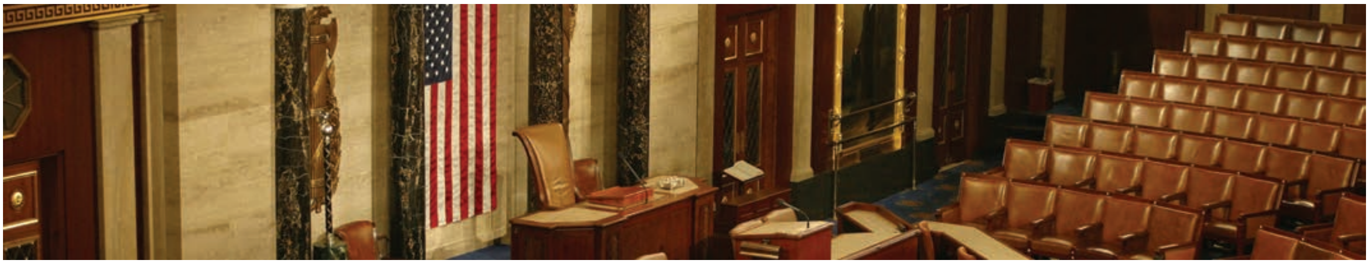

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Photo cropped on the top and bottom.

Math Societies to Lawmakers: This Is Why You Should Fund Basic Research

Sophia D. Merow

Biannual Congressional Briefings

The American Mathematical Society (AMS)—jointly with the Mathematical Sciences Research Institute (MSRI)—sponsors two congressional briefings per calendar year. These briefings provide an opportunity for the mathematics community to impart information to policymakers and, in particular, to tell compelling stories of how federal investment in basic research in mathematics yields rich dividends.

May 22, 2018 found the far-flung AMS leadership gathered on Capitol Hill in a room secured for their use by the office of Senator Chuck Schumer (D-NY). President Kenneth A. Ribet had traveled to DC from California, President Elect Jill C. Pipher from Rhode Island, Vice President Ken Ono from Georgia. Associate Executive Director Karen Saxe, head of the Society's Office of Government Relations, had had a shorter commute, from the division's digs on Eighteenth Street.

Erik Demaine, professor of computer science and engineering at MIT, was there in the Russell Senate Office Building, too. He wore a suit and had scissors.

By noon, when Saxe stepped to the lectern to kick off a briefing titled "Origami Meets Math, Science, and Engineering," more than 50 people had claimed boxed lunches and arrayed themselves around the room's circular tables. Besides AMS brass, MSRI's Outreach Director Kirsten Bohl and Director David Eisenbud, and math enthusiasts young and old, the audience included staffers from the offices of Senators Amy Klobuchar (D-MN), Bill Nelson (D-FL), and Chuck Schumer, and Representatives Michael Capuano (D-MA), Mike Kelly (R-PA), Jerry McNerney (D-CA), Grace Meng (D-NY), Nancy Pelosi (D-CA), and Jacky Rosen (D-NV). The US Senate Committee on Energy and Natural Resources, the Senate Democratic Policy Committee, the House Appropriations Committee, the National Science Foundation, and the Simons Foundation also had affiliates on hand.

"You're in for a real treat today," Saxe told the crowd.

Taking the mic after Saxe and California congressman Jerry McNerney (see sidebar, p. 104), MSRI director David Eisenbud explained the purpose of the briefing. He underscored the importance of basic research—and thus funding

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DOI: http://dx.doi.org/10.1090/noti1767

for it—and the impossibility of predicting which lines of inquiry will lead to future breakthroughs.

"Who knew," he asked rhetorically, "that the ancient art in Japan of folding cranes would turn out to be something that's important in engineering?"

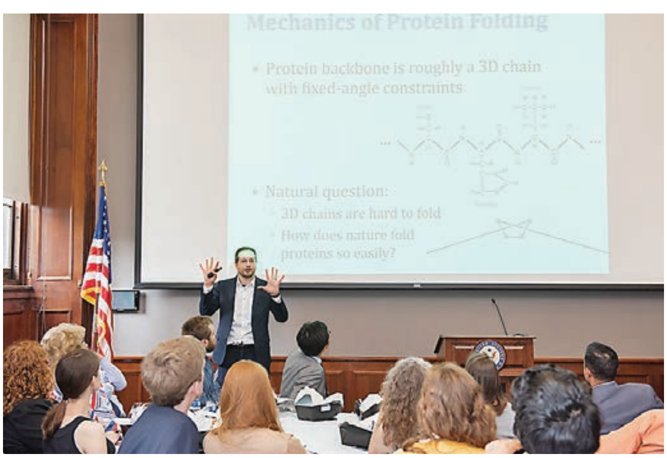
In the presentation that followed, Demaine regaled his audience with example after example of origami-related work with real-world relevance.

Consider, for instance, Origamizer, the freeware collaboration of Demaine and Tomohiro Tachi that generates a crease pattern to reproduce any 3D shape in origami. It seems like a boon only to those few keen to craft from a single square of paper a Jedi or a samurai helmet beetle, but the Origamizer algorithm in fact invites far broader application: It suggests a new approach to manufacturing. Sheets of steel or cardboard or plastic are easier and cheaper to ship than hollow 3D forms, after all, and with creases laser-scored pre-shipment…

"I imagine a future where, when you go to buy a chair, it comes flat and you pop it out and fold it," Demaine said. "It's sort of an extreme form of IKEA®."

And deployable origami structures have uses in environments more extreme than a family room or den. Telescope lenses can be folded to fit into space vehicles for transport, arterial stents inserted compactly then expanded once placed. A team at Brigham Young University incorporated origami's Yoshimura crease pattern into its design for a portable ballistic barrier to shield emergency personnel from gunfire (see `bit.ly/2L0heN6`).

Demaine's discussion of linkages, which he called a "sort of a one-dimensional type of folding," highlighted another potentially life-saving application. A protein is essentially a complicated linkage, and a paper co-authored by Demaine [1] leveraged this similarity to hypothesize the algorithm biology follows to fold proteins. Such insights into protein production could inform the development of new drugs, Demaine explained, speeding the eradication of disease.



Erik Demaine explains that solving problems about linkages could help unravel the mystery of how proteins fold.

"This is why you should fund basic research," he said, "so that we can understand the mathematics and the geometry of how linkages fold. The hope is we can then solve how proteins fold and solve world health."

Demaine not only repeatedly plugged the importance of basic research, but refrained (per instructions from his AMS/MSRI coaches) from delving deeply into the mathematics underlying the wonders—the folding microscopes and microscale ingestible robots and programmable matter—he described. When he did mention a theorem—the "Fold & One Cut Theorem"—he used his scissors to illustrate.

Demaine flourished a piece of paper, folded it flat, and—with a single straight cut—made the (polygonal) outline of a swan.

"Okay, you're not impressed," he deadpanned. "I'll do another one. Here we have a—one straight cut, and when we unfold—we get a little angelfish."

Houdini did this trick, Demaine said, and a perhaps apocryphal story has Betsy Ross speedily populating star-spangled banners, one snip per five-pointed star. It turns out that every pattern (plane graph) of straight-line cuts can be produced in this manner, by folding flat and making one complete straight cut (see `erikdemaine.org/foldcut`).

"This is a problem motivated by magic, essentially," Demaine said. "This is a result we thought would be useless. But it turns out to save lives. It gives you a way to fold an airbag flat."[1]

In the Q&A that followed Demaine's prepared remarks, he fielded questions about the potentially fruitful intersection of origami and materials science, about the elaborate corrugations of poppy flowers. A Congressional staffer wondered whether Demaine has considered possible negative outgrowths of the work he surveyed, self-deploying weapons, perhaps, or manufacturing jobs dwindling in the face of fully automated assembly lines.

"I think almost any technology can be used for positive and negative applications," Demaine answered. "My hope is that the positive applications will dwarf the negative ones. It's hard to prevent negative applications, but you do the best you can."

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[1] *The airbag simulation Demaine showed during his presentation is actually not an implementation of his fold-and-one-cut work; German firm EASi Engineering (now carhs) in fact used Robert Lang's TreeMaker,* (see `bit.ly/2mG6rHX`), *to devise a systematic way to flatten an airbag. Lang notes that TreeMaker's algorithm and Demaine's One Cut algorithm "solve very similar problems, of folding a shape so that all of its edges lie on a straight line, and for certain classes of polygon, they give exactly the same answer." But neither algorithm enables the accident protection airbags provide. "The method never made its way into the car development as today real airbags are folded and mostly tucked by machine, and those machines don't care about a mathematically correct folding," says carhs Managing Director Rainer Hoffmann. "The textile nature of the material allows enough crumpling to get the material into the box."*

Erik Demaine talks after the briefing to Daniel Kim from the office of Representative Mike Kelly (R-PA).

When a self-described "old budget officer" asked about the current state of funding for work like Demaine's, Demaine replied that, in these early days of origami technology, most of his projects fall under the 'basic research' umbrella.

"It's hard to go to the more applied funding sources and say, 'We're going to solve cancer,'" he explained. "We don't know what we're going to solve."

The briefing's final word went to the Honorable Bart Gordon, a long-time supporter of science who represented Tennessee's 6th District in Congress for more than a quarter of a century.

"The first person who can make their lunchbox into a robot will be able to take the scissors home," he joked, but then grew serious.

The private sector is unlikely to fund basic research, Gordon observed, given the uncertainty of it generating near-term profits. "Let the private sector do a lot of the applied research," he said. "But the federal government has got to do the basic research. So please carry that message."

Help spread the word about the importance of funding basic research:

- Write a letter to your senator or representative (to get started, see https://bit.ly/2G1Vav1).
- Write an op-ed for a local publication.
- Organize a talk at your institution about the unexpected utility of basic math. Invite your representative and work with your institution's government relations office.

Representative Jerry McNerney (D-CA) addressing the room

Votes on the House floor prevented Nancy Pelosi and other legislators from attending the briefing, but Jerry McNerney (D-CA), the only math PhD in Congress, caught the beginning of the event and offered some remarks. An excerpt:

"I think as mathematicians you want to stick to reality, to facts, and to truth, and nowadays that's even more important than ever. We need people that are really evidence-based, people that want to get things done for the good of the country and not so much for the political gain that we seem to think is good. And so I encourage you to get involved in the process a little bit. There is a lot at stake now in Washington, and it's good to see people engaged at some level."

References

[1] Demaine Erik D, Langerman S, and O'Rourke J, Geometric Restrictions on Producible Polygonal Protein Chains, *Algorithmica*, volume **44**, number 2, February 2006, pages 167–181. Special issue of selected papers from the 14th Annual International Symposium on Algorithms and Computation, 2003. MR2194474

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