

ORIGAMI

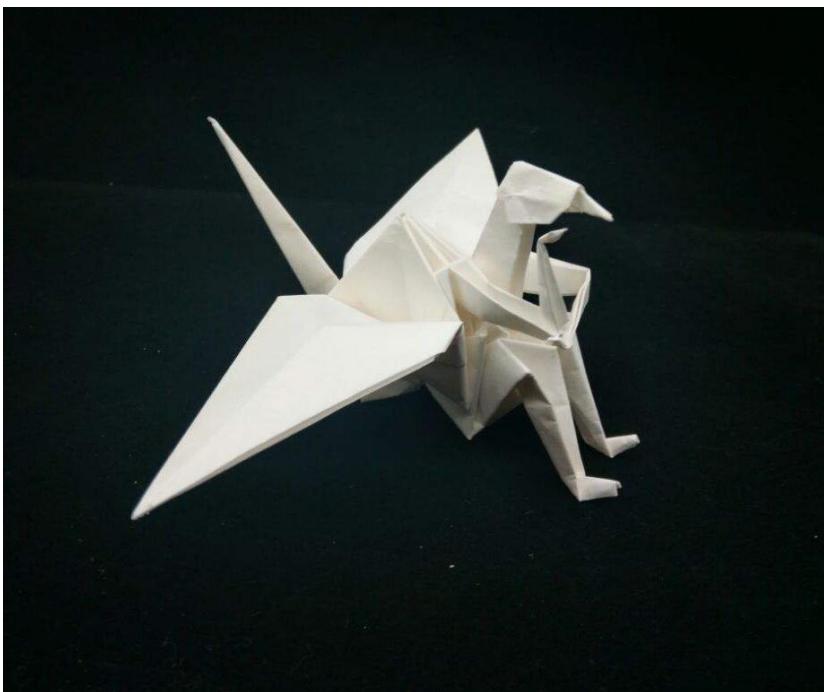
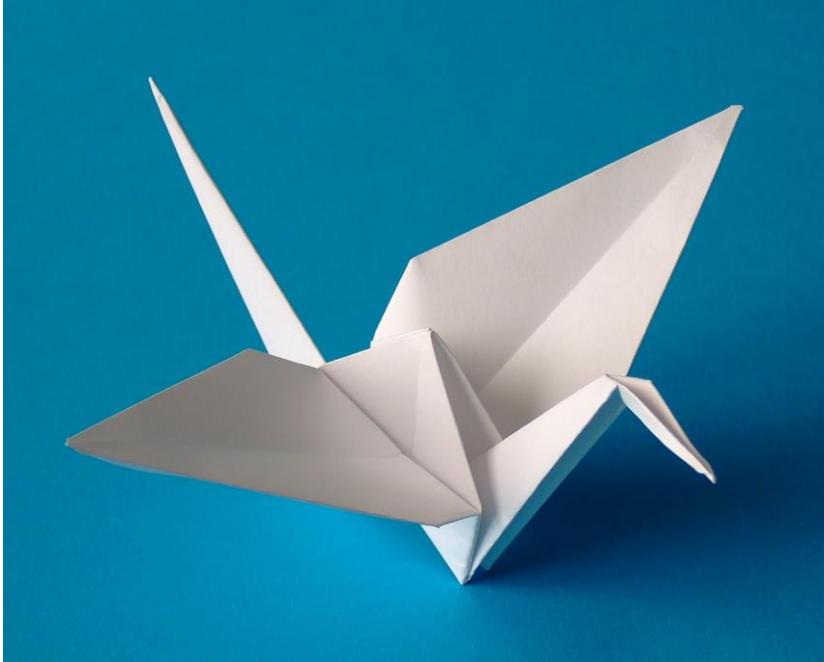
Bridging Art, Mathematics, and Engineering

Chaewon Baek

Seoul National University

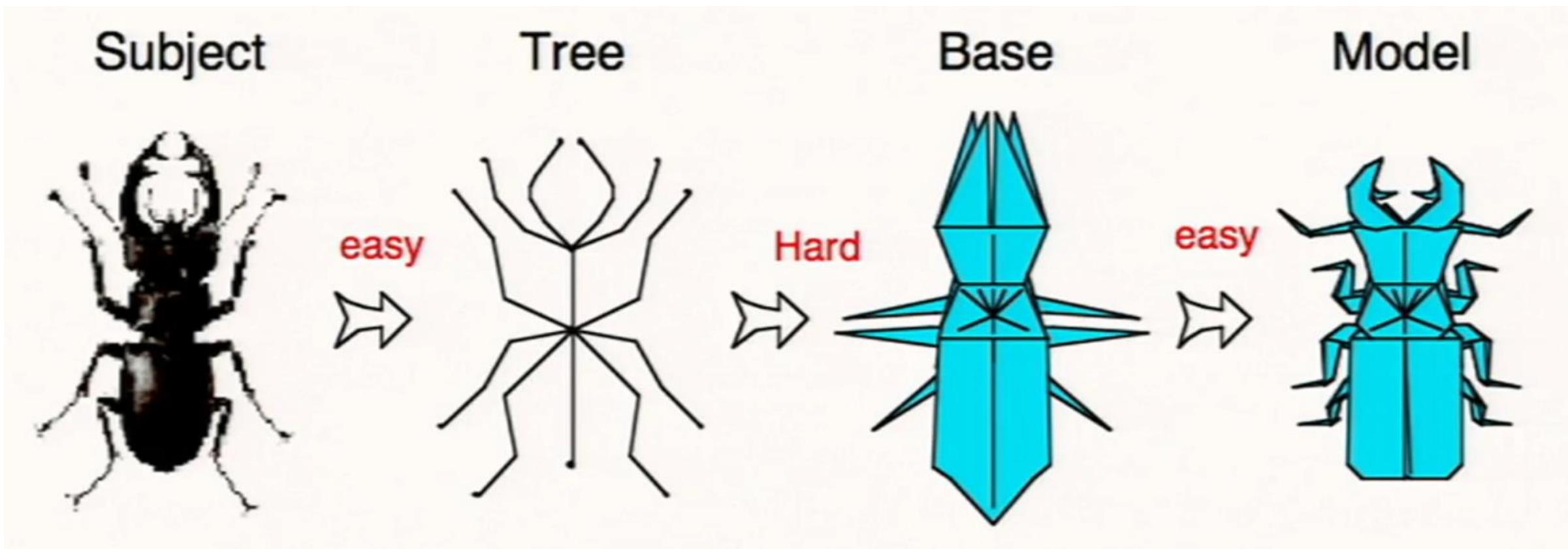
Dep. of Mech. Eng.

I.Art



2. Mathematics

How?



How to make 'Flaps'?

Circle Packing

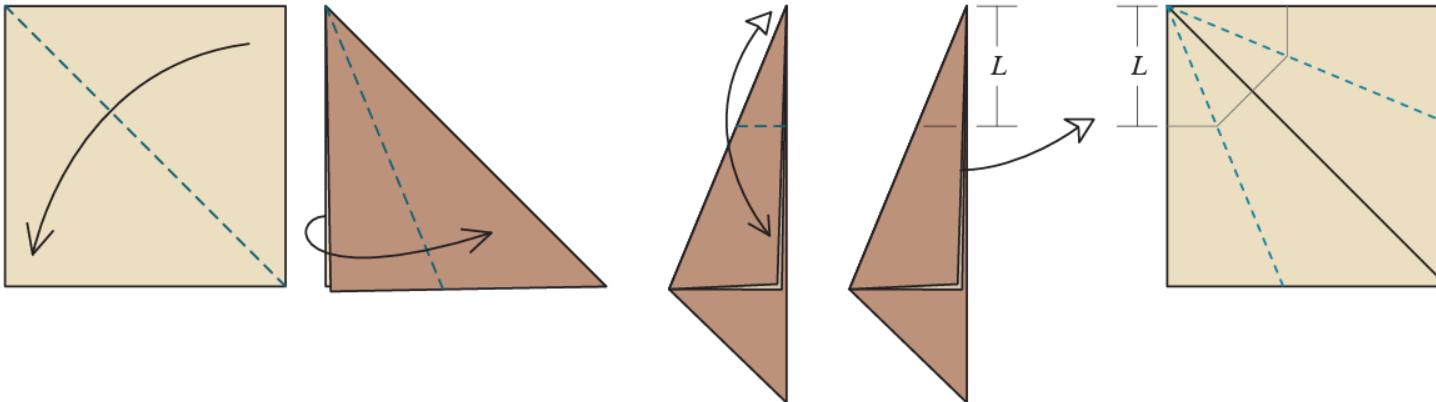


Figure 9.2.

Folding a corner flap of length L from a square.

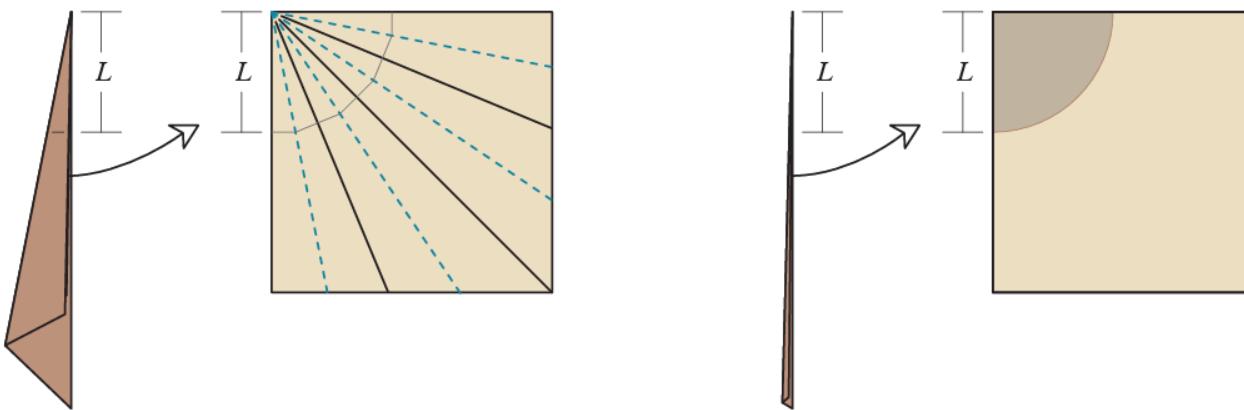


Figure 9.3.

Left: making a narrower flap makes the boundary a quarter of a hexadecagon.

Right: the limit of the boundary as the flap becomes infinitely thin approaches a quarter circle.

Circle Packing

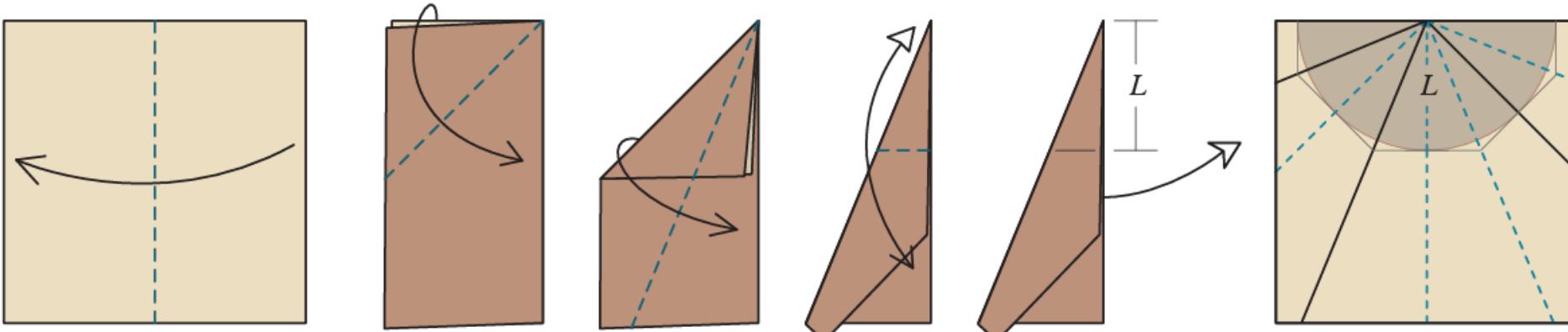


Figure 9.4.

Folding an edge flap of length L from a square.

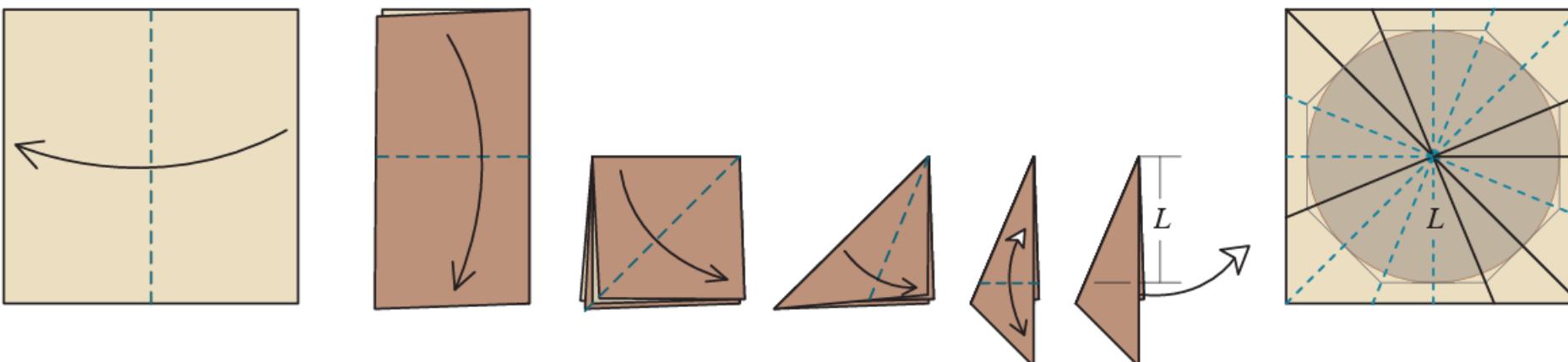


Figure 9.5.

Folding a middle flap of length L from a square.

Circle Packing

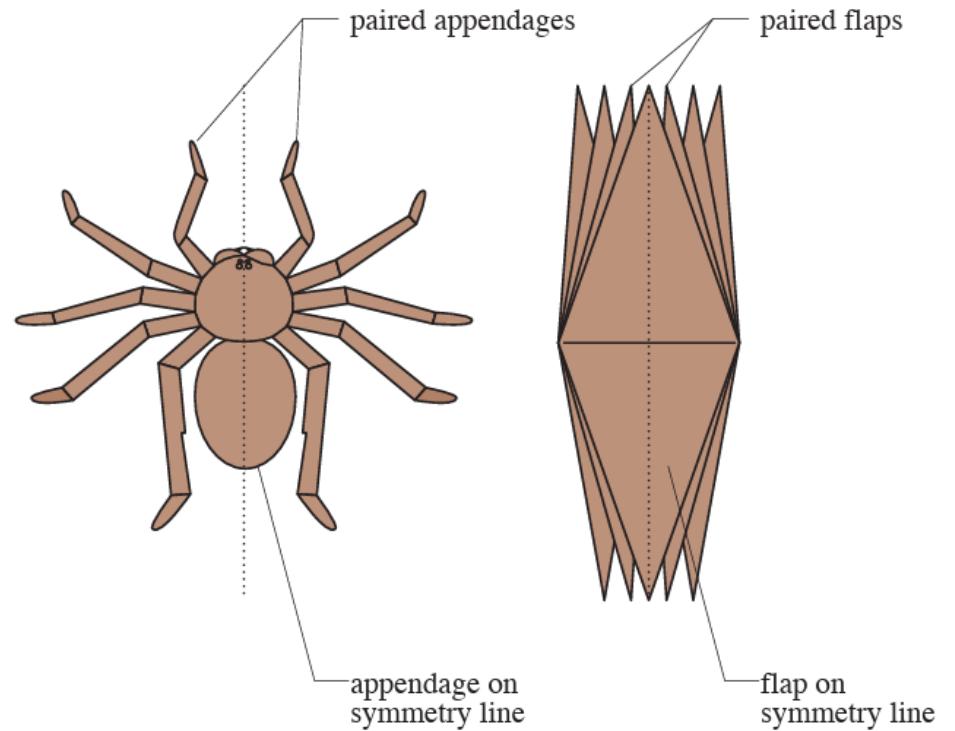
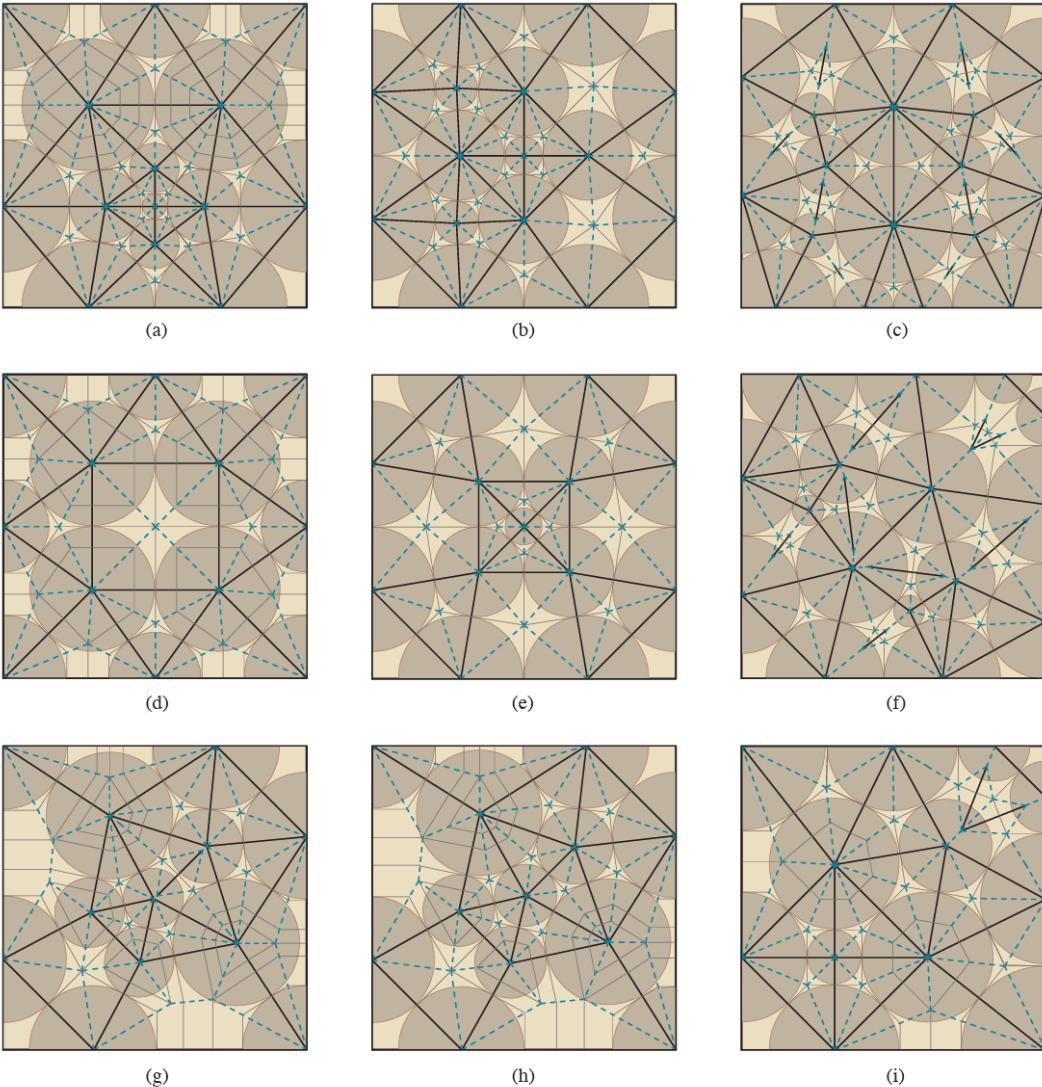


Figure 9.23.

An assortment of possible tarantula crease patterns.

Circle Packing

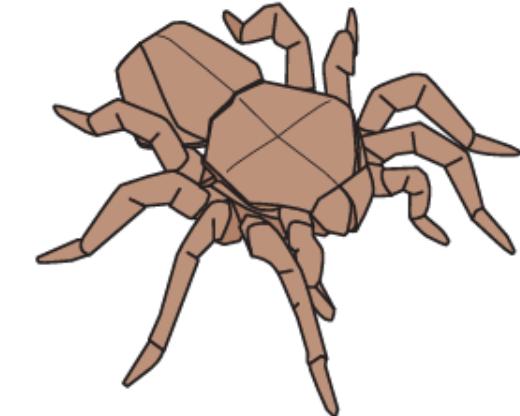
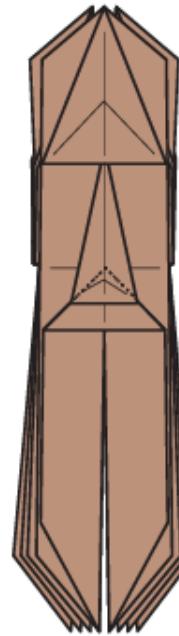
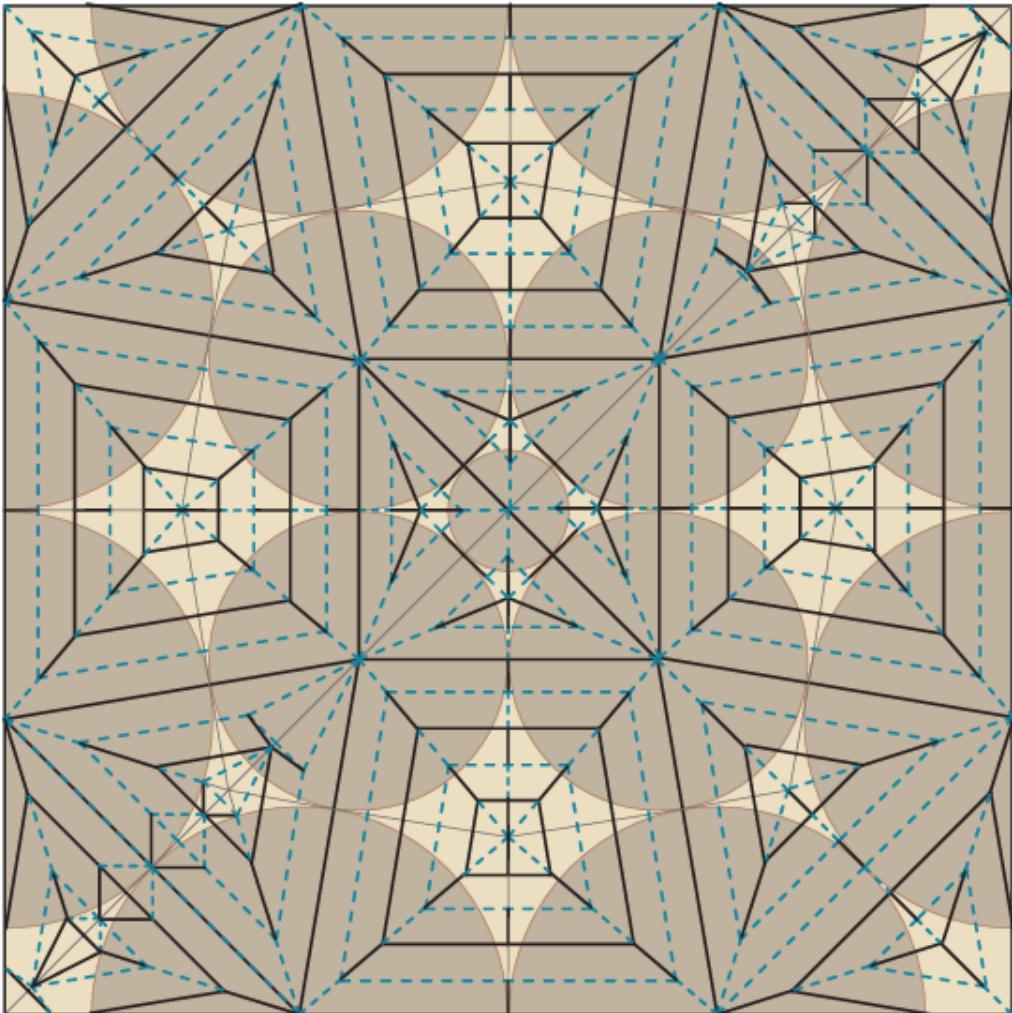
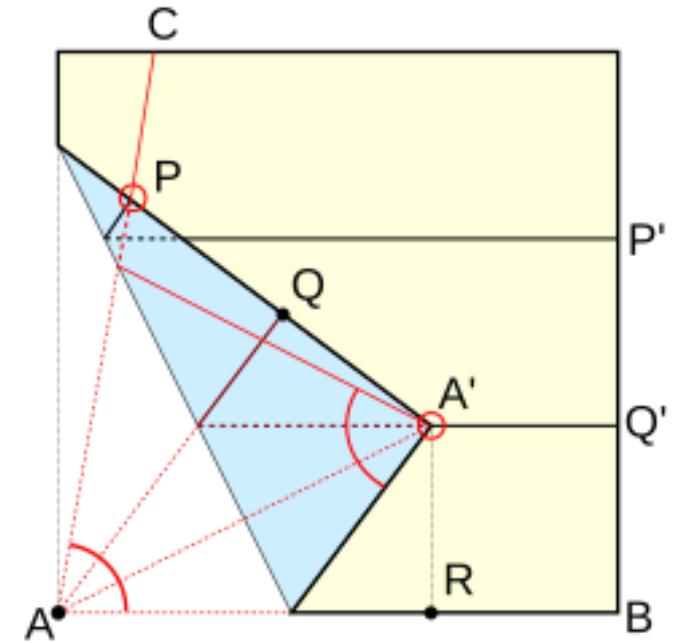
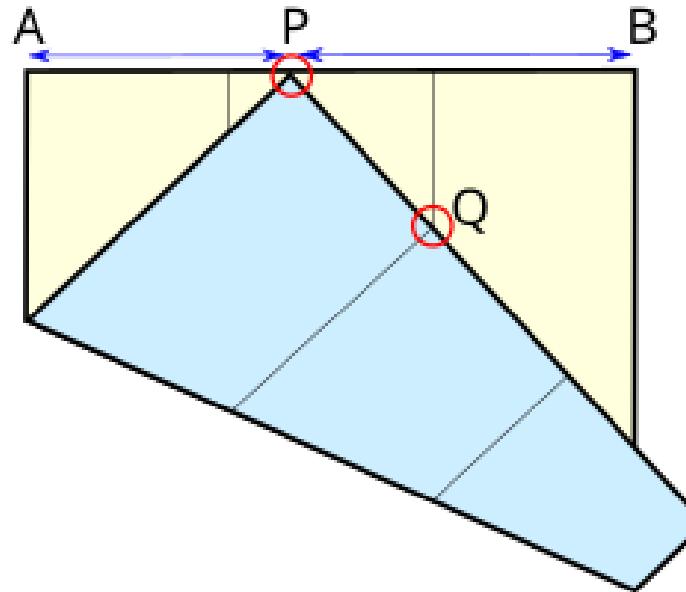
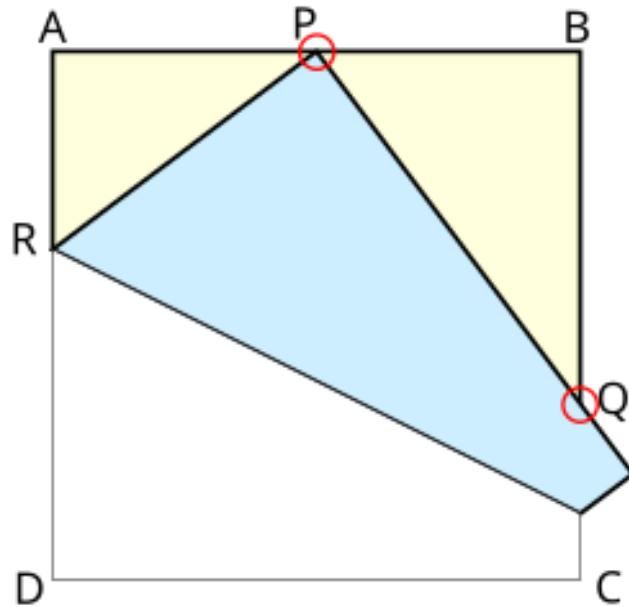


Figure 9.24.
Crease pattern, base, and folded model of the Tarantula.

Construction using Origami



Haga's first theorem

AP	BQ	QC	AR	PQ
x	$\frac{2x}{1+x}$	$\frac{1-x}{1+x}$	$\frac{1-x^2}{2}$	$\frac{1+x^2}{1+x}$
$\frac{1}{2}$	$\frac{2}{3}$	$\frac{1}{3}$	$\frac{3}{8}$	$\frac{5}{6}$
$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{4}{9}$	$\frac{5}{6}$
$\frac{2}{3}$	$\frac{4}{5}$	$\frac{1}{5}$	$\frac{5}{18}$	$\frac{13}{15}$
$\frac{1}{5}$	$\frac{1}{3}$	$\frac{2}{3}$	$1\frac{12}{25}$	$1\frac{13}{15}$

$$\frac{\overline{PB}}{\overline{PA}} = \sqrt[3]{2}$$

Angle Trisection

Origami provides stronger constructing method

Circle Packing

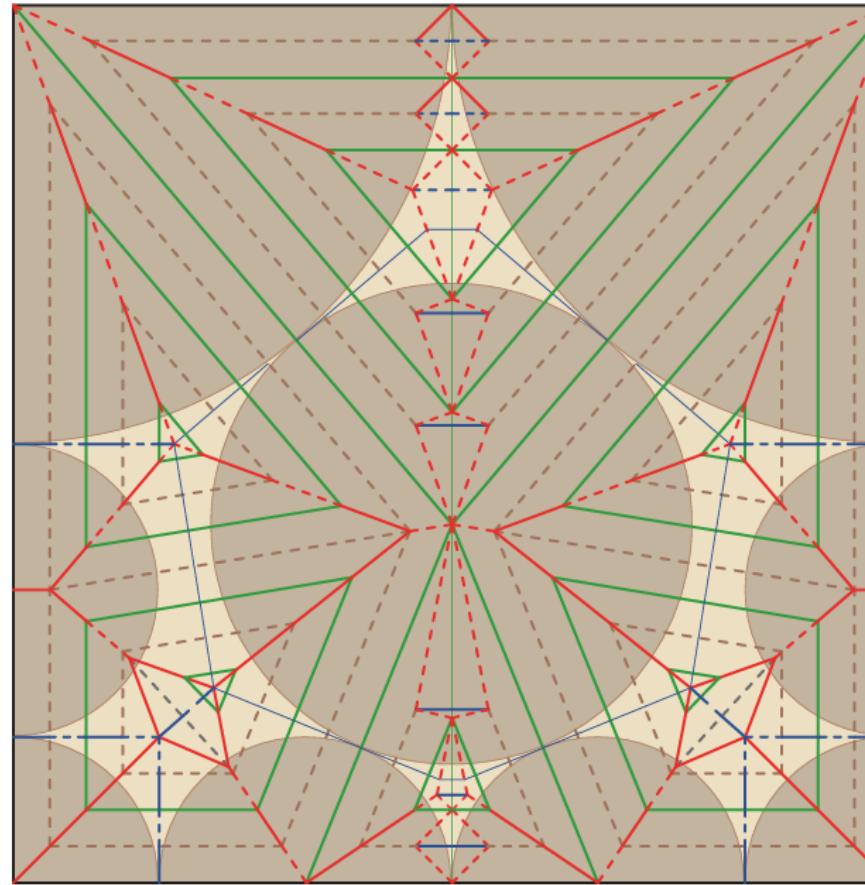
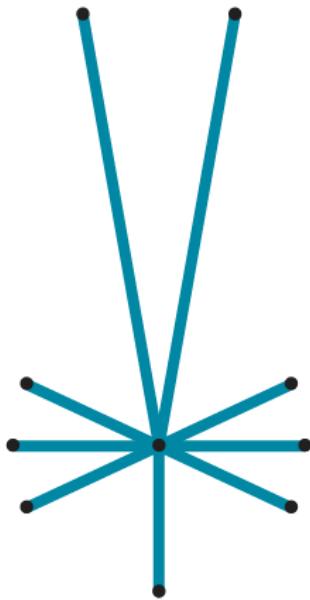
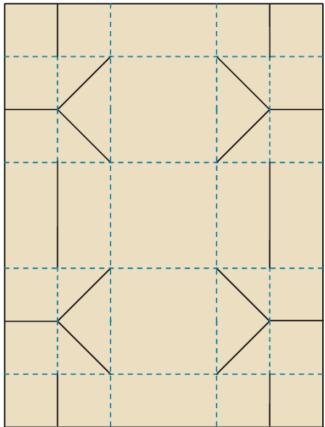
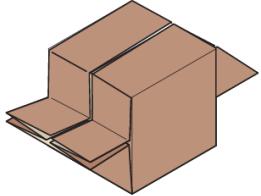


Figure 13.40.

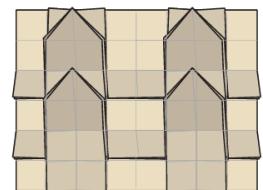
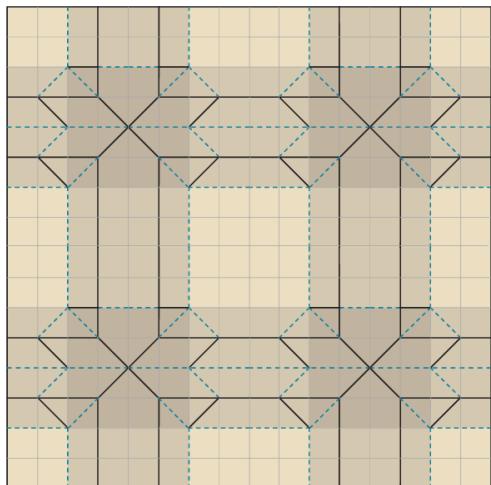
Stick figure and fully assigned crease pattern with structural coloring for a long-antennae beetle using circle/river packing and universal molecules.

Circle Packing does not guarantee Constructability...

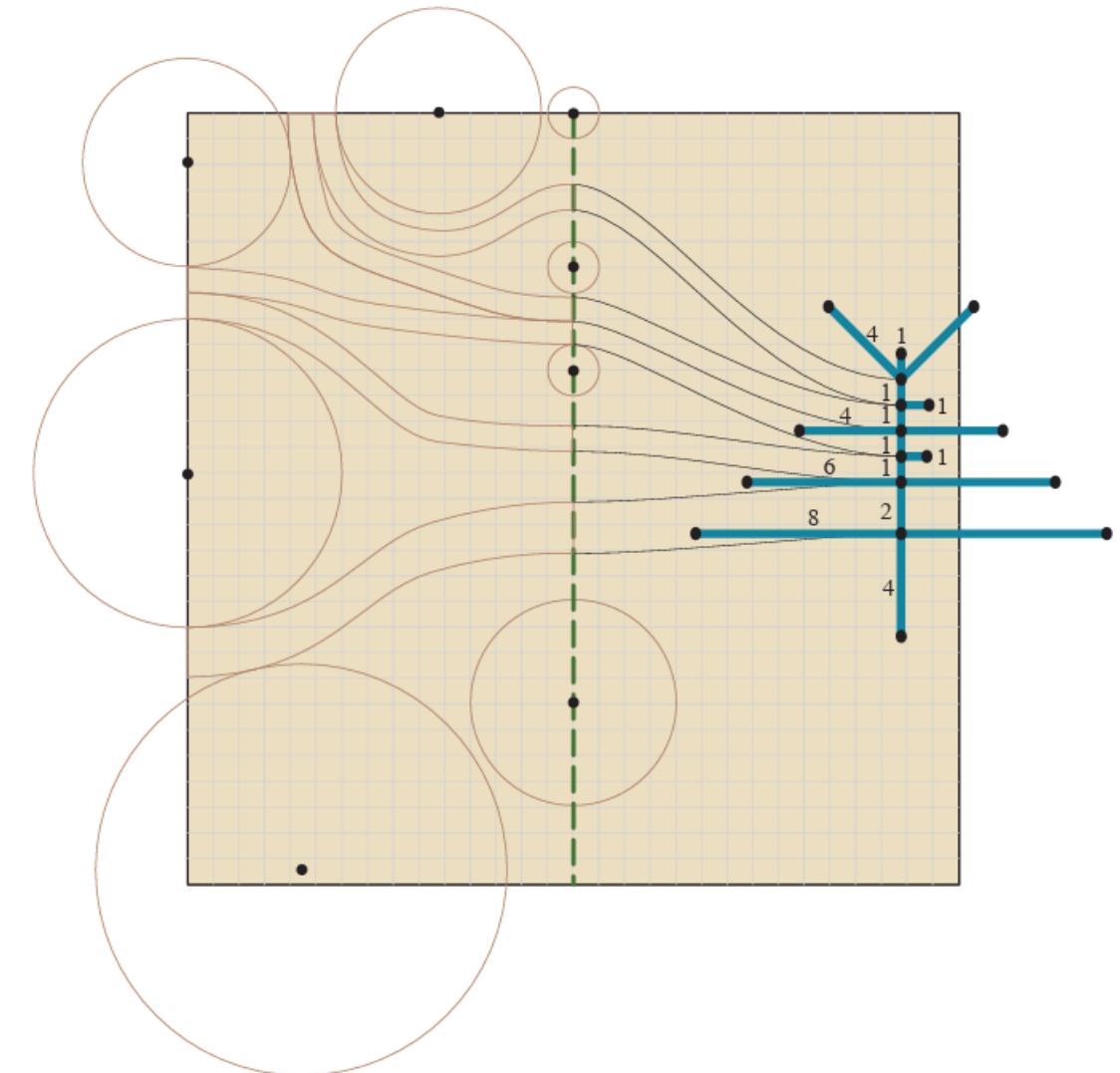
Boxpleating



Folding of Box

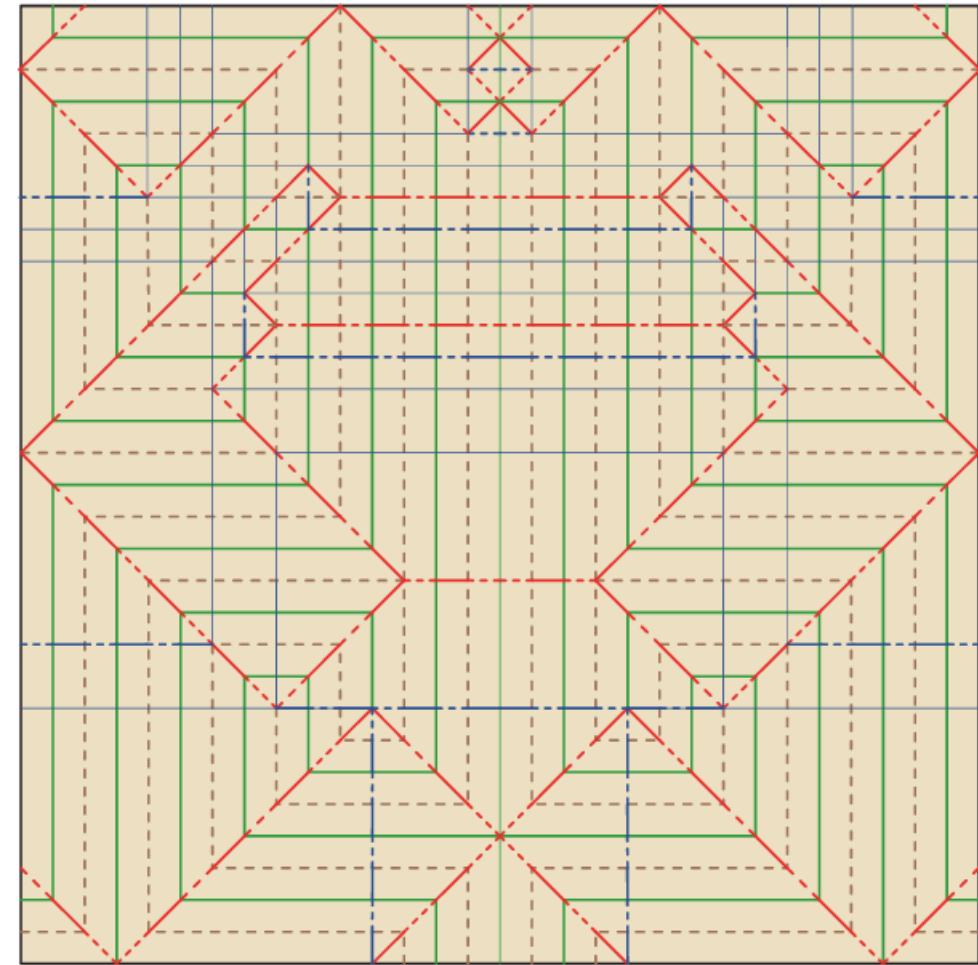
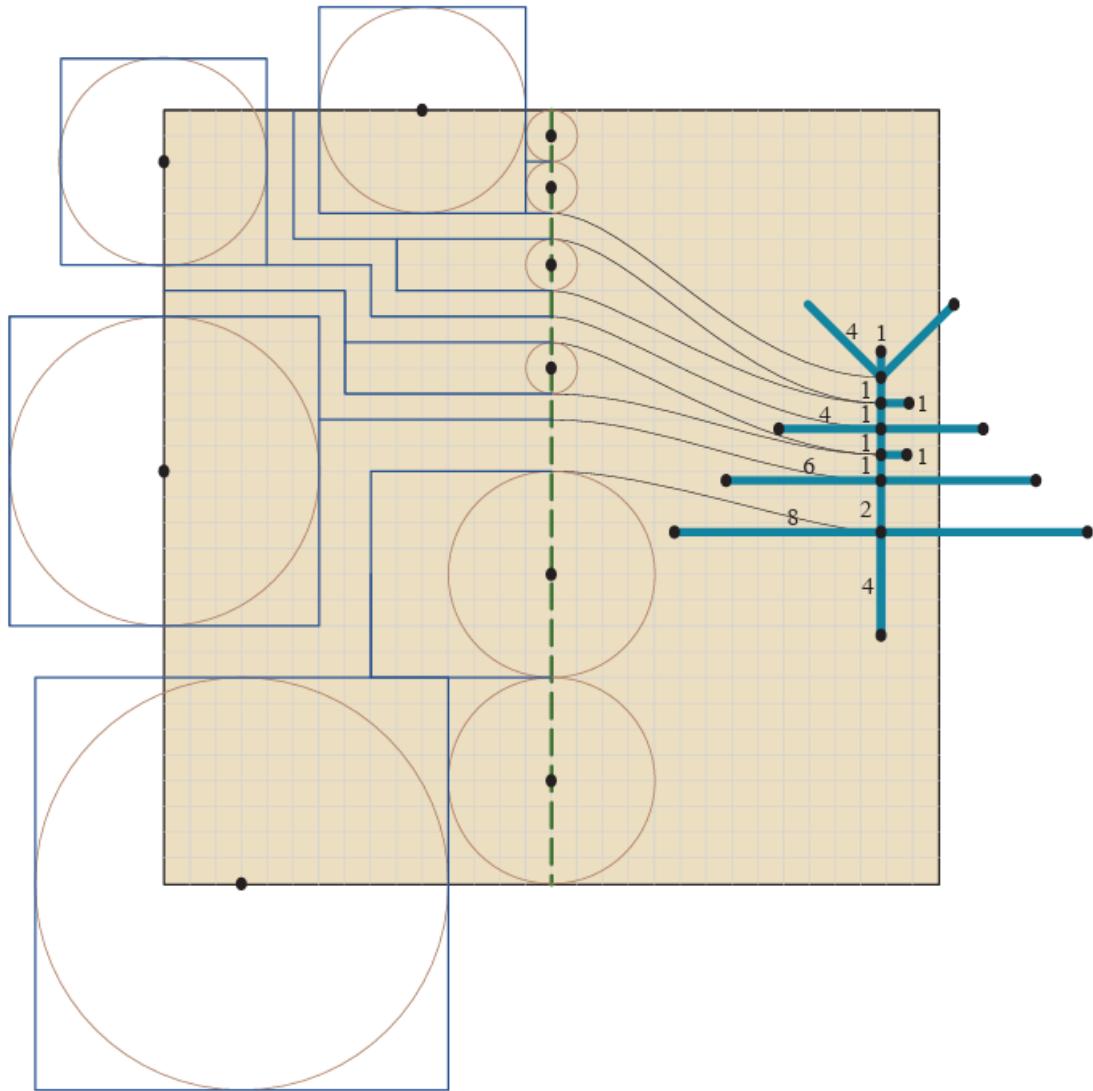


Variant of Box generates 'Flaps'

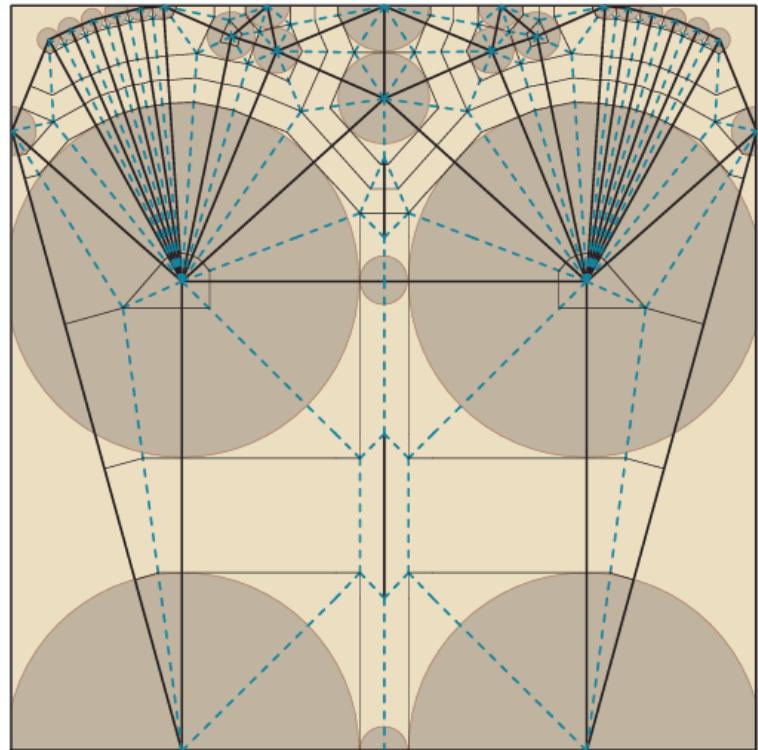


What if we place circles on 'Grid'?

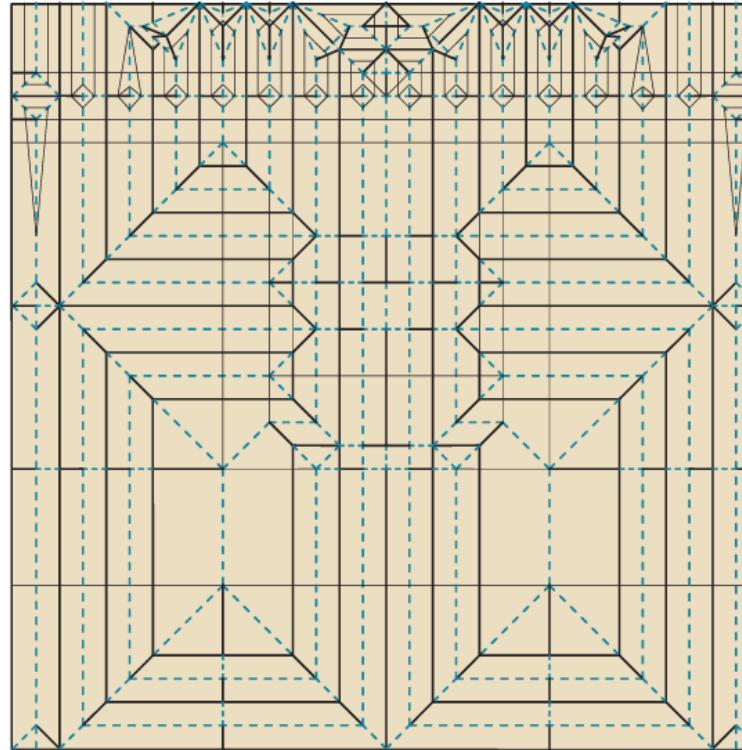
Boxpleating



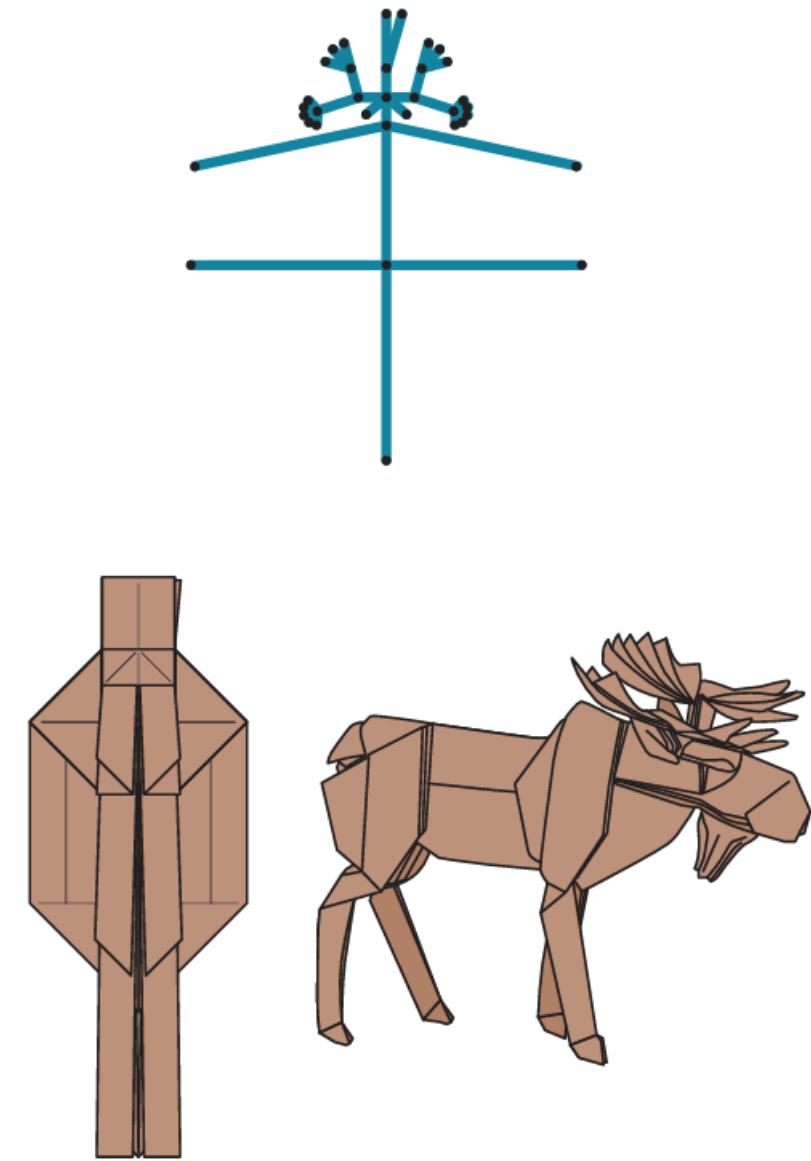
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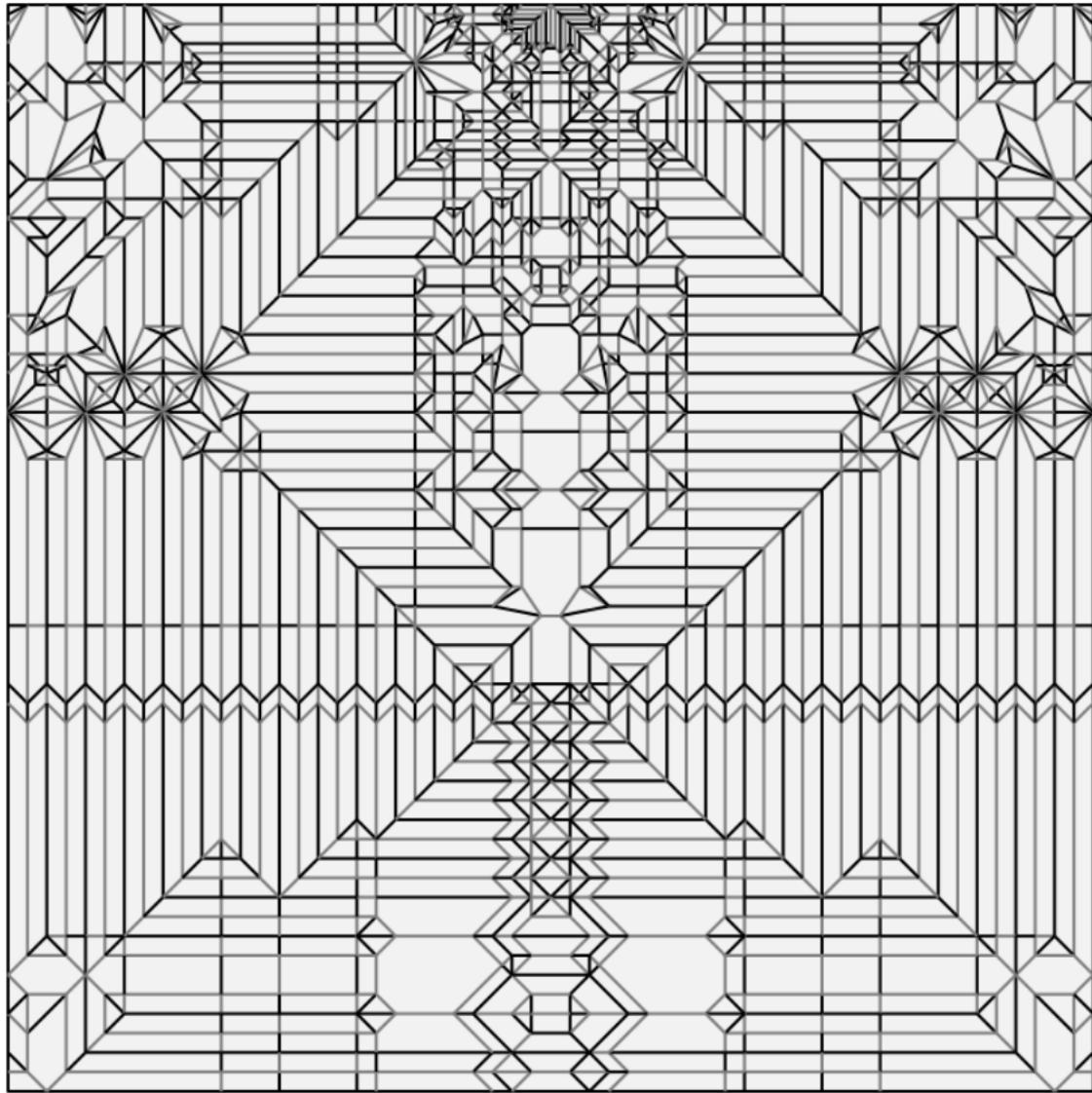
Circle Packing



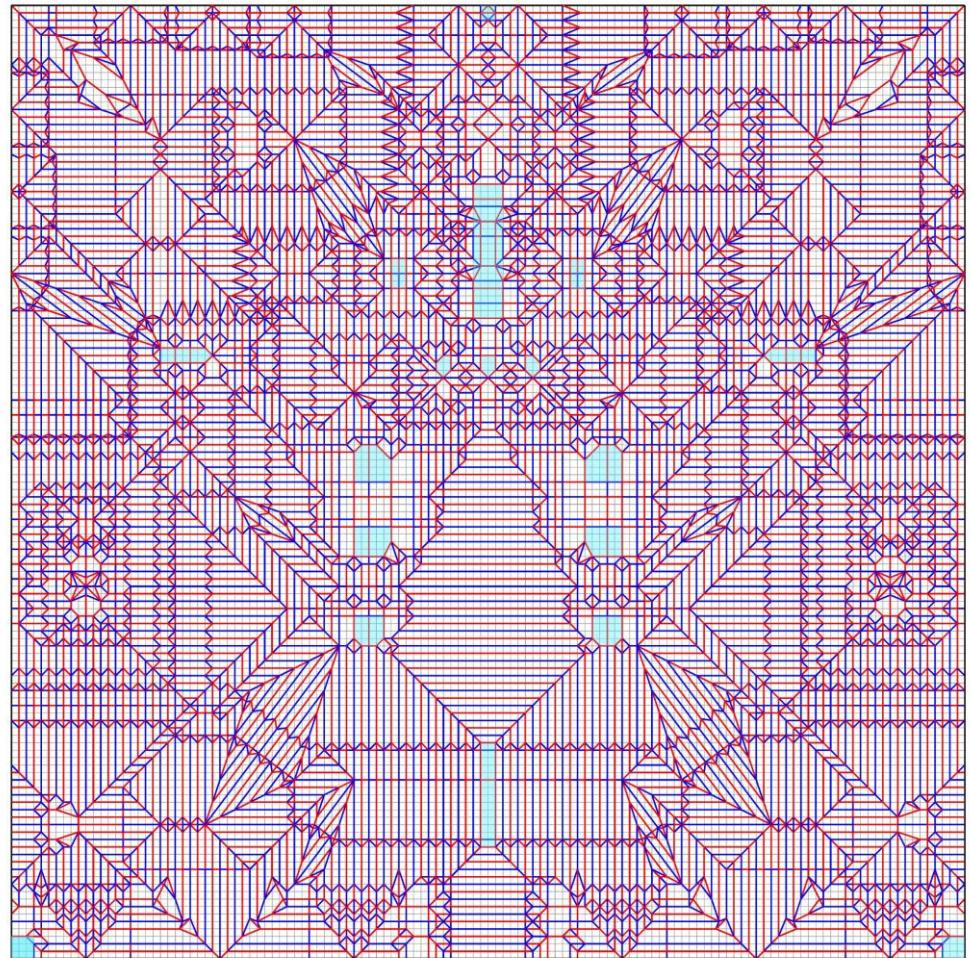
Box Pleating



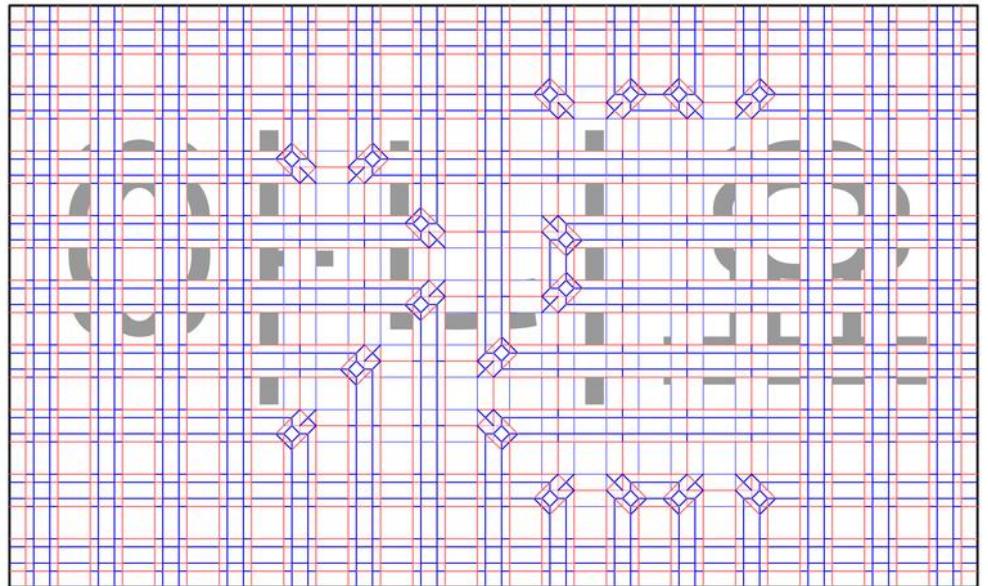
Boxpleating



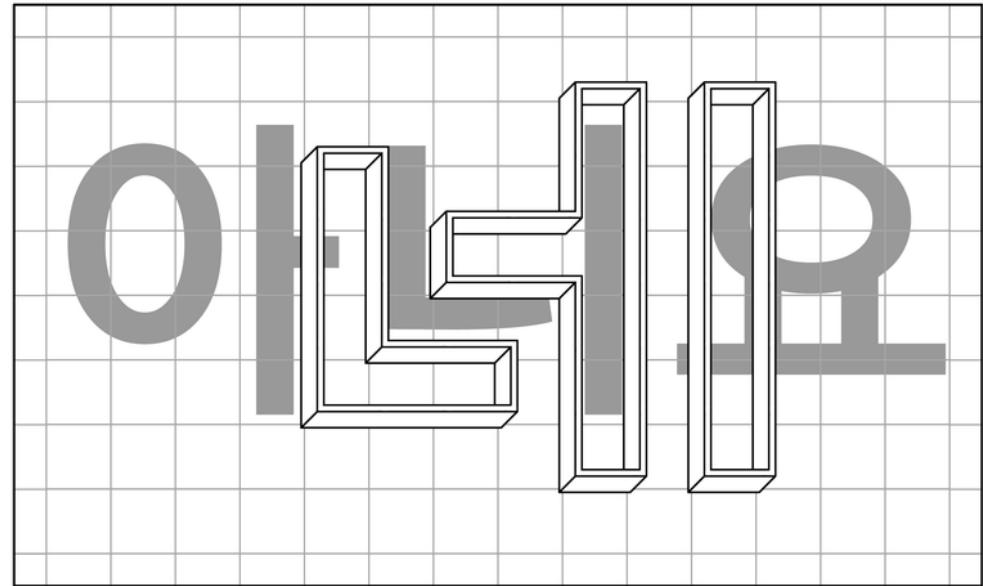
Boxpleating



Origami Maze?(By Erik Demaine, MIT)



$(2h + 1)n \times (2h + 1)n$ grid



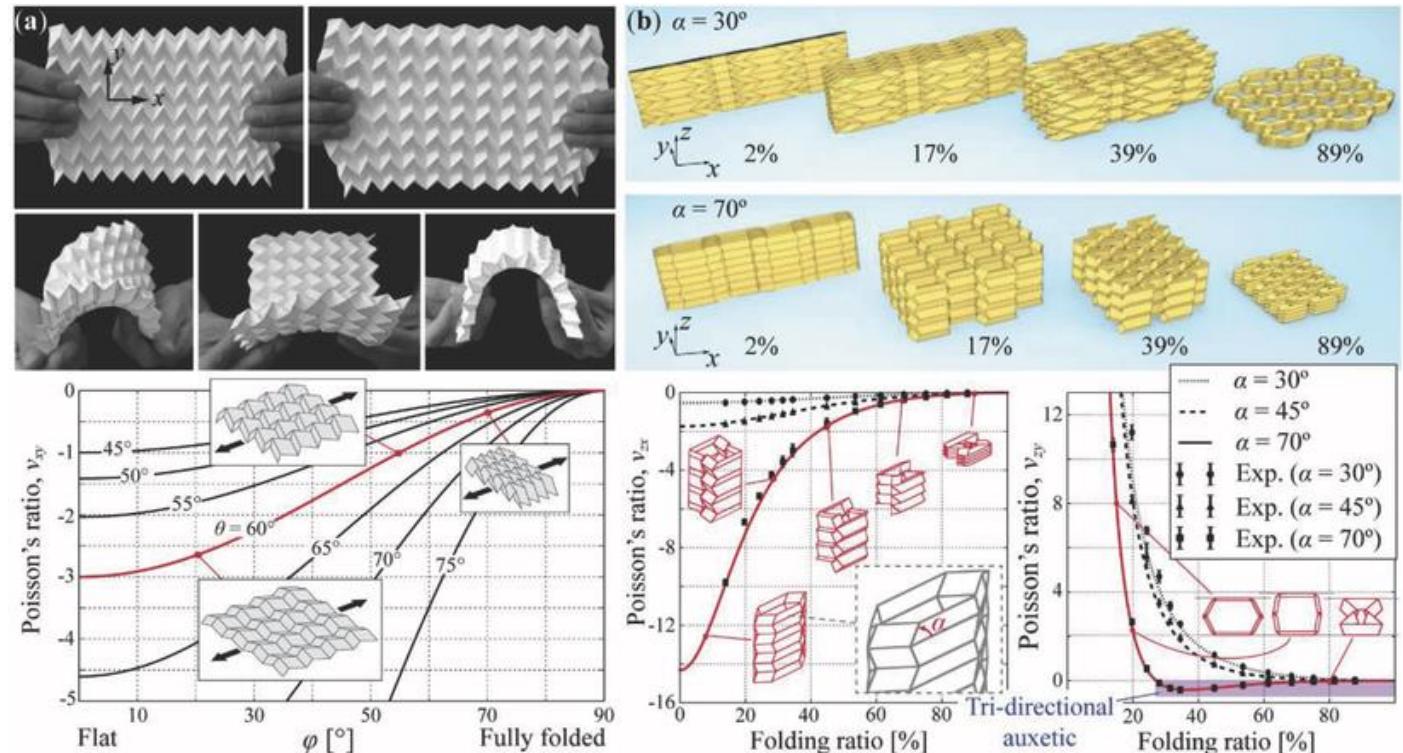
$n \times n$ maze with uniform height h

3. Engineering

Why Origami?



Deployability, Scalability



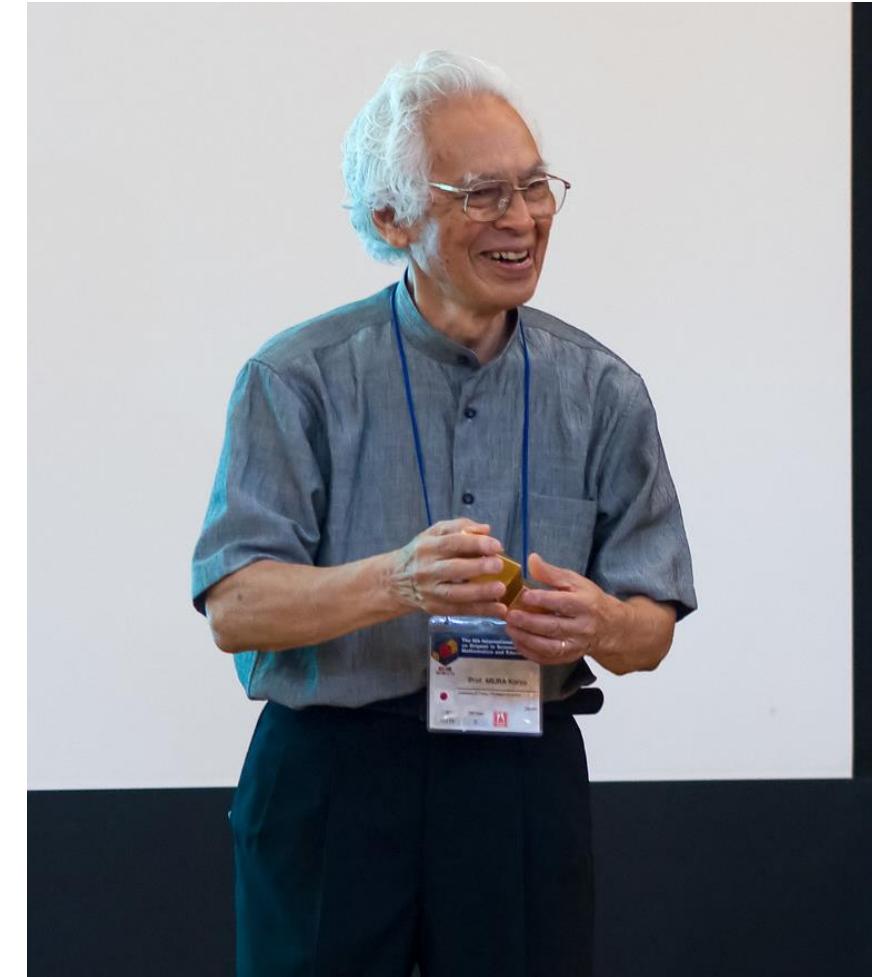
Unique material properties:

- High strength to weight ratio
- Multistability, self deployment
- Tunable mechanical property
- Self-locking

Miura-ori

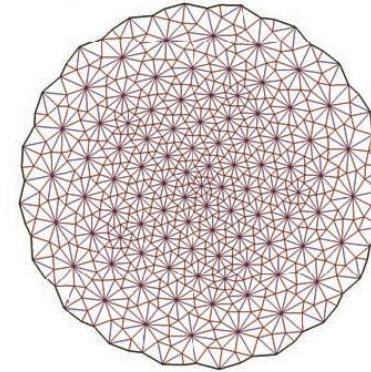
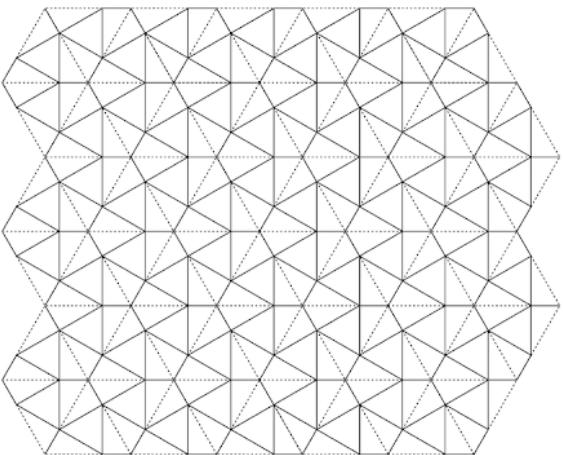
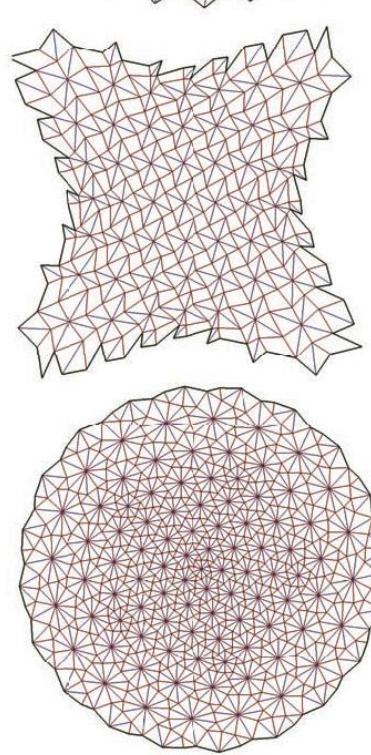
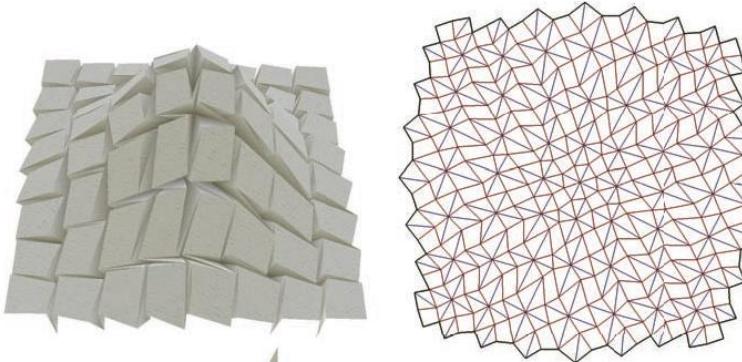
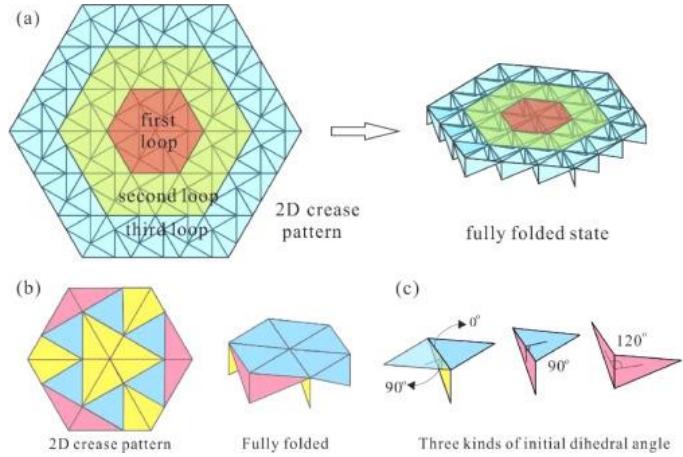


- 1-DOF
- Rigid Foldable
- Large Packing Ratio

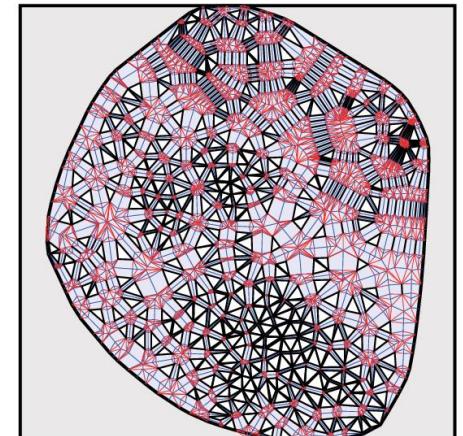


Prof. Koryo Miura (1930~)
Even at 95, he is academically active....
'A Living Legend'

Ron Resch Pattern



Prof. Tomohiro Tachi



Able to approximate arbitrary developable surfaces

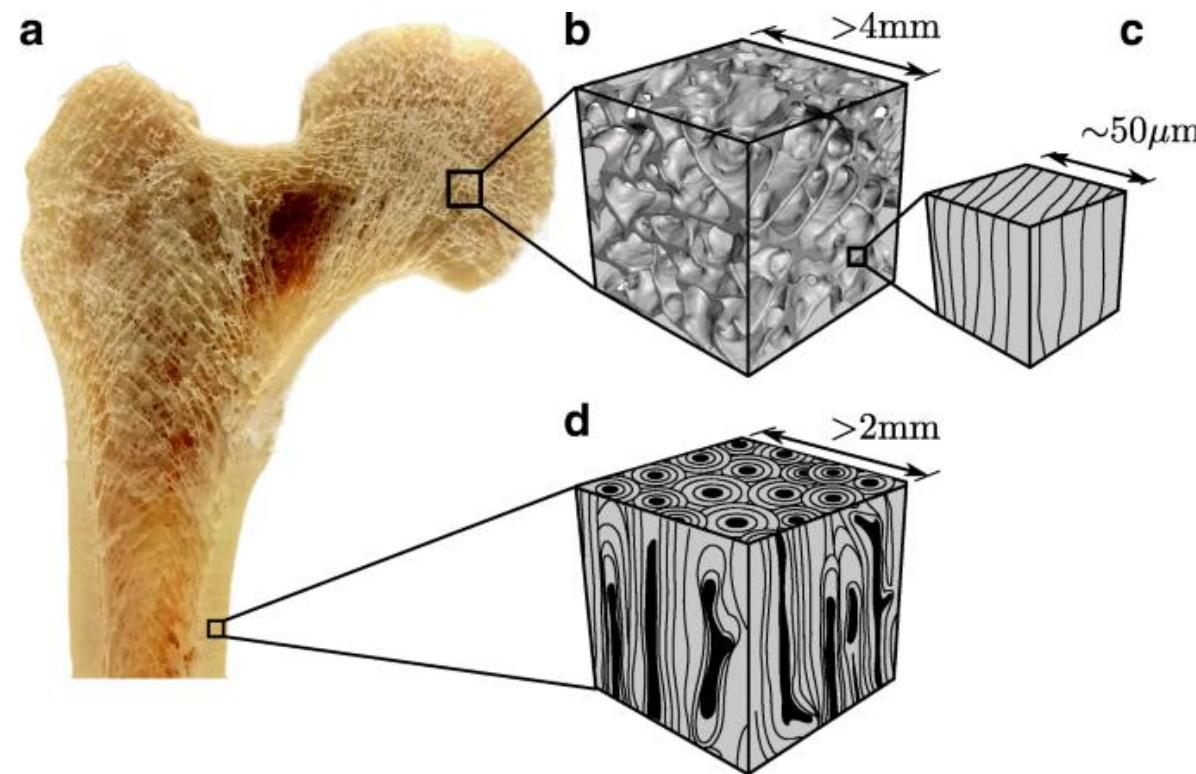
4. My researches

Chaewon Baek

Mech Eng, Seoul National University

Collaborated with JAXA ISAS, UTokyo, Waseda, Nov 14th, 2025

Introduction

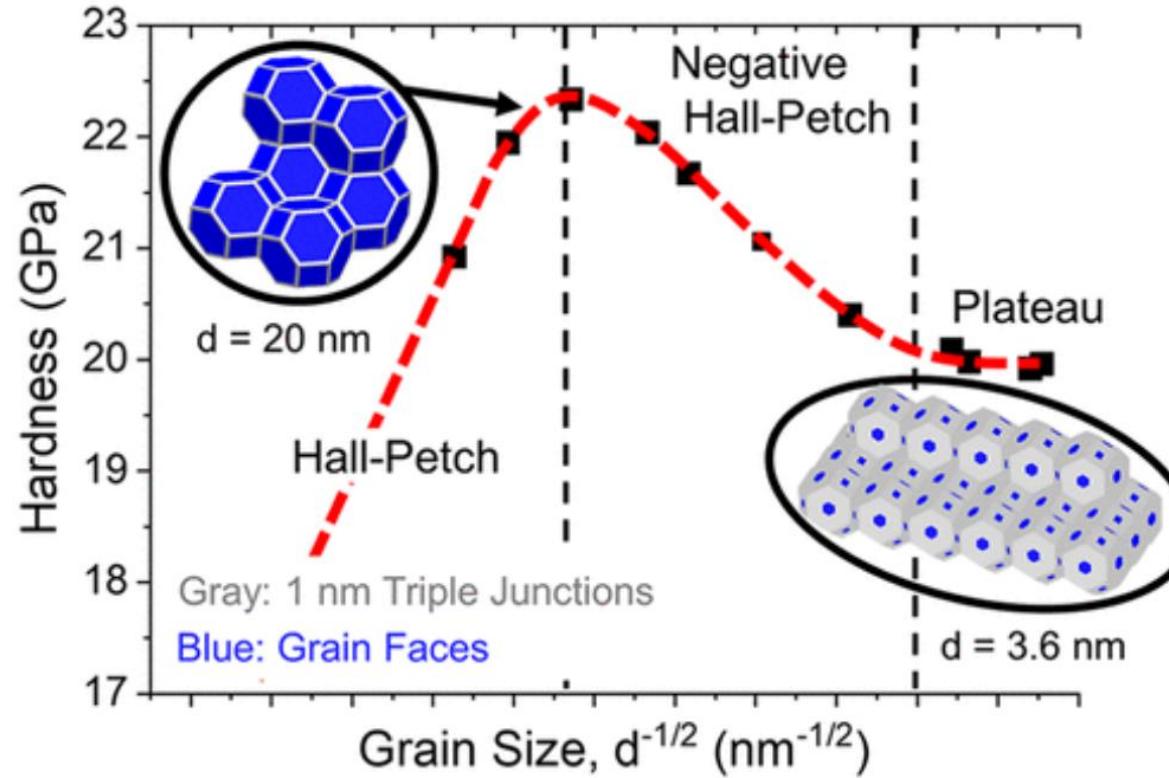


Pahr, D.H., Reisinger, A.G. A Review on Recent Advances in the Constitutive Modeling of Bone Tissue. *Curr Osteoporos Rep* 18, 696–704 (2020). <https://doi.org/10.1007/s11914-020-00631-1>

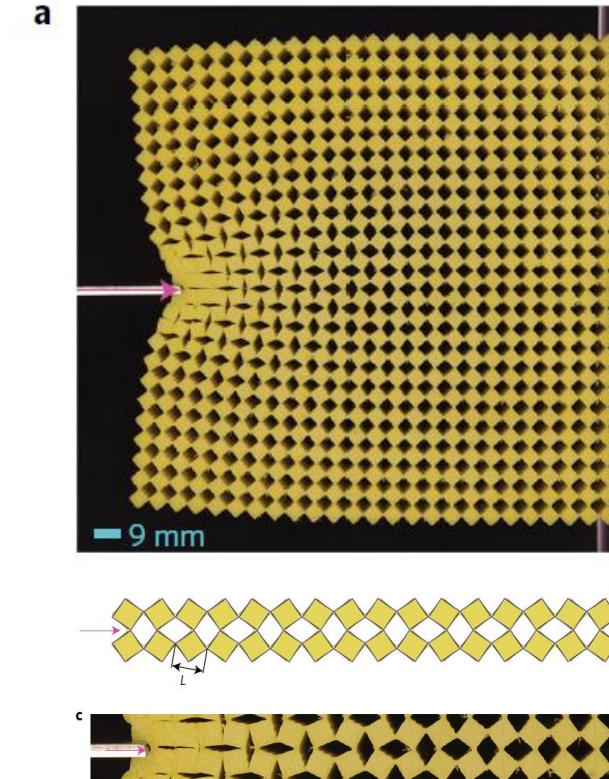
In nature, many materials are **Anisotropic**,
showing load bearing capabilities yet lightweight

Can we design materials with transformable anisotropy?

Introduction



Heonjune Ryou, John W. Drazin, Kathryn J. Wahl, Syed B. Qadri, Edward P. Gorzkowski, Boris N. Feigelson, and James A. Wollmershauser. Below the Hall-Petch Limit in Nanocrystalline Ceramics. ACS Nano 2018 12 (4), 3083-3094. DOI: 10.1021/acsnano.7b07380

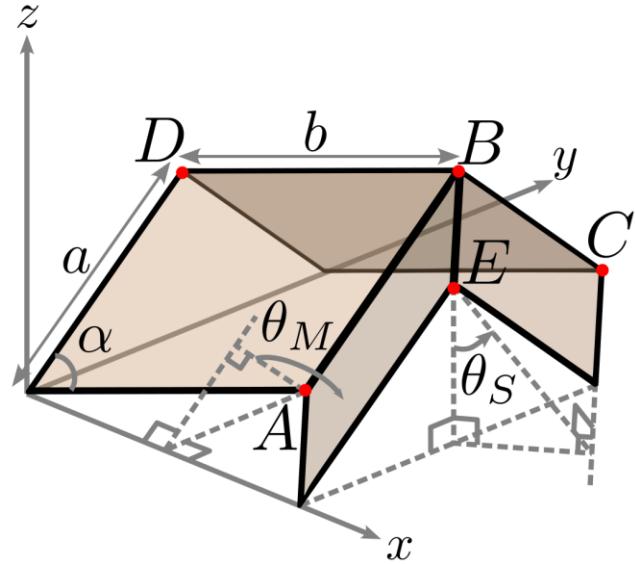


Coulais, C., Kettenis, C. & van Hecke, M. A characteristic length scale causes anomalous size effects and boundary programmability in mechanical metamaterials. Nature Phys 14, 40–44 (2018). <https://doi.org/10.1038/nphys4269>

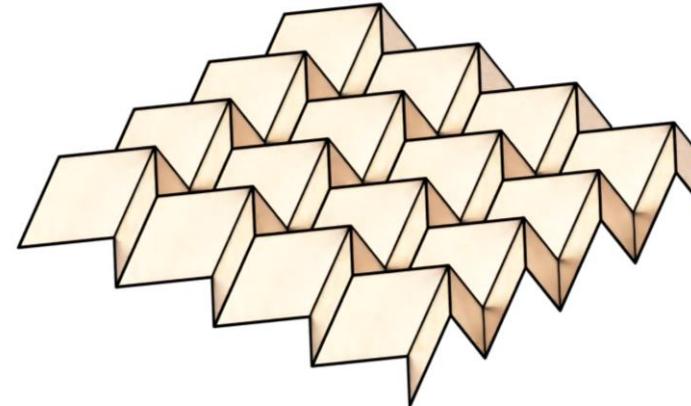
Size dependence of mechanical property is a fundamental concept in material science

What about Origami based metamaterials?

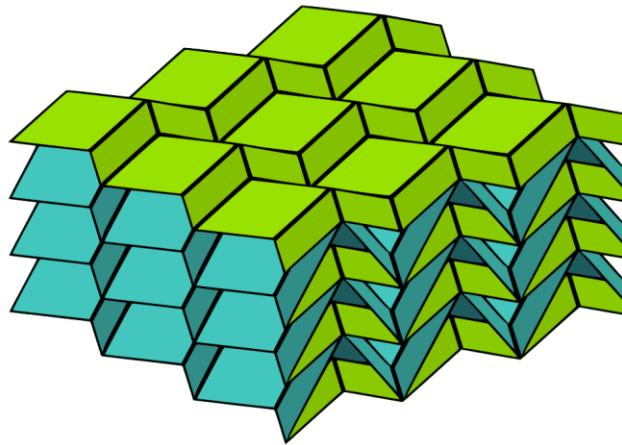
Research Objectives



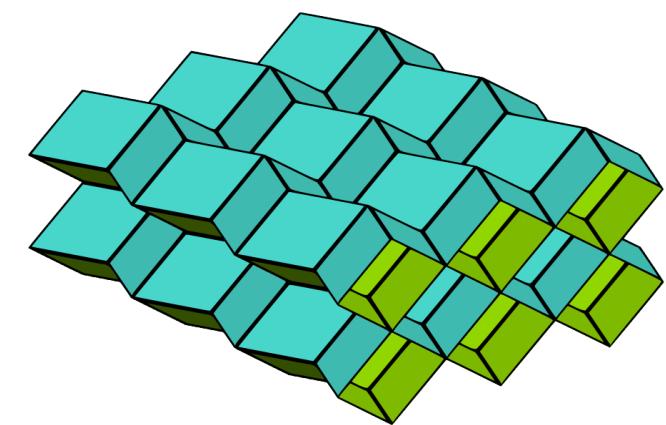
Miura-Ori Unitcell



2D Miura-Ori



Stacked Miura-Ori

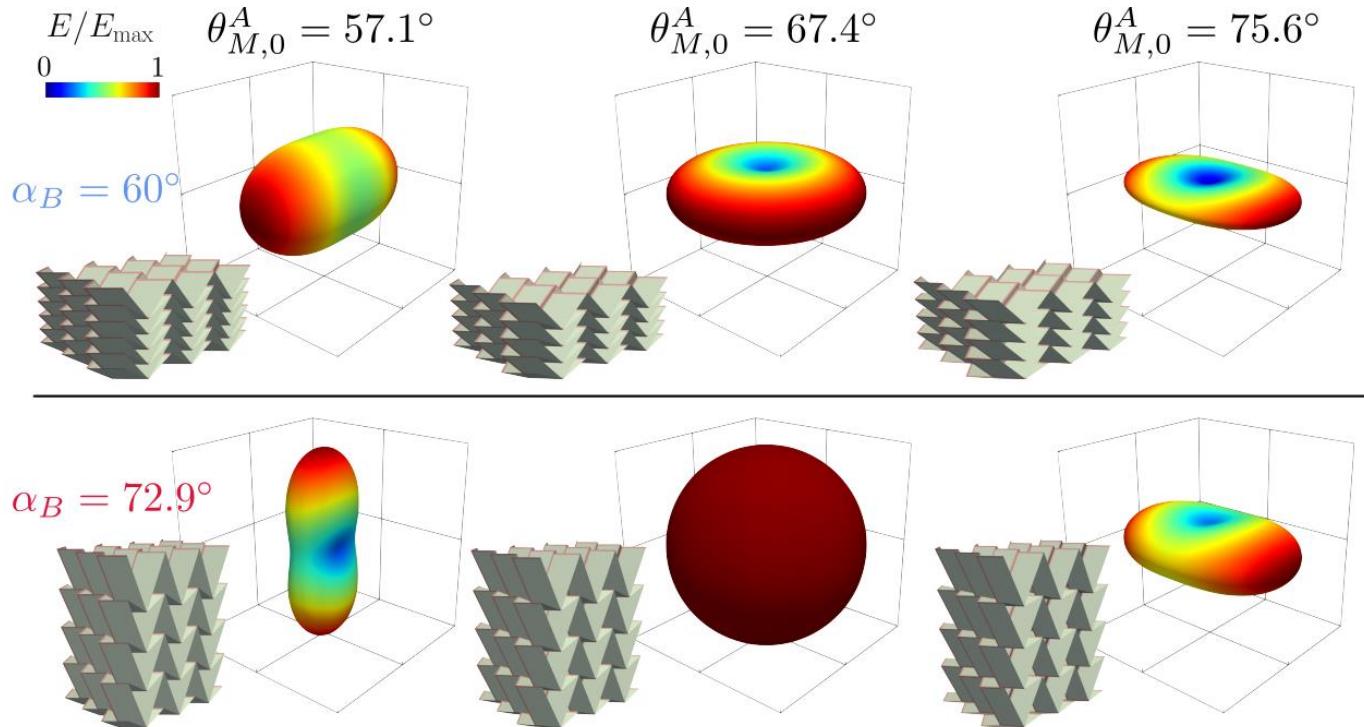
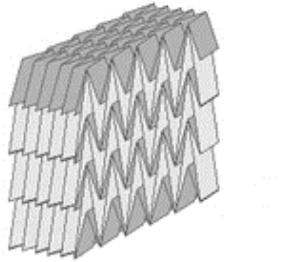


Miura-Ori Tube

We analyze the mechanical properties of Miura-Ori based architectures of various geometry and sizes

Technical Approach - Analytical Modeling

Rigid Origami Assumption

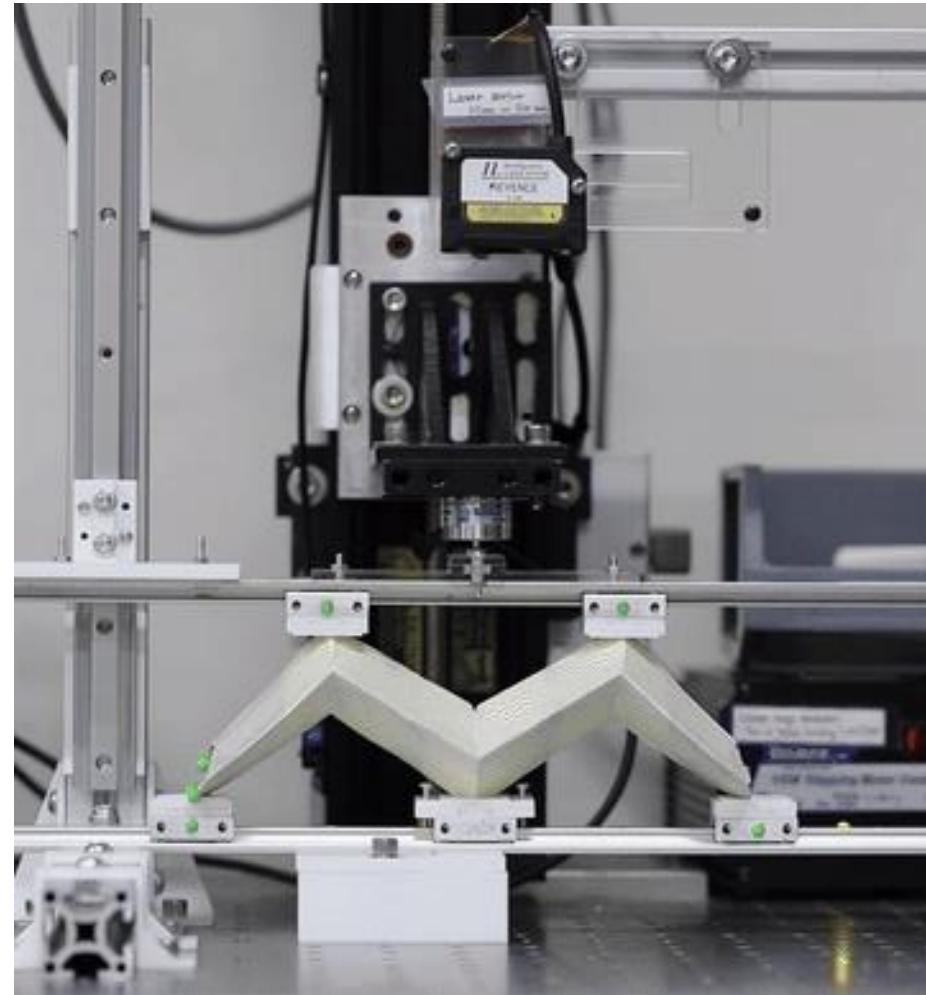
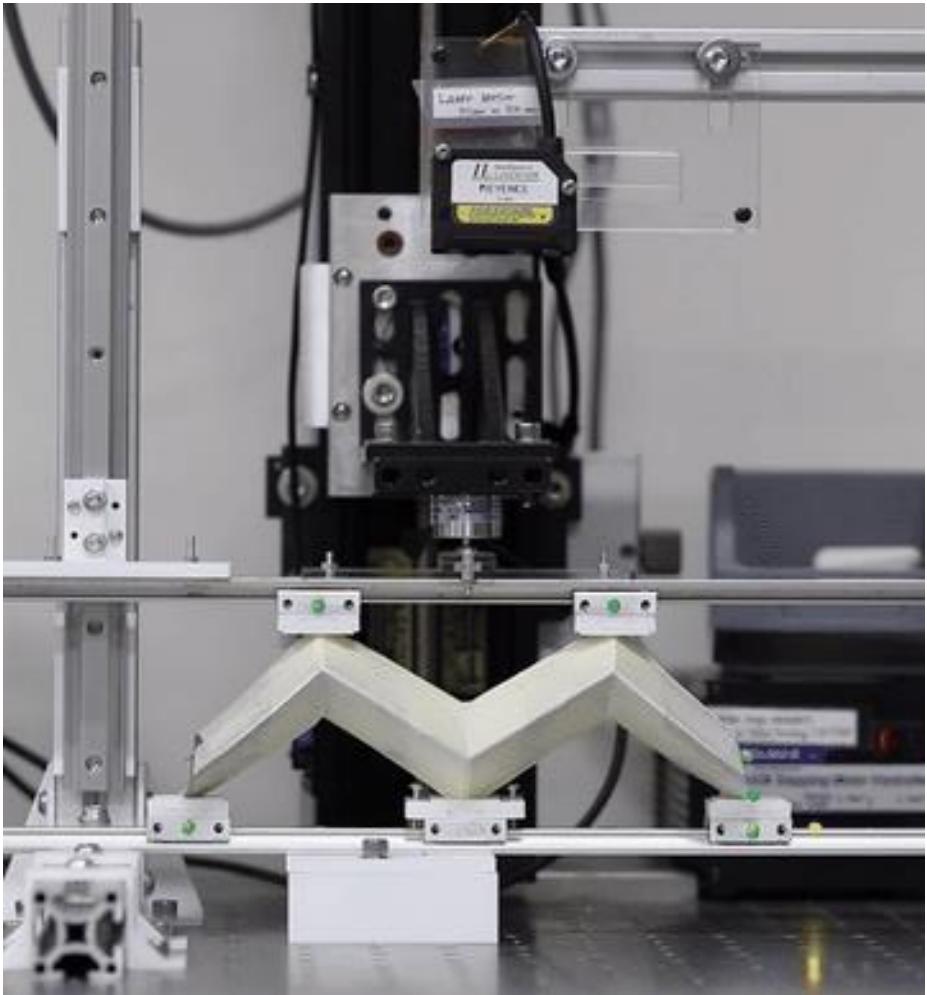


Schenk, M., & Guest, S. D. (2013). Geometry of Miura-folded metamaterials. Proceedings of the National Academy of Sciences, 110(9), 3276-3281.

**Deformations only at creases
No facet bending
Degree of Freedom becomes 1**

Homogenized mechanical properties
analytically expressible with unit-cell parameters

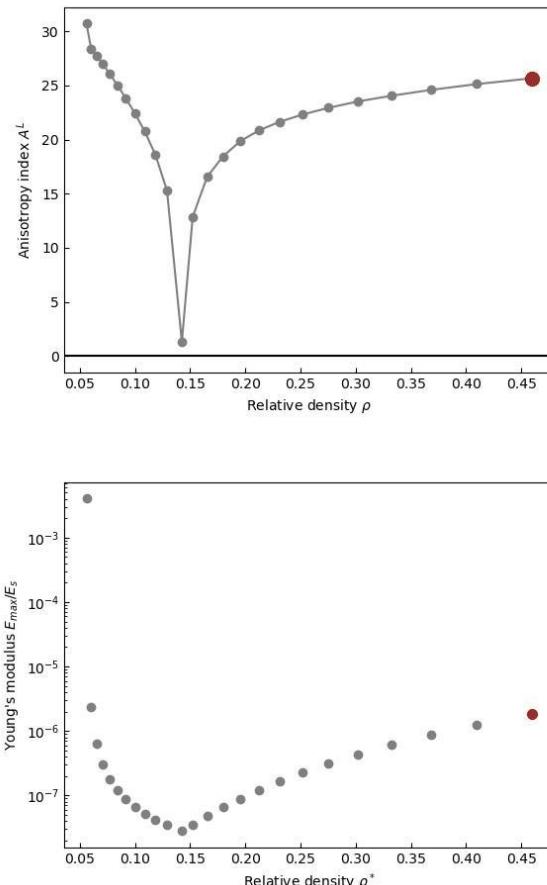
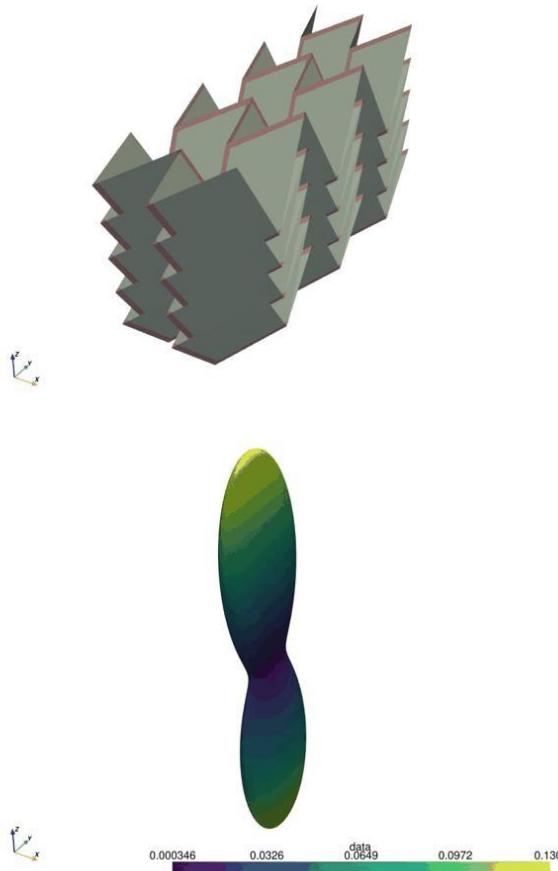
Technical Approach - Compression tests to verify Locking



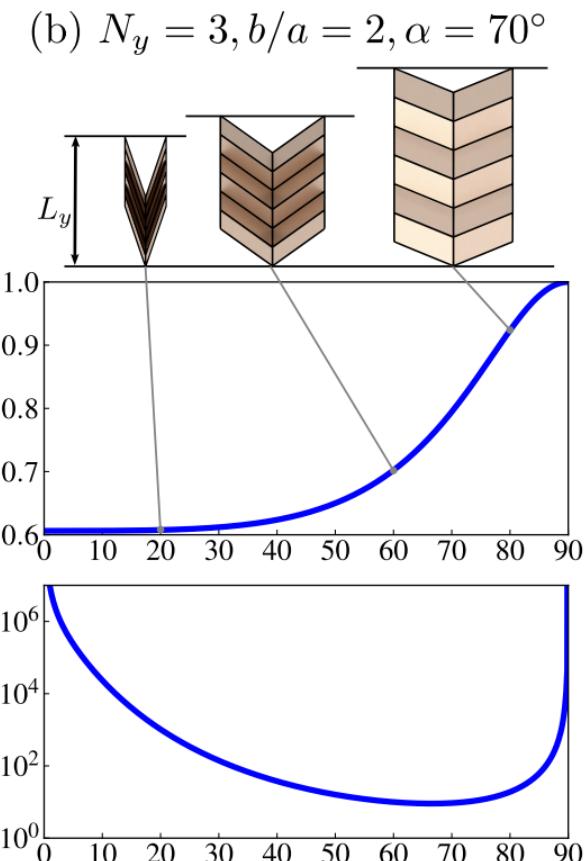
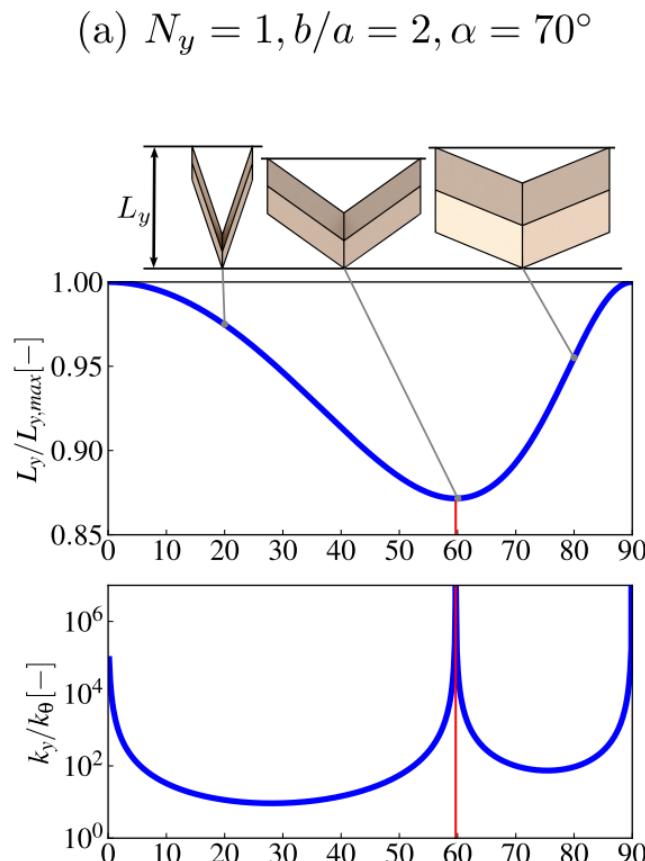
The structure is 'Locked' during deployment,
Leading to drastic stiffening

Results

Homogenized System



Size Dependence



In small Miura tessellations
Size-dependent Locking

References

- Origami Design Secrets, Robert J. Lang

ARTWORKS



SRT Logo
Chaewon Baek
Drawing



Reby from Black Lagoon
Original work by Rei Hiroe, drawn by Chaewon Baek
Drawing



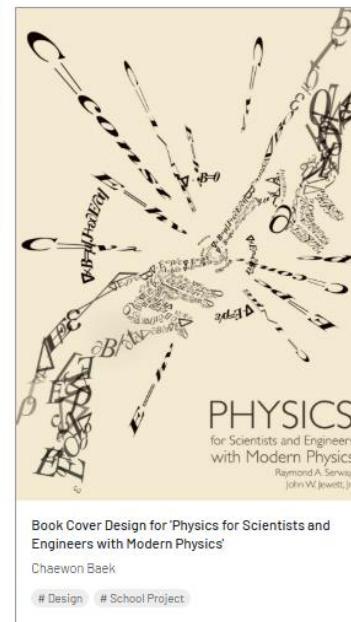
Edward Elric from Fullmetal Alchemist
Original work by Hiromu Arakawa, drawn by Chaewon Baek
Drawing



Howl's Moving Castle
Original work by Miyazaki Hayao
Drawing



Gally (Alita) from GUNNM(Battle Angel Alita)
Original work by Yukito Kishiro, drawn by Chaewon Baek
Drawing



Book Cover Design for 'Physics for Scientists and Engineers with Modern Physics'
Chaewon Baek
Design # School Project



kaygon.github.io