Lecture 6
Writing the discussion section of a paper

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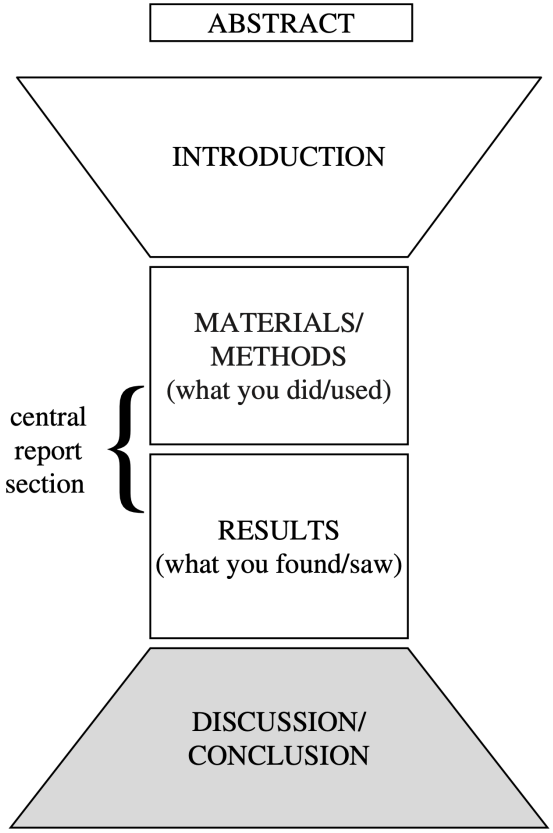
What is the discussion section?

- The discussion should provide the answer to one simple question: **what do the results mean?**



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

Possible elements of the discussions

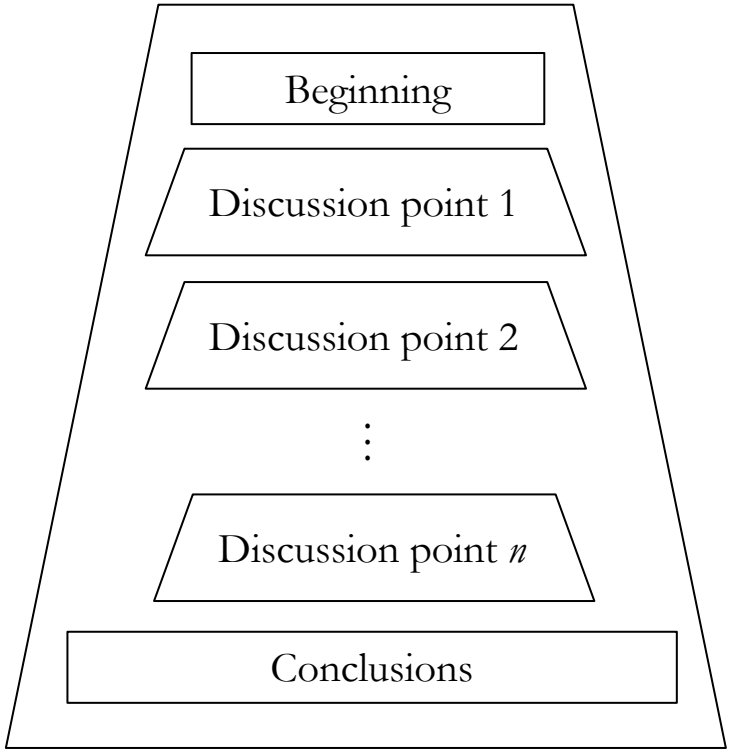
- Present summary of your findings and how the findings address the hypothesis or questions posed in the introduction;
- Explain why the findings occurred;
- Show how your results agree with or differ from previous work;
- Discuss the significance of your results;
- Discuss the implications of your results;
- Present limitations of your work;
- Provide take-home messages or future directions.

Things to avoid in discussion

- Do not repeat results;
- Do not introduce new results;
- Do not pretend to have solved everything;
- Do not finish with throwaway sentences;
- Do not try to discuss every possibility, especially if speculative.

Overall Structure of the discussion

- Discussion can be divided into subsections, each dealing with a particular aspect of the findings.
- Discussion can start with a brief reiteration of research question or major findings and usually ends with a concluding remark.



How to begin the discussion

- One strategy to start the discussion is to summarize the main findings of the work;
- This is particularly useful when there are one or few major points of findings to discuss;

> The results presented here show that long-term average weathering- derived solute concentrations vary from catchment to catchment as a function of mean runoff and that on timescales shorter than several years, these solute concentrations in individual catchments vary little from their long-term averages, even during floods or droughts (Figure 3a). The average concentration for a given site and solute can be thought of as a chemical set point, around which geochemical feedbacks act to maintain approximate equilibrium. Expressed in this terminology, the main result presented above is that weathering- derived solute concentrations tend to be quasi-chemostatic, but their set points may vary from catchment to catchment as a function of mean runoff.

(Godsey et al 2019, Hydrological Processes)

How to begin the discussion

- When providing a summary of your findings, you could clearly point out whether the hypothesis were supported or not;
- This is an effective strategy when your introduction has very clearly stated hypothesis that motivates the work;

The results of this study showed consistent support for the hypothesis that V_{max} and K_m are temperature sensitive for soil microbial EHEs. However, our hypothesis that cold-adapted EHEs would show greater temperature sensitivity for Km than warm-adapted EHEs was only supported for the cellulose-degrading enzyme β-glucosidase. No clear patterns were observed for the four other EHEs investigated. To our knowledge, this is only the second study to examine the temperature sensitivity of K_m in soil EHEs, and in the other, Stone *et al.* (2012) also observed more variation in the K_m response to temperature than in the V_{max} response.

(German et al 2012, Global Change Biology)

How to begin the discussion

- You can also begin the discussion by reiterating the significance and purpose of the work.

Nonindependence among observed effect sizes from the same source paper is common in ecological meta- analyses and can arise through a variety of mechanisms, such as shared experimental subjects, common experimental sites, or similar methodology (Noble *et al.* 2017). The variety of mechanisms leading to within-paper non-independence gives rise to different patterns and strength of correlations among observed effect sizes from the same source paper. Our simulations, using ecologically realistic parameter values, represent a broad range of scenarios. We found that...

(Song et al 2022, Ecology)

Structure of each discussion point

- **OCAR strategy**: reiterating the problem and reenergizing curiosity before going on to nailing down the answer with the resolution.

> It is well-known that factors such as the nature of the nucleophile, solvent, and leaving group directly affect the rate of the bimolecular nucleophilic substitution (SN2) reactions; yet, in the case of carbanions, little has been documented with absolute rate constants...
>
> Photoinduced decarboxylation of suitable substituted carbanions pro- vides a route for the formation of substituted cycloalkanes that proceeds in high yields in nonhydroxylic solvents and with good leaving groups such as bromide and iodide.

Structure of each discussion point

- **LD strategy**: identify the main contribution of the paper and then develops and elaborates the findings.
- This is the most common strategy when writing each discussion subsection.
- The example below first summarize the relevant findings and then move on to discuss them in detail.

> We have identified a novel class of GGT inhibitors that are not glutamine analogues. Kinetic studies of the lead compound OU749 revealed that the mechanism of inhibition was uncompetitive relative to the γ–glutamyl substrate, indicating that the inhibitor bound the enzyme-substrate complex. In contrast to competitive inhibitors, which lose potency as substrate...

What to discuss: put your work in context

- How do your findings **compare with existing work/theory**?
- Discussing how your findings confirm or contradict previous work is an effective way to put your work in context.
- This lends support/credibility to your findings (if consistent) or gives you an opportunity to explain your findings (if inconsistent).
- This may also give you an opportunity to highlight how your work improves previous work, i.e., the implications of your work.

What to discuss: explanation of your findings

- **Why** did the findings occur?
- When explaining your findings, relate your speculation to concrete evidence from your study or previous work. Pure speculation without evidence is not very convincing.

The important role of consumers in explaining our results is supported by previous research at our study site. Small forest streams at Coweeta (North Carolina, USA) are extremely retentive of CPOM, their primary OM source. CPOM exports from the reference and treatment streams are typically 2.5% of CPOM inputs and 4% of total OM export (Cuffney et al. 1990, Wallace et al. 1995). Particulate OM export is consequently dominated by suspended FPOM (Wallace et al. 1991). Although peak FPOM export coincides with storms, manipulations of invertebrate biomass (using insecticide) have showed that the role of invertebrate feeding activity (especially by shredding detritivores) is at least as important as discharge in controlling the magnitude of FPOM export from these headwater stream ecosystems (Cuffney and Wallace 1989, Wallace et al. 1991).

(Benstead et al 2009, Ecology)

What to discuss: implications

- Discussing implications is usually a necessary part of the discussion. It answers the question: **“so what?”**
- What is considered the implications of your work?
  - Does it extend or supplement previous work?
  - Does it deepen our understanding of a scientific question?
  - Does it challenge or confirm a theory?
  - Does it solve an existing problem?
  - Does it offer a novel prediction about a phenomenon?
  - Does it inform us about new or improved methodologies?

What to discuss: implications

- Example: how the current findings help us form new predictions.

We observed strong and consistent seasonal decreases in BDOC, potentially due to the fact that changes in thaw depth are more pronounced in warm permafrost regions such as the QTP. In contrast to Arctic catchments with 20–50 cm of seasonally thawed soil, QTP flow paths can penetrate to over a meter by the end of the flow season. This provides a potential analogue for predicted Arctic and Boreal conditions in 50 to 100 years (Slater & Lawrence, 2013), suggesting that increasing active layer depth could decrease DOC export and biodegradability, though more work is needed to constrain predictions of lateral carbon transport.

(Mu et al 2017, Geophysical Research Letters)

What to discuss: implications

- Example: how the findings extend previous work, deepen the understanding of a phenomenon, and test an existing theory.

Our work shows that temperature-driven selection, in driving complete temperature compensation of organism-level metabolism, had important implications for understanding the temperature dependence of ecosystem-level GPP across the catchment. GPP increased with temperature across the catchment (Fig. 3a) with a temperature dependence equal to another recent study on metabolism in geothermal streams (Demars et al. 2016), but it did so because biomass also positively covaried with temperature (Fig. 3b). This is likely driven by a shift in algal community composition, with warmer streams being dominated by cyanobacteria capable of fixing nitrogen, alleviating the constraints imposed by the limiting concentrations of inorganic nitrogen observed in these streams (Table S4) (Welter et al. 2015; Williamson et al. 2016). After accounting for covariance with biomass, biomass-specific GPP was independent of temperature (Fig. 3c), consistent with the effects of temperature compensation of organism-level metabolism. These findings confirm the predictions of our model and previous suggestions (Kerkhoff et al. 2005; Enquist et al. 2007) that local adaptation and species sorting can yield the paradoxical phenomenon that rates of biomass-specific ecosystem metabolism are independent of temperature over thermal gradients that have been maintained over long timescales.

(Padfield et al 2017, Ecology Letters)

What to discuss: limitations

- What are the **limitations** of your work?
- This can be a few sentences in the section where you discuss a particular point, or you can dedicate a separate section for it;
- Limitation should be short and concise; Avoid putting limitations at powerful positions, i.e., opening or end of the section.
- Only discuss limitations critical for the interpretation or applicability of your study;
- Common issues causing limitations:
  - Unique study settings that lead to lack of general applicability;
  - Limited sample size, study sites, or study time;
  - Potential artifacts due to instruments/methods;

What to discuss: limitations

- It is usually most effective to address limitations immediately after a particular discussion point;
- In this example, the discussion of limitation comes right after the relevant discussion point; but the discussion does not end with limitation. Rather, it ends with statements about the significance of the finding.

We quantified warming–induced changes in NEP, the difference between GPP and ER, based on the simulated warming experiment. We estimated...

The predictions for how GPP/ER and NEP will change with warming do not come without caveats....Despite these caveats,...

(Song et al 2018, Nature Geoscience)

Tying it all together: a model

- Putting the above elements of discussion together, we may put together a simple template for discussion.
- Template can be useful to guide your writing when you are a beginner. But I do not recommend you always following the same template religiously.

Our experiment demonstrated that_____. In particular, we found that_____. Our findings are consistent/in contrast with previous work. For example, XXX et al. (20XX) showed that_____. _____was found to_____ (XXX et al. 20XX). We speculate that_____may be responsible for the observed consistency/contradiction. Such a speculation is supported by previous work where_____may explain_____. Taken together, these results mean that_____. We therefore suggest that_____.

Conclusions

- Conclusions usually start with a concise summary of your major findings and end with the implications of your work or guidance for future work.
- Conclusions should be evidence-based and concrete. Conclusions should have close link to the major findings of the current work.

There was an extraordinarily large amount of ice bottom melting in the Beaufort Sea region in the summer of 2007. Solar radiation absorbed in the upper ocean provided more than adequate heat for this melting. An increase in the open water fraction resulted in a 500% positive anomaly in solar heat input to the upper ocean, triggering an ice–albedo feedback and contributing to the accelerating ice retreat. The melting in the Beaufort Sea has elements of a classic ice–albedo feedback signature: more open water leads to more solar heat absorbed, which results in more melting and more open water. The positive ice–albedo feedback can accelerate the observed reduction in Arctic sea ice. Questions remain regarding how widespread this extreme bottom melting was, what initially triggered the increase in area of open water, and what the summer of 2007 portends for 2008 and beyond.

(Perovich et al 2008, Geophysical Research Letters)

Bad conclusions: weak conclusions

- A weak conclusion fails to clarify the take-home message and gives a vague statement about the implications of the work.
- Avoid using statements like “provide new insights” or “have profound implications” without clarifying what they are.
- The example below is a weak conclusion. It ends with a throwaway sentence that are neither concrete or supported from the current research.

A proteomic evaluation of hummingbirds under simulated migratory conditions revealed evidence of several stress-associated processes: protein degradation in wing muscle tissues, depletion of metabolic cofactors, and enhancement of stress-response proteins. These results suggest that changes in the hummingbird proteome may provide new insights into the complex physiology of avian systems biology.

Bad conclusions: undermine your conclusions

- Avoid undermining your own conclusions. Conclusions should emphasize the value of the work. While it is necessary to admit limitation, do not end with it.

  To conclude, 3-methyl-ambrosia offers a new approach for thyroid carcinoma therapy. Our data provide evidence on safety and in vivo activity of this compound in patients with this condition, although the proof for clinical benefit remains to be established in future clinical trials.

- The conclusion can be improved by simply switching the order of the sentences. This helps put the emphasis on the contributions of the work.

  While further clinical trials will be necessary to establish the full benefits of 3-methyl-ambrosia as a therapeutic agent, our data provide evidence that it is safe and shows in vivo activity against thyroid tumors. 3-Methyl-ambrosia therefore may offer a new approach for treating patients with thyroid carcinoma.

Writing style: tense

- The tense of the discussion section may switch between present tense (when mentioning established knowledge or general principles) and past tense (when mentioning your own results or previous studies).

Despite the consistency of this average result with predictions of the MTE (Gillooly et al. 2001, Brown et al. 2004) and with findings from other studies at the global scale (Yvon-Durocher et al. 2012), we observed a large degree of variation in E among individual streams (Fig. 2A, Table C1). Slight differences in the value of this slope can translate to substantial differences in respiration rate (Gilooly et al. 2001). For example, the E values that we estimated for individual tributaries spanned the entire range included in a recent global meta-analysis of temperature sensitivity in rivers and streams (0.57–1.08; Yvon-Durocher et al. 2012). In fact, the only other study to evaluate the variation in temperature sensitivity among individual tributaries at the river basin scale, also found a similar magnitude of variation (0.24 – 0.86; Acuna et al. 2008). Taken together, these data suggest that using a universal value to describe the temperature sensitivity of C processing across a river basin does not accurately reflect the variation in C metabolism that occurs as rivers drain heterogeneous landscapes with spatial variation in geomorphic and chemical conditions.

(Jankowski et al 2014, Ecology)

Writing style: modal verb

- Modal verbs are often used in the discussions to communicate that something is a possible reason or a probably interpretation.
- Compare the different amount of “certainty” conveyed in the following three sentences:

The drop in pressure **was** due to a crack in the pipe.

The drop in pressure **must have been** due to a crack in the pipe.

The drop in pressure **may have been** due to a crack in the pipe.

Writing style: metacommentary

- Metacommentary is a way of commenting on your claims and telling others how—and how not—to think about them.
- Because the written word can be interpreted in many different ways, we need metacommentary to keep misinterpretations and other communication misfires at bay.
- Metacommentary adds clarity and depth to the writing. It helps you avoid misunderstanding, elaborate ideas, or preemptively address objections.

Templates for metacommentary

- Avoid misunderstanding:

  We do not suggest that_____, but that_____.

  This does not mean that_____, but rather_____.

  XXX is concerned less with_____than with_____.

- Elaborate ideas:

  In other words,_____.

  To put it another way, _____.

  What XXX suggest here is that_____.

- Address potential objections:

  Although one may object that_____, we argue that_____.