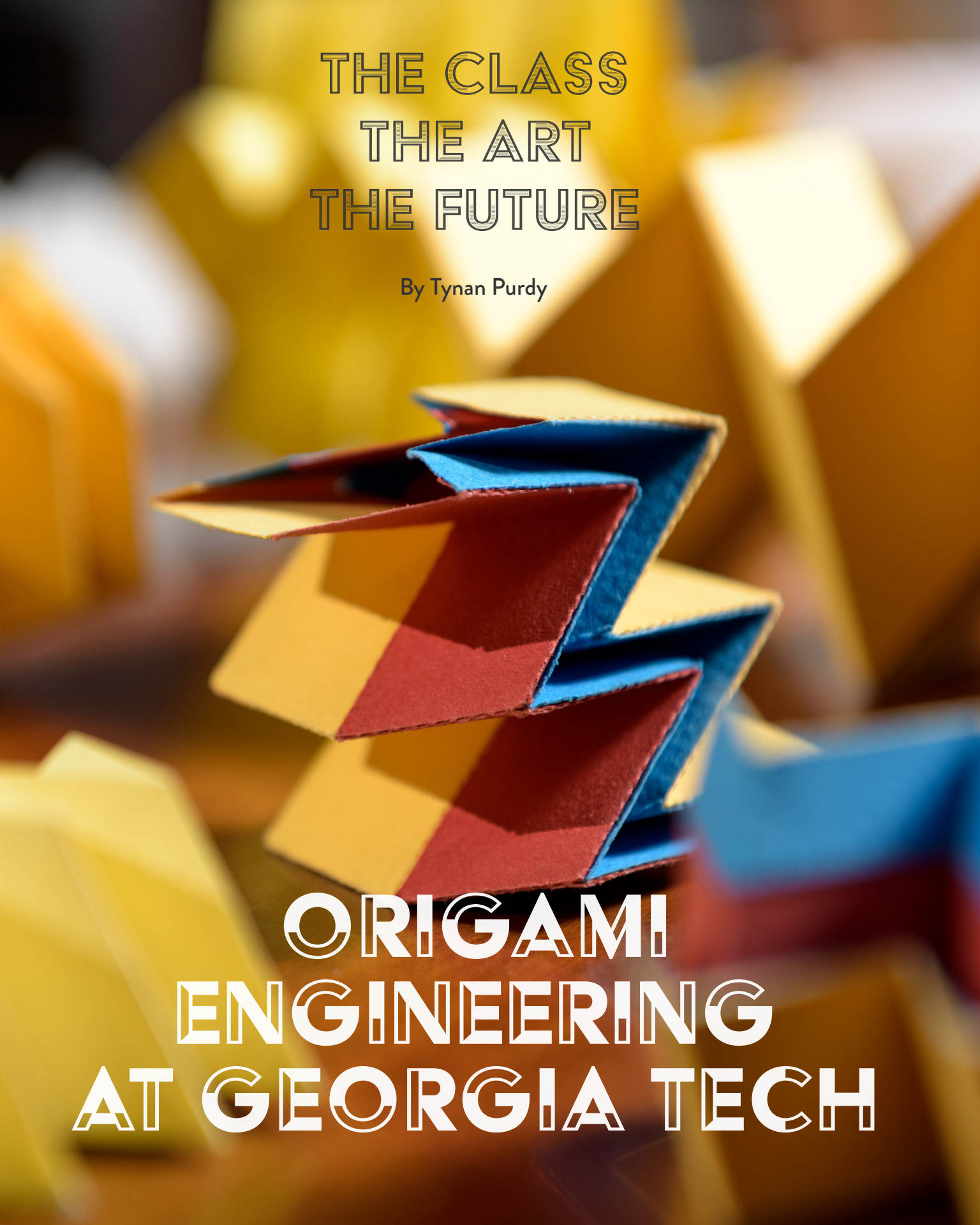


THE CLASS
THE ART
THE FUTURE

By Tynan Purdy

ORIGAMI ENGINEERING AT GEORGIA TECH

CLASS DETAILS

CEE 4803: Special Topics

Ref. Number: 88452

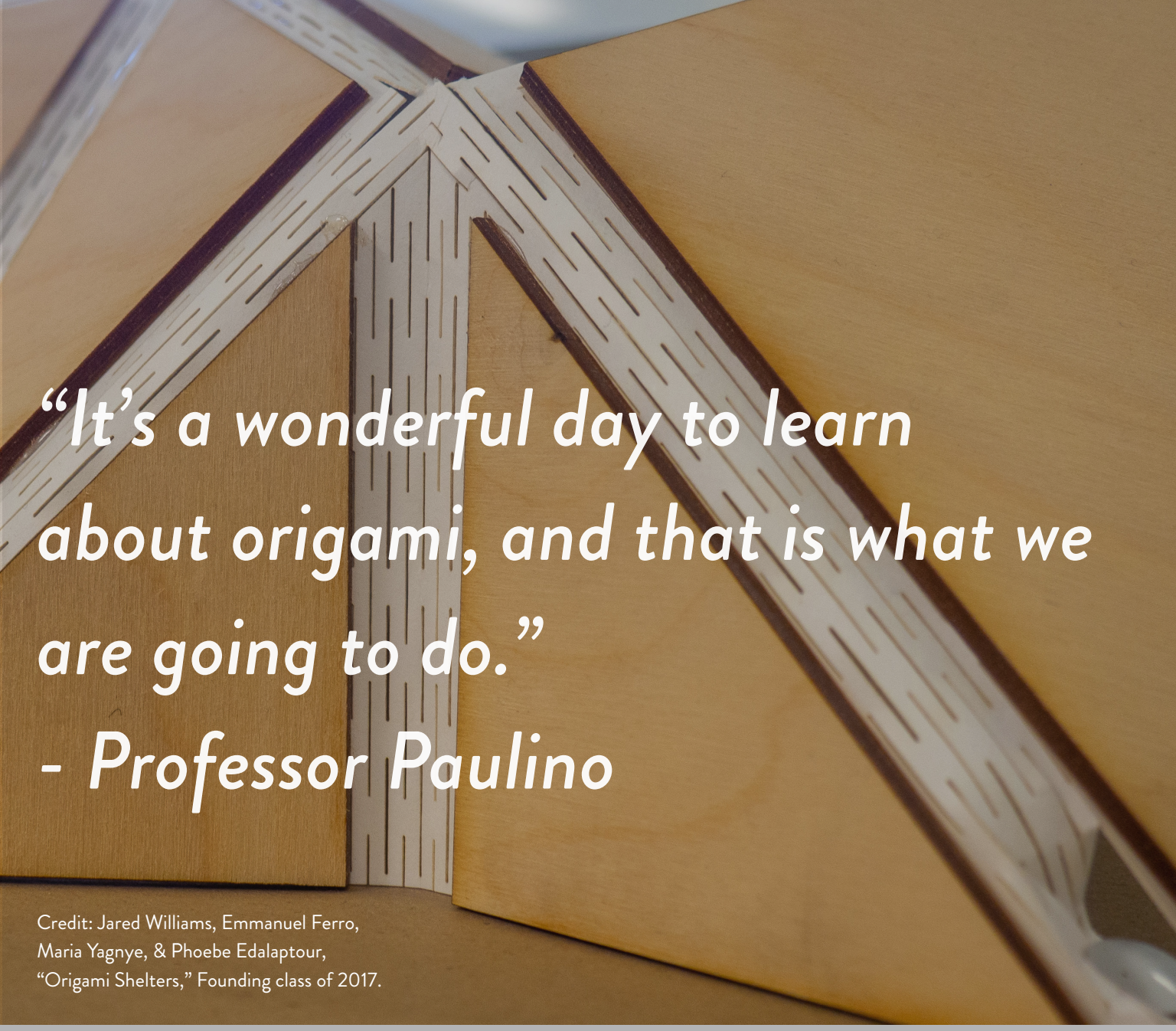
Section: H*

Credits: 3

Instructor: Glaucio H Paulino

Location: Mason 2117

** Offered during fall semesters only*



"It's a wonderful day to learn about origami, and that is what we are going to do."
- Professor Paulino

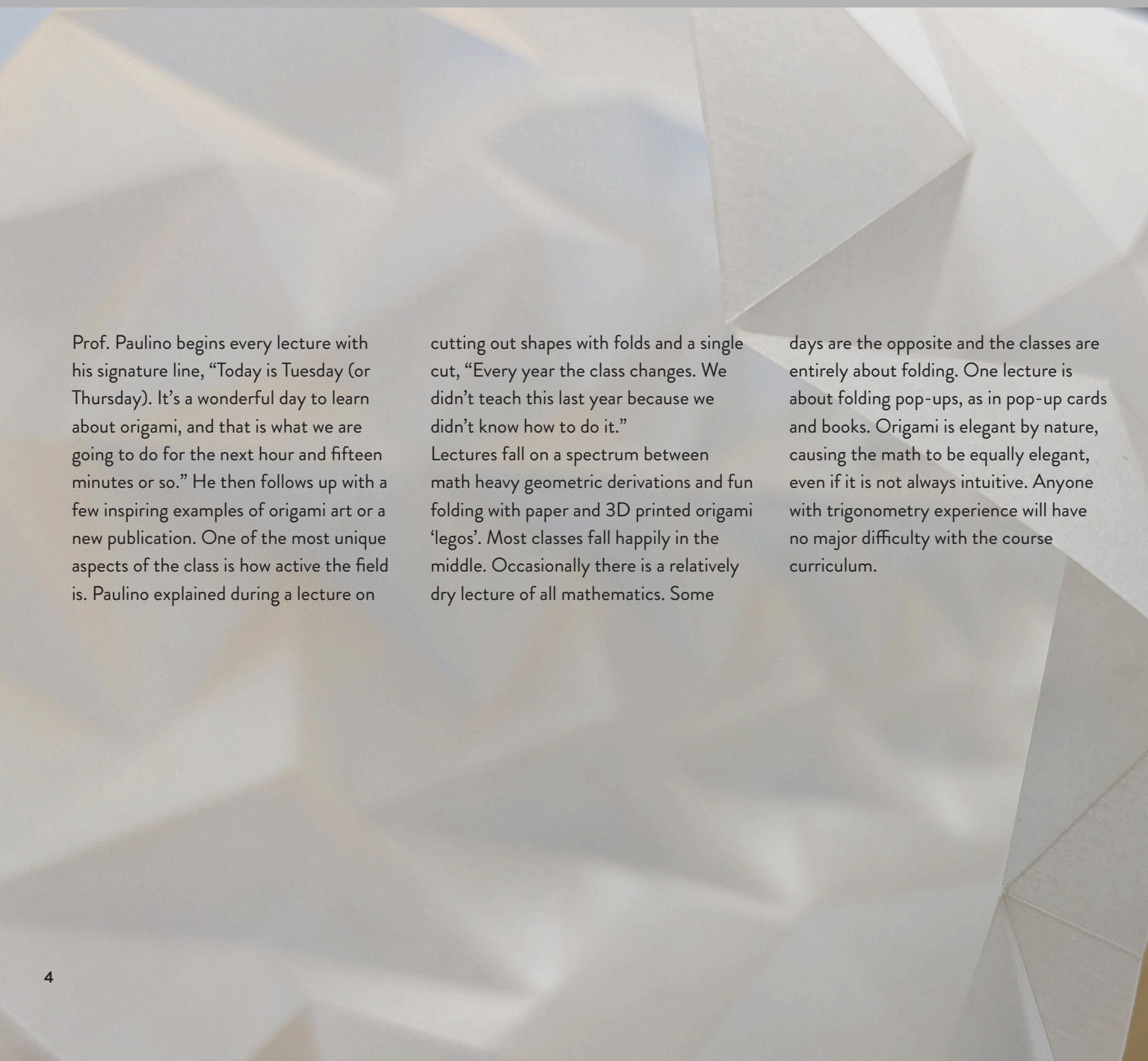
Credit: Jared Williams, Emmanuel Ferro, Maria Yagnye, & Phoebe Edalaptour, "Origami Shelters," Founding class of 2017.

Yes, that is correct. The ancient art of paper folding has its own 3 credit hour class in Georgia Tech's School of Civil and Environmental Engineering. Professor Glaucio Paulino and his team of incredible teaching assistants, Tuo Zhao, Larissa Novelino, and Yipin Si have crafted a fun, engaging, and widely applicable curriculum that attracts students from all corners of Georgia Tech. The inception of the class in 2017 received invaluable help from Dr. Ke Liu (Chris), who did his PhD with Prof. Paulino, and is presently a Post-Doctoral scholar at Caltech.

Origami has had a strong resurgence in the modern age of engineering. Our modern understanding of mathematics combined with origami's basis in geometry has allowed researchers to discover and learn to control the unique mechanical properties found in origami patterns. In recent decades, origami has been found to have thousands of untapped applications and abilities not found in any other materials or processes, such as programmable material properties and behaviors.

Professor Paulino has authored over 138 research publications this decade alone, with dozens more before then and more to come. His research is focused on using origami to advance material sciences and create positive social impact.

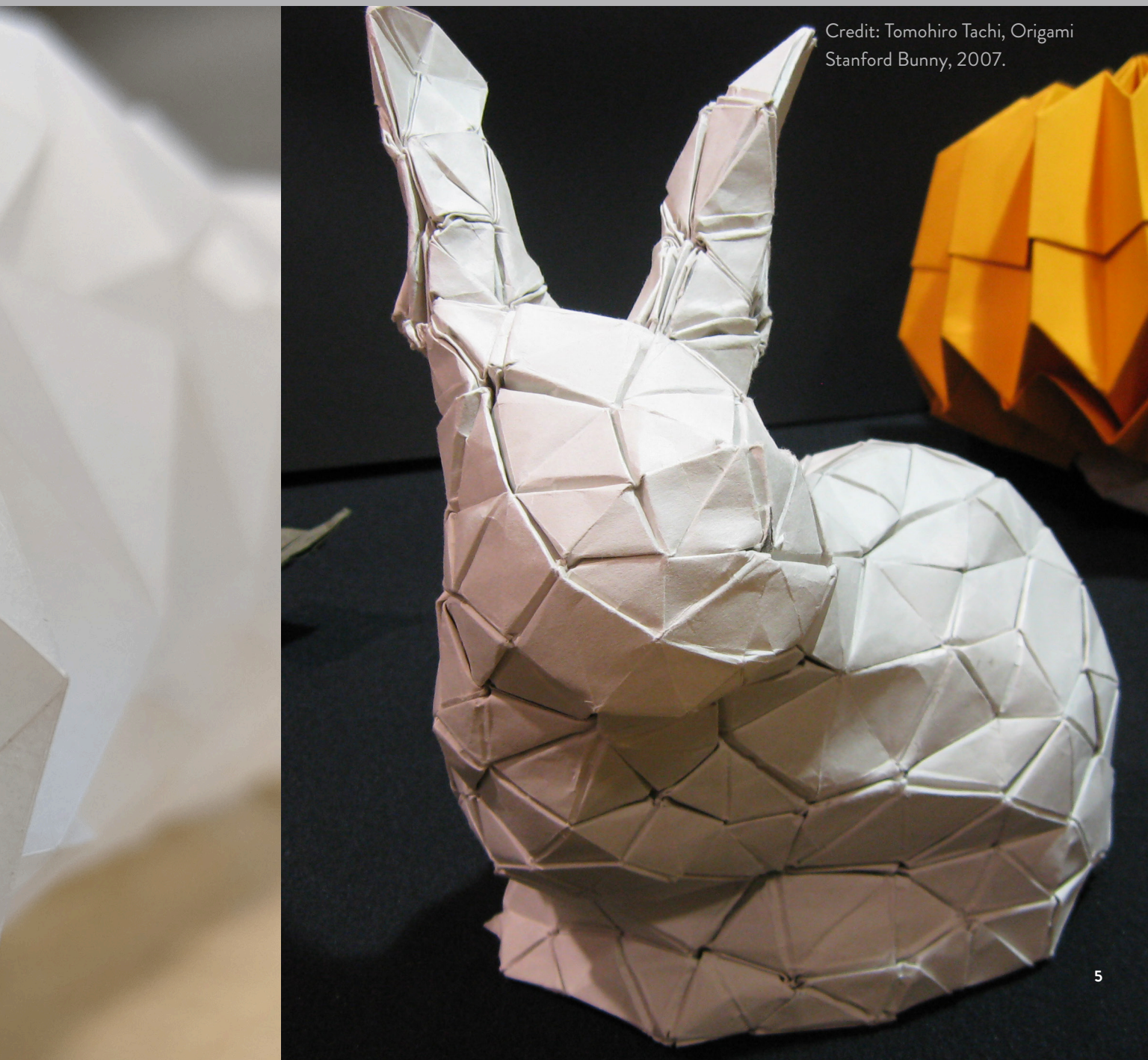
"Origami has been shown to be one of the most natural and



Prof. Paulino begins every lecture with his signature line, "Today is Tuesday (or Thursday). It's a wonderful day to learn about origami, and that is what we are going to do for the next hour and fifteen minutes or so." He then follows up with a few inspiring examples of origami art or a new publication. One of the most unique aspects of the class is how active the field is. Paulino explained during a lecture on cutting out shapes with folds and a single cut, "Every year the class changes. We didn't teach this last year because we didn't know how to do it."

Lectures fall on a spectrum between math heavy geometric derivations and fun folding with paper and 3D printed origami 'legos'. Most classes fall happily in the middle. Occasionally there is a relatively dry lecture of all mathematics. Some days are the opposite and the classes are entirely about folding. One lecture is about folding pop-ups, as in pop-up cards and books. Origami is elegant by nature, causing the math to be equally elegant, even if it is not always intuitive. Anyone with trigonometry experience will have no major difficulty with the course curriculum.

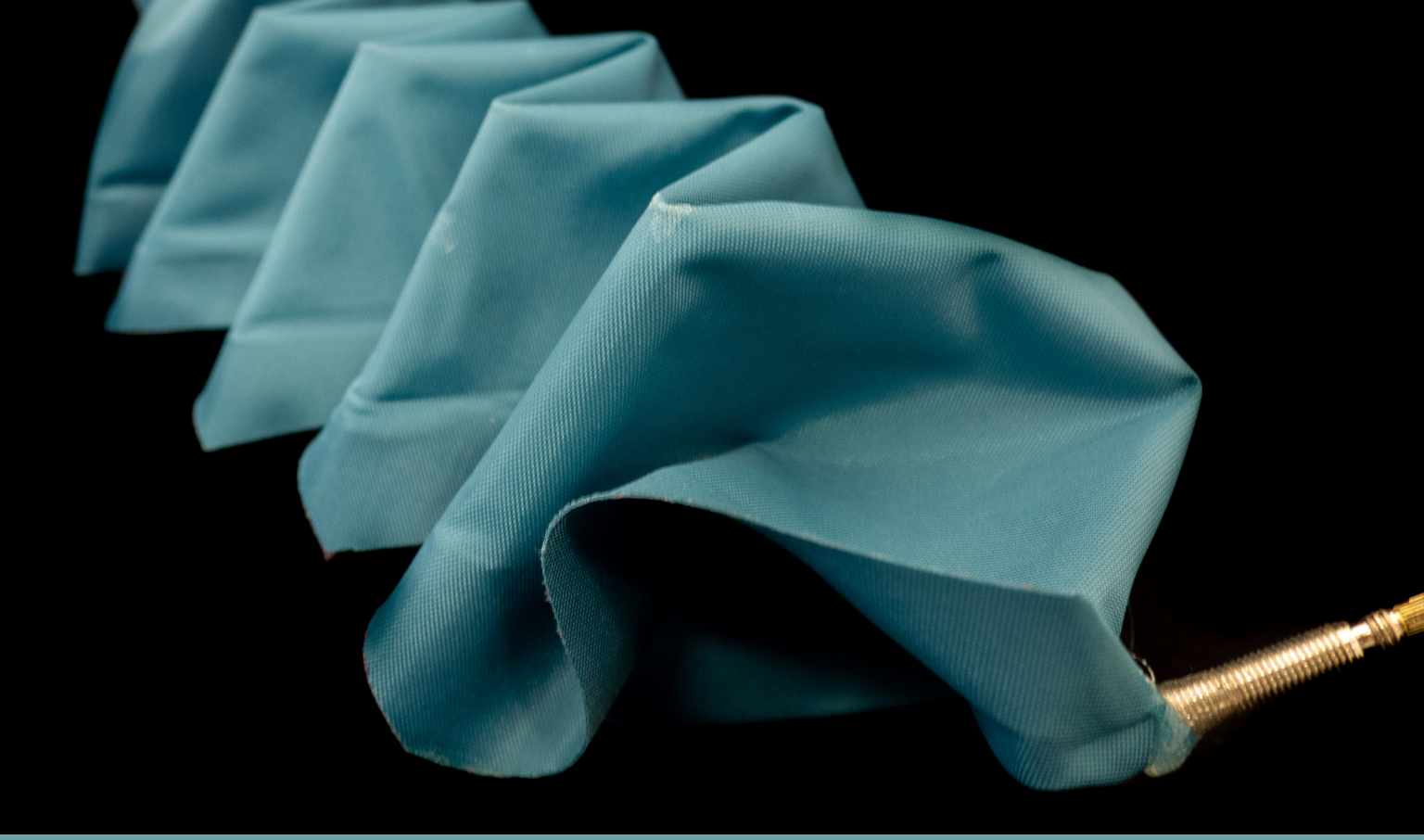
effective techniques to teach math" - Professor Paulino



Credit: Tomohiro Tachi, Origami Stanford Bunny, 2007.

STUDENT FINAL PROJECTS

Students are given a team final project to apply their talents and new knowledge to benefit society. With such a diverse class, no group of 4 is all from one major. Every team member brings a unique perspective to the use of geometry given their background, producing impressively creative solutions. The projects are presented and displayed at a trade show style event at the end of the semester.



PNEUMATIC ORIGAMI MUSCLE

Soft actuators and biomimicry have been a recent focus of engineering. The search is for a mechanism that can imitate a contracting muscle in the safest and simplest way possible, both to construct and to control. A group of Paulino's students produced a prototype for an air powered origami strip that behaves as a muscle. The system is safely powered by negative pressure, and the origami strip offers a consistent behavior with a basic pattern that is easy to produce.

Credit: Garrett Cashwell, Timothy Lai, Jevons Li, & Benjamin Rutherford "Inflatable Miura-Ori Tubes", Class of 2018.

COMPACT SCOOTER HELMET

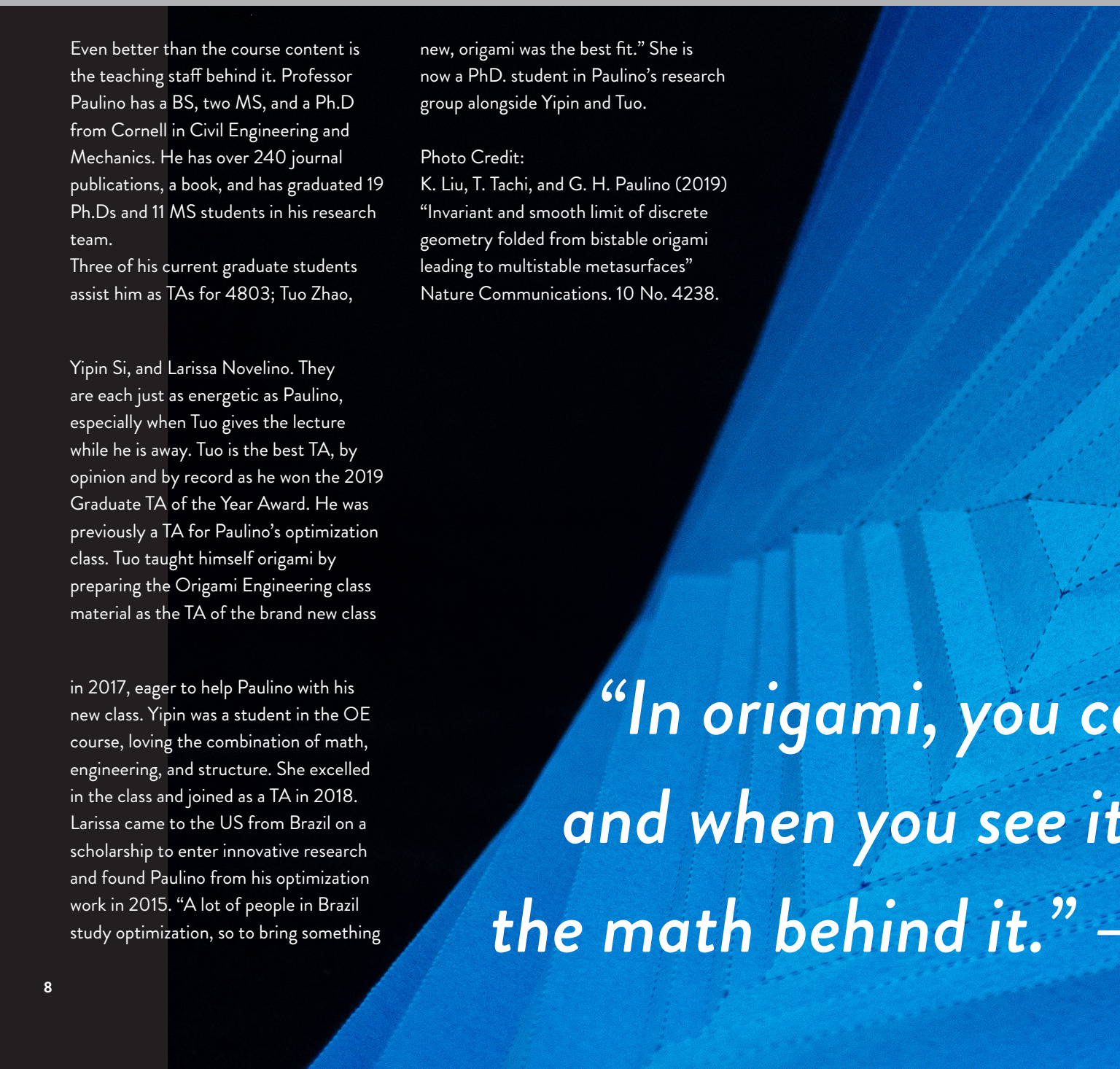
One would think riding a scooter is easy, but ask anyone in a city invaded by electric scooters and they will tell how dangerous the vehicles can be in the wrong hands. Why? Because riders almost never wear a helmet. The renting business model leaves users without a helmet unless they carry their own. This team from 2018 built a prototype for a flat-folding origami helmet to protect riders without adding bulk to their everyday carry. The project was later developed to become a full product and is now being deployed in JUMP bikes.

Credit: Carmela Chaney, Anupama Shah, Yipeng Xue, "Origami helmets to prevent concussions," Class of 2018.

THE TEAM

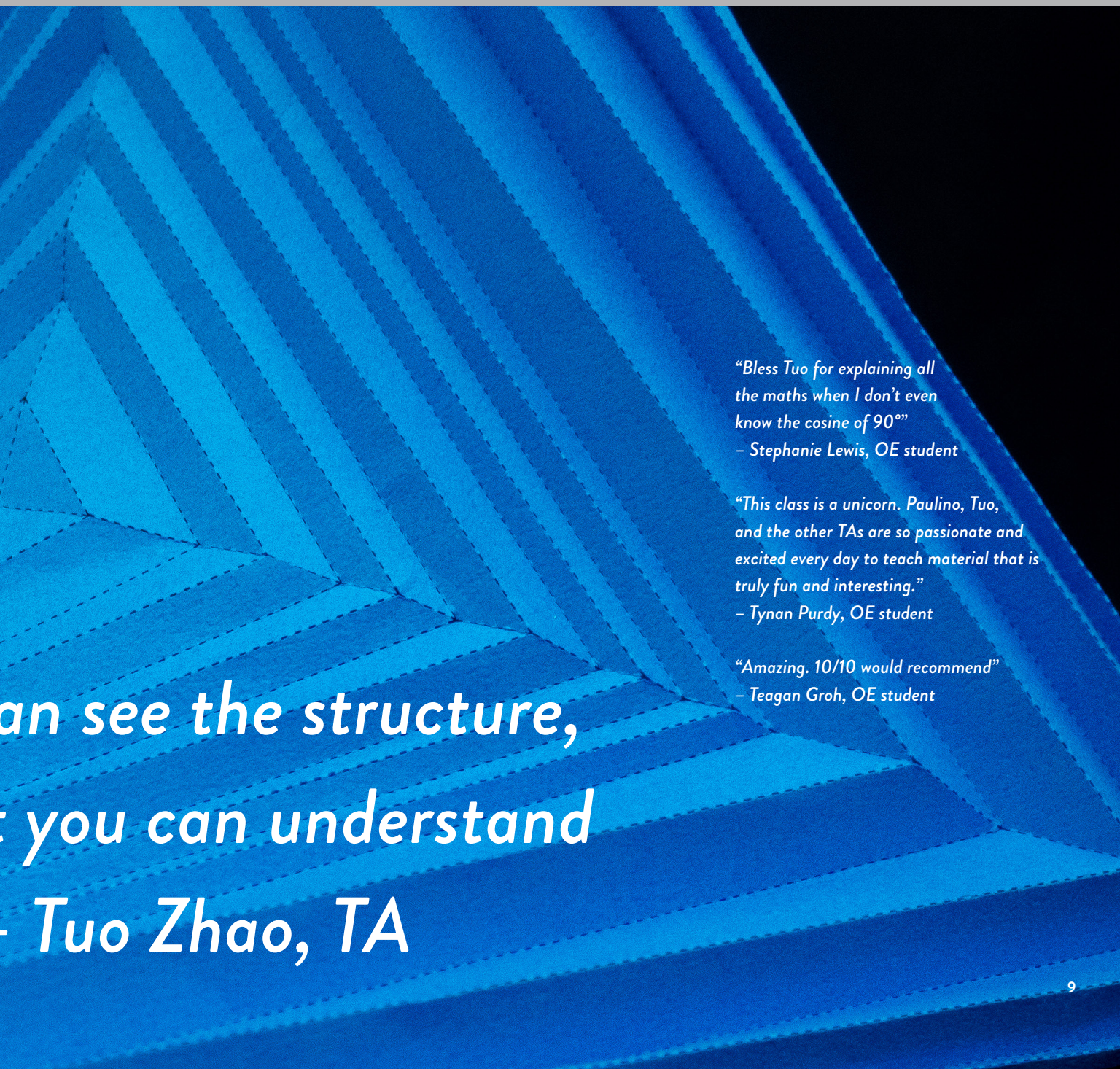
Even better than the course content is the teaching staff behind it. Professor Paulino has a BS, two MS, and a Ph.D from Cornell in Civil Engineering and Mechanics. He has over 240 journal publications, a book, and has graduated 19 Ph.Ds and 11 MS students in his research team.
Three of his current graduate students assist him as TAs for 4803; Tuo Zhao, Yipin Si, and Larissa Novelino. They are each just as energetic as Paulino, especially when Tuo gives the lecture while he is away. Tuo is the best TA, by opinion and by record as he won the 2019 Graduate TA of the Year Award. He was previously a TA for Paulino's optimization class. Tuo taught himself origami by preparing the Origami Engineering class material as the TA of the brand new class in 2017, eager to help Paulino with his new class. Yipin was a student in the OE course, loving the combination of math, engineering, and structure. She excelled in the class and joined as a TA in 2018. Larissa came to the US from Brazil on a scholarship to enter innovative research and found Paulino from his optimization work in 2015. "A lot of people in Brazil study optimization, so to bring something new, origami was the best fit." She is now a PhD. student in Paulino's research group alongside Yipin and Tuo.

Photo Credit:
K. Liu, T. Tachi, and G. H. Paulino (2019) "Invariant and smooth limit of discrete geometry folded from bistable origami leading to multistable metasurfaces" Nature Communications. 10 No. 4238.



"In origami, you c
and when you see it
the math behind it." –

STUDENT REVIEWS

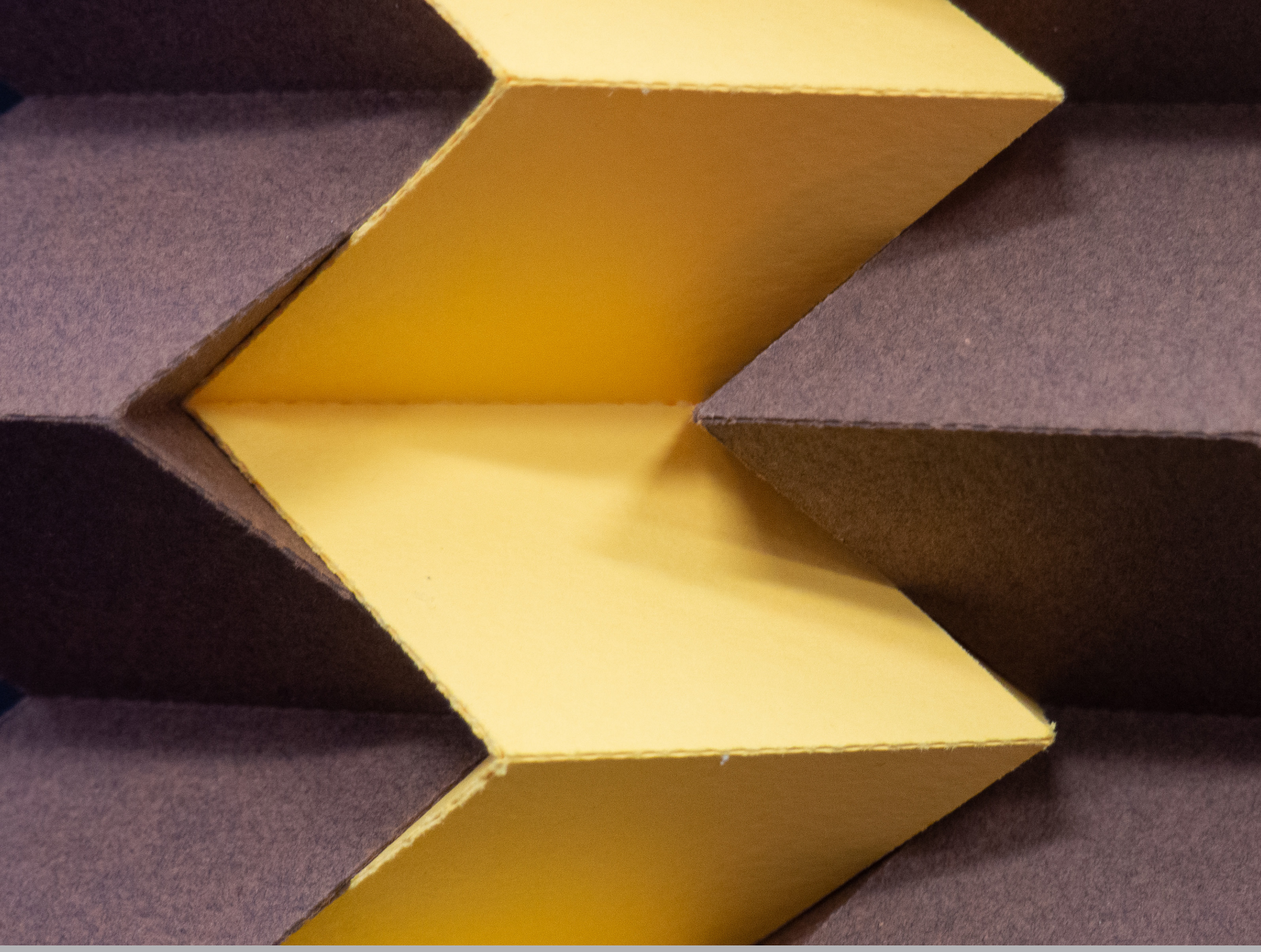


"Bless Tuo for explaining all the maths when I don't even know the cosine of 90°"
– Stephanie Lewis, OE student

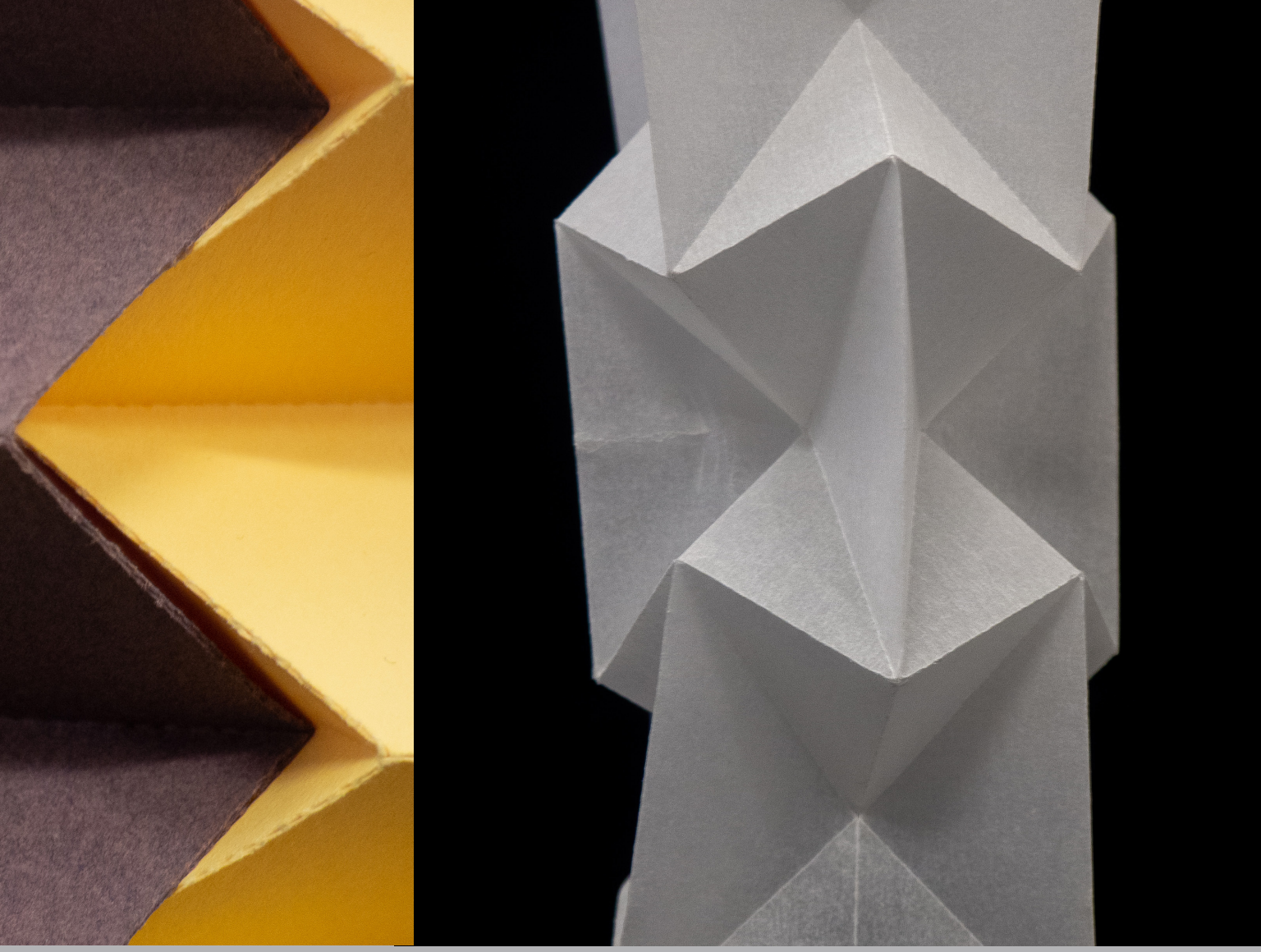
"This class is a unicorn. Paulino, Tuo, and the other TAs are so passionate and excited every day to teach material that is truly fun and interesting."
– Tynan Purdy, OE student

"Amazing. 10/10 would recommend"
– Teagan Groh, OE student

an see the structure,
t you can understand
– Tuo Zhao, TA



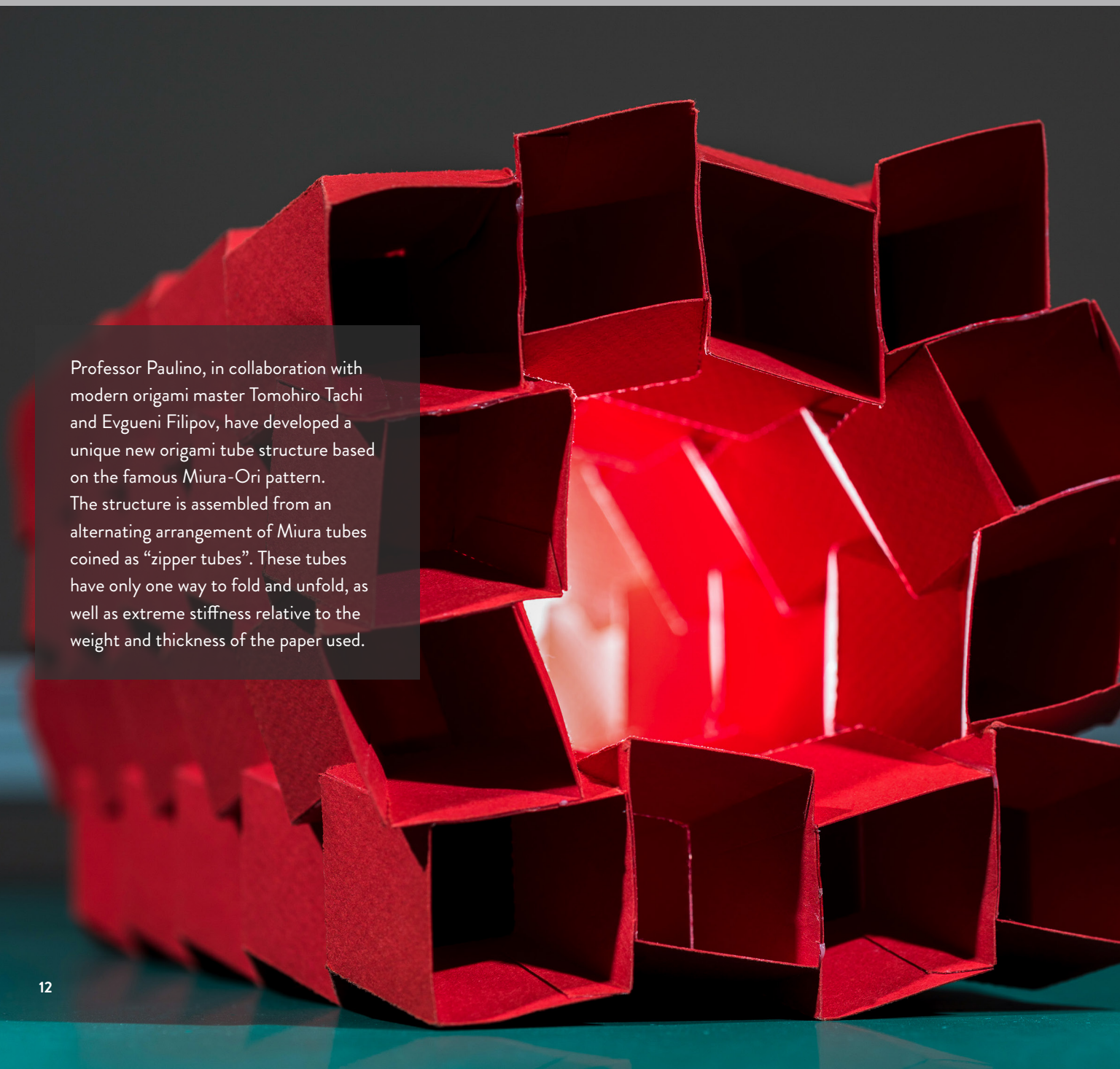
ORIGAMI ENGINEERING IS THE FUTURE



The recent rise in origami research in the US can be attributed to Professor Paulino himself. He served as a program director at the National Science Foundation. Paulino saw the beauty and potential in origami engineering, so he proposed it as the topic for the NSF's Emerging Frontiers in Research and Innovation program. The submission was met with resistance. Paulino said, "It was a struggle. People were very resistant to the idea." By 2010, the Origami Design for Integration of Self-assembling Systems for Engineering Innovation (ODISSEI) program was approved, sponsoring 13 research teams with $2 million in funding each. Paulino envisions the next generation will grow with the tools of origami and not dismiss it as his colleagues once did.

In a world of maturing technologies and understanding of our world, it can be hard to find a field with as much untapped potential as origami. The versatility and beauty of what was thought to be just a centuries old art form is now one of the most exciting fields of research in engineering. Any student at Georgia Tech can utilize the vast knowledge that Prof. Paulino and his team are so happy to share, and if not, it is still a fun elective.

ORIGAMI RESEARCH AT GEORGIA TECH

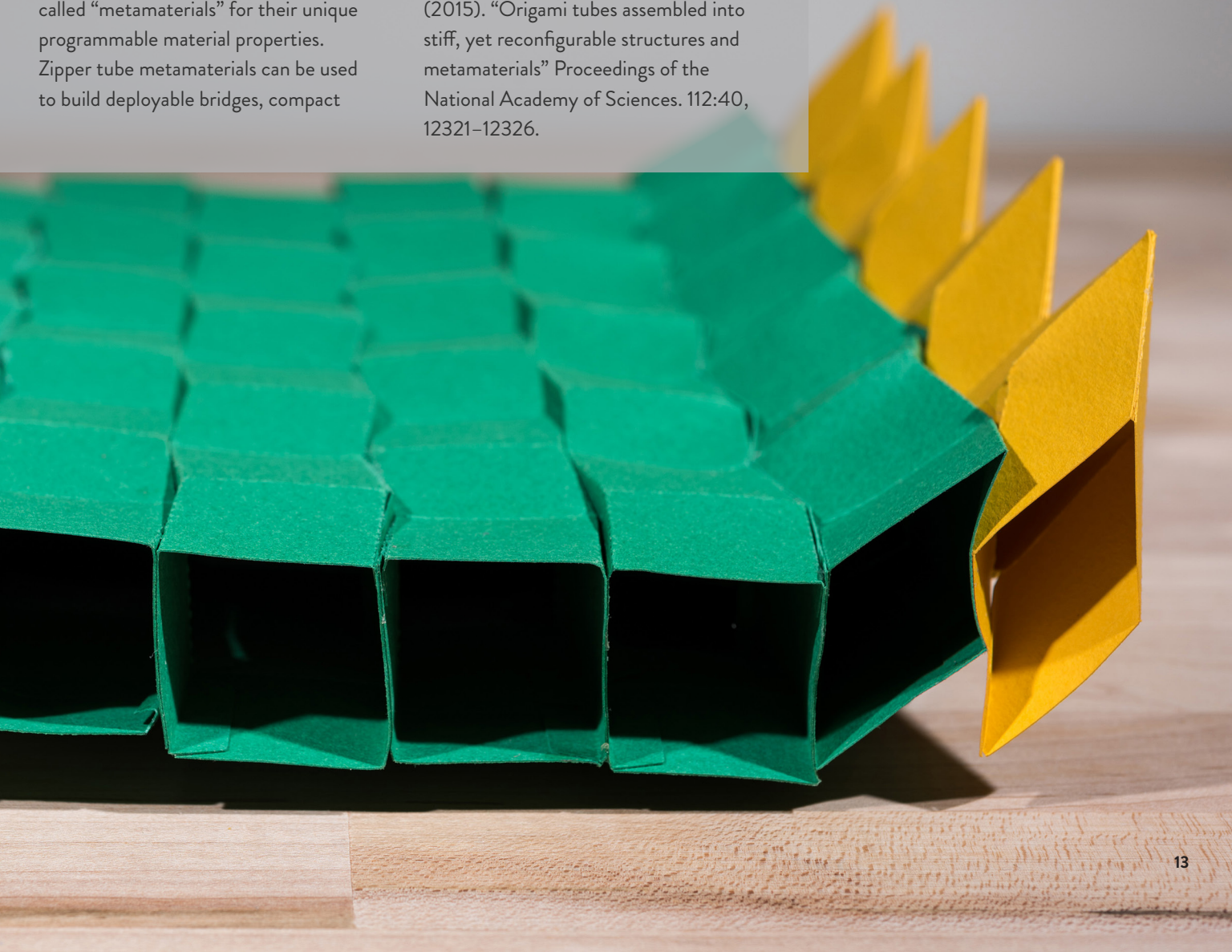


Professor Paulino, in collaboration with modern origami master Tomohiro Tachi and Evgueni Filipov, have developed a unique new origami tube structure based on the famous Miura-Ori pattern. The structure is assembled from an alternating arrangement of Miura tubes coined as “zipper tubes”. These tubes have only one way to fold and unfold, as well as extreme stiffness relative to the weight and thickness of the paper used.

PROF. PAULINO

Zipper tube structures have a wide range of applications as a building structure. The stiffness and extension properties of the tube are programmable by simply adjusting the geometry of the origami. These origami structures are called “metamaterials” for their unique programmable material properties. Zipper tube metamaterials can be used to build deployable bridges, compact deployable emergency shelters, and so much more. Paulino and his team built a paper prototype of a zipper tube bridge to demonstrate.

Photo Credit:
E. T. Filipov, T. Tachi, and G. H. Paulino (2015). “Origami tubes assembled into stiff, yet reconfigurable structures and metamaterials” Proceedings of the National Academy of Sciences. 112:40, 12321–12326.



TRY IT YOURSELF

ORIGAMI 101

Miura-Ori is the most famous pattern in origami engineering. It demonstrates many of the essential properties of origami such as flat foldability, developability, a negative Poisson ratio, and single degree of freedom movement. Miura is also easy to fold!

Red lines are Mountains and are folded down.
Blue lines are Valleys and are folded up.

Fold zig-zags first, then complete by flat folding.