Lecture 3
Writing the Introduction Section of a Paper

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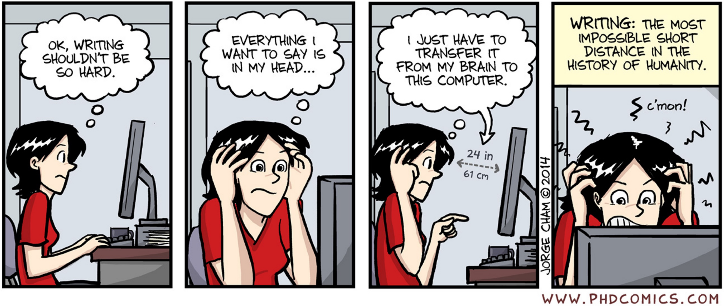
Scientists and writing

You do not succeed as a scientist by merely getting papers published. You succeed by getting them **cited**. Writing is not only something a scientist **does**. Being a writer is something a scientist **is**.

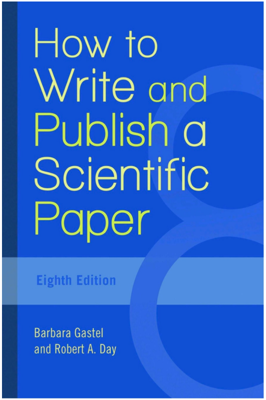
Writing can be a painful process of rewriting, rewriting, and more rewriting until your work gets good enough to be sent off.

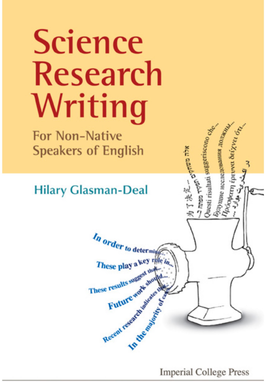


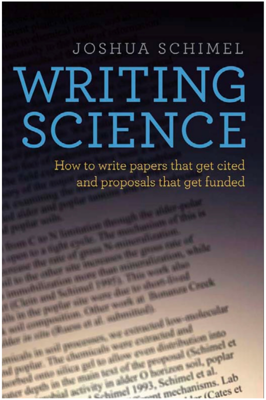
“Writing: the most impossible short distance in the history of humanity.”

Some references on scientific writing

Gastel and Day book: comprehensive cover of the fundamentals;
Glassman-Deal book: useful language tips for non-native speaker;
Schimel book: techniques for cohesive and intriguing writing.







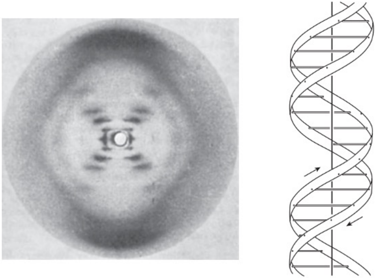
Scientific writing as story telling

The role of scientists is to collect data and transform them into understanding. Their role as authors is to present that **understanding**.

Scientific writing is not merely outlining what you did and present what you found, its essence is to **extract and distill a story**.

A. Photo 51

B. Model of DNA



(Schimel 2012, Writing Science: How to write papers that get cited and proposals that get funded)

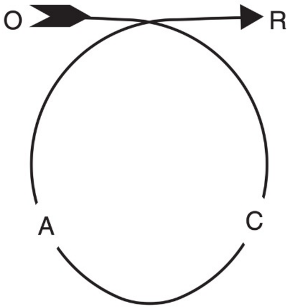
Structure of a story

Stories usually have the **OCAR** structure:

- **Opening**: Whom is the story about? Who are the characters? Where does it take place? What do you need to understand about the situation to follow the story?
- **Challenge**: What do your characters need to accomplish?
- **Action**: What happens to address the challenge?
- **Resolution**: How have the characters and their world changed as a result of the action?

OCAR structure in the scientific writing context

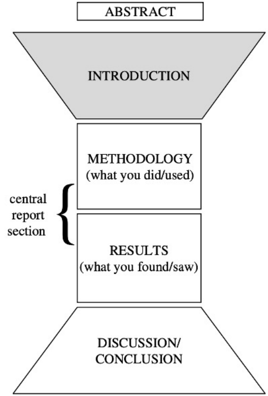
Opening: what is the larger problem you are addressing?
Challenge: what specific question do you propose to answer?
Action: what did you do to address the question?
Resolution: what did you learn from your work?



(Schimel 2012, Writing Science: How to write papers that get cited and proposals that get funded)

Structure of a scientific paper

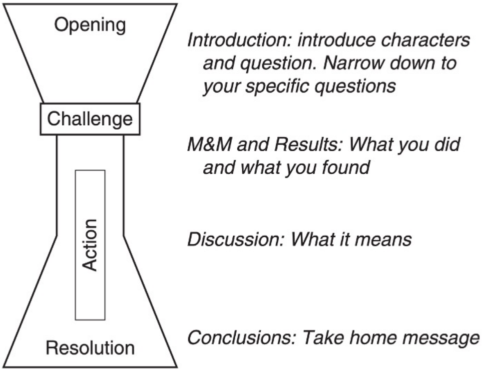
A typical scientific paper contains the introduction, methods, results, and discussion sections, commonly referred to as the **IMRaD** structure.



(Glasman-Deal 2010, Science Research Writing for Non-Native Speakers of English)

Mapping story structure to paper structure

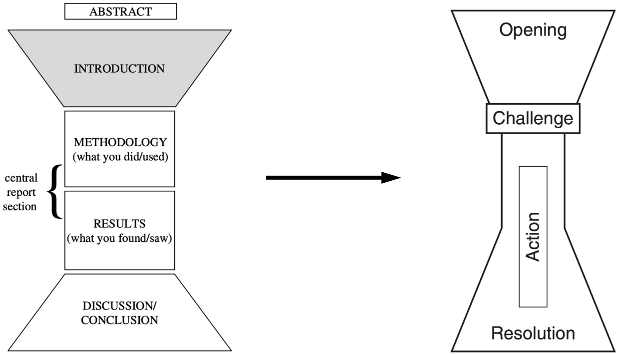
The **OCAR** structure corresponds well with the typical **IMRaD** structure of scientific papers.



(Schimel 2012, Writing Science: How to write papers that get cited and proposals that get funded)

Combining story and paper structure in writing

Establish basic structure of writing based on the conventional IMRaD structure; Refine the writing based on the OCAR story structure.



General guidelines for the introduction

The introduction should have the following essential components:

- Present the nature and scope of the problem investigated;
- Review pertinent literature to orient the reader;
- Identify current knowledge gaps;
- Make clear the question or hypothesis of the research;
- State the methods of the investigation briefly;
- If necessary, state the principal results of the work.

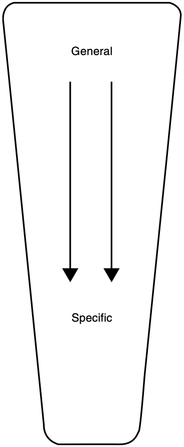
A general model for introduction

In general, the introduction section may comprise the following:

- Introduce the general background and establish the significance of the problem (1–2 paragraphs);
- Review literature relevant to the focal problem (1–3 paragraphs)
- Identify knowledge gap and specify the questions/hypothesis to be addressed (1 paragraph)
- Describe your own research briefly (1 paragraph)

A general model for introduction

We can divide the writing of the introduction into four stages, going from general to specific.



(1) Statements about the field of research to provide the reader with a setting or context for the problem to be investigated and to claim its centrality or importance.

(2) More specific statements about the aspects of the problem already studied by other researchers, laying a foundation of information already known.

(3) Statements that indicate the need for more investigation, creating a gap, a need for extension, or a research niche for the present study to fill.

(4) Very specific statements giving the purpose/objectives of the writer's study or outlining its main activity or findings.

(5) Statement(s) that give a positive value or benefit for carrying out the study (optional).

(6) A "map": statements telling how the rest of the article is presented (only in some research fields).

(Cargill and O'Connor 2013, Writing Scientific Research Articles)

A general model for introduction: example

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NOTE

Habitat complexity mitigates trophic transfer on oyster reefs

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ABSTRACT: Structured habitats within several aquatic systems have been characterized as having higher abundances of both predators and their prey. Understanding this somewhat paradoxical phenomenon requires teasing apart how habitat complexity influences predator-prey dynamics. To determine whether habitat complexity influences predator foraging efficiency, we measured predator foraging rates within structurally simple and complex habitats. We selected as our test system mud crabs feeding on juvenile hard clams within biogenic reefs formed by the eastern oyster. At low and intermediate crab densities, foraging rates of mud crabs were similar between simple and complex habitats. However, at high crab densities foraging rates were higher for crabs in the complex reefs than in the simple reefs. In addition to providing refuge to both intermediate predators and their prey, habitat complexity appears to enhance predator foraging efficiency by reducing interference competition among predators. In systems where interference competition among densely populated predators may be intense, complex habitats may not provide survival benefits to all trophic levels.

KEY WORDS: *Mercenaria mercenaria* · *Panopeus herbstii* · Habitat complexity · Interference competition · Density dependence · Oyster reefs

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INTRODUCTION

Biogenic habitats such as seagrass beds, oyster reefs, and coral reefs create structurally complex habitats that generally have higher densities of macroinvertebrate prey than unstructured mud bottom habitats (Summerson & Peterson 1984, Lenihan & Peterson 1998). Within a particular habitat of varying complexity (e.g. sea grass patches with different grass blade densities), macroinvertebrate densities and species richness generally are positively correlated with structural complexity (Crowder & Cooper 1982, Diehl 1988, Diehl 1992, but see Fonseca et al. 1996, Kelaher 2003). Experimental studies have demonstrated that enhanced habitat structure increases prey survival (Heck & Thoman 1981, Crowder & Cooper 1982, Schriver et al. 1995, Beukers & Jones 1997, Grabowski 2004), and that the spatial extent of prey is often constrained by the availability of refuge (Beck 1997, Gutierrez et al. 2003). Irrespective of reducing predatory controls, biogenic habitats that create emergent structure may enhance densities of prey by baffling water and subsequently enhancing the deposition of food and settlement of larvae or post-larvae (Tegner & Dayton 1981, Summerson & Peterson 1984, Commito & Rusignuolo 2000, Reise 2002).

In addition to small-invertebrate prey, intermediate predators such as juvenile fish and transient macroinvertebrates also aggregate within complex habitats (Summerson & Peterson 1984, Lenihan et al. 2001, Heithaus & Dill 2002). Although foraging in structurally complex habitats may be more difficult than unstructured habitats for intermediate predators (Summerson & Peterson 1984), added structural complexity reduces the foraging success of higher-order consumers and thus may increase survivorship of intermediate predators (Diehl 1992, Schriver et al. 1995, Corona et al. 2000, Grabowski 2004). Intermediate predator use of suboptimal foraging habitats that offer refuge suggests that predation risk from higher-order consumers is intense (Sih 1980, Werner et al. 1983, Werner & Hall 1988). Several investigations have determined that top predators induce many intermediate predators such as juvenile American lobsters *Homarus americanus* and other crustaceans to seek shelter and forage less in open habitat (Wahle 1992, Appleberg et al. 1993, Spanier et al. 1998). Yet other studies have found that foraging efficiency of top predators is maximized within intermediate or even higher levels of structural complexity, presumably as a result of increased prey densities or decreased predator detection within more complex habitats (Crowder & Cooper 1982, Winfield 1986).

Independent of prey density, habitat complexity may also impact predator foraging efficiency by influencing behavioral interactions among predators and their prey (Werner & Peacor 2003, Schmitz et al. 2004). In systems where competitive interactions among predators are strong, habitat complexity could alter predator foraging efficiency by decreasing encounter rates of predators and thus reducing interference behavior. Clark et al. (1999) documented that interference behavior among blue crabs *Callinectes sapidus* reduced their foraging efficiency, and that more widely distributed prey patches decreased interference interactions by reducing intraspecific encounter rates among crabs. Increased structural complexity also may decrease encounter rates and thus increase foraging efficiency. Experiments that address how habitat complexity impacts intra- and interspecific competitive interactions among predators and the consequences for prey survivorship are limited. In this study, we identify whether habitat complexity affects mud crab *Panopeus herbstii* predation on juvenile hard clams *Mercenaria mercenaria* at multiple predator densities to assess if habitat complexity influences intraspecific interactions among mud crabs. Specifically, we manipulated mud crab density and structural complexity of oyster reef habitats within mesocosms to determine how these factors influence crab foraging rates.

MATERIALS AND METHODS

We conducted experiments in a concrete settling tank ($6 \times 9 \times 1.2$ m) at the University of North Carolina Institute of Marine Sciences (UNC-IMS) laboratory in Morehead City, North Carolina, in May 2002. Unfiltered seawater from Bogue Sound, North Carolina, was pumped (0.27 to 0.29 l s^{-1}) into the concrete tank continuously during the experiment, maintaining a constant depth of 1.2 m. To test the effects of predator density and habitat complexity, we submerged individual square ($0.6 \times 0.6 \times 1.0$ m) mesocosms evenly spaced within the settling tank. Mesocosms consisted of a wooden tray ($0.6 \times 0.6 \times 0.2$ m) as the base and 6.25 mm mesh plastic fencing along the sides and top. Each mesocosm was elevated on cinder blocks 0.5 m above the bottom of the settling tank so that mesocosms extended just above the water surface. Tops were removable to permit construction and breakdown of experimental reefs.

We tested whether habitat complexity affects foraging rates of mud crabs on hard clams at 3 densities (11, 22, and 44 m^2) of mud crabs. These 3 densities represent a realistic range of mud crabs on oyster reefs in the wild (Meyer et al. 1996, Grabowski 2002). Reef construction consisted of a sand (20 l) base in each mesocosm followed by unaggregated oyster shell (20 l) in each of 6 mesocosms (simple reefs), or oyster clusters (20 l) on top of unaggregated shell (20 l) in each of the other 6 mesocosms (complex reefs). Oyster clusters extended 10 to 30 cm upward from the unaggregated shell, and created an irregular, high vertical relief in contrast to simple reefs (<5 cm vertical relief). One hundred juvenile clams (mean 13.7 ± 0.1 SE mm shell length) were deposited after adding sand to each experimental mesocosm, and were buried before adding shell material. Clams were obtained from D. Gilgo's aquaculture lease in the Newport River, Carteret County, North Carolina, and were stored in upwellers at UNC-IMS prior to use in the experiment. Each of 2 high and 2 low complexity reefs received 4, 8, and 16 mud crabs (32.8 ± 0.7 mm carapace width) after mesocosms were submerged in seawater. Previous experiments of crab consumption on oysters and clams within this experimental arena demonstrated that bivalve survivorship is >98% in the absence of crab predators (Grabowski 2004, unpubl. data). Mud crabs were collected on oyster reefs in Back Sound, Carteret County, North Carolina, and held in upwellers at UNC-IMS prior to use in the experiment.

Living, dead, and missing mud crabs and clams were quantified after 48 h to avoid prey depletion (maximum prey depletion of 59.9 ± 4.2% occurred in the high crab density–complex habitat treatment). A very small proportion (2.4%) of mud crabs was missing or dead at the end of each experimental run. Broken remnants of clam shells were retrieved in all pools and suggested predation by crabs. Because pre-

A few comments on the example

The example in the previous slides has a few notable features:

- The introduction was written with a very clear logical order using the common structure of the introduction section;
- The authors used the topic sentence of each paragraph to guide the readers through the logic flow;
- An effective way of drafting the introduction, or more generally a manuscript, is to write down the first and/or last sentence of each paragraph before filling up all paragraphs.

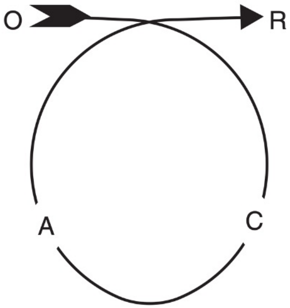
Back to story writing

Opening: what is the larger problem you are addressing?

Challenge: what specific question do you propose to answer?

Action: what did you do to address the question?

Resolution: what did you learn from your work?



(Schimel 2012, Writing Science: How to write papers that get cited and proposals that get funded)

Opening

What is a good opening for a scientific paper?

- A good opening of a scientific paper should **define the general problem** and **indicate or hint at the direction of the paper.**
- The opening typically encompasses the first paragraph and sometimes several more.

Good opening

This is the openning for a synthesis paper on nitrogen processing in soils (Schimel and Bennett 2004, Ecology).

> Since the late 1800s, N mineralization has been perceived as the center point of the soil N cycle and the process that controls N availability to plants.

Comment: This opening is effective for two reasons:

- The opening hints at the readers the direction of the paper. The word "perceived" draws readers' attention and makes it clear that the paper will challenge that perception.
- The opening also indicates that there will be a historical element, which is suitable for a synthesis paper on how understanding of N processing in soils changed over time.

Good opening

This opening comes from a paper evaluating the effects of timing, dose, and source of folate during pregnancy on childhood asthma (Whitrow et al 2009, American Journal of Epidemiology).

> Current public health guidelines in the United States, the United Kingdom, and Australia recommend that women consume a supplemental dose of 400 μg of folic acid per day in the month preceding and during the first trimester of pregnancy to reduce the risk of neural tube defects in children.

Comment: This is an effective opening as it introduce the general problem and hint at the reader that the paper is going to evaluate and potentially challenge the current recommendation of taking 400 μg folic acid during pregnancy.

Good opening

This opening comes from a review paper on conjugated polmyers as molecular materials (Schwartz 2003, Annual Review of Physical Chemistry)

> Conjugated polymers are novel materials that combine the optoelectronic properties of semiconductors with the mechanical properties and processing advantages of plastics…Thus, conjugated polymers offer the possibility for use in devices such as plastic LEDs photovoltaics, transistors, and in completely new applications such as flexible displays.

Comment: The first sentence frames the overall topic while the last sentence set the story in concrete terms, making it clear what this paper is going to focus on.

Good opening

This opening is from a paper on Arctic soil organic matter chemistry (Weintraub and Schimel 2003, Ecosystems).

> The arctic has become a focus of attention because global warming is expected to be the most severe at extreme latitudes. The thick organic soils of the tundra contain large stocks of carbon and these soils may act as either a source or a sink for atmospheric carbon dioxide...Thus, the direction the C balance of the arctic will shift with warming is unclear and depends on interactions between soil C and N cycling that we still do not understand in the tundra

Comment: When you need to engage a wider audience, open with a general issue that engages your target audience, but then modulate it to the one you want to work with.

Bad opening

Misdirection: this paper is about how plant transport CH_4, but the opening talks about how plant-derived carbon drives CH_4 dynamics. The opening does not point to the direction where the paper is heading to.

> Plants are a critical control of CH_4 dynamics in wetland ecosystems. They supply C to the soil methanogenic community both through production of soil organic matter, and as fresh exudates and residues. Fresh plant material may be an important CH_4 precursor even in an organic matter-rich peat soil. Strong correlations between net primary productivity and system-level CH_4 fluxes across a wide range of ecosystems highlight the importance of plant C inputs.
>
> Vascular plants, however, also transport CH_4 out of soil and sediment, effectively bypassing the aerobic zone of CH_4 oxidation.

Bad opening

No direction: the opening talks about common knowledge of meiosis but did not indicate what the paper will focus on. It offers no direction to the reader.

> In meiosis, genes that are always transmitted together are described as showing "linkage". Linkage, however, can be incomplete, due to the exchange of segments of DNA when chromosomes are paired. This incomplete linkage can lead to the creation of new pairings of alleles, creating new lineages with distinct sets of traits.

Changing styles for your audiences

For specialists, one can use more technical terminology.

> Larry Pameroy's seminal paper revolutionized our concepts of the ocean's food web by proposing that microorganisms mediate a large fraction of the energy flow in pelagic marine ecosystems. Before 1974, bacteria and protozoa were not included as significant components of food web models. Pomeroy argued forcefully that heterotrophic microorganisms, the "unseen strands in the ocean's food web," must be incorporated into ecosystem models.

(Azam et al 1994, Microbial Ecology)

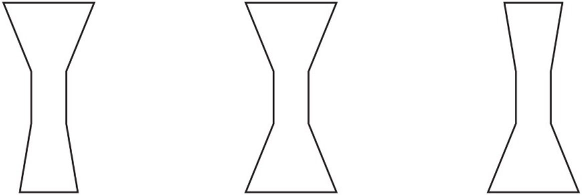
For non-specialists, use characters that are familiar to the general readers.

> Antonie van Leeuwenhoek (1632–1723), the first observer of bacteria, would be surprised that over 99% of microbes in the sea remained unseen until after Viking Lander set out to seek microbial life on Mars.

(Azam and Worden 2004, Science)

How wide should your opening be?

The opening should have similar “width” as your resolution. If you err, it is better to err slightly onthe wider side.



A. Opening wider than resolution: overpromising. Your readers will feel cheated.

B. On target. Your readers will be satisfied.

C. Resolution wider than opening: underpromising. Your readers won’t ever see that you are telling a story that would interest them.

(Schimel 2012, Writing Science: How to write papers that get cited and proposals that get funded)

The challenge

General guidelines for writing the challenge of a story:

- Define the challenge as a question, not merely describing your objective.
- Some scientists, particularly those in biology, suggest stating clearly your hypothesis is a necessity for scientific paper.
- After posing the question, a good challenge briefly lays out the research approach. This is where you tell us about specific objectives and the information you will generate.
- The challenge should be logically motivated. Statements like “something has not been done” or “something has not been done at this location” are weak and not persuasive.

Good challenge

The authors lay out the problem explicitly first. The literature review, coupled with logic, makes a strong case for the current study (del Pilar Gomez and Nasi 2015, Journal of Biological Chemistry).

> Despite the tantalizing evidence for DAG and/or its downstream products in visual transsuction and the synergistic role of calcium, in no instance has application of such chemical stimuli fully reproduced the remarkable size and speed of the photocurrent. This may imply that yet another signal may be missing from the proposed schemes. In other systems PIP_2 has been shown to possess signaling functions of its own, independent from those of its hydrolysis products. These observations prompted the conjecture that in microvillar photoreceptors PIP_2 may help keep the channels closed and its hydrolysis could promote their opening. In the present report, we examined the consequences of manipulating PIP_2 on membrane currents and light responsiveness in isolated photoreceptor from *Pectren* and *Lima*.

Good challenge

The authors laid out their hypotheses and provided justification for them (Bengtson and Bengtsson 2007, Ecology Letters).

> The experiment was set up to test three hypotheses: first, DOC was hypothesized to be the source of respired CO_2 in forest soils. There are several reasons to justify that: (i) DOC consists partly of sugars and amino acids that are readily amenable to microbial uptake; (ii) being essentially aquatic, micro-organisms would be expected to use compounds dissolved in the soil water and (iii) models of DOC dynamics indicate that microbial–DOC relationships are important in regulating C fluxes in surface soil horizons. However, one can raise the objection that the DOC pool of forest soils is small relative to the CO_2 fluxes, and that at least a part of the DOC pool is old and slowly turned over. Therefore, our second hypothesis was that the rate of DOC production, rather than the DOC concentration, was the rate-limiting step for microbial respiration. Finally, given that enzymes catalyse the DOC production and enzymatic activity depends on temperature, the rate of respiration was hypothesized to be dependent on the temperature rather than on the size of different C pools.

Good challenge

It is common to find **signal words or phrases** that indicate the existence of knowledge gap, such as however, remain a major challenge, rarely, not well understood, and presently unclear.

> However, understanding how these processes interact to regulate invasions remains a major challenge in ecology.
>
> Despite its acknowledged importance, propagule pressure has rarely been manipu- lated experimentally and the interaction of propagule pressure with other processes that regulate invasion success is not well understood.
>
> It is presently unclear how different disturbance agents influence long-term patterns of invasion.

(Britton-Simmons and Abbott, 2007, Journal of Ecology)

Bad challenge

The specific question of the study was not clearly defined here.

> Some T-cells may be anergic–that is, unable to proliferate after being restimulated with an antigen. Some anergic T-cells are unable to link to the T-cell-antigen presenting cell (APC) interface. Here we examined the structural characteristics of anergic mouse T-cells and we tested their functional response to being rechallenged with antigen-loaded APCs

This can be improved by simply stating what the researchers intend to achieve. The **“To learn X, we did Y”** template is an effect way to do this.

> To determine what causes mouse T-cells to be anergic, we evaluated the structural characteristics of T-cells and how they responded to being rechallenged with antigen-loaded APCs

Bad challenge

The authors presented the challenge in chronological order, but the core question came in second.

> The study had two goals. First, we aimed to constrain our estimates of grassland plant production by comparing measurements based on two techniques: maximum biomass at the end of the season and periodic measurements of photosynthesis. Second, we examined the response of grass growth to a combination of elevated CO_2 and increased temperatures, conditions that are expected to occur with climate warming.

To fix this problem, we highlight the core question first.

> The primary goal of this study was to evaluate how grass growth responds to a combination of elevated CO_2 and increased temperatures, conditions that are expected to occur with climate warming. To validate the plant growth measurements, we used to approaches: maximum biomass at the end of the season and periodic measurements of photosynthesis.

Connecting the opening and the challenge

The opening of a paper identifies a large problem, while the challenge defines a specific question. The main body of the introduction narrows the focus and leads readers from the general to the specific, drawing them along the story and framing in the knowledge gap

Tip 3 - Introduction: work on that funnel shape!

Effective connection: an example

Dissolved organic carbon (DOC) undergoes numerous transformations as it flows from land to ocean, with both positive and negative effects on ecosystem services. Mineralization of DOC into greenhouse gases contributes to climate warming but also removes organic contaminants from potable water reservoirs. Simultaneously, DOC that escapes mineralization may contribute to carbon sequestration and, thus, climate change mitigation, for example, via sedimentation. Thus, DOC turnover and fate are critical to both society and the global carbon cycle.

There are three main pathways of DOC transformation–biological reactions, sunlight-induced photochemical reactions, and immobilization by flocculation–each controlled by the intrinsic chemical composition of the DOC but also by extrinsic physical, chemical, and biological factors. However, despite recent advances in the conceptual understanding of large-scale DOC turnover and how to model it, the combined intrinsic and extrinsic controls on these transformation pathways are inadequately described. Thus, the fates of DOC inputs from land to water in a changing environment remain unclear.

(Berggren et al 2022, Ecology)

Introduction vs. literature review

Although the introduction usually involves literature review, they are different in purpose and thus in how we approach them in writing:

- A literature review builds a solid wall—describing knowledge—whereas an Introduction focuses on the hole in that wall—describing ignorance.
- Pointing out **lack of research in a important topic** or **inconsistencies in existing literature** is an effective way to present knowledge gap.

Introduction vs. literature review

This example points out inconsistent results from existing research on the temperature sensitivity of whole ecosystem metabolism, thus giving strong motivation to the current work.

> Given the complexity of ecosystem–level temperature sensitivities and the challenges associated with quantifying them, it is not surprising that various patterns have been reported. Some studies have found consistent temperature sensitivities of ER at the ecosystem and the cellular levels, but others have demonstrated considerable deviation of ecosystem–level activation energies of GPP from the values of their cellular analogs. In studies that simultaneously examined the temperature dependence of GPP and ER in streams, a shift toward heterotrophy with warming has been observed in some instances, but a recent synthesis based on geothermal streams concluded that warming increases GPP and ER to the same extent and results in no net change in metabolic balance.

(Song et al 2018, Nature Geoscience)

Tense

A few general principles on using tense in the introduction section:

- Present or present perfect tense are common in the introduction to describe existing knowledge;
- Past tense should be used to describe past actions;
- Pay attention to the meanings different tenses convey. The difference can be subtle, but correct use of tense can make it more effective to convey the desired meaning.

Tense

Past tense indicates that the phenomenon only applies to when the experiment was done.

> We found that the pressure **increased** as the temperature **rose**, which indicated that temperature **played** a significant role in the process

Present tense indicates that the findings are generally true and thus provide a much stronger statement.

> We found that the pressure **increases** as the temperature **rises**, which indicated that temperature **plays** a significant role in the process.

Tense

Past tense indicates that little attention was paid over two years ago but did not hint at what happened after that.

> However, although the effect of the rubber particles on the mechanical properties of copolymer system was demonstrated over two years ago, little attention **was paid** to the selection of an appropriate rubber component.

Present perfect tense indicate that not much attention was given to the question ever since two years ago. It thus offers a stronger motivation for the current study.

> However, although the effect of the rubber particles on the mechanical properties of copolymer system was demonstrated over two years ago, little attention **has been paid** to the selection of an appropriate rubber component.