a referee (“You are not right in pointing out that...”)
- Do not judge their intentions (“The question is ill-motivated, since...”). Side remark: never second-guess what is behind a question.
- Assume that their points are those of the average reader, implying that some improvement to the paper is necessary. Also, never dismiss a point a referee has made as being too detailed. (“This question is too detailed for the paper”). The explanation of a point may be too detailed for inclusion in the paper. But ALL points must be responded to, detailed or not.
- Don’t imply rudeness. (“No. It’s not true.”). Make the responses as polite as possible.

# Guideline for responding the referees

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- Do not thank a referee in your response to any particular point (it implies that the other points are not so good or welcome).
- When there are multiple referees, we provide individual responses to the points of each. If a certain point is mentioned by both Ref. #1 and Ref. #2, we repeat the response given to Ref. #1 in the responses to Ref. #2, as well (i.e. we do not direct Ref. #2 to an earlier response to Ref. #1).
- Do not address a referee directly. Your point of contact will be the editor

# Guideline for responding the referees

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Assume that a question raised by a referee is one that the average reader of the paper will also have.

- It is thus not enough to provide a paragraph in the responses, clarifying something only for a referee.
- This paragraph (or an appropriately abbreviated/reformulated summary) should be propagated to the paper, as well.

# Sample Cover letter for the Journal editor

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Dear Editor,

*We would like to thank the referee for reviewing this paper and furnishing this report.*

*We have carefully considered all comments, and we have applied several changes to the original version of the paper to address the issues*

*raised. Detailed responses to all the comments can be found below.*

*We are at your disposal for any further clarifications and/or additional information.*

Sincerely,

YOUR NAME

## PART 3: Read Papers and compare

It is adopted from Dr. Jennifer Huber's "Writing in Science Series"

# Let's read two papers

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Paper 1: <https://arxiv.org/pdf/1207.7235.pdf>

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC

Paper 2: <https://arxiv.org/abs/2209.06197>

Search for exotic Higgs boson decays  $H \rightarrow AA \rightarrow 4 \text{ Gamma}$  with events containing two merged diphotons in proton-proton collisions at  $\sqrt{s} = 13 \text{ TeV}$

# Group Activity

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Form a group of 2 and read the papers together

Do not read the full paper: skim through the sections

- Abstract
- Figures and tables
- Intro
- Conclusion

