EARLY CAREER

The Early Career Section is a compilation of articles that provide information and suggestions for graduate students, job seekers, early career academics of all types, and those who mentor them. Angela Gibney serves as the editor of this section. Next month's theme will be good ideas.

Planning Ahead for the Joint Meetings

Giving Good Talks

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Motivation

Mathematicians are like rock stars: after recording an album, they need to go on tour. Like an album, a paper conveys a polished, finished product, with all the notes perfectly in place. A talk, on the other hand, is akin to a concert performance, highlighting the essential parts of our mathematics through the brushstrokes of intuition and person-

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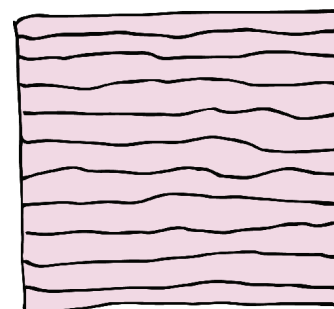
ality. Sharing our work through seminars, colloquia, and presentations offers an invitation for a far larger audience to explore our writings, building community and fostering collaboration. Although the skills for publication have some overlap with those for performance, the distinctions are greater: giving good talks involves not just a command of words and images but speech, body movement, control of time, and a disproportionate emphasis on storytelling.

Developing and sharpening these skills is important now more than ever, for our data-driven world is hungry for quantification, paying particular attention to mathematics. Consider the notion of "applied" mathematics: The twentieth century relegated this to certain subjects such as PDEs, numerical analysis, and probability. In our twenty-first century, however, nearly every area of mathematics is rich in applications, from algebraic geometry (phylogenetics) and homotopy theory (data analysis) to complex analysis (computer graphics) and number theory (cryptography). And so, the opportunities to present and showcase all types of research mathematics to corporations, government agencies, think tanks, and a thirsty public are proliferating, highlighting further the importance of proper presentation.
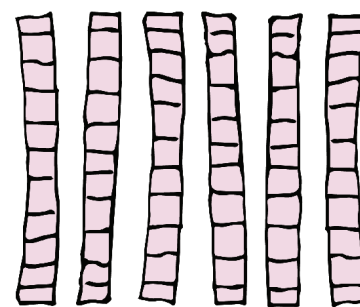
My communication philosophy can be explained by considering a steak (or a stalk of celery, from a vegetable view-

mathematical steak
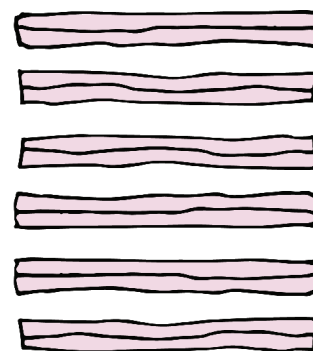
cut *with* the grain

cut *against* the grain

Figure 1.

point); see Figure 1. The steak is the sum total of information, and the job of the presenter is to cut the steak into digestible pieces for the audience.

If the steak is cut *with* the grain, the listeners are forced to chew through the tough fibers; a piece of lovely mathematics is turned into an unpleasant meal. On the other hand, if we're intentional beforehand and cut *against* the grain, the hard work of breaking up the fibers has already been done, leaving the audience with an enjoyable taste in their mouths. This article offers a few general principles of how to do just that.

Story Driven

More fundamental than the label of mathematician is that of human. And as humans, we're hardwired to use stories to make sense of our world (story-receivers) and to share that understanding with others (storytellers) [2]. Thus, the framing of any communication answers the key question, what is the story we wish to share? Mathematics papers are not just collections of truths but narratives woven together, each participating in and adding to the great story of mathematics itself.

The first endeavor for constructing a good talk is recognizing and choosing just one storyline, tailoring it to the audience at hand. Should the focus be on a result about the underlying structures of group actions? Or the process in which a topological invariant was discovered? Or possibly the relationships between competing numerical approximation methods? Once chosen, the next (and likely the most difficult) task is to adhere firmly to this decision. Keep the bits that move the story forward and remove the pieces that digress from it. The hardship arises due to the special love we have for certain parts of our work (theorems, remarks, connections) that do not follow the chosen narrative. Unaddressed, these embellishments lead to tangents (at best) and distractions (at worst) that might bring us personal satisfaction at the cost of confusing the listener. Sir Arthur Quiller-Couch gave the following advice to writers [5], which is equally applicable in crafting talks:

> Whenever you feel an impulse to perpetrate a piece of exceptionally fine writing, obey it—whole-heartedly—and delete it before sending your manuscript to press. Murder your darlings.

Do the hard work in killing the parts that move away from the central point, regardless of how fabulous they are. The main thing is to keep the main thing the main thing.

Another facet of the connection between humans and stories is realizing that the storyteller is important to the story itself. As Francis Su argues, the pursuit of mathematics is a human endeavor, and mathematical thinking can help fulfill such longings as love, freedom, play, justice, and community [6]. Theorems are not the only stars of the show; you are as well! Your viewpoint and approach to mathematics make your talk unique, and your frustrations

and joys are part of this story. Analogous to the contrast between a musical score and a musical recording, a talk allows your personality to come forth and shine through. Highlighting rather than hiding this aspect will not only improve the experience of the listener but your enjoyment as the presenter. Being a showperson or a comedian isn't what matters: your passion for your mathematics will be the fuel. And as your storytelling skills improve, so will your writing prowess.

Words and Images

Although the content of a talk is similar to a written paper, they carry out different functions. In most cases, the presentation serves as a pointer to your research paper. Thus the amount of precision involved, especially when framing definitions and theorems, is substantially different between the two mediums. A paper requires a high degree of precision, a mathematical composition of clarity and accuracy, a place of reference for future works. A presentation format, with its time constraint, forces ideas to be painted in broad strokes, denying opportunities to consider the finer details. High precision stands in tension with intuitive storytelling.

precision ●————————————● intuition

Consequently, you should hide subtle nuances in definitions and give only a framework for important proofs, relegating their details to the paper. The talk should be a pointer and not a substitute for written mathematics. Having said this, however, do not abuse this freedom to do sloppy mathematics. The balancing act comes in providing clarity without magnifying subtlety.

For talks involving slides (rather than a wonderful chalkboard), it becomes even more paramount (and more difficult) to kill your darlings. Overwhelming the audience with information becomes easy, simply by adding extra slides or jam-packing each one. All of this is done with very little cost to the speaker, while the listener pays the price. Keep each slide limited to a handful of sentences, with a large font, and generous whitespace in the margins and between sentences. If there are appropriate illustrations or figures, please, please, please use them. Pictures serve as marvelous substitutes for a thousand awkward words.

Figure 2 shows two examples of good slides: note the clean fonts, clear images, abundant spacing, and simple titles. Each of these slides can easily take one to five minutes of presentation time, depending on the listening audience and the chosen storyline.

If you need to use notes, carry a notepad, keeping your slides uncluttered. Let each slide breathe, giving them a welcoming look. When (not if) people get distracted during your talk, the slide titles should offer a smooth reentry back into the presentation. And if the slides have been properly written and formatted, the need for a laser pointer should

ENUMERATIVE GEOMETRY

Let N_d be the number of plane rational curves of degree d that pass through $3d-1$ points.

Theorem: [Kontsevich]

$$N_d = \sum_{a+b=d} a^2\, b\, N_a\, N_b \left[b\binom{3d-4}{3a-2} - a\binom{3d-4}{3a-1} \right].$$

Geometric Theorem: [Vafa, Witten, Kontsevich]
There exists a *quantum* product structure, giving rise to the cohomology ring $H_q^*(V)$.

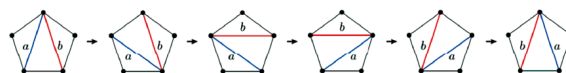**Corollary:** The N_d formula expresses the associativity of the quantum product of $\mathbb{CP}^2$.

COLOR TRIANGULATIONS

Orbit Theorem: [Lubiw, Masárová, Wagner, 2018]
Two edge-colored triangulations T_1 and T_2 are connected by flips if and only if for every color c, the edges of T_1 and T_2 having color c belong to the same orbit.

Proof:

1. Walk around the 2D associahedron K_4.

2. The 2-skeleton of the *flip complex* is a homotopy ball.

Figure 2.

evaporate, with the hands and the body more than capable of being the guide.

Just as every written word conveys information, the same is true of images. Pay careful attention to the choice of colors, shading, line widths, compositions, and other aspects of figures and drawings. A classic book by Edward Tufte [7] is a good place to start, offering terrific advice on how best to present visual information. Realize that images themselves are a form of notation. The great John Littlewood writes [3]:

> *A heavy warning used to be given that pictures are not rigorous. This has never had its bluff called and has permanently frightened its victims.*

For example, a pentagon whose interior is shaded is different from one that is not; the former conveys a two-dimensional object whereas the latter shows its one-dimensional boundary. If certain figures pack a high amount of information or are of particular importance, make them fill the entire slide. Have the audience fall into the beauty of such pictures.

Time and Space

A radical difference between a paper and a talk is the importance of time and space. The use of space is the greatest untapped potential in most presentations. Being human, we're gifted with not just minds and mouths but bodies. Use your whole body during your talk, including your hands and feet. (Under the rare circumstances when restricted to a podium, your hands play a far more important role.) For instance, when transitioning from one point to the next, move from one side of the room to the other. Walk with intention, stopping to emphasize critical ideas, coordinating your body movements with the arcs of your storyline. When making a key point, speak quieter and slower, to draw your audience in. Not moving at all or moving with abandon (both of which can be attributed to

nervousness) creates a dissonance between what is being said and what is being enacted, distracting the listener.

Although time is the most restraining element in a talk, any mathematical work can be presented in 50 minutes, 30 minutes, or 5 minutes, or even as a 20-second elevator pitch. What it requires is hard work to distill the vast range of ideas in your work into a laser-focused story. Blaise Pascal [4] once famously wrote:

> *Je n'ai fait celle-ci plus longue que parce que je n'ai pas eu le loisir de la faire plus courte.*[1]

In other words, it's easy to give a long talk but takes discipline to make it shorter. Speaking faster or cramming more lines of text doesn't convey more information but muddles it, wasting precious time. If the pace is hurried, the audience will feel your anxiety and stress. So spend the days and weeks before the talk doing the heavy lifting, shaving off unnecessary darlings. Learn to enjoy the silence, using it to both highlight key points and allow your ideas to be absorbed. Silence is a powerful tool that most in the Western Hemisphere fail to appreciate [1].

In spite of seeming like a waste of time, spend an inordinate amount of time on the introduction. It's reasonable to allocate 40% of allocated time to it, with 50% for the body and 10% for a conclusion. Without this long runway of time to develop an opening gambit, instrumental in providing motivation and foundation, there'll be little interest or investment from the listeners for the remainder of your talk. Of course, experts in the field will not be in need of this, but the talk isn't for them. They're already equipped to read your paper without a need for motivation. (Having said this, I'm always pleasantly surprised to hear that even the experts are quite appreciative of a lovely and lengthy introduction.)

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[1]*I would have written a shorter letter, but I did not have the time.*

Most importantly, do not go over the allocated time. No one complains about a talk that ends early, but each and every minute outside the timeframe becomes exponentially excruciating (as we can all testify). The best method in helping perfect your timing is practice, practice, practice, either in front of others or by yourself. Ideas that look reasonable in notes or on slides often don't work when said out loud. Giving voice to the written word also reveals new and better ways to frame and articulate your mathematics.

Through all of this, keep in mind that attending a talk is a far costlier investment than reading a paper. While the latter can be done at leisure, the performative nature of the former forces the audience to arrive at a specified space at a specified time. We should honor their sacrifice by cutting the steak properly to give them an enjoyable and enriching presentation of mathematics.

Myth

A word of warning as your ability to give good talks improves. There is a disproportionate number of seminars and colloquia given by high-caliber mathematicians that leave most of the audience bewildered and confused. Over time, we come to expect this outcome, due to the following mathematical myth:

> *The deeper the mathematics involved, the worse the talk will be.*

This correlation exists not because this myth is true, but the skillset needed for creating extraordinary mathematics is quite different from the one needed for talking beautifully about it. And so, having digested your delectable meal, some might assume that your mathematics must be simplistic, without appreciating the skill and time it took in framing complex ideas through a strong narrative. A word of encouragement: it is undoubtedly worth the effort and the cost in pushing through these judgments, bringing mathematics that is a joy to hear to a world that is eager to listen.

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Credits

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References

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[2] Gottschall J. *The Storytelling Animal*, Houghton Mifflin Harcourt, 2012.

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[4] Pascal B. *Provincial Letters*, Letter XVI, 4 December 1656.

[5] Quiller-Couch A. *On the Art of Writing*, Lectures delivered at the University of Cambridge, 28 January 1914.

[6] Su F. *Mathematics for Human Flourishing*, Yale University Press, 2020.

[7] Tufte E. *Envisioning Information*, Graphics Press, 1990.