Academic Communication
in (Astro)Physics

Lecture 7: Academic Journal Papers I

Pre-Writing

The Title

Introduction

Credit: Elisabete da Cunha

Today's lecture

- The writing process; pre-writing and drafting
- Paper structure
- The Title
- The Introduction

Luca’s

Disclaimer

Writing papers is much more of an art than writing codes.

These lectures are meant to provide you with some guidelines, though–as you’ll see–people often have different approaches, tricks, and preferences.

The key is to find what works best for you.

The writing process

1) Pre-writing
2) Drafting
3) Revising
4) Editing
5) Evaluating
6) Publishing

Pre-writing: need to plan well before you start writing

- During research work: keep a logbook as detailed as possible of what you did!
- Make sure the scientific analysis is streamlined: you will likely have to re-do calculations/figures multiple times.
- Collect your references as you go:
  - read lots of papers related to your topic (both the "classic papers" and the recent papers)
  - keep extensive notes as you read on what the papers say and how they relate to your work
  - this will help you place your research on the broader context of the field

You got an exciting result… now what?

Pre-writing: audience and journal choice

Choose the best match of topic, audience, and journal.

Consider: specialized vs generalist journals, whether they charge for publication, impact factors etc.

Specialized

ApJ
ApJS
MNRAS
A&A
PASA
PASP
ARA&A

Generalist

Nature
Science
RSOS

- Aim to publish in the most highly-ranked journals (high impact factors)
- Submit to *Nature* or *Science* for important results that will appeal to a more general audience.
- Consider publication costs!

<u>Once you've chosen a journal:</u> find the journal's "Instructions to authors" (on the website); this usually includes detailed instructions on how to submit, format and style, and you can usually find their LaTeX template.

Pre-writing: Authorship
(or better how to plan and manage interactions with co-authors)

- Consider very carefully who to include as author and in which order: this can be a minefield at times!
- Having co-authors can be beneficial: help with the science, comments on early drafts, etc. But it can also be problematic: disagreement over authorships can easily result in wrecked professional relationships (and even friendships at times)!
- Decide who you want to bring in as early as possible – but wait **until final draft to set the final author list and order** (I usually circulate drafts among co-authors with just "da Cunha et al." in the author section)
- **First author** (usually corresponding author too): usually the person who lead the project, did most of the work, and wrote the paper.
- Often, "**core authors**" who made significant contributions come right after the 1st author in order of level contribution. Then, other co-authors who made minor contributions in **alphabetical order** (of last name). Note: it can be tricky to distinguish between these two groups because contributions vary a lot!
- Be sensible when navigating authorship issues and ask for advice if in doubt!

Pre-writing: Authorship

- All co-authors should agree to be on the paper and approve of it before submission to the journal (usually by sending feedback). They should also confirm their name spelling, affiliations, acknowledgements etc.

- Papers shouldn't be written by more than one person (but there are exceptions!). Beware this often results in style/language inconsistencies, weak transitions, illogical formats. Ideally the first author should write the whole paper, incorporating comments/adapting material/revisions from the co-authors.

High-redshift star formation in the Atacama large millimetre/submillimetre array era

J. A. Hodge[1] and E. da Cunha[2,3,4]

[1]Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands
[2]International Centre for Radio Astronomy Research, University of Western Australia, 35 Stirling Highway, Crawley, Western Australia 6009, Australia
[3]Research School of Astronomy and Astrophysics, Australian National University, Canberra, Australian Capital Territory 2611, Australia
[4]ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D)

This one was written by two authors.

When to start writing a paper? What's new?

- A paper needs to tell a story – first you need to work out what that story is.
- Before you write, you need to have at least tentative answers to the following questions:
  - What are the conclusions of the paper (qualitative and/or quantitative)?
  - What is the evidence for those conclusions?
  - How do these results relate to prior work?
  - What are the implications of this work – i.e. what theories are being tested/questions are being answered etc?
- **A single paper should involve a single theme**; if its logical structure does not proceed from a single stem, you should write more than one paper.

Slide credit: Sarah Leslie

Drafting: shitty first drafts

Almost all good writing begins with terrible first efforts. Start by getting something — anything — down on paper. What I've learned to do when I sit down to work on a shitty first draft is to quiet the voices in my head.

Shitty first drafts. All good writers write them. That is how they end up with good second drafts and terrific third drafts.

Anne Lamott

The first draft of anything is shit.

Ernest Hemingway

Structure of a scientific paper

Title, Authors, Abstract, Keywords

Descriptive information: helps readers search for an article.
Most people will only read these, so try to encapsulate the main story!

Opening → Challenge (Knowledge Gap) → Action → Resolution

Introduction

What is the context/background for this project?
How does it fit with the other research in the topic?
What is the research question the paper addresses?

WHY?

Methods

What did the author(s) do to answer the question?

HOW?

Results

What did the author(s) find?
This is often shown in figures and tables.

WHAT?

Discussion/ Conclusion

Did you answer the question?
What is the significance of your results?
How does this fit in with what is known about the topic?
Are there any limitations/remaining open questions?

SO WHAT?

References

Materials the author(s) cited when writing this paper.

Acknowledgments

Thank the reviewer, colleagues, funding agencies, etc.

Reading levels – most people will only read the title and maybe the abstract! A few specialists will read the whole paper.

Title

Abstract

Whole Paper

Slide credit: Henri Boffin

Start with an outline

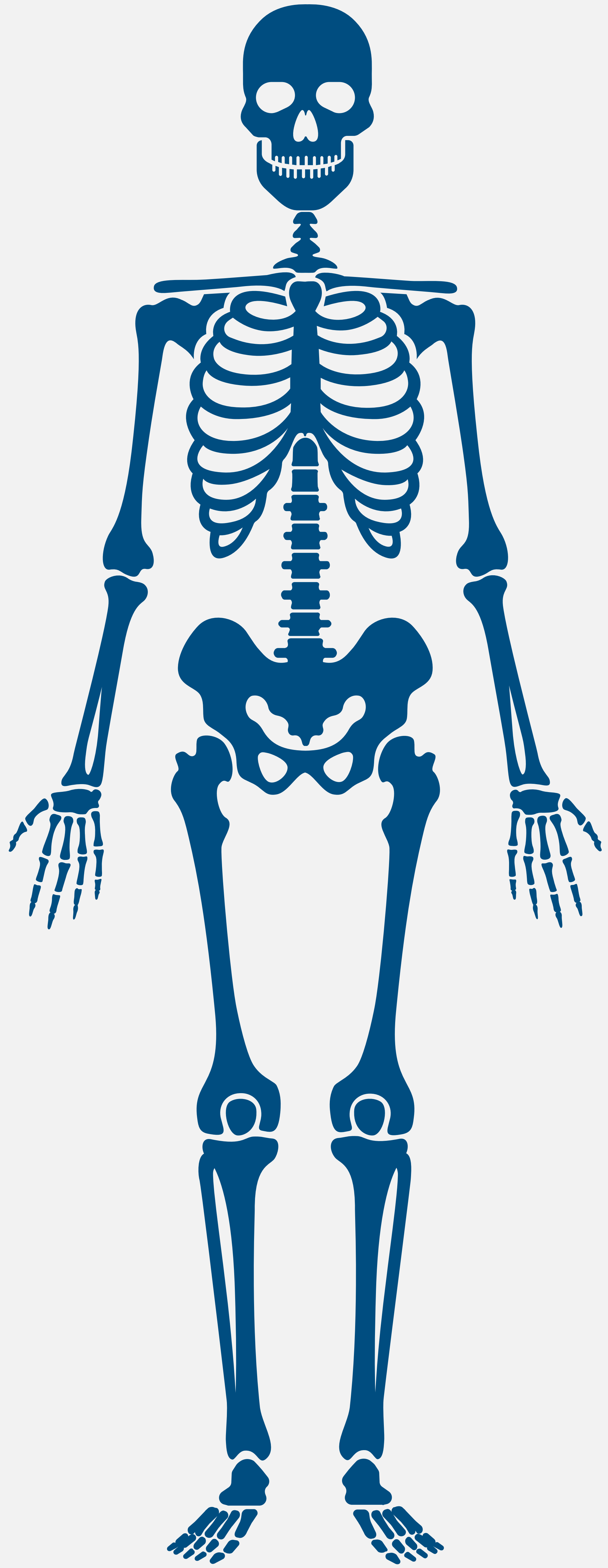
<u>Break big task (the paper) into bite-sized chunks:</u>

section by section, or even paragraph by paragraph.

Basic sections:

- <u>Introduction</u> – Present the problem, what has been done before, and the proposed solution
- <u>Methods (Data/Observations)</u> – including data reduction steps, sample selection, …
- <u>Results</u> – your showstopper plots go here
- <u>Discussion</u> – the interpretation, implications, and limitations of your results
- <u>Conclusions</u> – restate your result and why it's important

Stuck? Find a similar paper and outline its structure; start from there.



Slide credit: Sarah Leslie

Start filling your outline (Elisabete's version)

STEP 1

What is the point of the paper?

What result are you presenting?

STEP 2

Think about the logical flow

- what background does the reader need to know to understand why this topic is interesting? What gap in our knowledge of the topic is your work addressing? **(Introduction)**
- Show your result(s) and supporting evidence to convince the reader that it is real **(Results)**
  - How did you achieve your result? You want the reader to be able to reproduce it if they had the same data. **(Methods)**

What do your results mean? Implications for your field. Bring it back to the gap of knowledge you identified in the introduction. **(Discussion)**

STEP 3

Read your outline

Ask yourself: if I were new to the project, would this sound like a complete and convincing story? (and/or ask someone)

Start filling your outline (Luca's version)

Step 1

What is the point of the paper?

What result are you presenting?

Step 2

Think about the logical flow

- Show your result(s) and supporting evidence to convince the reader that it is real **(Results)**
  - How did you achieve your result? You want the reader to be able to reproduce it if they had the same data. **(Methods)**

What do your results mean? Implications for your field. Bring it back to the gap of knowledge you identified in the introduction. **(Discussion)**

Step 3

Read your outline

Ask yourself: if I were new to the project, would this sound like a complete and convincing story?

Step 4

Get a first draft of Methods/Results/Discussion

Is there everything I need to show/discuss? Is the emphasis on the various results correct?

Step 5

Tackle the Introduction

Only once the Results/Discussion are set you will know how to structure the introduction

Start filling in the sections

- **Set realistic goals.** Writing is hard, and good writing is time-consuming. Remember you will edit it all later.

- **Start with the easiest parts.**

  - Some sections will be straightforward and you can write them quickly / early. (Where did my data come from? What did I do to reduce it, analyze it?)

  - Other sections might take much longer: break it up into paragraphs (bullet points on your outline).

- **The title, abstract, conclusions, and figure captions are the most important parts: most people will only read those.** **Write and rewrite them.**

The Title

The Title

The single most important phrase of the paper.

clear

complete

succinct

Two functions

To attract readers

To provide information for search engines

It is the most visible part of the paper and often the only thing people will read!

The Title: some guidelines

- Compress the main message of the paper into about 10 words. **“Abstract to the abstract”**
- Make the title match the abstract and rest of the paper.
- Make it **short and accurate**; use simple words, no jargon, no abbreviations, no new concepts.
- Make **descriptive** or **catchy** – or both! Avoid jokes or references to modern culture.
- If possible, package the **main conclusions** of the paper into it.
- Use a title that separates your paper from others in the field.
- Avoid **vague directionless terms** like “effect”, “influence”, or “change” (e.g., “reduce”, “increase” etc. are better)
- Include important **keywords**: the title is a main source of information for indexing services and search engines.
- Note: sometimes collaborations have specific policies for titles e.g. always include survey name.
- Running title: should be identifiable as a short version of the main title.

Let's look at some titles...

1. "Kerrr" black hole: The lord of the string

2. The first minutes of a binary-driven hypernova

3. Schrodinger's Galaxy Candidate: Puzzlingly Luminous at z~17, or Dusty/Quenched at z~5?

4. Can accreting primordial black holes explain the excess radio background?

5. HD 65949: Rosetta stone or red herring

6. Star cluster formation with externally driven turbulence

7. Inferred properties of planets in mean-motion resonances are biased by measurement noise

8. The Gaia-ESO Public Spectroscopic Survey: Motivation, Implementation, GIRAFFE data processing, analysis, and final data products

9. OzDES reverberation mapping program: MgII lags and R-L relation

10. Panic! At the Disks: First Rest-frame Optical Observations of Galaxy Structure at z>3 with JWST in the SMACS0723 Field

- Does the title inspire you?
- Does it make you want to read the abstract?
- Is it silly, or cheesy?
- is it so technical or complicated that it puts you off reading further?

The Introduction

"Well begun is half done." — Aristotle

The Introduction

Purpose

To get your audience interested.

To provide sufficient context (background) for the reader to understand your work.

To give an overview of what to expect in the paper.

What is the paper about?

Why is this important?/ Why should one care?

What we currently know. Where has other work fallen short?

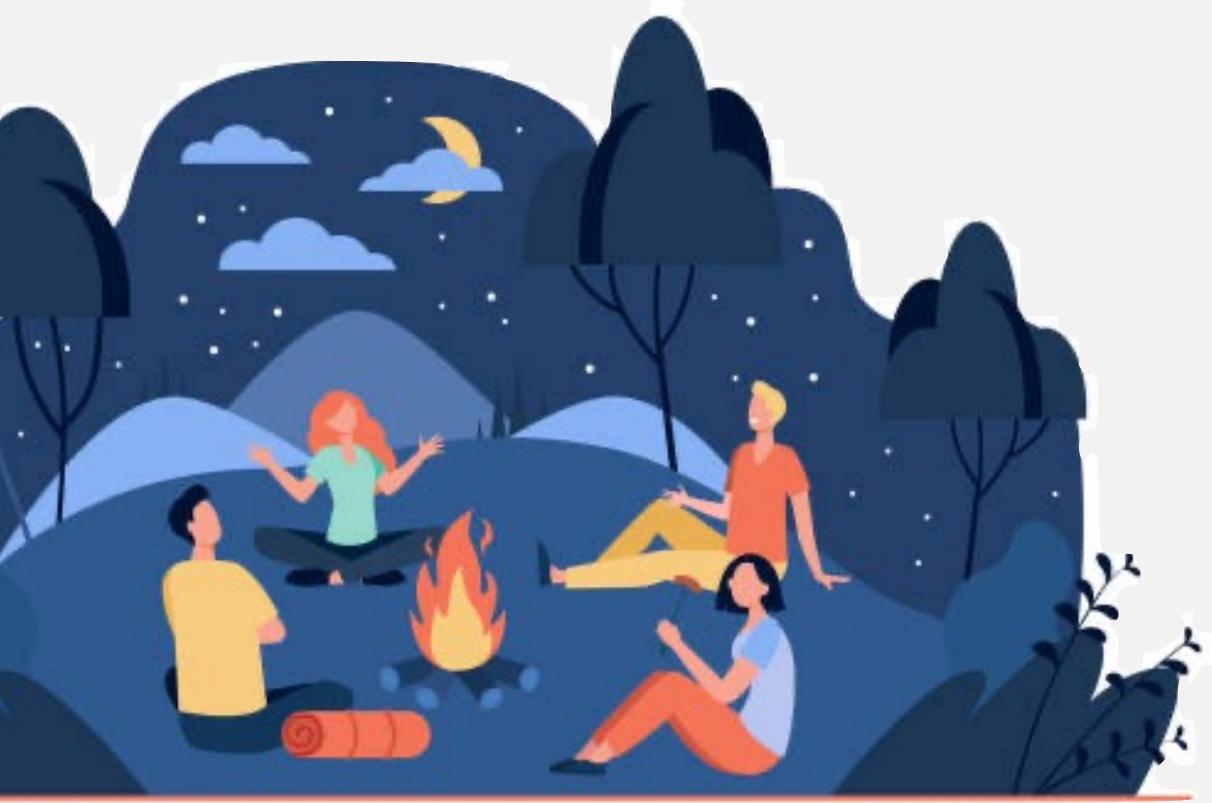
What is the gap in our knowledge?

What is your purpose/ question?

What did you do to answer the question?

Why your approach offers significant results

Outline paper

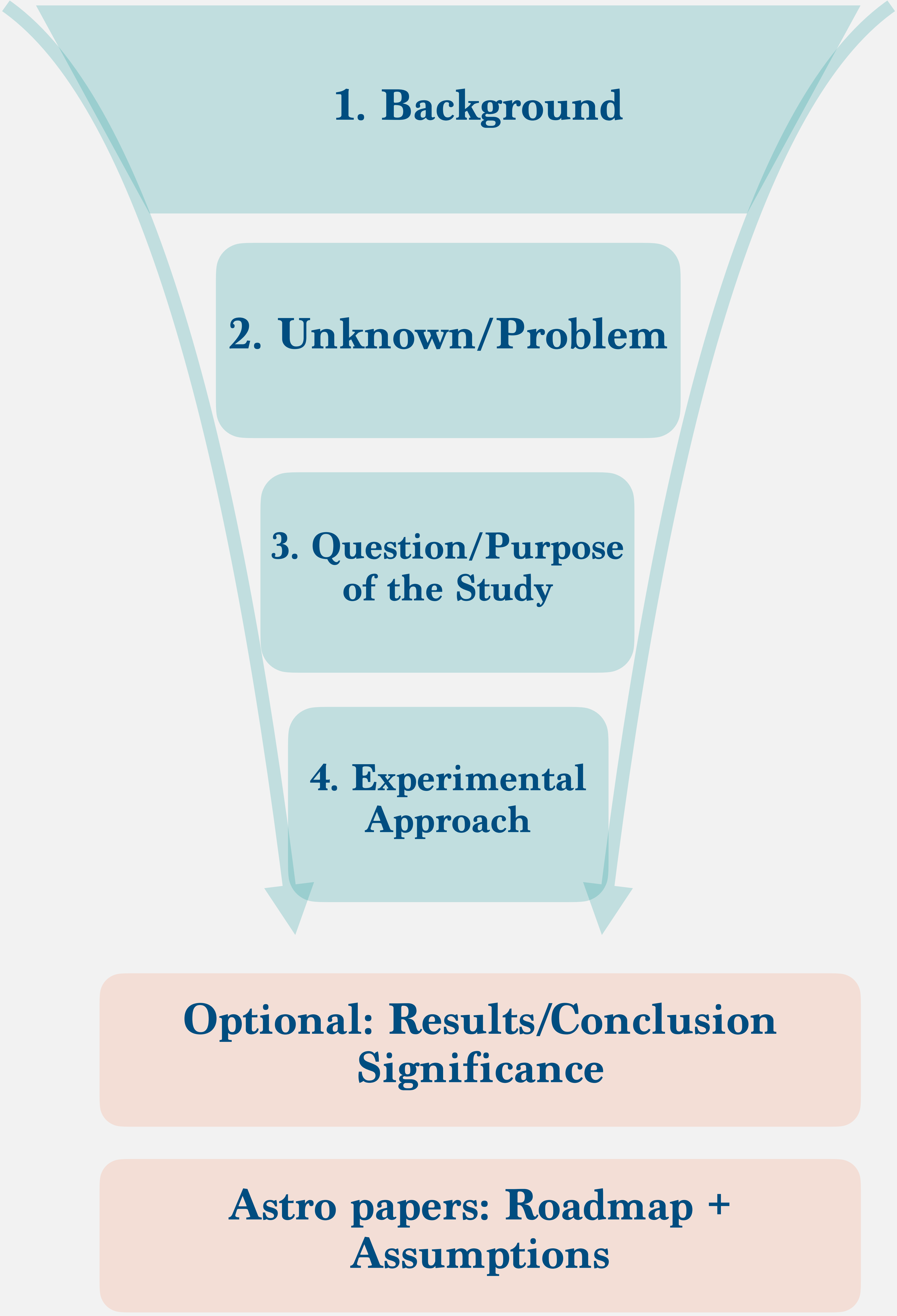


A good Introduction converts the reader from a passive and relatively disinterested recipient of the information in the paper into an enthusiastic seeker of the information.

The Introduction: components

1) Follow a <u>funnel structure</u>

2) Keep it short (1-2 double-spaced pages)

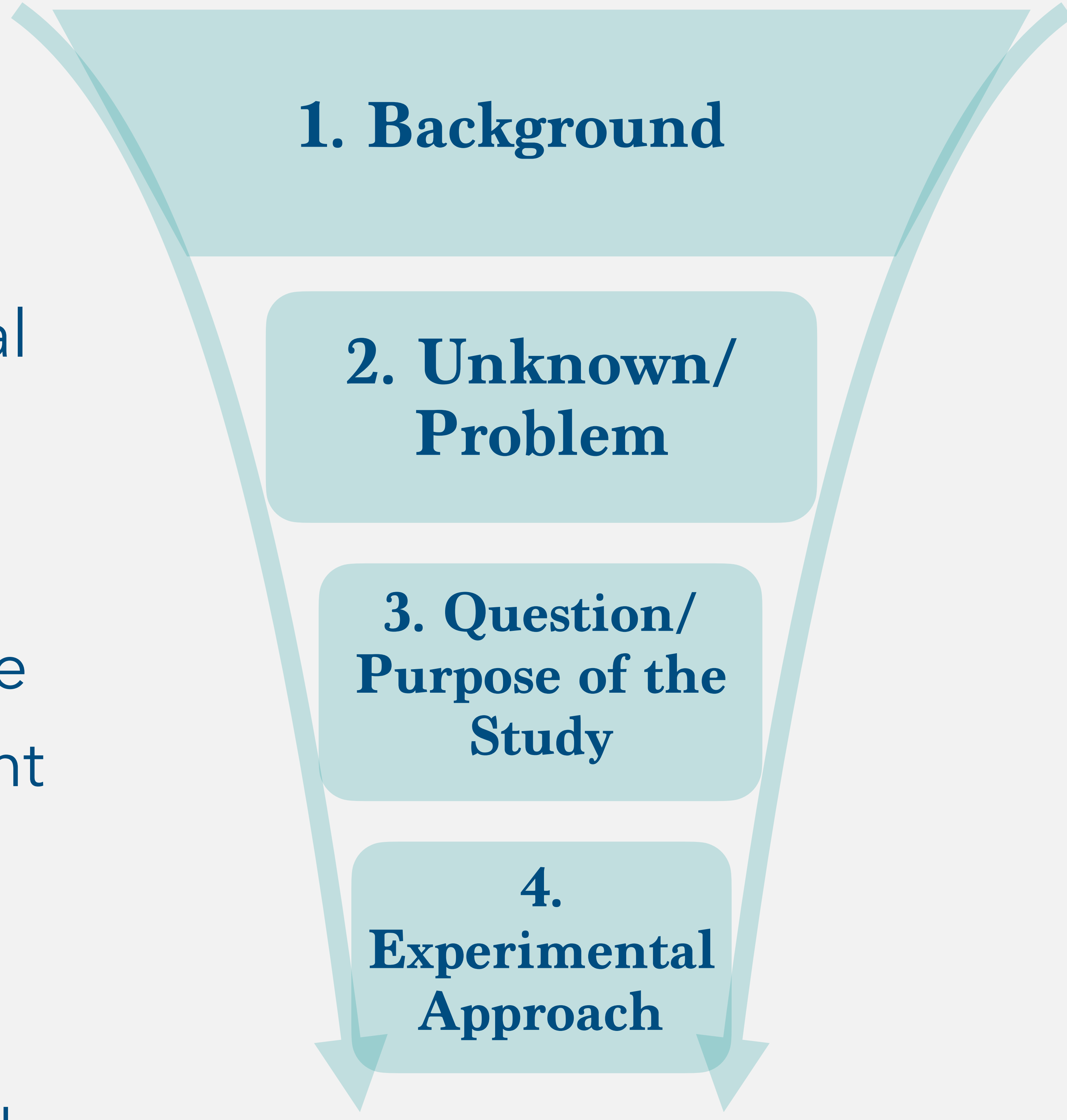


Remember: readers have relatively fixed expectations on where to find information in a document. Place elements in the right order to keep readers interested and make sure they follow the logical argument.

1) Background

Provide pertinent background information, but do not review the literature.

- The amount of information needed depends on the **audience knowledge**.
- **Broad background.** This is the big picture! Start very broad to provide some general context of your work. <u>This information would be information that any article on that topic could include.</u>
- **Specific background.** (Quickly) funnel down to write about the specific aspect of the topic that is of interest; mention the existing research in the area, and discuss current beliefs. <u>This is information that is pertinent to your particular study.</u>
- **Reference the work of others** as needed.
- **Do not review the topic!** You should not describe every finding or paper in the field ever obtained, no matter how interesting. The aim is a summary pertinent to the research you are presenting in the paper. This helps funnel down to the topic of interest; if it's too broad, readers won't know what to focus on and will get lost!

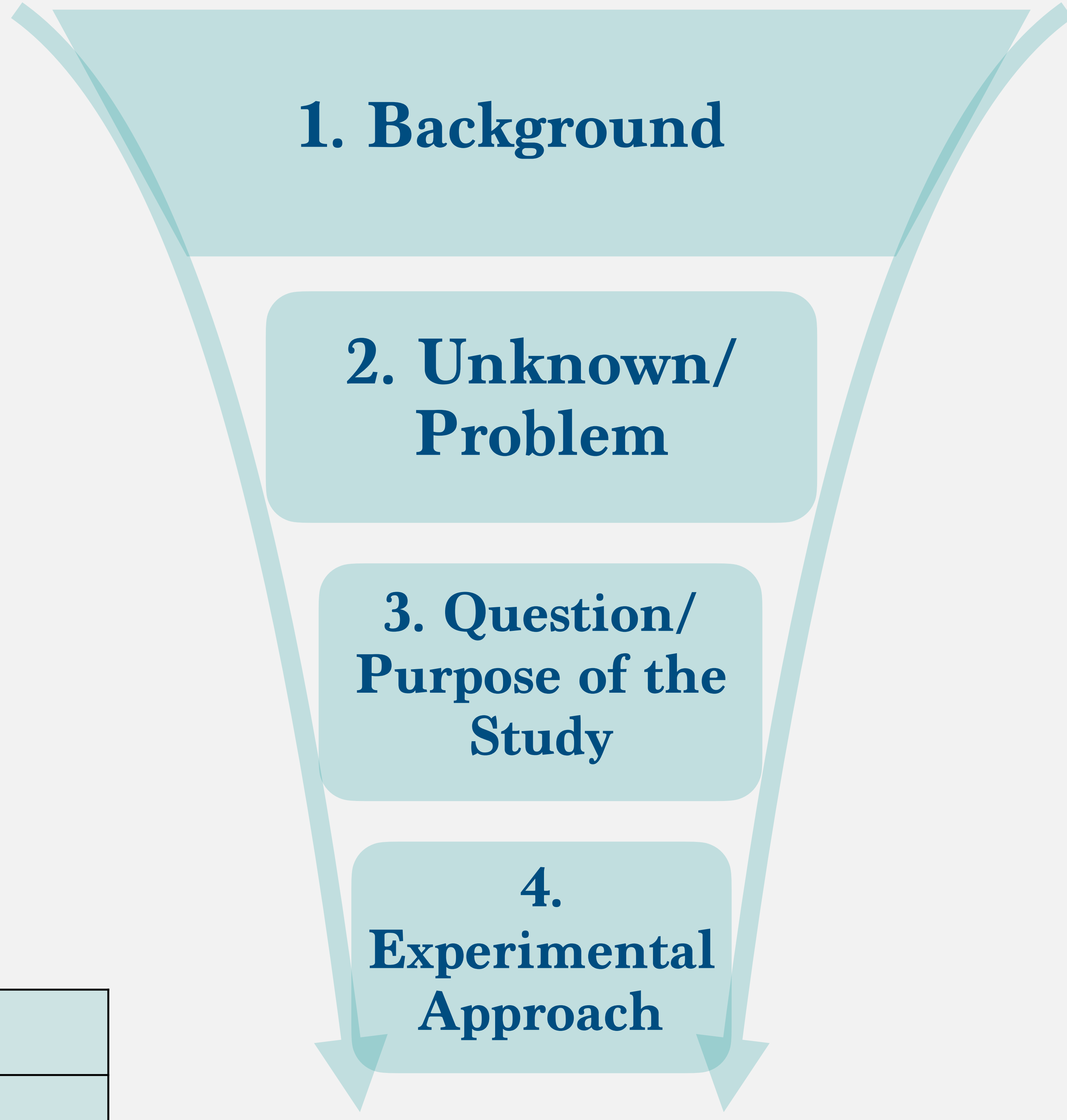


2) Unknown/Problem

State the problem or unknown.

- After discussing background and specific aspects of existing research, describe what the problems with the existing research are or what is the unknown – **the gap in knowledge.**
- The problem or unknown is clearest if you **signal it with appropriate language**.
- Use an **objective tone** when criticising previous work. Avoid antagonistic phrases. Do not blame individual authors or teams – you don't want to make enemies!

...does not seem to understand...	The results of study X have been questioned.
...failed to...	One study found A; another study found B.
...made the mistake of...	Findings on X are controversial.
...used improper methods...	Although A showed X, our results do not agree...

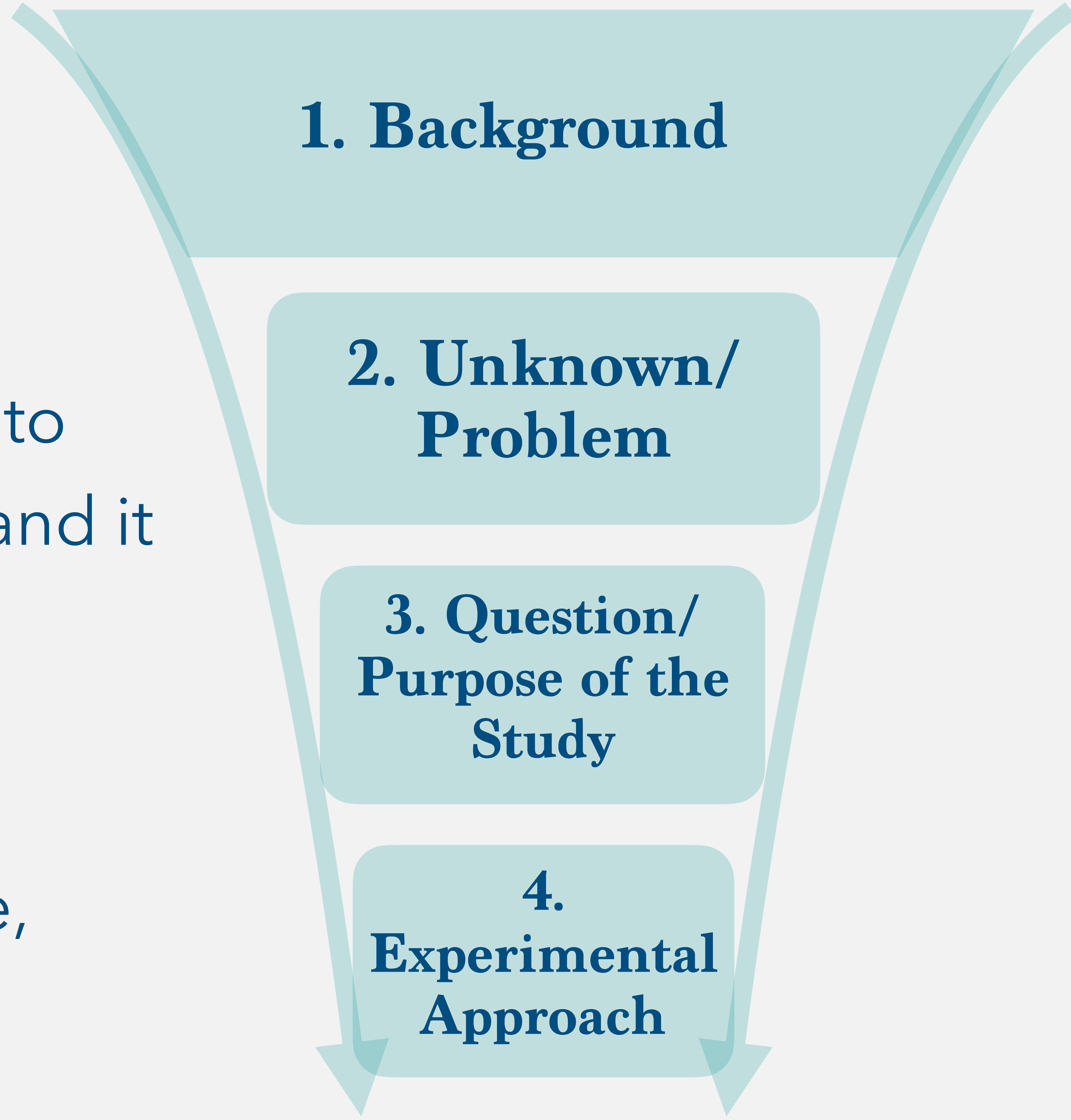


3) Question/Purpose

CENTRAL POINT

State the central point (question/purpose) directly. This is different than simply stating aims.

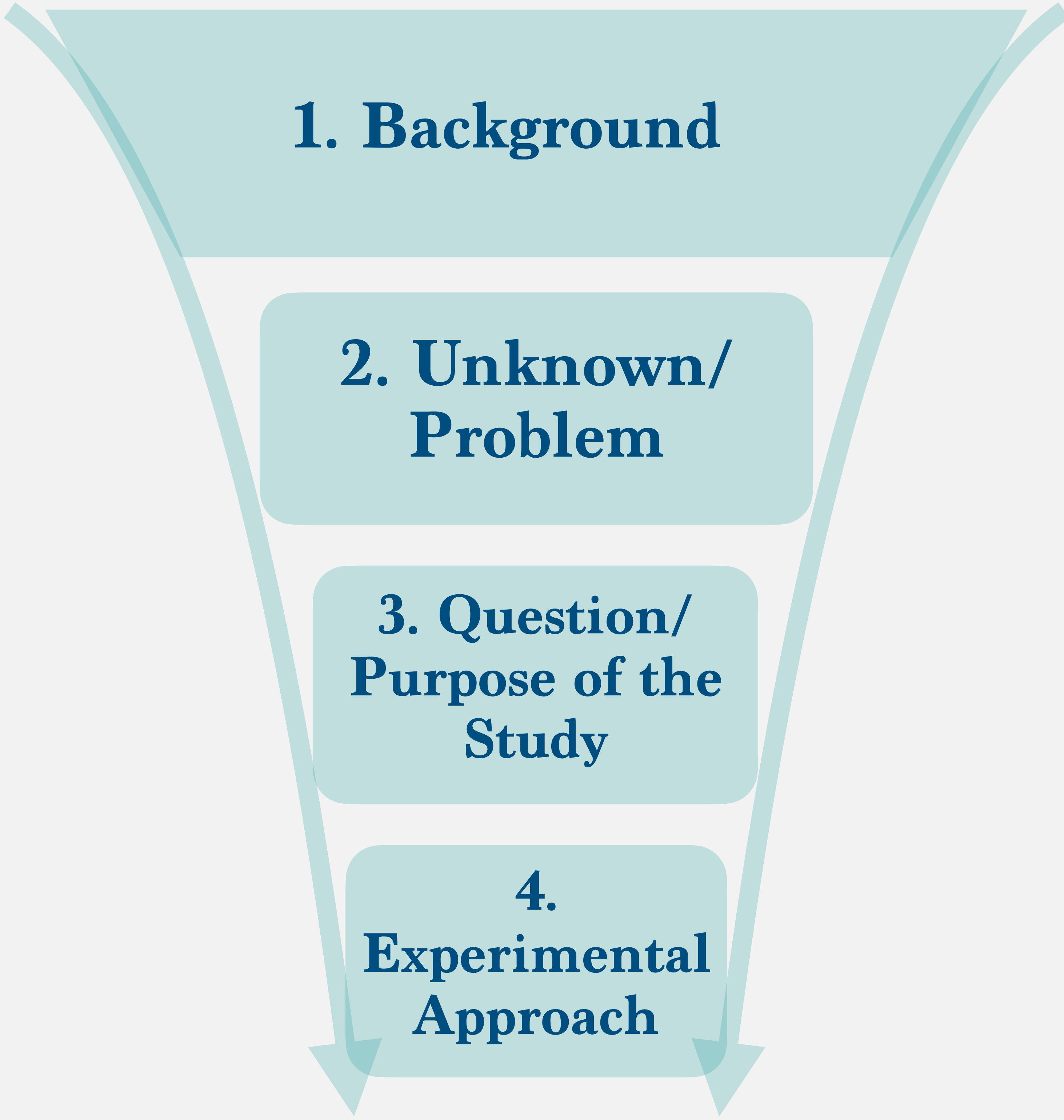
- The research question/purpose is the **central point** of your Introduction and the paper as a whole; it therefore needs to be worded very carefully.
- State this central point **precisely**, so the reader immediately has an idea of what to expect in the paper. The reader can **read in a directed way rather than blindly**, and it all makes more sense.
- It should name the **variables** studied as well as the **main features** of the study.
- It is **usually not written as a question**, but as an infinitive phrase or as a sentence, using a present tense verb.
- **Logical flow: the question/purpose and the unknown/problem have to make sense together.** The question/purpose should be the statement one would assume following that of the unknown or problem, which itself derives from what has been presented in the background.



4) Experimental Approach

State the experimental approach briefly.

- Keep it **short**: 1 – 3 sentences.
- It should be **signalled** so readers can identify it immediately ("we analysed", "we used", "we characterized", etc.)



Optional: Results/Conclusion

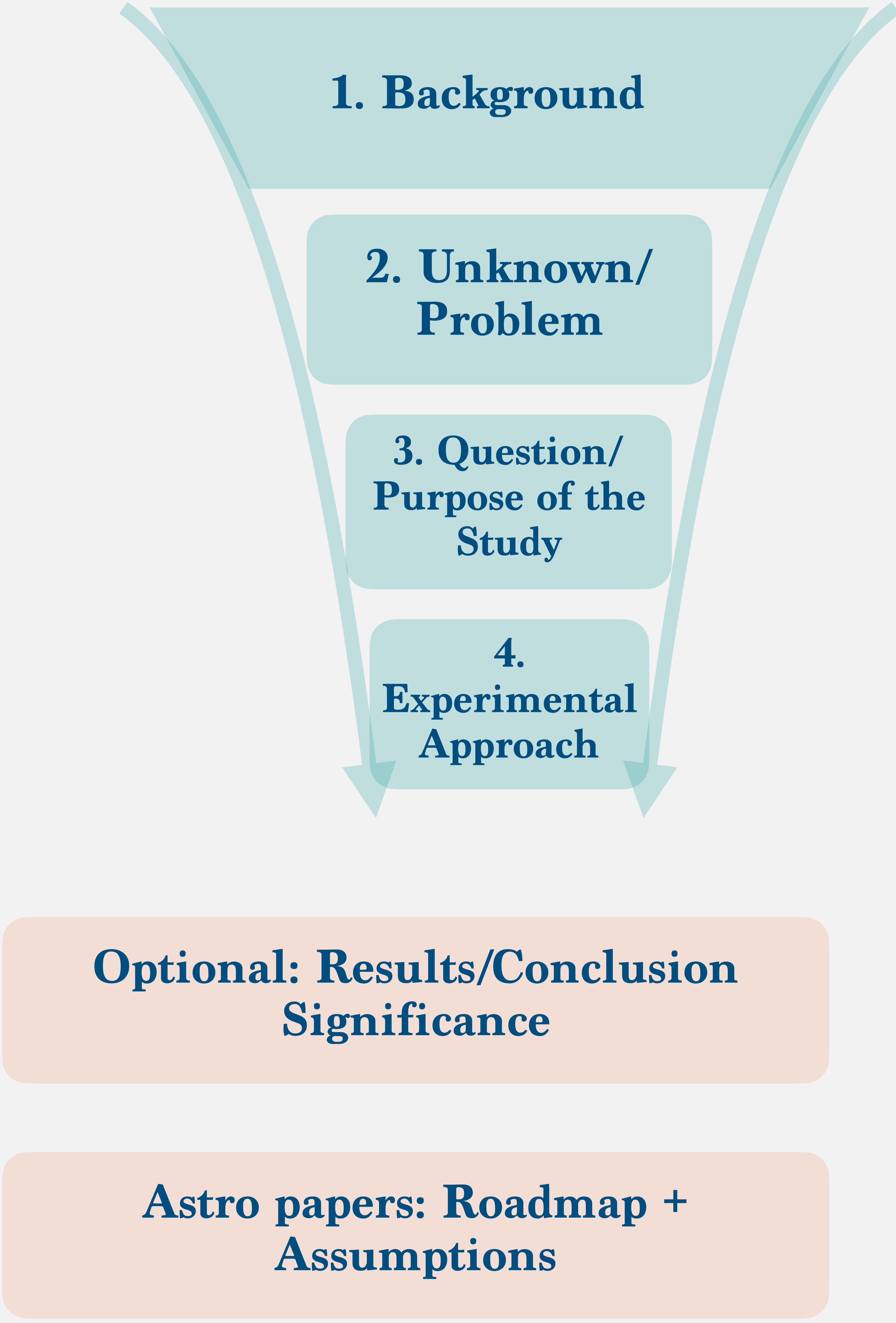
- Briefly state the main results and conclusion (1–5 sentences).
- Some readers like to read the main conclusions in the Introduction.
- Should be clearly signalled.

Optional: Significance

- It rounds up the Introduction nicely and provides the overall perspective of your work for the reader.

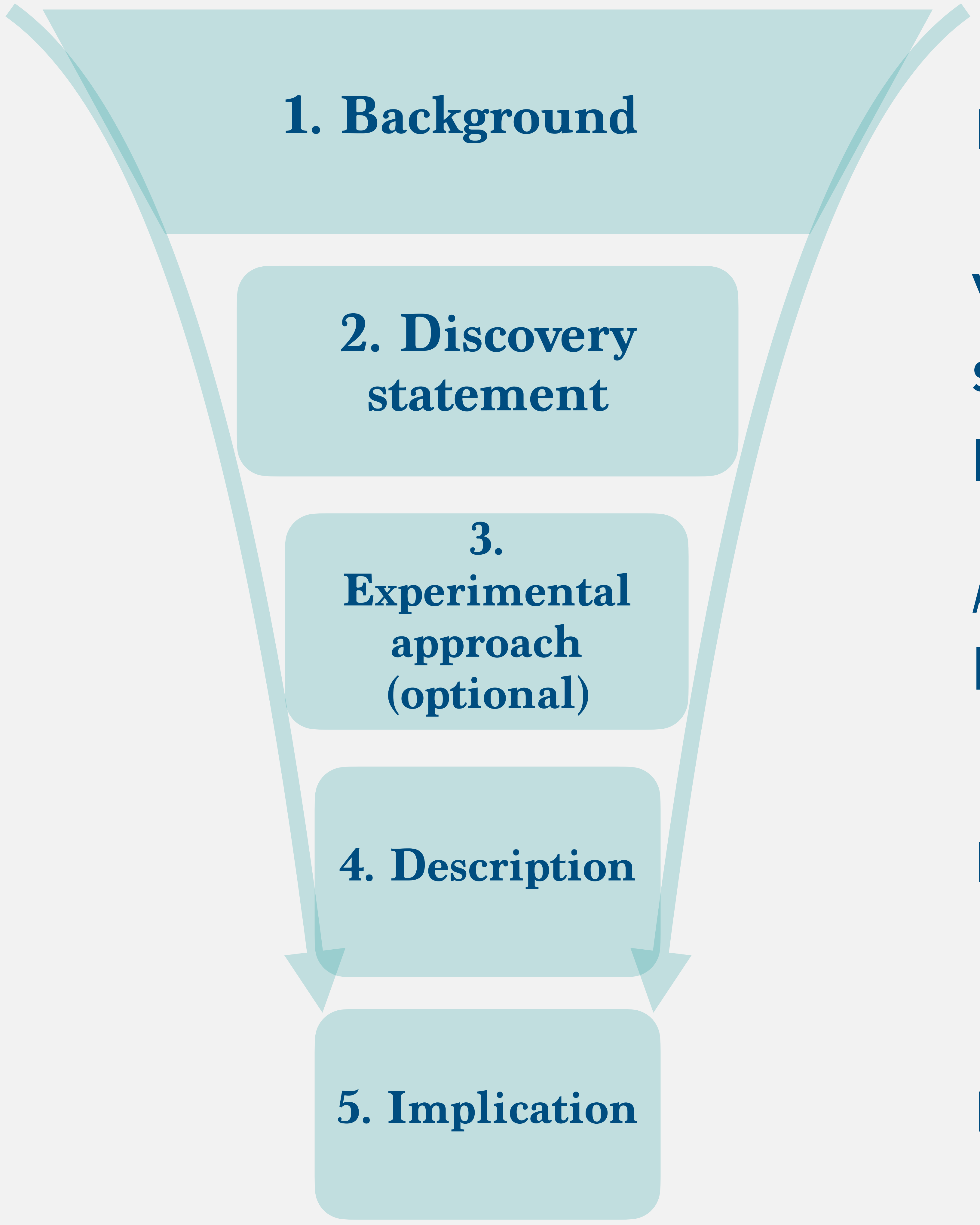
Roadmap

- Contents of each section.
- Major assumptions and conventions (e.g., H_0, IMF, magnitude units).



Special case: descriptive papers

Some research papers are not written to answer specific questions or to test a hypothesis but rather to describe a new finding, e.g., a very distant galaxy, a new emission mechanism, etc.



Background information and previous research in the area.

Your new discovery – the most important element. Usually written as a sentence, which should flow logically from the background information provided.

Approach taken toward analysing this discovery. May also include information on how the discovery was made or tested.

Description of the new element.

Importance of the findings.

Writing guidelines for the Introduction

- **Distinguish between past and present tense.**
  - **Past:** completed actions, e.g., referring to previously reported studies, describing your experimental approach.
  - **Present:** statements of general validity and those whose information is still true, e.g., if a finding is a general rule/well established, when describing the question/purpose of your research.
  - Note: Previously established knowledge in the Introduction should be in present tense. If you use past tense to describe results of previous work you are implying to the reader that you do not consider these to be true "facts".
- **Ensure good flow, cohesion, coherence:**
  - cohesive story in each paragraph;
  - weave paragraphs together logically;
  - ensure that all the elements are clearly identifiable and in correct order: background, unknown, research question and/or discovery statement, experimental approach.
- **Write clearly and concisely:** we will cover writing style advice in detail in later lectures.

Signals for the reader

Background	Unknown	Question/Purpose or Discovery	Experimental Approach	Results	Implication
X is... X affects... X is a component of Y X is observed when Y happens X is considered to be... X causes Y	...is unknown ...has not been determined The question remains whether... ...is unclear ...does not exist ...is not known	We hypothesized that... To determine... To study... To assess... To analyze... In this study we examined... Here we describe/ report This paper describes... We examined whether X is... We assessed if...	To test this hypothesis... We... We analyzed... For this purpose, we... ...by... ...using... For this study, we... To evaluate..., we... To answer this question, we...	We found... ...was found We determined... Our findings were... We observed that... Based on our observations...	...consistent with... ...indicating that... ...make it possible to... ...may be used to... ...is important for... Our analysis implies/ suggests... Our findings indicate that...

Common problems of Introductions

1) Missing elements: do not omit any of the elements

- Readers get confused and frustrated because they come away feeling that they have not fully understood what the paper is about.
- Most common elements missing:
  - unknown
  - experimental approach
  - sometimes even the question/purpose!
- **Failing to define the problem** (unknown):
  - "little is known about X" – usually not true. Also, linguistically, not concrete: what specifically do we not know? A concrete statement that defines a small gap in knowledge will do better than a fuzzy one that fails to define one.
  - offering a solution before defining a problem: **to sell us a solution, first sell us a problem.**

Common problems of Introductions

2) Excessive length: do not write a literature review!

- Often happens when the authors review a topic rather than funnel down stringently from background information to the research question.
- Readers expect the author to guide them through the pertinent information on the topic. If the author reviews the topic, the reader does not know what to focus on or what is pertinent for the paper.
- **Introduction vs literature review:**
  - **a literature review builds a solid wall – describing the knowledge.**
  - **a good introduction focuses on the hole in that wall – describing ignorance.**
    - focus on telling what we don't know rather than what we do;
    - when describing something we know, use it to identify the boundaries of knowledge.

Common problems of Introductions

3) Poorly posed question/purpose: focus on the "why" rather than "what"

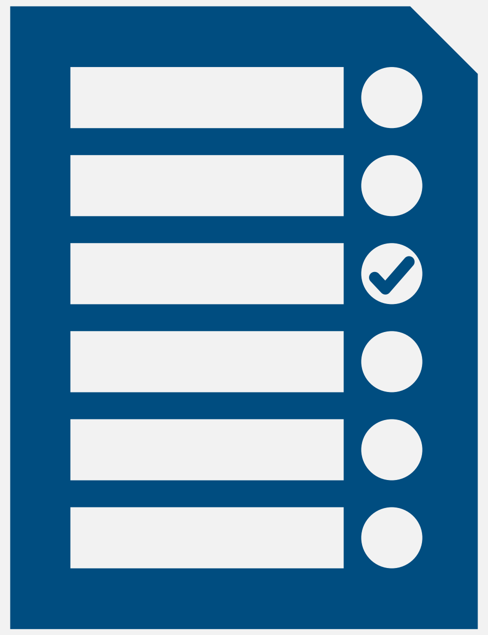
- The Introduction needs to describe precisely the specific knowledge you hope to gain. ***If you don't have a question, you are not doing good science. If the reader can't tell what it is, you are not writing good science.***
- **Questions vs objectives:** "Our objectives were" rather than "Our question was" – focus on the information they will collect, rather than the knowledge they hope to gain. The authors assume often wrongly that the question is obvious from the introduction and that they don't need to state it explicitly. ***Focussing on objectives instead of questions is weak science and weak storytelling.***
- After posing the question, briefly lay out the research approach: **"To learn X, we did Y"**, i.e., present the question and lay out an approach to answering it (here, stating objectives can be useful in providing a map that helps readers assess the rest of the paper). ***The critical part is not "we did Y" but "to learn X"*** – even more in the case of proposals!

Checklist for Introductions — structure & content

- [ ] Does the topic present something new and interesting?
- [ ] Are all the components there? (Clearly mark them on the margins)
- [ ] Is the research question stated precisely? (Is it in the present tense?)
- [ ] Do all the components logically follow each other? (Is the unknown what one would expect after reading about what is known? Is the research question really the question one would anticipate based on the unknown? Does the answer really answer the research question?)
- [ ] Is all background information directly relevant to your research question? Did you list only the most pertinent literature and not review the topic? Is the Introduction less than two pages?
- [ ] Have all the elements been signalled clearly?
- [ ] Did you keep the Introduction short?
- [ ] Are references placed correctly and where needed?
- [ ] Is the Introduction cohesive and coherent?
- [ ] Has sentence location been considered?
- [ ] Are topic sentences used well?

Checklist for Introductions — style & composition

- [ ] Are paragraphs consistent and cohesive?
- [ ] Are key terms consistent?
- [ ] Are key terms linked?
- [ ] Are transitions used, and do they make sense?
- [ ] Is the action in the verbs? Are nominalizations avoided?
- [ ] Did you vary sentence length and use one idea per sentence?
- [ ] Are lists parallel?
- [ ] Are comparisons written correctly?
- [ ] Have noun clusters been resolved?
- [ ] Has word location been considered? (Verbs close to subjects, Old/new information)
- [ ] Have grammar and technical style been considered? (person, voice, tense, prepositions, articles)
- [ ] Are words and phrases precise?
- [ ] Have unnecessary terms (redundancies, jargon) been reduced?
- [ ] Have spelling and punctuation been checked?



Summary: Introduction guidelines

- Interest your audience, and provide context.
- Follow a funnel structure.
- Keep the Introduction short.
- Provide pertinent background information; do not review the literature.
- State the problem or unknown.
- State the central point (question/purpose) precisely.
- State the experimental approach briefly.
- Distinguish between past and present tense.
- Use strong verbs and favour short sentences.
- Ensure good cohesion and coherence.
- Signal all the elements of the Introduction.
- Do not omit any element of the Introduction.

The Origin of the Mass-Metallicity Relation: Insights from 53,000 Star-forming Galaxies in the Sloan Digital Sky Survey

Tremonti et al., 2004, ApJ 613, 898

Background

Stellar mass and metallicity are two of the most fundamental physical properties of galaxies. Both are metrics of the galaxy evolution process, the former reflecting the amount of gas locked up into stars, and the latter reflecting the gas reprocessed by stars and any exchange of gas between the galaxy and its environment. Understanding how these quantities evolve with time and in relation to one another is central to understanding the physical processes that govern the efficiency and timing of star formation in galaxies.

The influence of stellar winds and supernovae on the interstellar medium (ISM) of galaxies, generally dubbed "feedback," has been regarded as an important ingredient in galaxy evolution since the 1970s (Larson 1974; Larson & Dinerstein 1975; White & Rees 1978). Feedback is believed to play a critical role in regulating star formation by reheating the cold ISM and by physically removing gas from the disk and possibly the halo via galactic winds. Various lines of observational evidence have established that large-scale outflows of gas are ubiquitous among the most actively star-forming galaxies at low and high redshift (e.g., Lehnert & Heckman 1996; Dahlem et al. 1998; Rupke et al. 2002; Shapley et al. 2001; Frye et al. 2002). However, detailed studies of winds in nearby starbursts have shown them to be a complex, multiphase, hydrodynamical phenomenon with the majority of the energy and newly synthesized metals existing in the hard-to-observe coronal and hot phases ($T = 10^5$–10^7 K; e.g., Strickland et al. 2002). This complexity has prevented both a direct assessment of the cosmological impact of galactic winds and the development of physically accurate prescriptions for incorporating feedback into semianalytical and numerical models of galaxy formation.

Fortunately, it is possible to obtain some quantitative information about the *impact* of galactic winds without a full understanding of the abstruse physics responsible for their morphology and kinematics. Galaxies that host winds powerful enough to overcome the gravitational binding energy of their halos will vent some of their metals into the intergalactic medium. Hence, one way of evaluating the importance of galactic winds is to look for their chemical imprint on galaxies. However, low metallicity is not necessarily a hallmark of wind activity. The metallicity of a galaxy is expected to depend strongly on its evolutionary state, namely, how much of its gas has been turned into stars. To detect metal *depletion*, it is therefore necessary to make some assumptions about the expected level of chemical enrichment based on a galaxy's star and gas content. Of course, other mechanisms besides winds could make a galaxy appear to be metal depleted, for example, the inflow of pristine gas, or the return of comparatively unenriched material from evolved low-mass stars. However, these scenarios can potentially be distinguished by examining the dependence of metal depletion on dynamical mass. To quantify the impact of feedback on the local galaxy population, we therefore compare the observed metallicities of galaxies spanning a wide range in total mass to the predictions of simple chemical evolution models.

The Origin of the Mass-Metallicity Relation: Insights from 53,000 Star-forming Galaxies in the Sloan Digital Sky Survey

Tremonti et al., 2004, ApJ 613, 898

Unknown

Interest in the relationship between mass and metallicity dates back several decades, beginning with the seminal work of Lequeux et al. (1979). However, because of the difficulty of obtaining masses, luminosity was generally adopted as a surrogate. A correlation between metallicity and blue luminosity was demonstrated by Garnett & Shields (1987) and extended by various authors (e.g., Skillman et al. 1989; Brodie & Huchra 1991; Zaritsky et al. 1994) to include a range of Hubble types and to span over 11 magnitudes in luminosity and 2 dex in metallicity. The interpretation of this striking trend has, however, remained a matter of some debate owing to the difficulty of transforming from observables to the ingredients needed for simple chemical evolution models (stellar mass, gas mass, and metallicity).

Purpose + Experimental Approach

In recent years, the development of more sophisticated models for stellar populations (e.g., Bruzual & Charlot 2003, hereafter BC03) and gaseous nebulae (e.g., Ferland 1996; Charlot & Longhetti 2001) has resulted in major advances in our ability to derive physical properties from observables. In this work we derive stellar mass-to-light (M/L) ratios according to the methods of Kauffmann et al. (2003a), which rely on spectroscopic line indices to help circumvent the classical age-metallicity-reddening degeneracy issues. We measure metallicity using the formalism of S. Charlot et al. (2004, in preparation), which makes use of all of the strong optical nebular lines in our bandpass (as opposed to more traditional methods that rely on a single line ratio). We couple these improved techniques with the enormous statistical power provided by the Sloan Digital Sky Survey (SDSS). We present the mass-metallicity relation of ~53,000 star-forming galaxies at $z \sim 0.1$ as a new benchmark for successful models of galaxy evolution.

Roadmap

We begin with a brief description of the SDSS data products and our data processing techniques in § 2. We outline our method for measuring metallicity and stellar mass in § 3. In § 4 we compare the luminosity-metallicity relation of the SDSS data with previous determinations. We present the mass-metallicity relationship in § 5 and consider its origin in § 6. We explore sources of systematic error in § 7 and conclude in § 8. Where appropriate we adopt a cosmology of $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 70$ km s^{-1} Mpc^{-1}.

A Simple Model for the Absorption of Starlight by Dust in Galaxies

Charlot & Fall 2000, ApJ 539, 718

Background

To interpret the observed spectral properties of galaxies, we require models for both the production of stellar radiation and its transfer through the interstellar medium (ISM). Currently, the accuracy of population synthesis models contrasts with the rudimentary way in which the absorption of starlight by dust is often treated. In many applications, dust is either ignored or assumed to be distributed in a uniform screen in front of the stars. The resulting uncertainties in the absorption of the ultraviolet radiation in galaxies can be as much as an order of magnitude. This problem has become especially acute in studies of galaxies at high redshifts. Nearby starburst galaxies may be suitable analogs of high-redshift galaxies and provide important clues for interpreting their spectral properties. The observations of nearby ultraviolet-selected starburst galaxies are numerous, including the ratio of far-infrared to ultraviolet luminosities, the ratio of H_α to H_β luminosities, the H_α equivalent width, and the ultraviolet spectral slope. In particular, there is a remarkably tight correlation between far-infrared luminosity and ultraviolet spectral slope (Meurer et al. 1995; Meurer, Heckman, & Calzetti 1999). This wealth of observations can potentially help us quantify the effects of dust on various spectral properties of galaxies.

Unknown + Purpose

There have been several analyses of the spatial distribution and optical properties of the dust in nearby starburst galaxies based on various subsets of the observations (e.g., Fanelli, O'Connell, & Thuan 1988; Calzetti, Kinney, & Storchi-Bergmann 1994, 1996; Puxley & Brand 1994; Meurer et al. 1995; Gordon, Calzetti, & Witt 1997). A generic result of these studies is that if the dust is distributed in a uniform foreground screen, it must have an unusually gray extinction curve. Otherwise, the distribution must be patchy. However, these analyses also raise questions of how to account self-consistently for all the observations. For example, the absorption inferred from the H_α/H_β ratio in starburst galaxies is typically twice as high as that inferred from the ultraviolet spectral slope. One interpretation of this result is that the ionized gas and ultraviolet-bright stars have different spatial distributions (Calzetti 1997). Issues such as this highlight the need for a simple yet versatile model to interpret simultaneously a wide range of phenomena related to the absorption of starlight by dust in galaxies. The purpose of this paper is to present such a model.

A Simple Model for the Absorption of Starlight by Dust in Galaxies

Charlot & Fall 2000, ApJ 539, 718

Experimental approach + Results

We begin with the conventional view that young stars ionize H II regions in the interiors of the dense clouds in which they are born. Line photons produced in the H II regions and the nonionizing continuum photons from young stars are absorbed in the same way by dust in the outer H I envelopes of the birth clouds and the ambient ISM. The birth clouds, however, have a finite lifetime. Thus, nonionizing ultraviolet and optical photons from stars that live longer than the birth clouds are absorbed only by the ambient ISM. This allows the ultraviolet continuum to be less attenuated than the emission lines. Our model builds on several previous studies. For example, Silva et al. (1998) considered the effects of a finite lifetime of stellar birth clouds on the continuum but not the line emission from galaxies. Here, we treat the transfer of radiation (especially scattering) in an approximate way, which would preclude a detailed description of surface brightnesses but should be appropriate for angle-averaged quantities such as luminosities. Our model succeeds in accounting quantitatively for all the available observations of an ultraviolet-selected sample of nearby starburst galaxies.

Roadmap

We present our model in § 2, where we express the effective absorption curve describing the global transmission of radiation in terms of the different components of the ISM. In § 3, we compare our model with observations and identify the specific influence of each parameter on the different integrated spectral properties of galaxies. One outcome of our detailed analysis is a remarkably simple recipe for absorption, which provides a good approximation to the observed mean relations and is easy to incorporate into any population synthesis model. In § 4, we explore how the spatial distribution of dust can be constrained by the observations. Our conclusions are summarized in § 5.