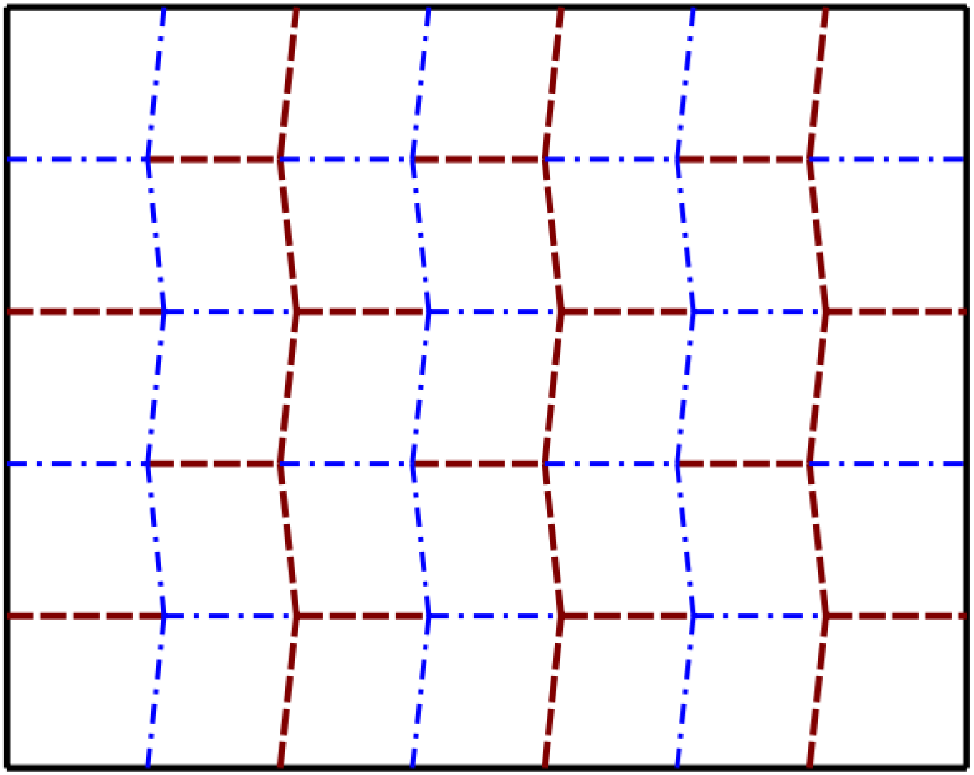
MIT Class 6.S080 (AUS)

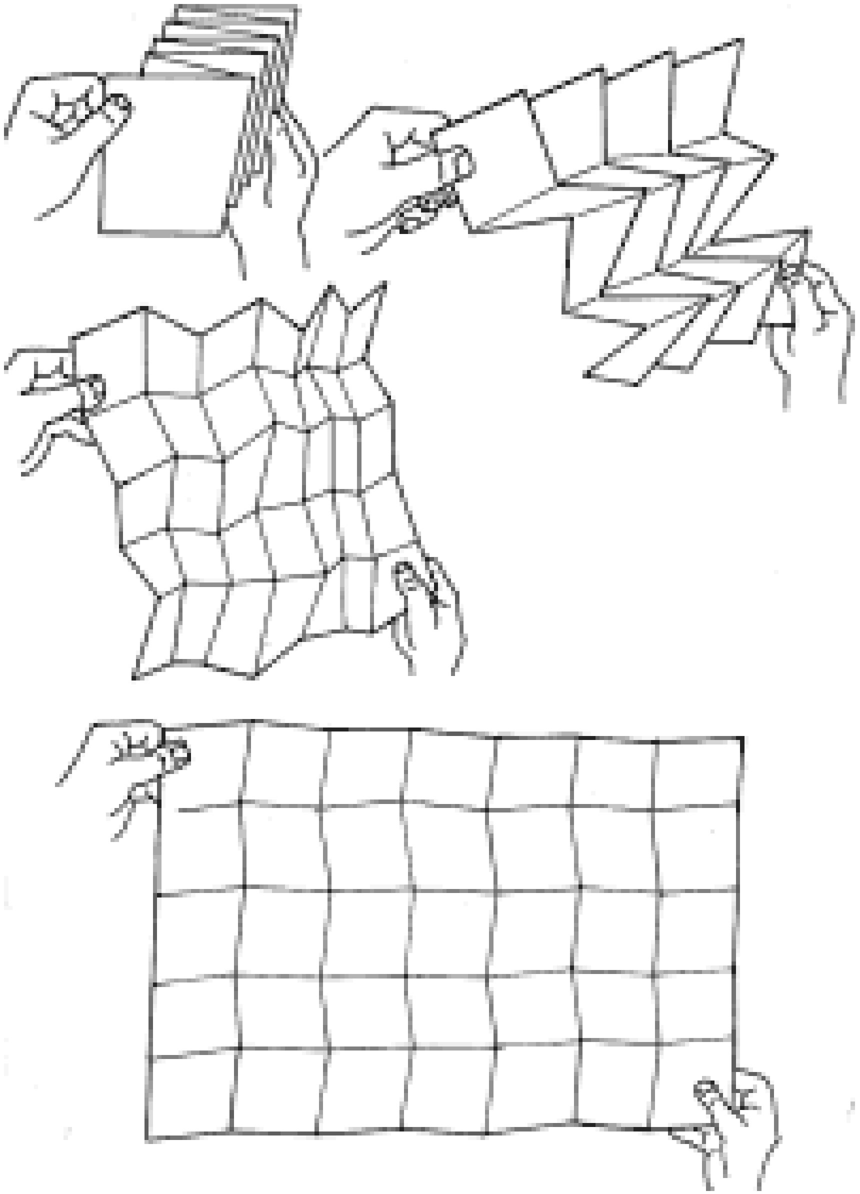
Mechanical Invention through Computation

Kinetic Origami

Miura Ori

Basis of much
Kinetic origami
(continuous folding)

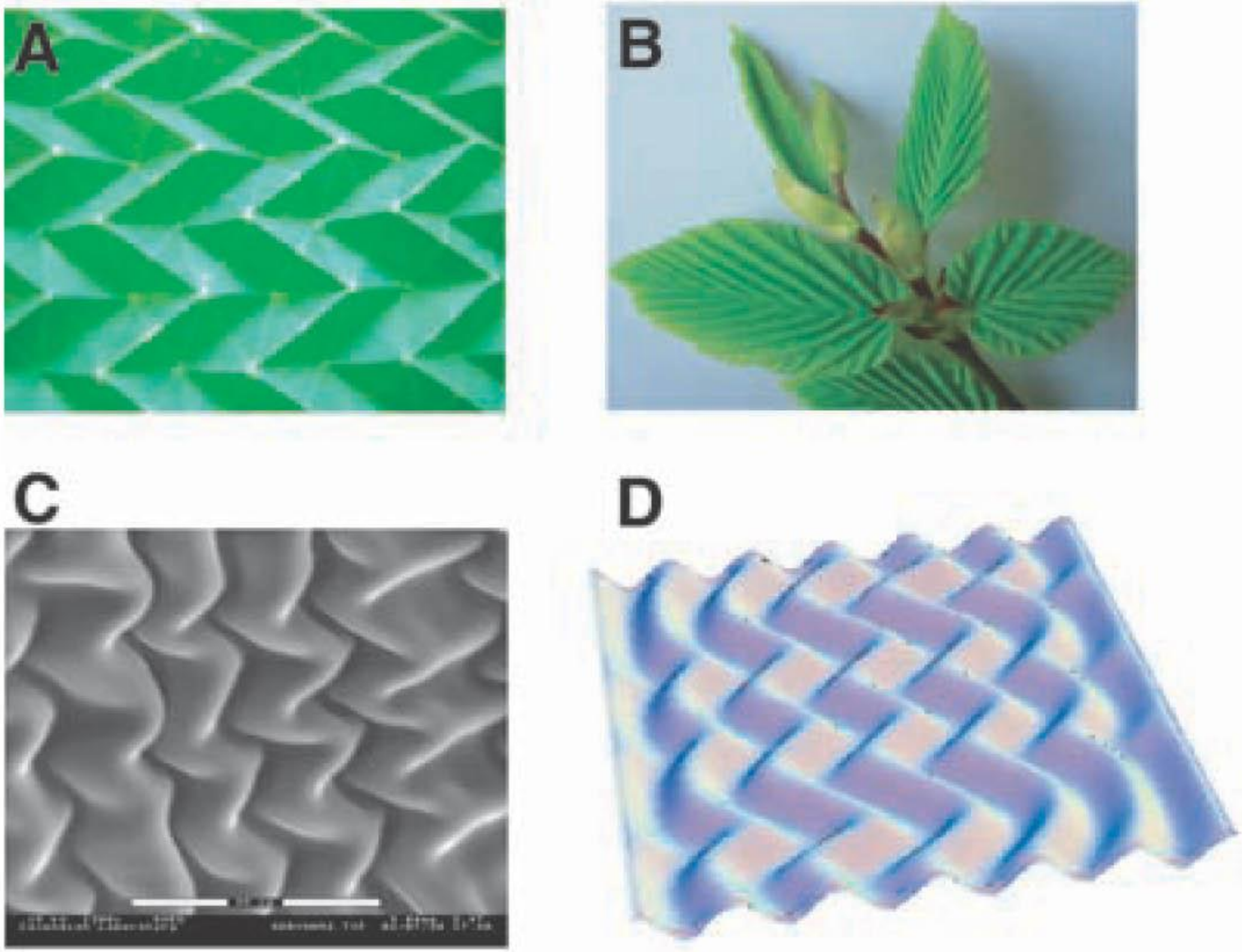




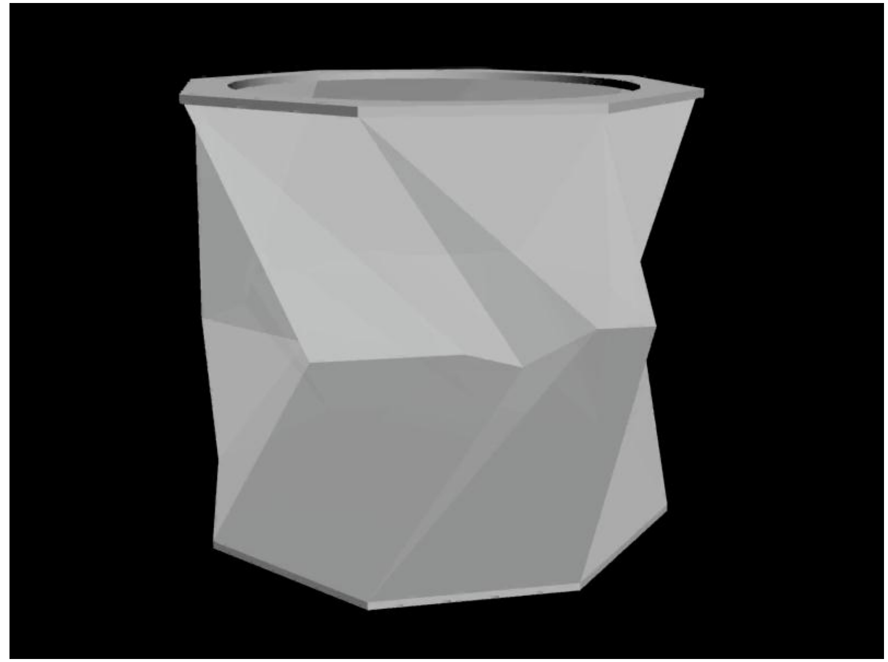
Miura Ori

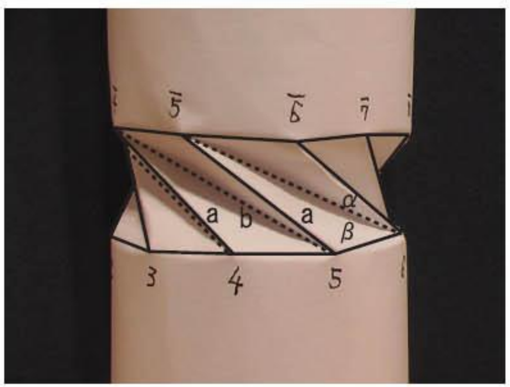
Miura Ori in Nature (L. Mahadevan, Wyss Institute)

Fig. 1. (**A**) Plan view of a paper Miura-ori pattern (size, 5 cm), showing the periodic mountain-valley folds. The sharp re-entrant creases that come together at kinks allow the whole structure to fold or unfold simultaneously. (**B**) Hornbeam leaves (length, 5 cm) in the process of blooming show a natural occurrence of Miura-ori. A single row of kinks along the midrib allows a folded leaf to be deployed once the bud opens (*2*), as seen in the different stages of leaf opening (clockwise from the top). (**C**) Zigzag Miura-ori patterns in a thin film atop a thick elastic substrate that is compressed biaxially manifest here in a drying slab of gelatin with a thin skin that forms naturally (*6*), showing the physically driven self-organization of Miura-ori. Scale bar, 35 μm. (**D**) Simulations of Eq. 1 yield Miura-ori patterns that arise as a modulational instability of the primary (straight) wrinkles (supporting online text).

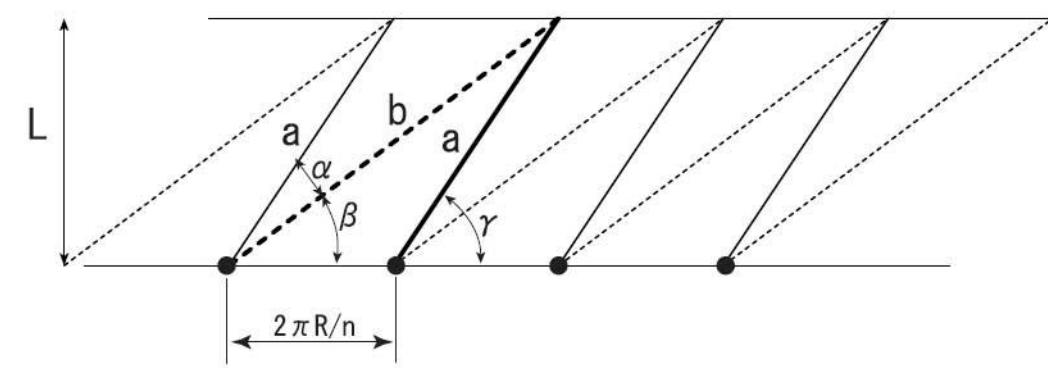


Buckling of a cylinder





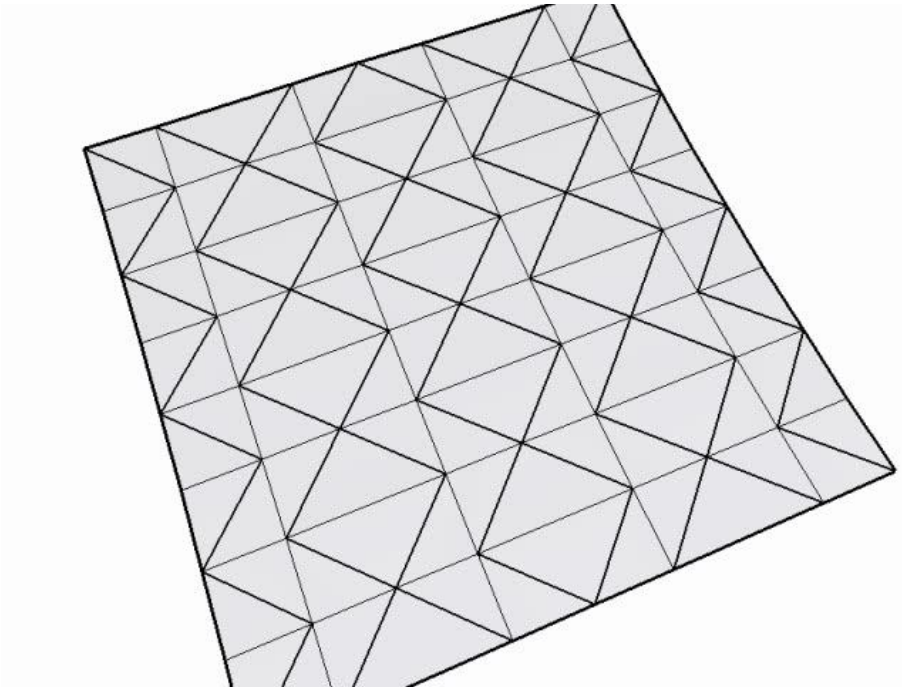
(a) Fold lines and angles of the folding mechanism



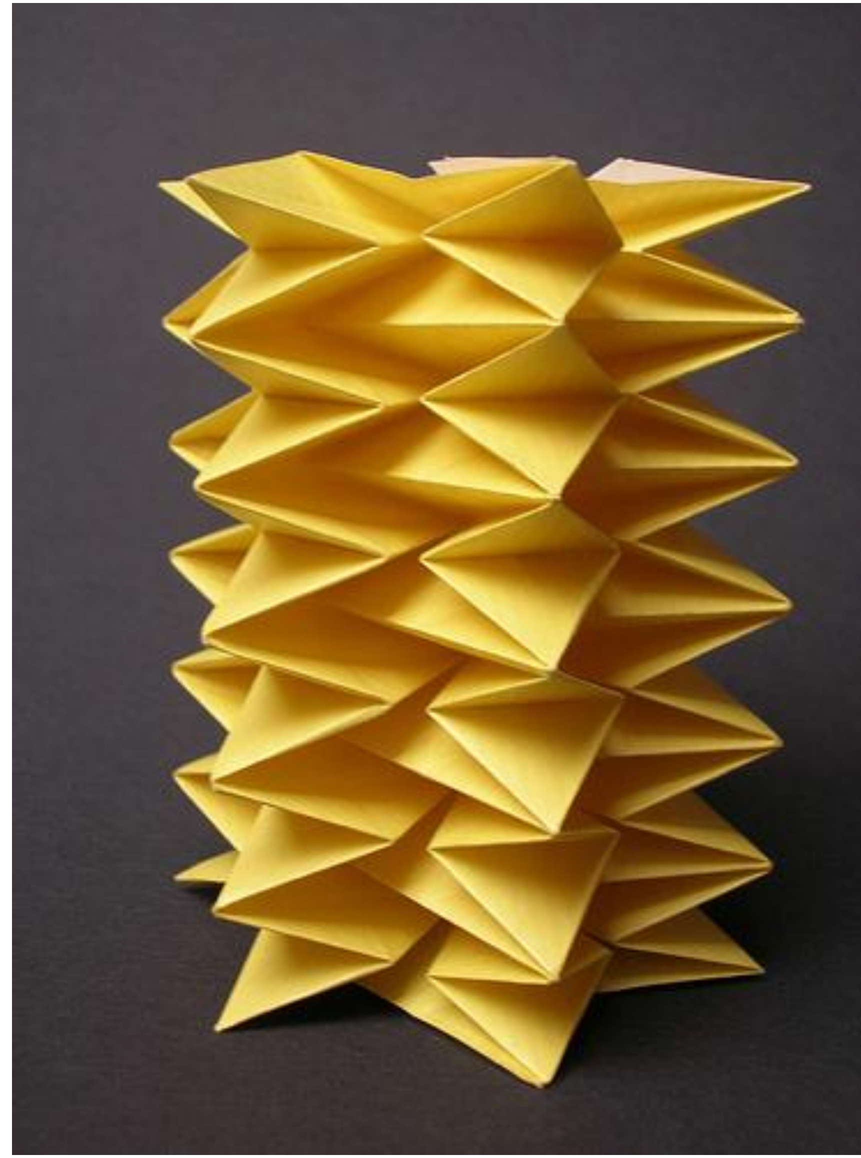
(b) Truss Geometry

Figure 1. The foldable cylinder based on twist buckling of a paper roll. Large deflections involve work being done primarily against bending, with very little stretching energy included; such behaviour is of interest for example, in the field of deployable structures.

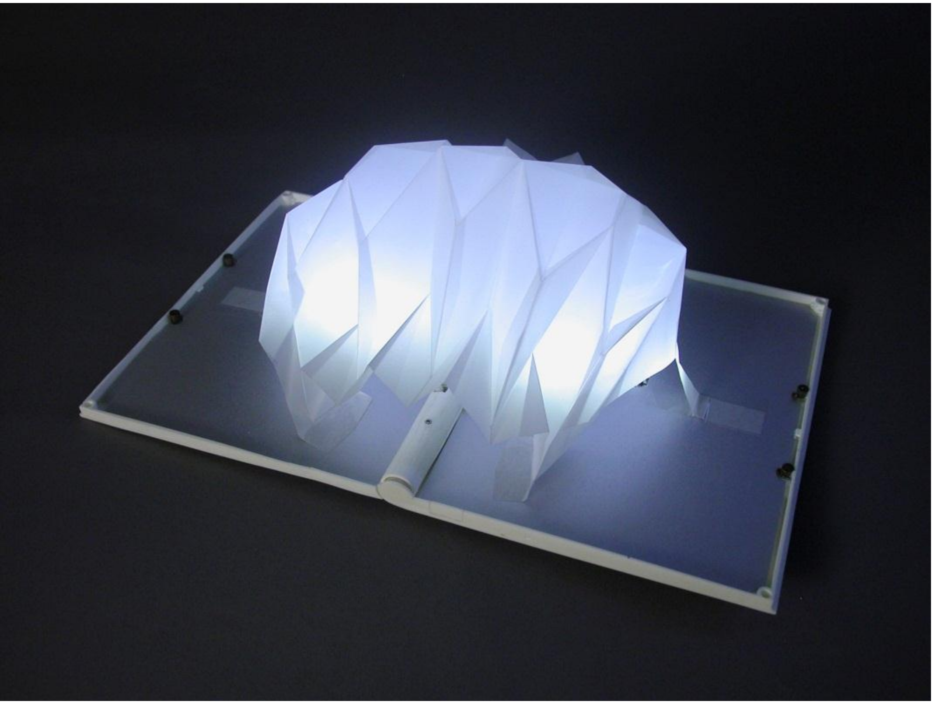
Curvature in patterned folding

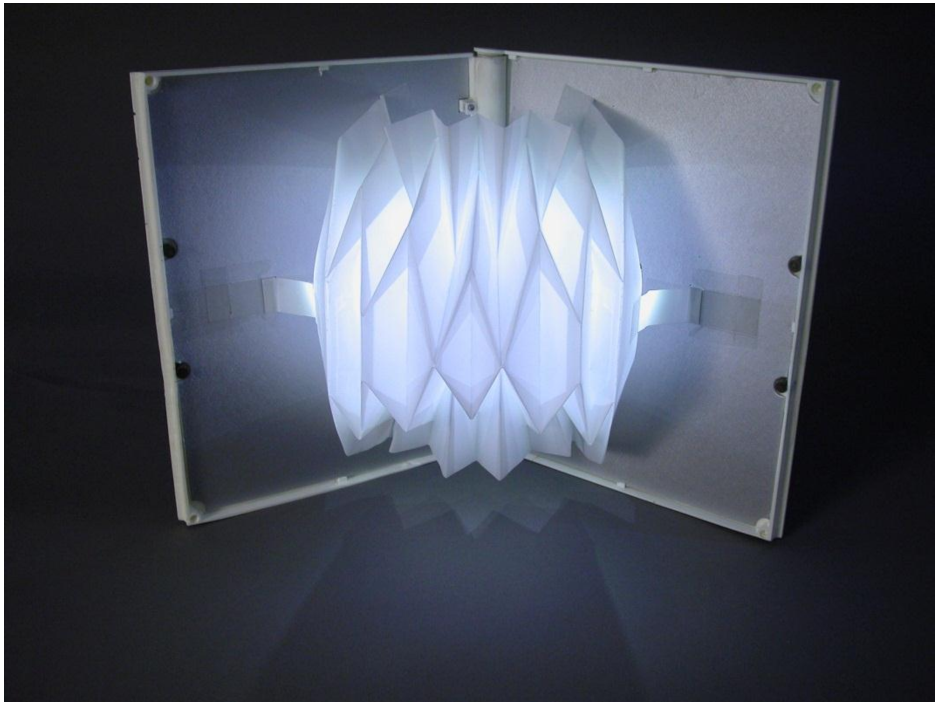


Waterbomb tessellation
("Namako" by Shuzo Fujimoto)



Kinetic Origami





Space-filling Origami

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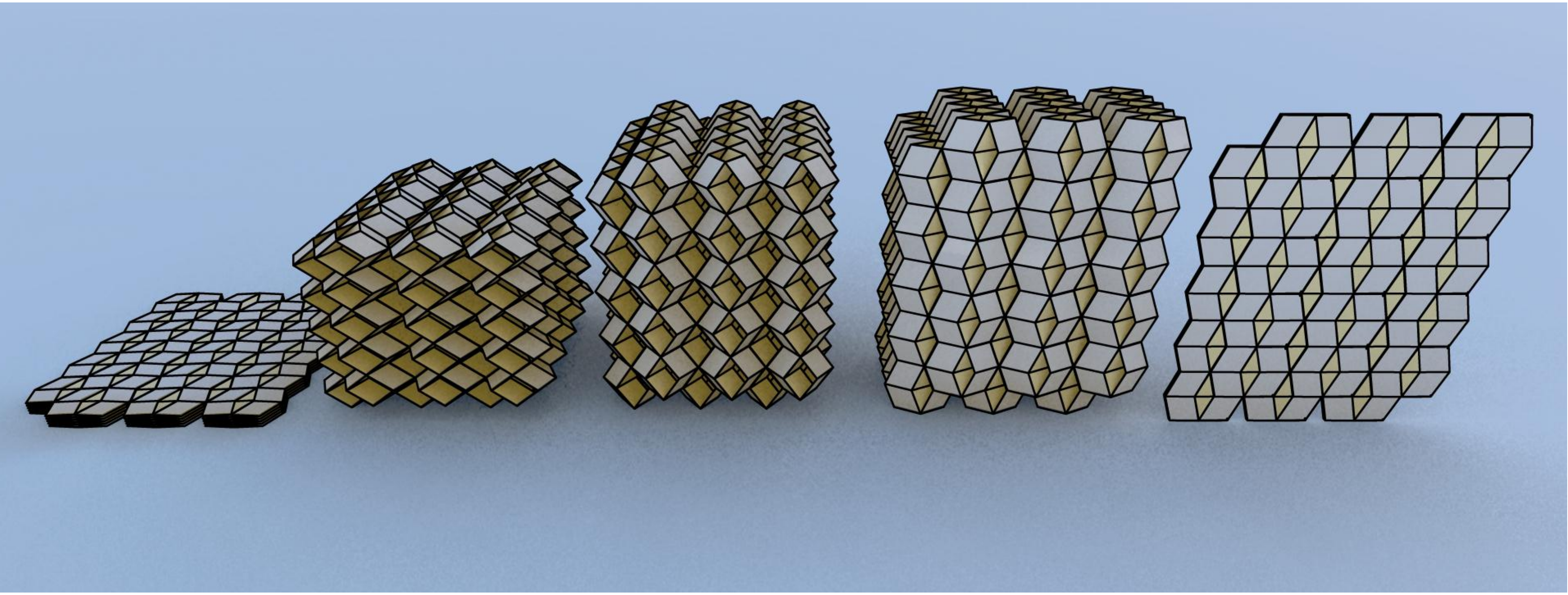

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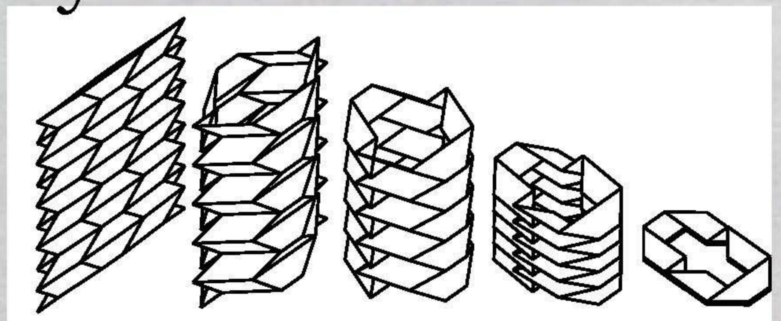
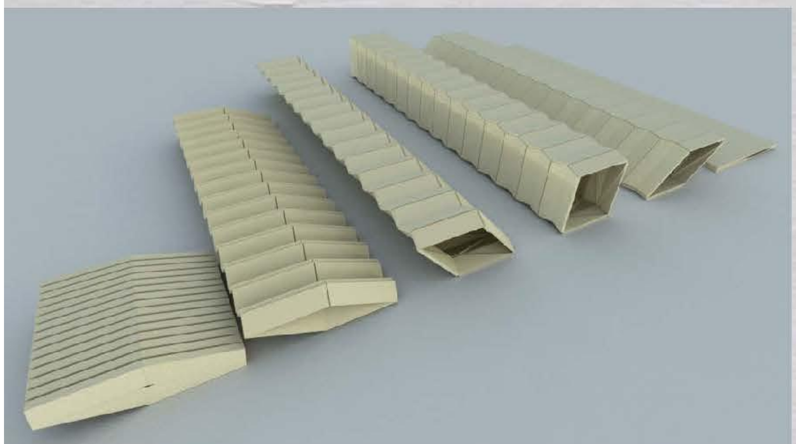
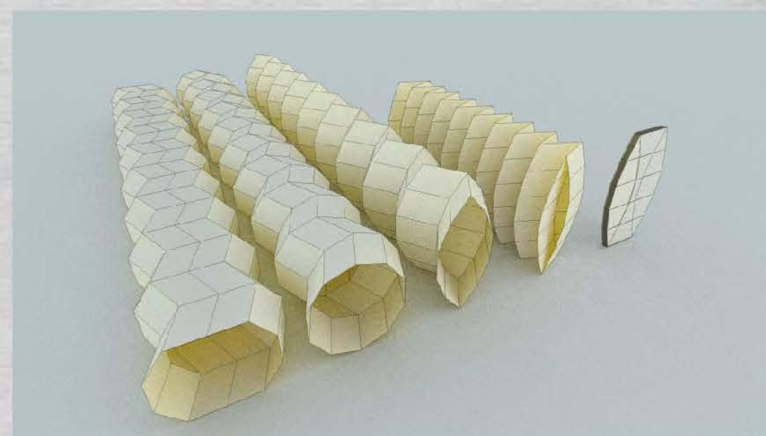
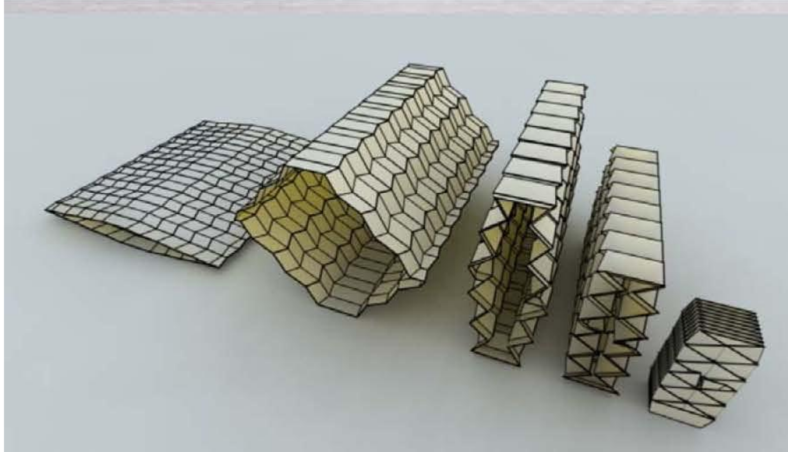
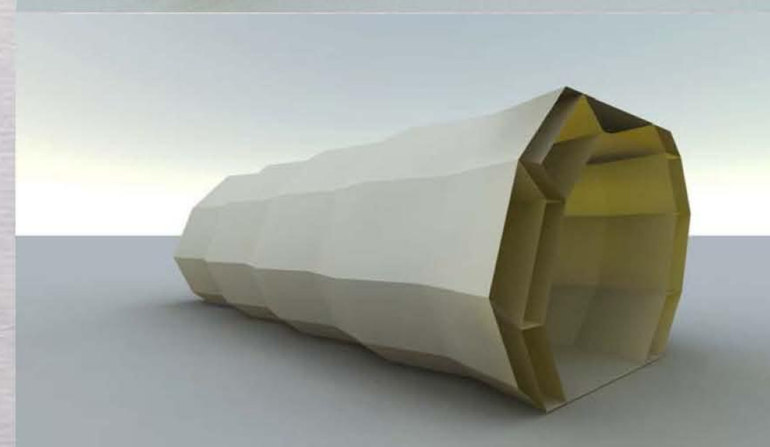
Symmetric Structure Variations



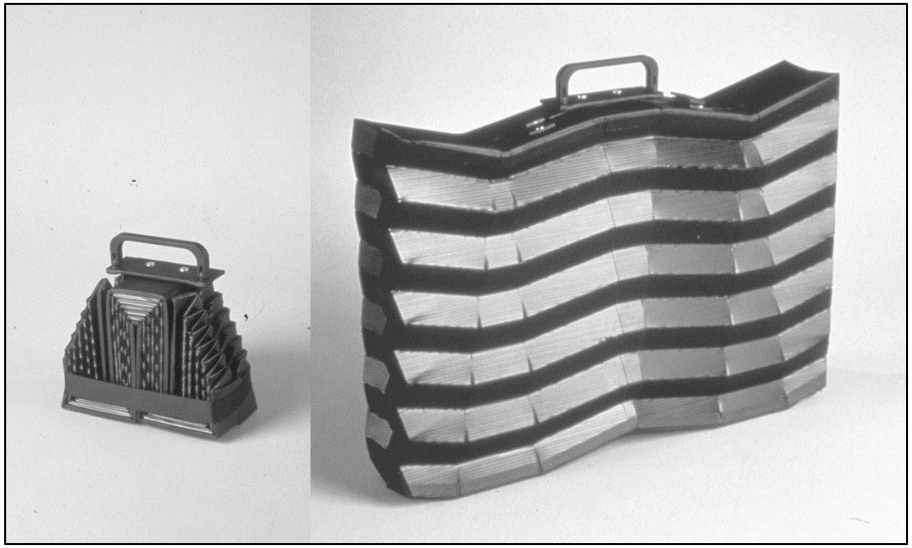




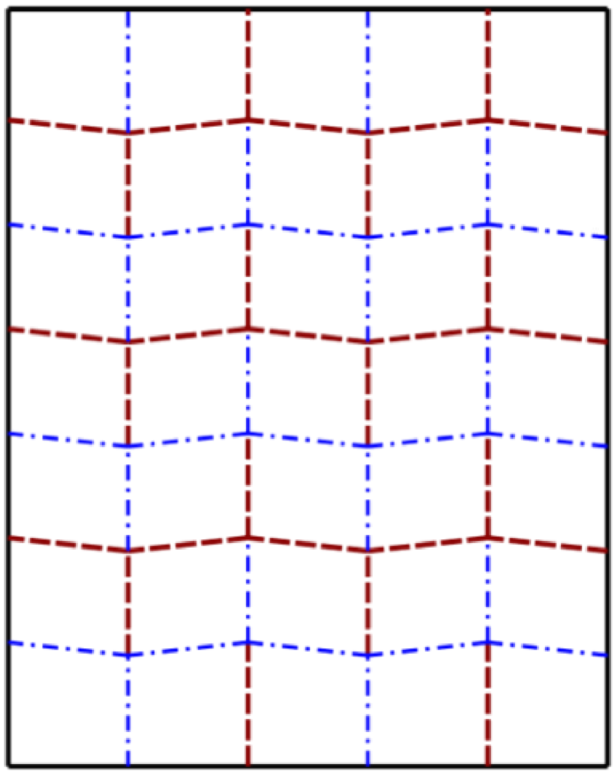




Miura folding with thick materials



Material Thickness in Miura Ori (Hoberman)



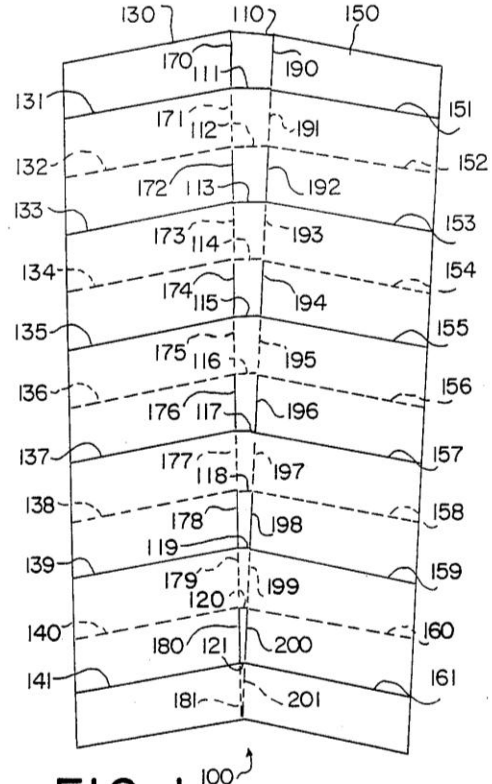


FIG. 1

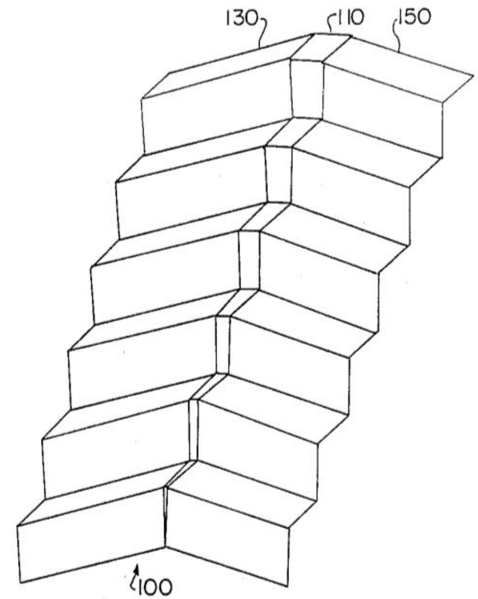


FIG. 2

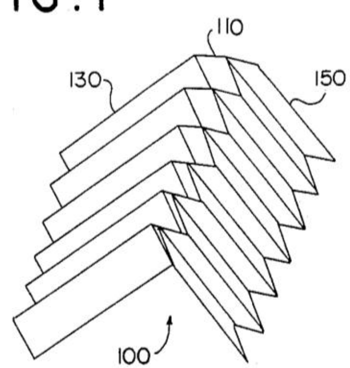


FIG. 3

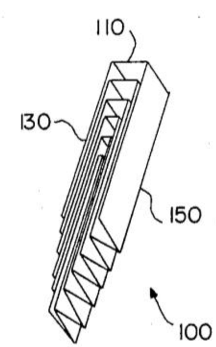


FIG. 4

FIG. 9

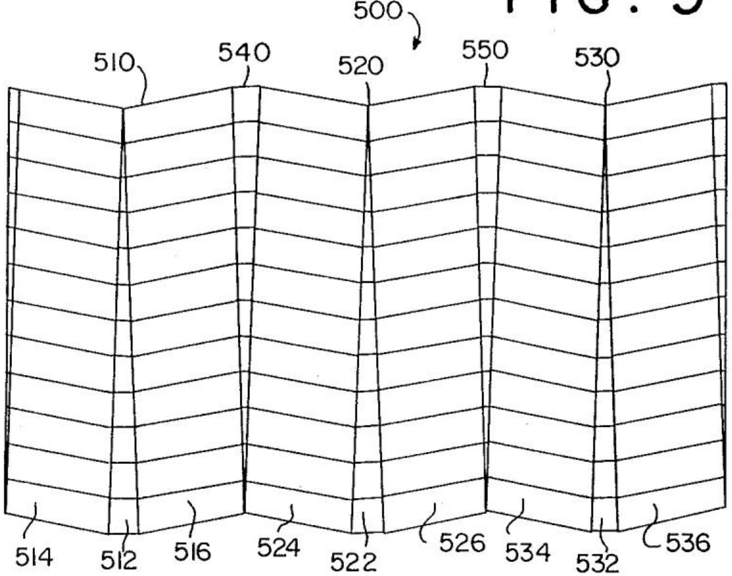
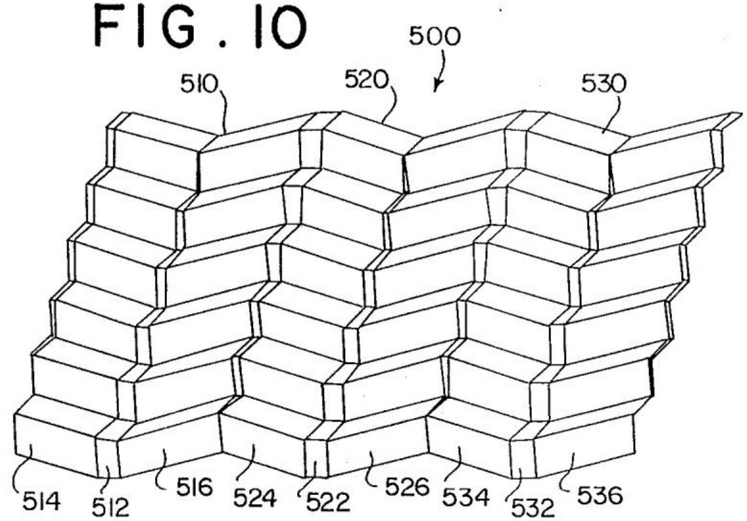


FIG. 10



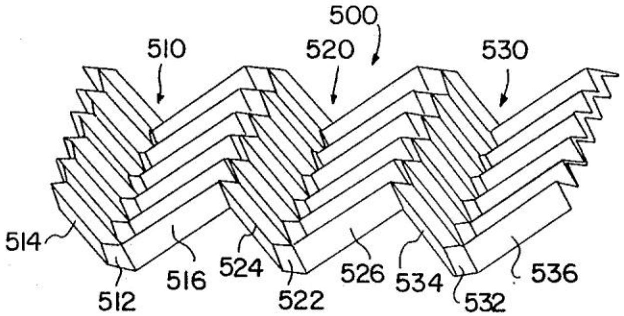


FIG. 11

FIG. 12

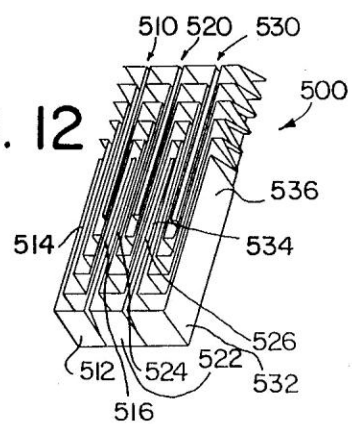
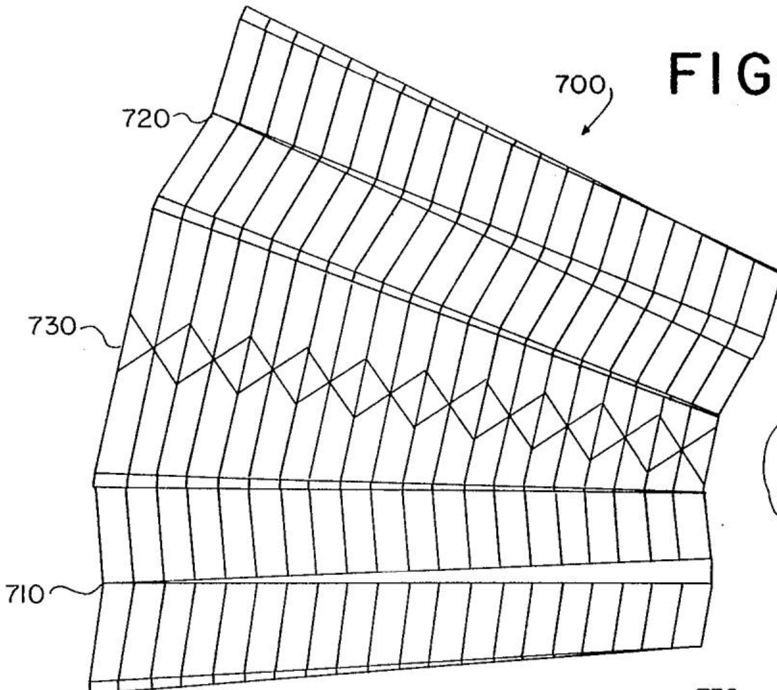


FIG. 17



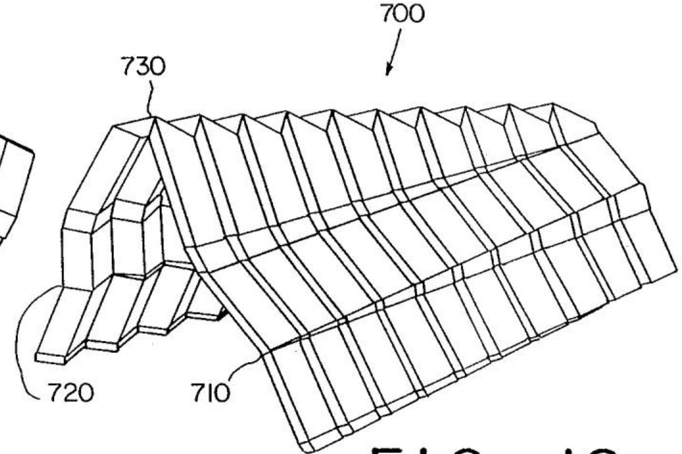


FIG. 18

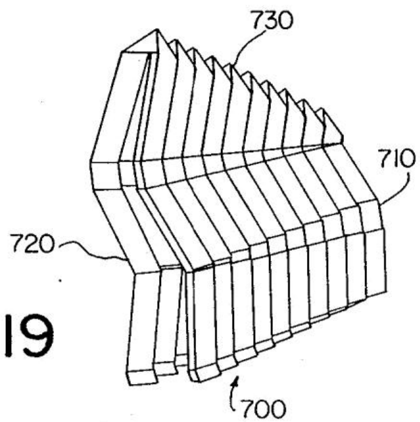
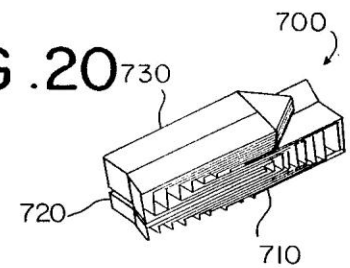


FIG. 19

FIG. 20



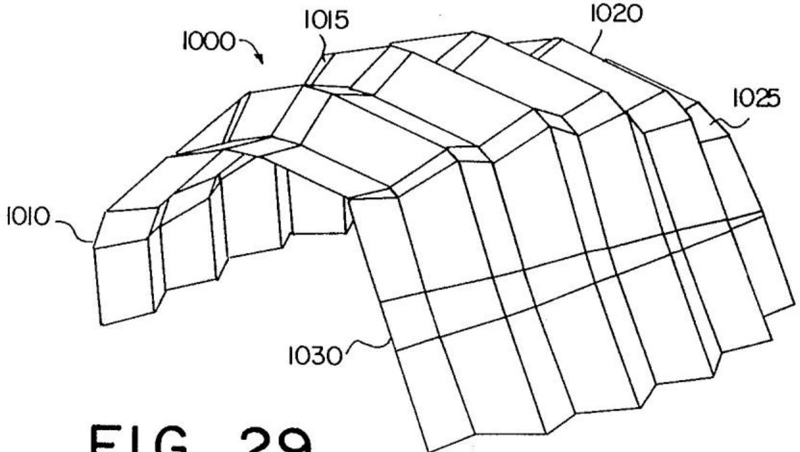


FIG. 29

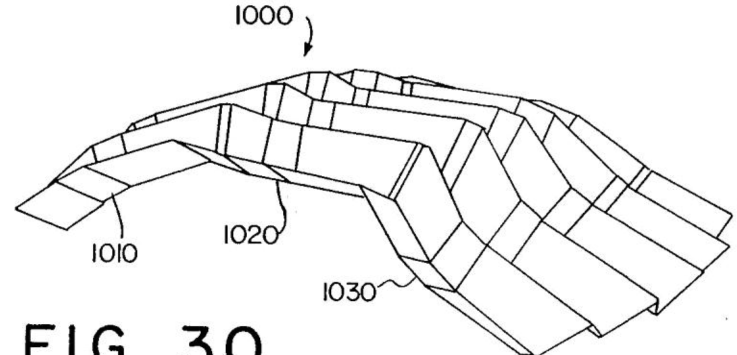


FIG. 30

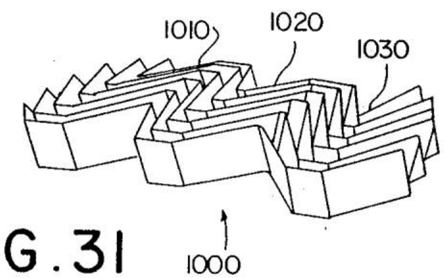


FIG. 31

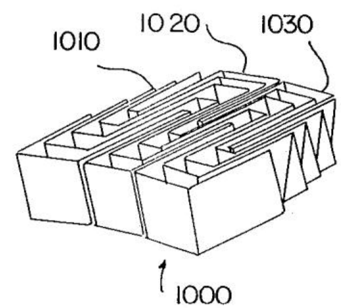
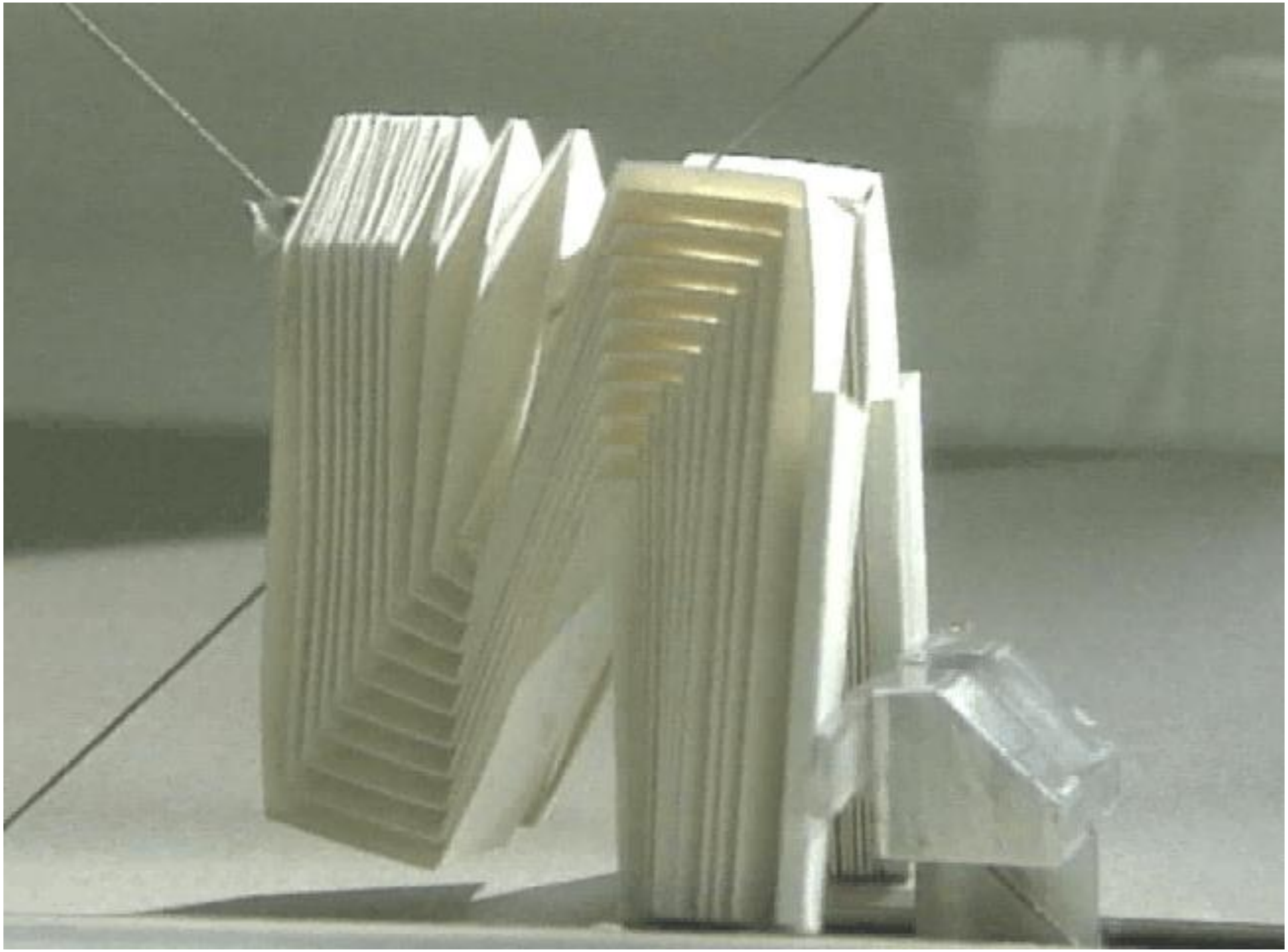
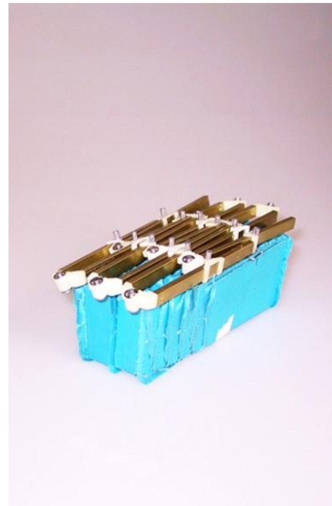


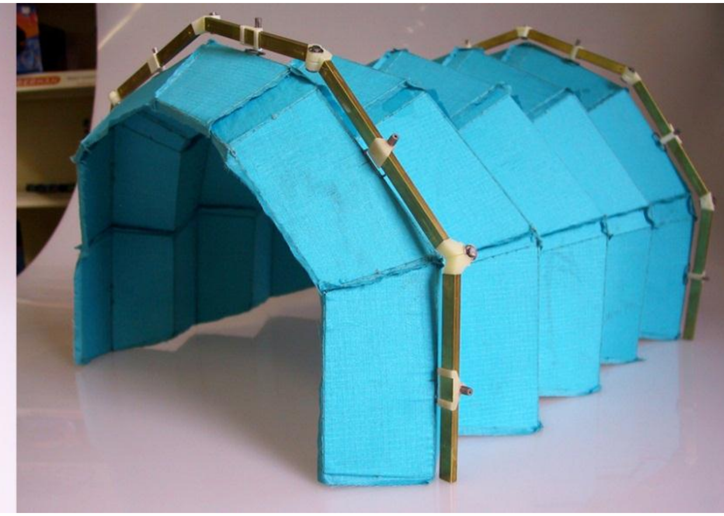
FIG. 32

Origami Mechanisms



Origami Mechanisms





Origami:Form

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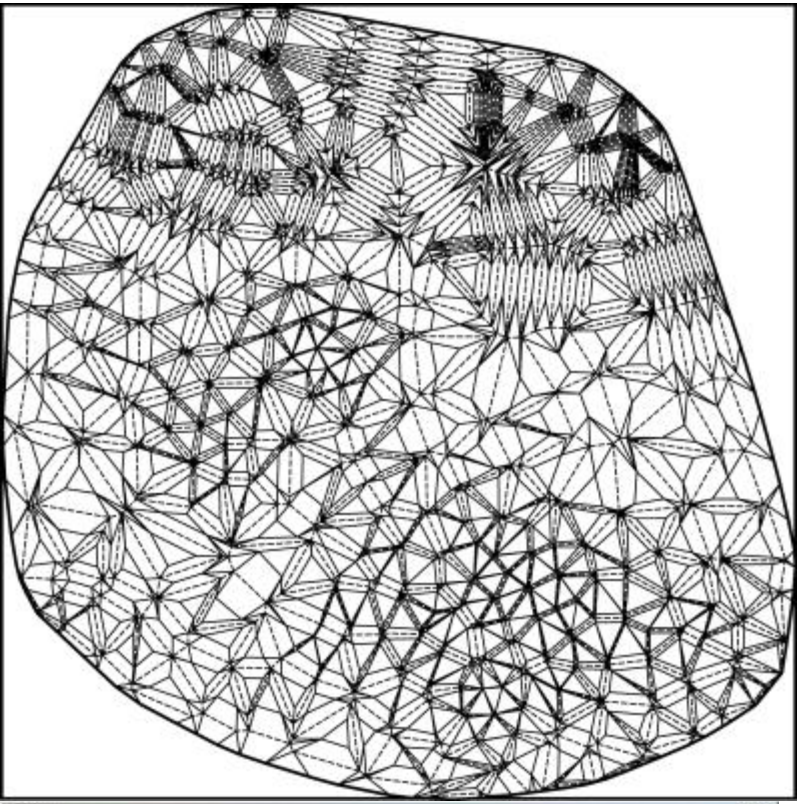

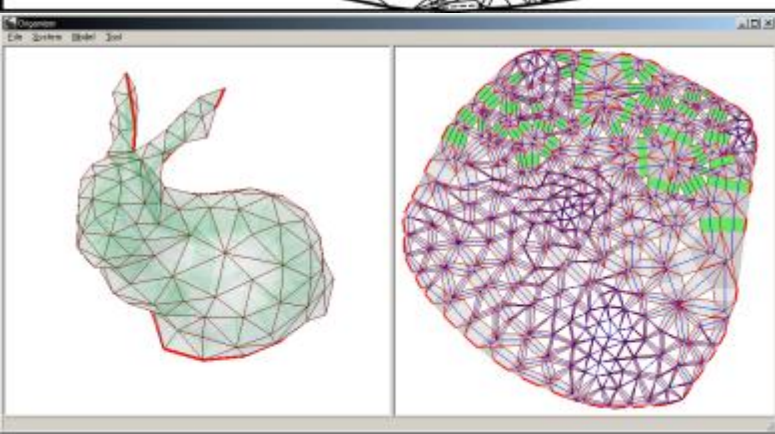

Origami: Form

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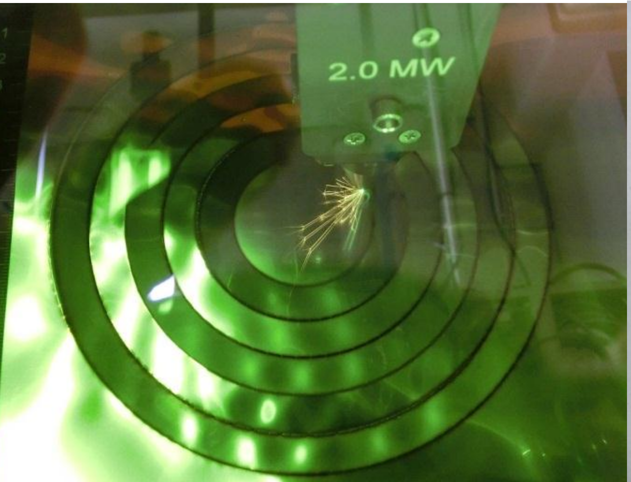

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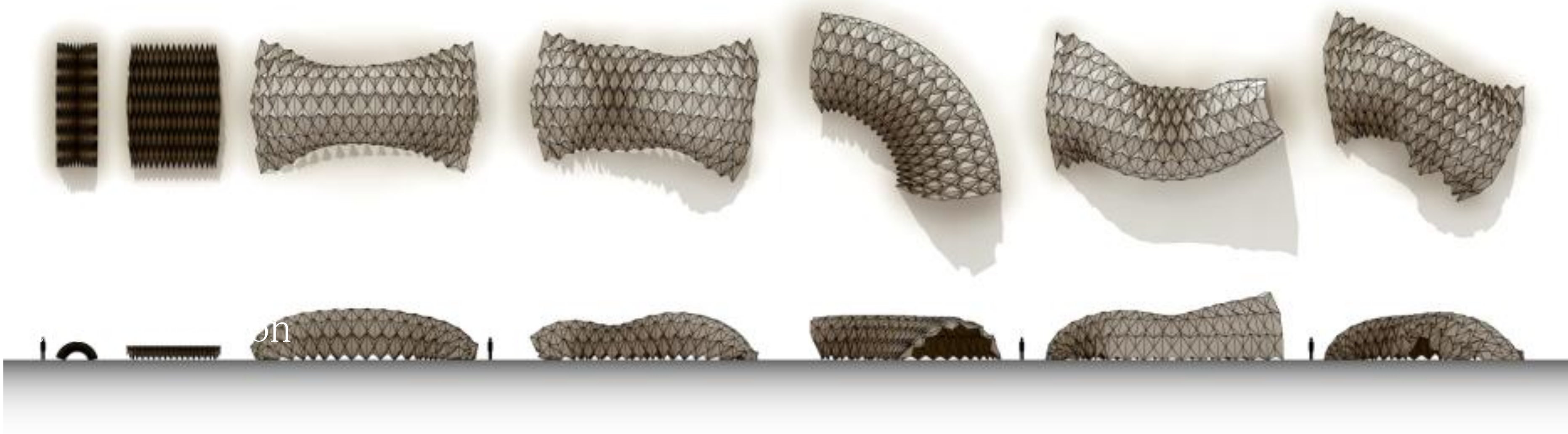

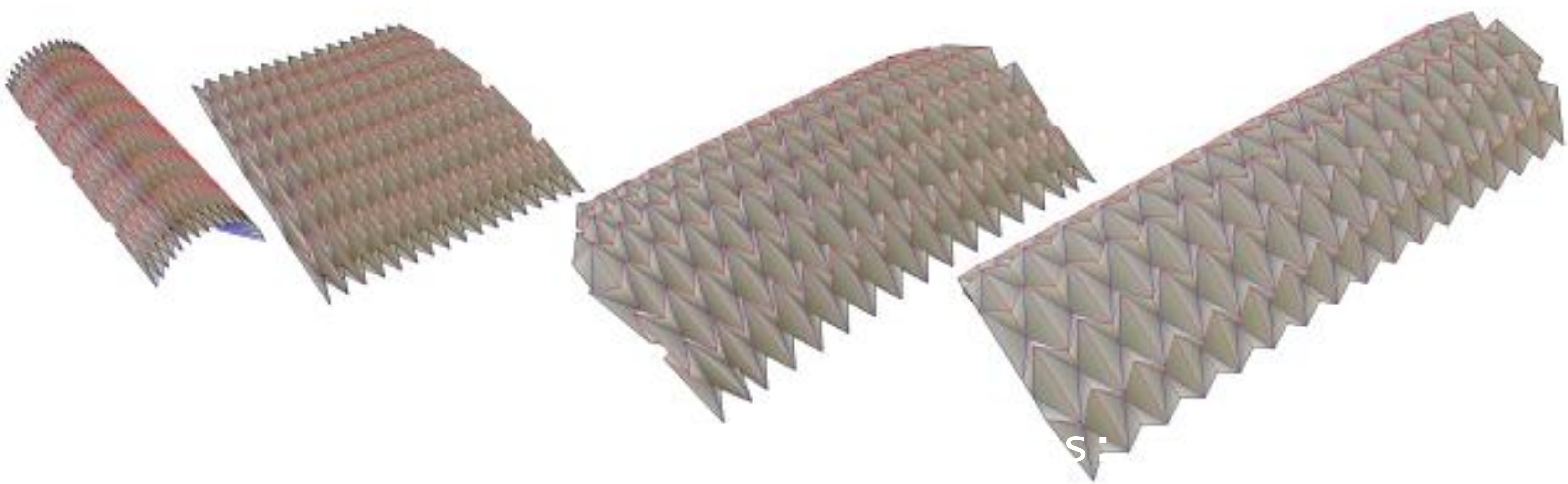

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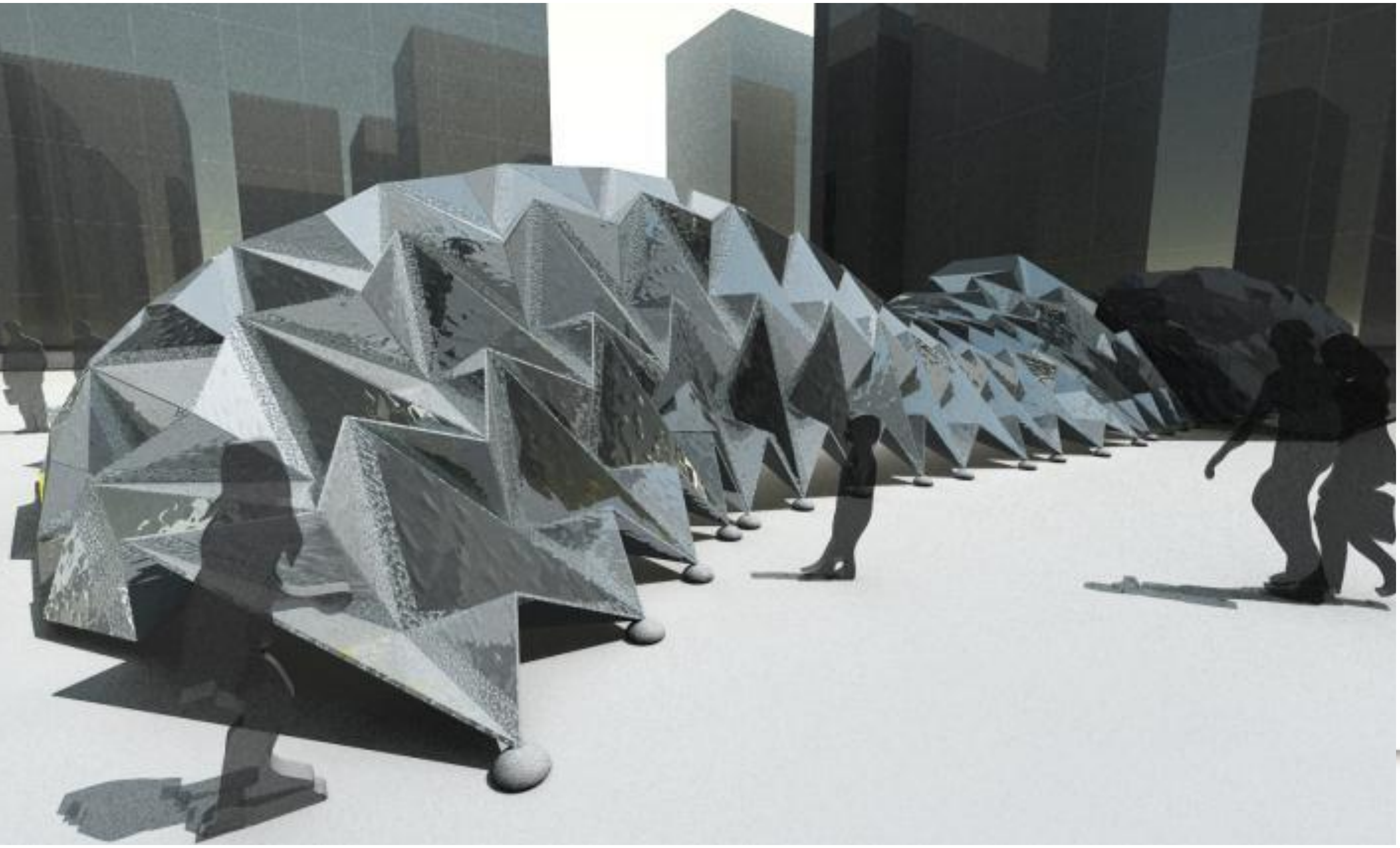

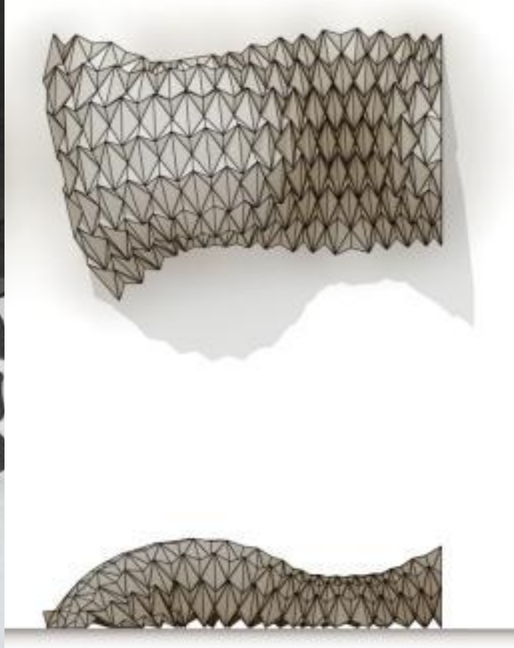

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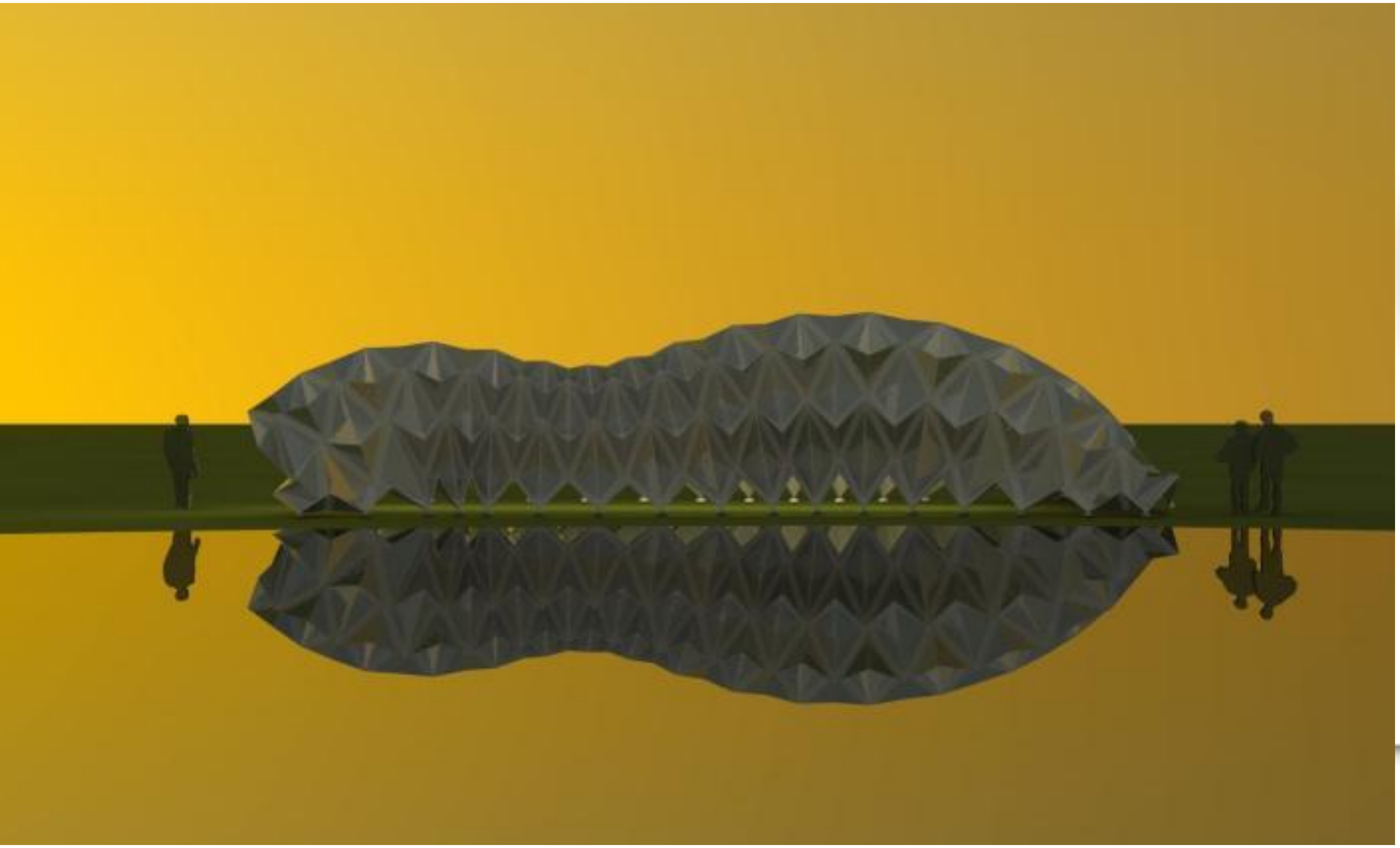

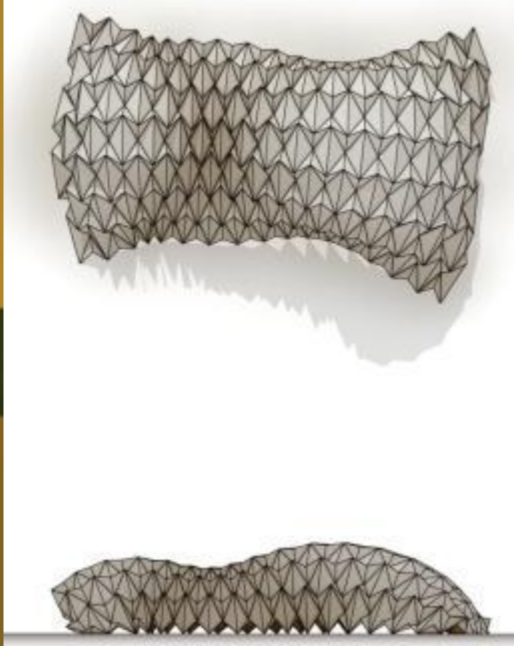

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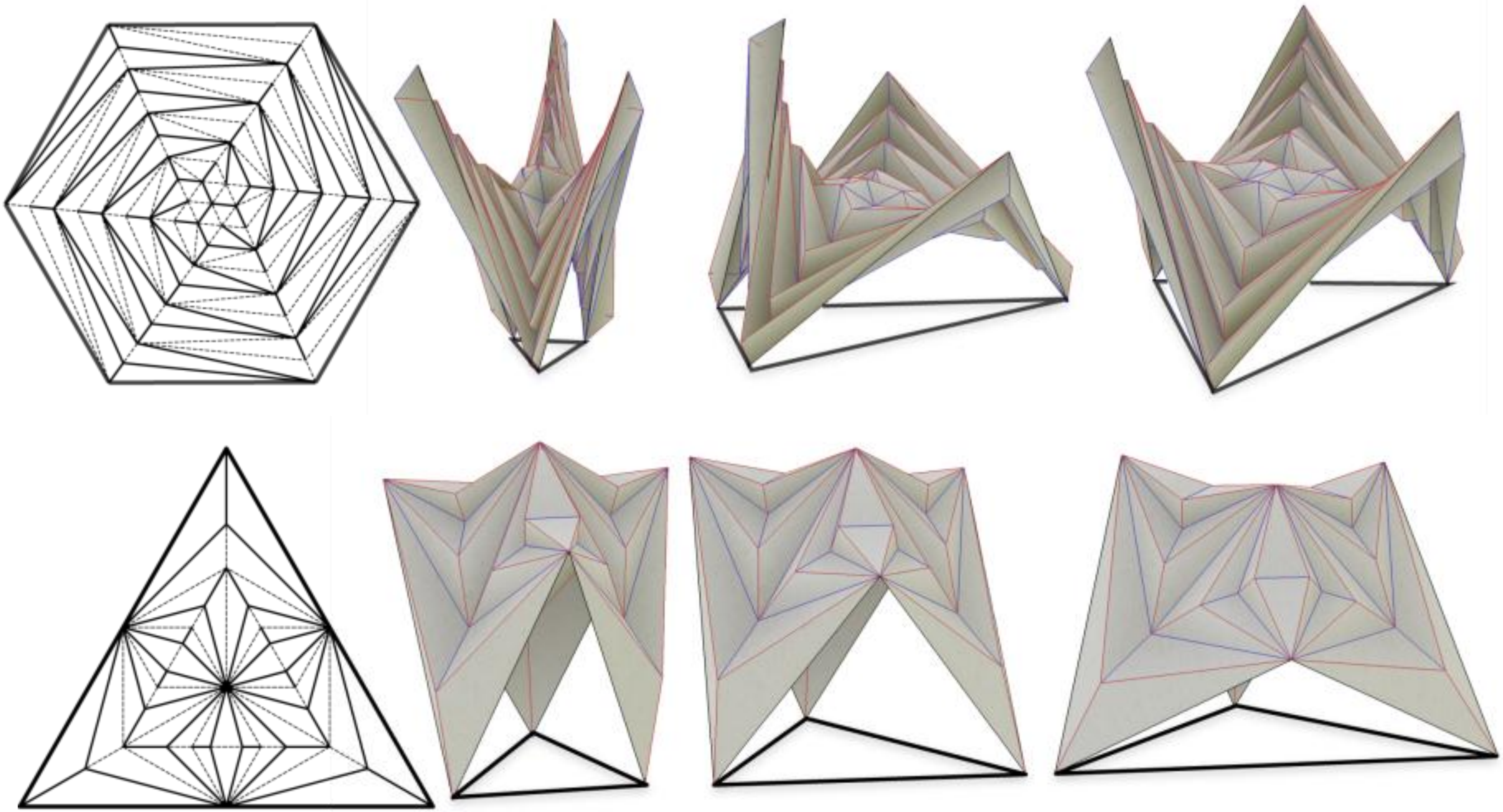
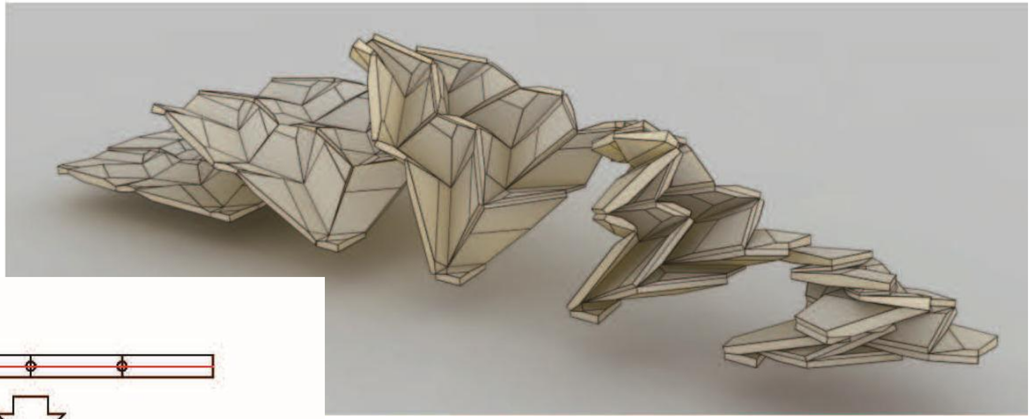
Hexagonal Tripod Shells



Alternate methods for thick origami



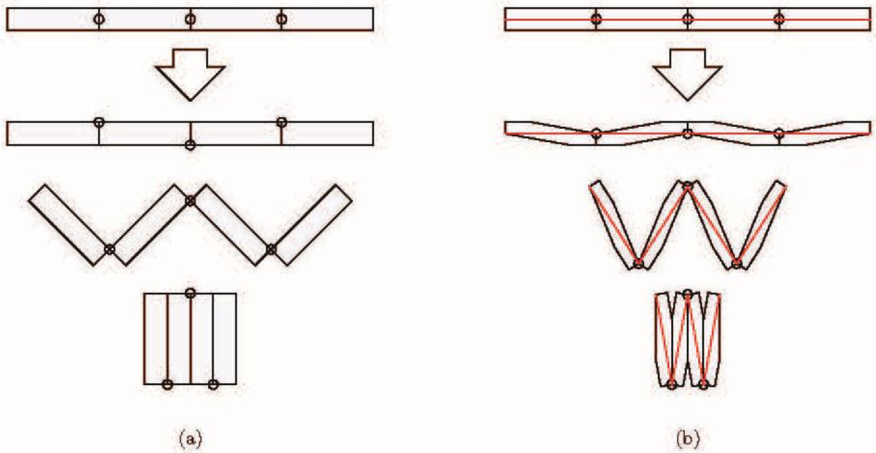
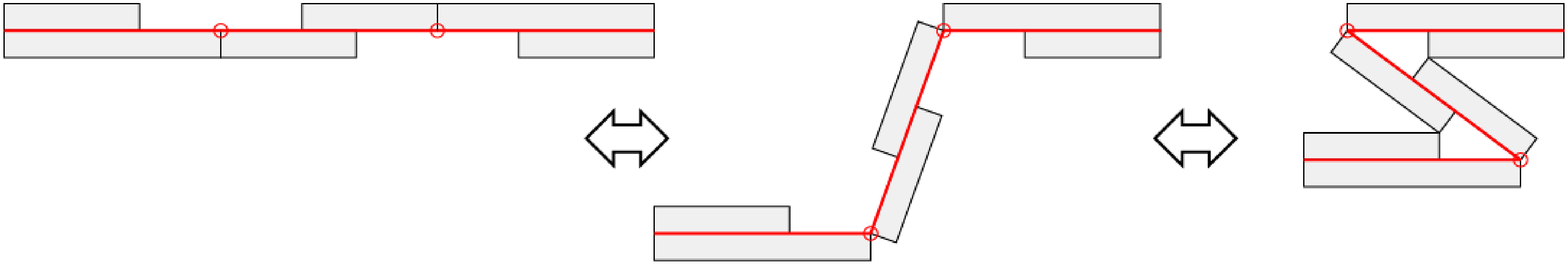


Figure 3: Two approaches for enabling thick panel origami. (a) Axis-shift. (b) The proposed method based on trimming by bisecting planes. Red path represents the ideal origami without thickness.



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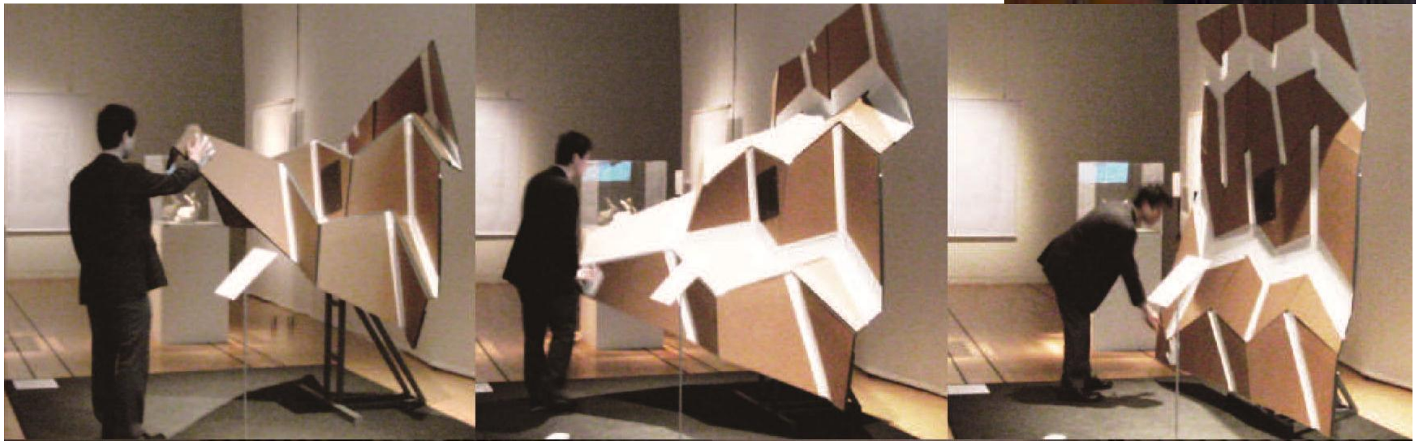
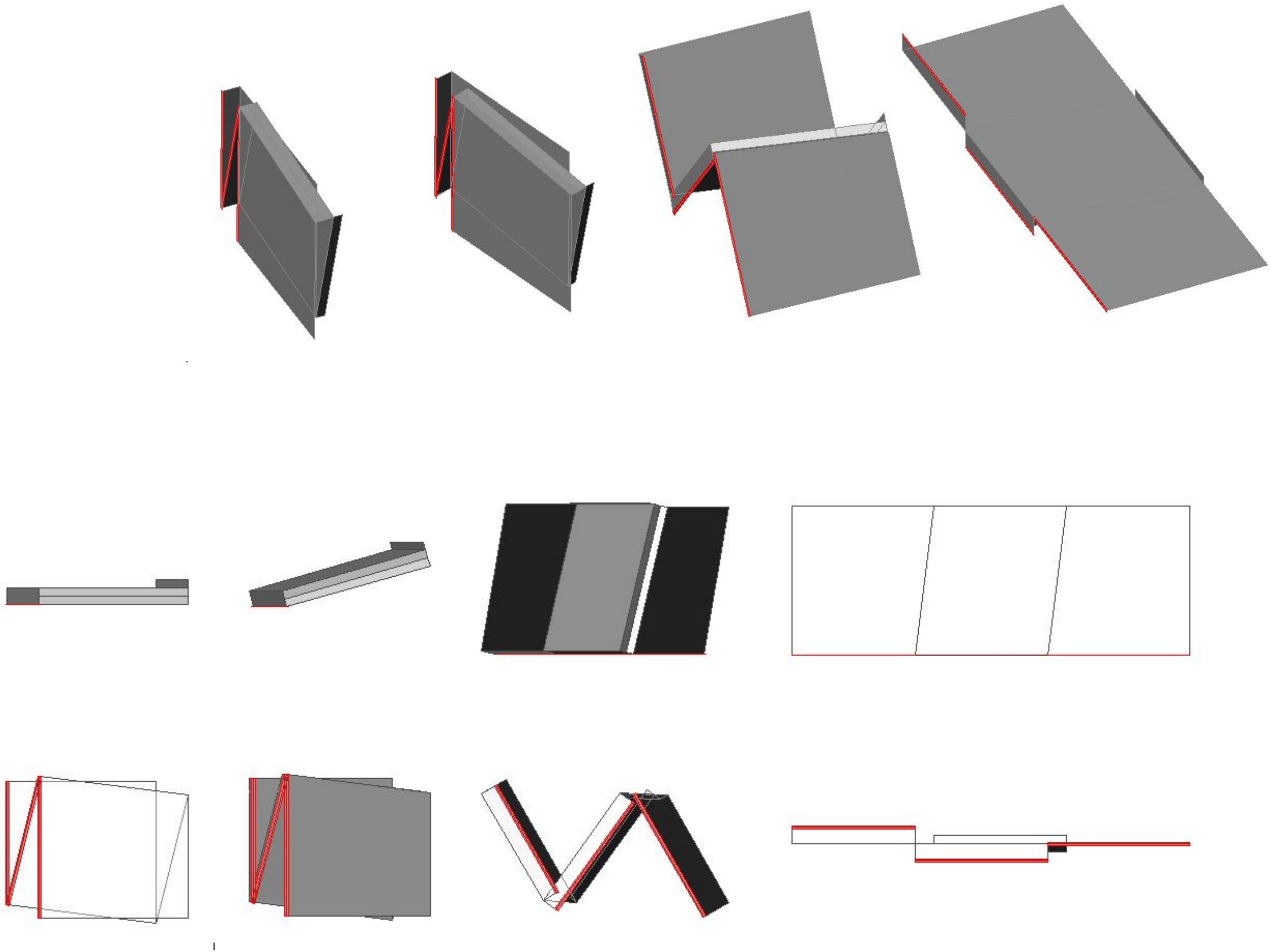
- Material
  - 10mm Structural Cardboard (double wall)
  - Cloth
- Size
  - 2.5m x 2.5m

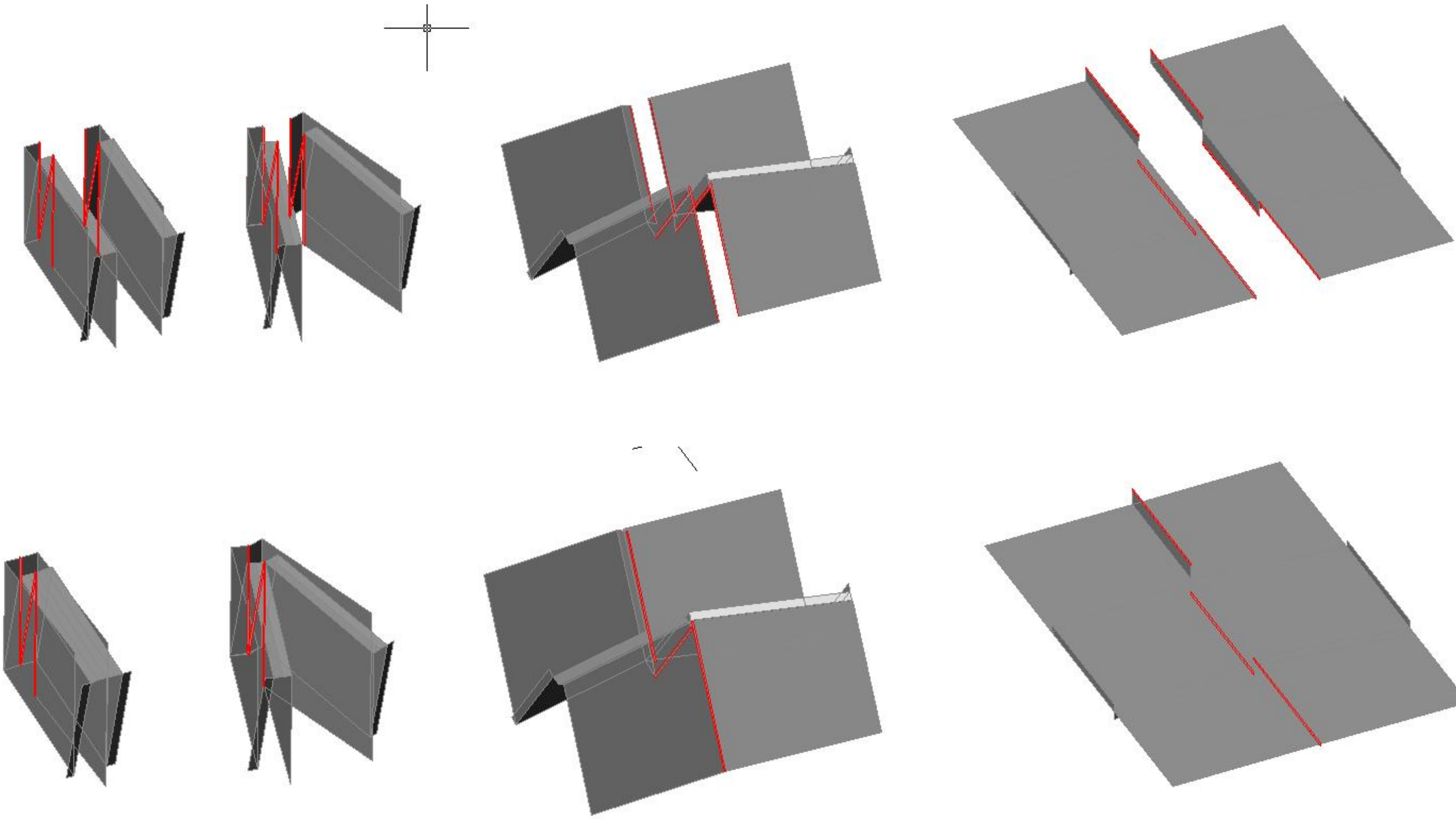
- exhibited at NTT ICC



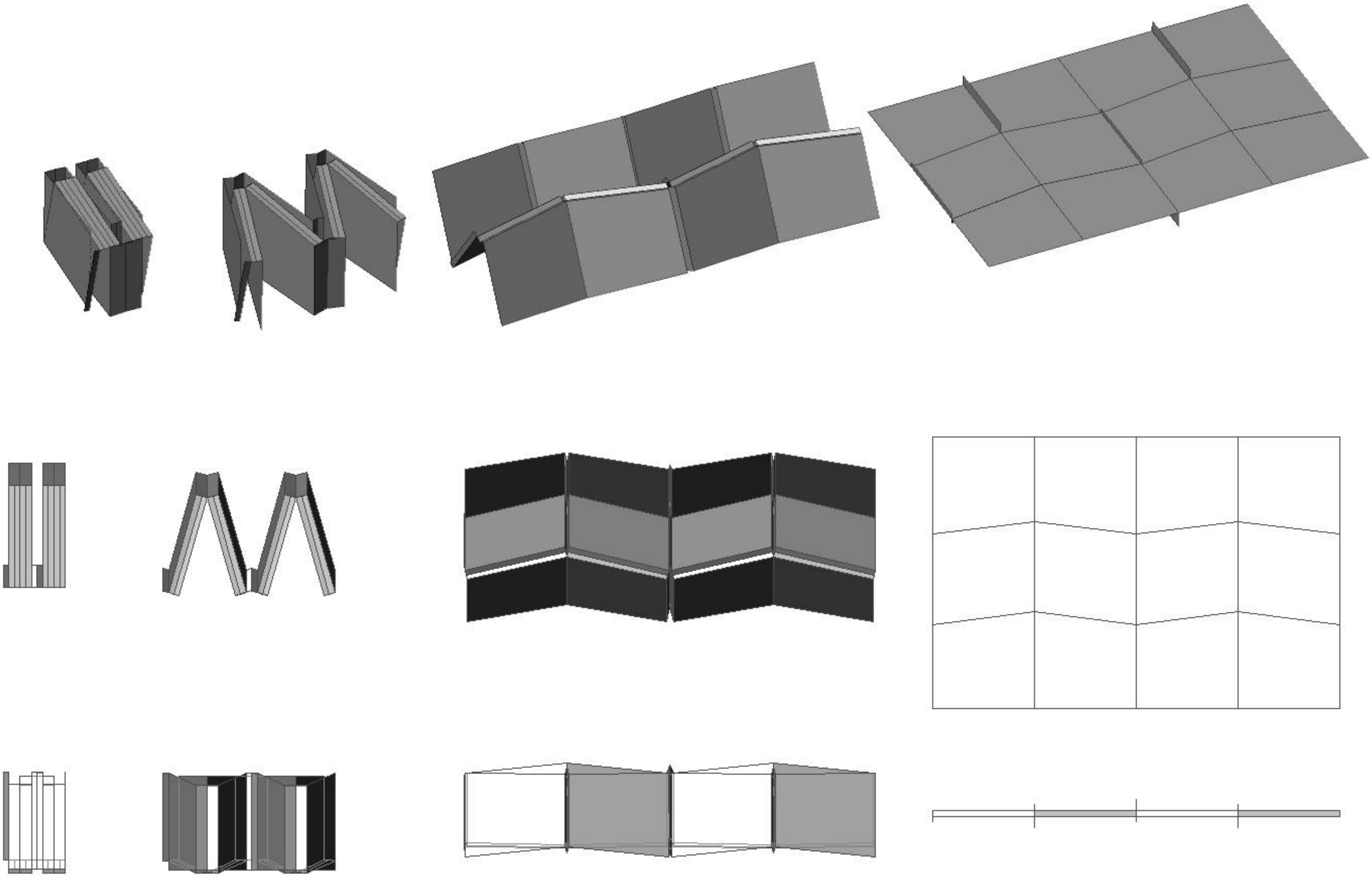
'Thick' Origami (Hoberman)



‘Thick’ Origami (Hoberman)



‘Thick’ Origami (Hoberman)



‘Thick’ Origami (Hoberman)

FIG.10

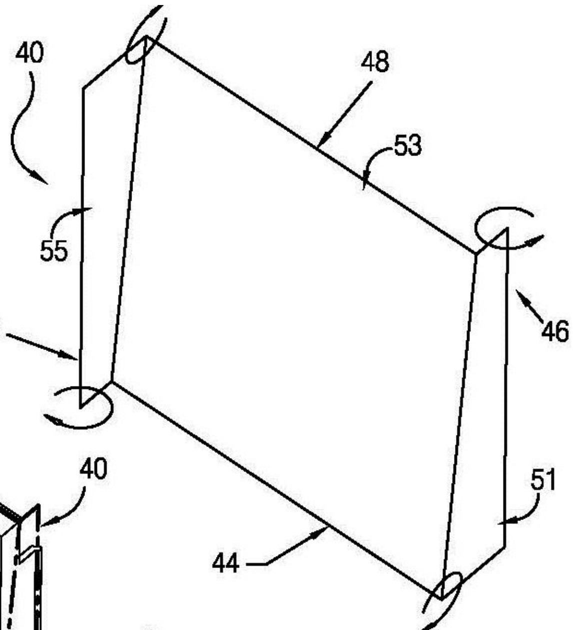


FIG.11

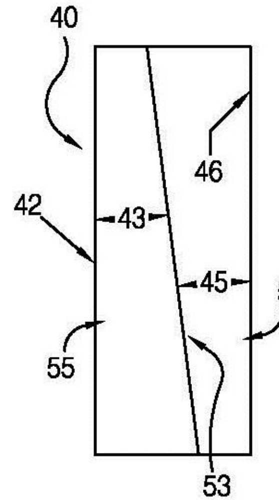
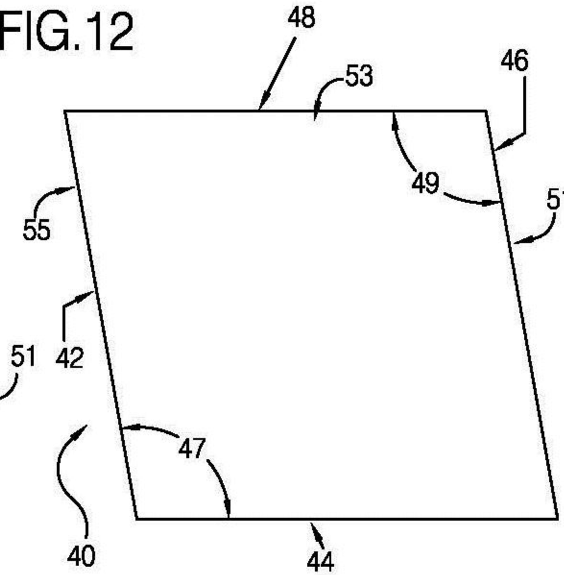


FIG.12



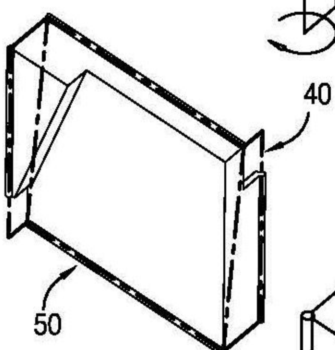


FIG.13

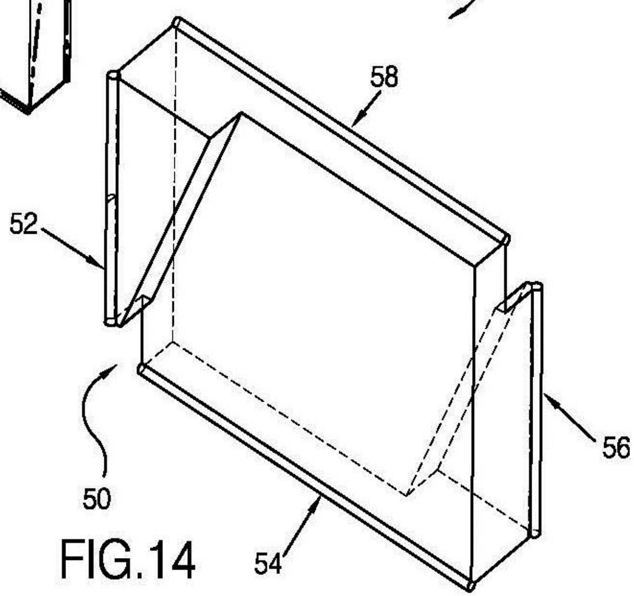


FIG.14

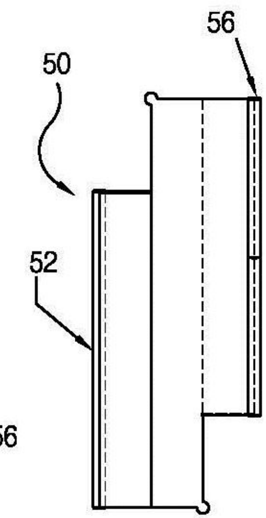


FIG.15

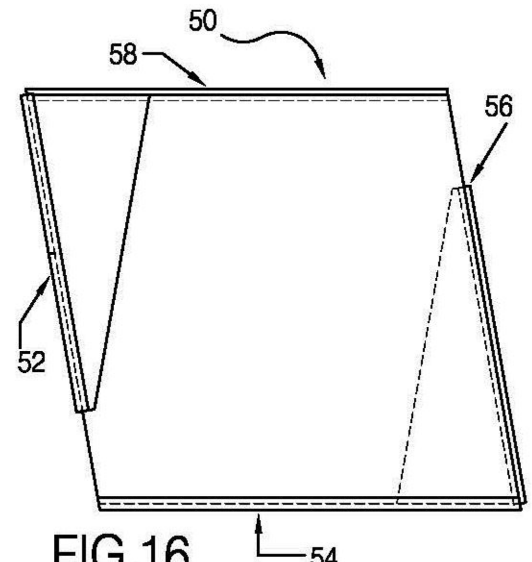


FIG.16

‘Thick’ Origami

FIG.17

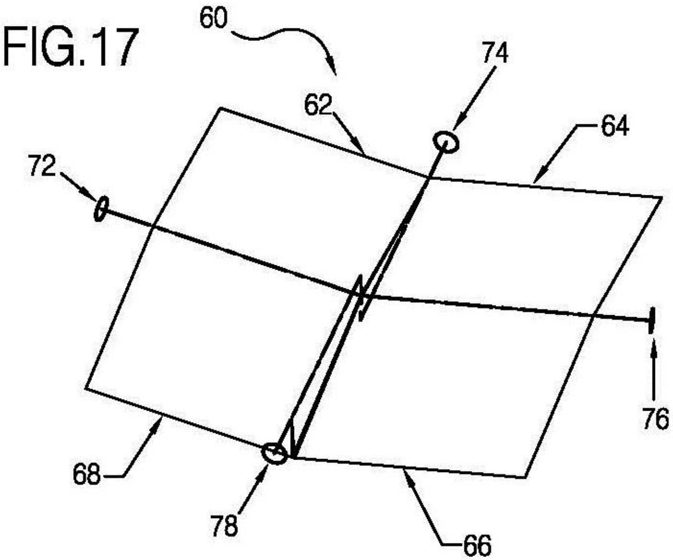
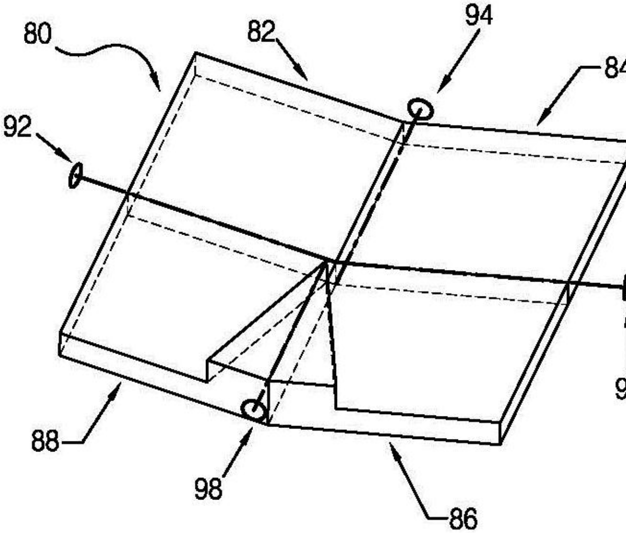


FIG.18



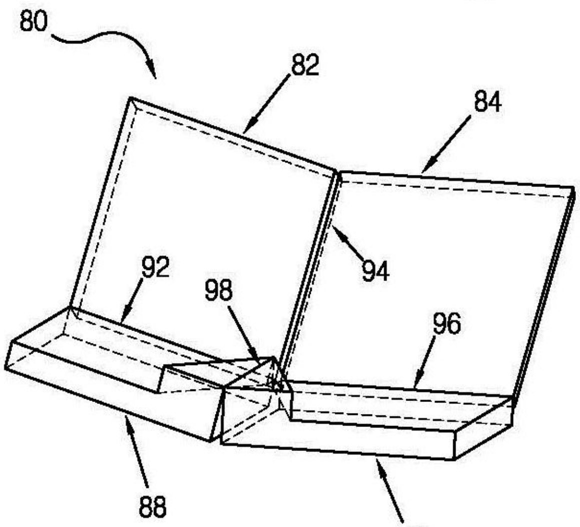


FIG.19

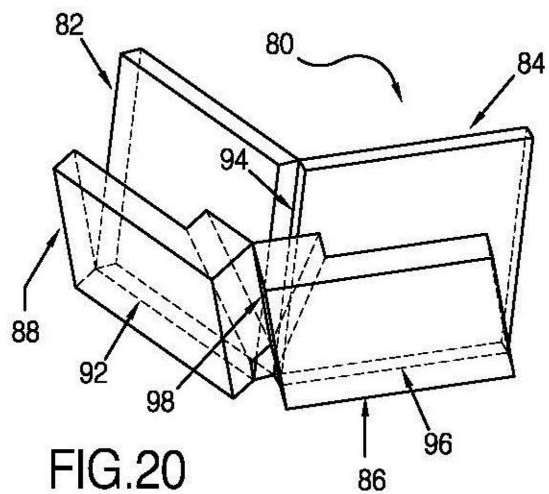


FIG.20

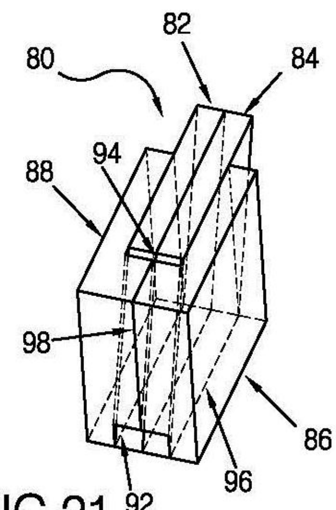


FIG.21

‘Thick’ Origami

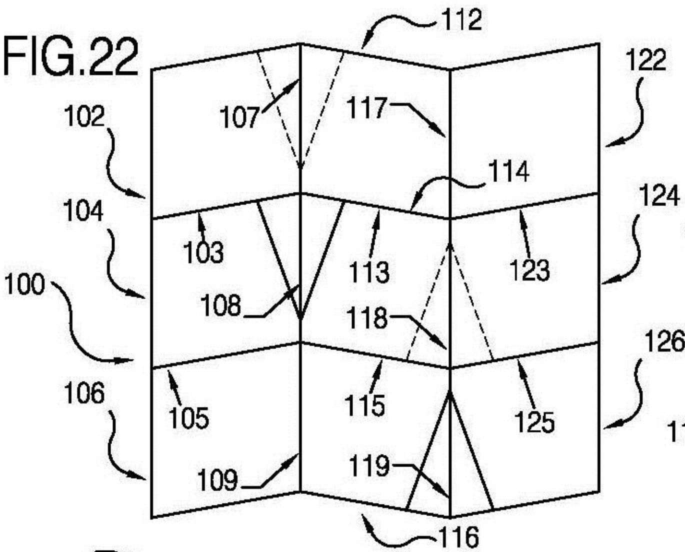


FIG.22

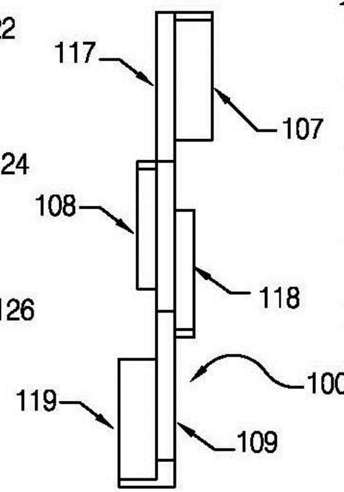


FIG.23

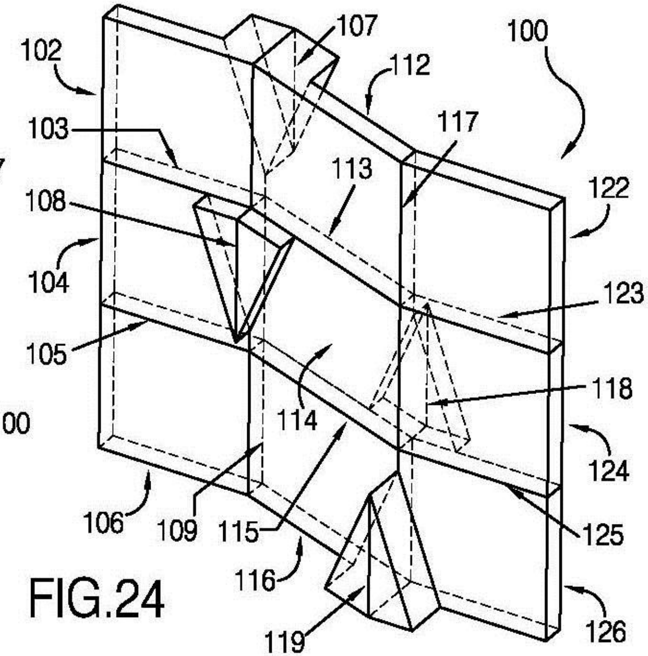


FIG.24

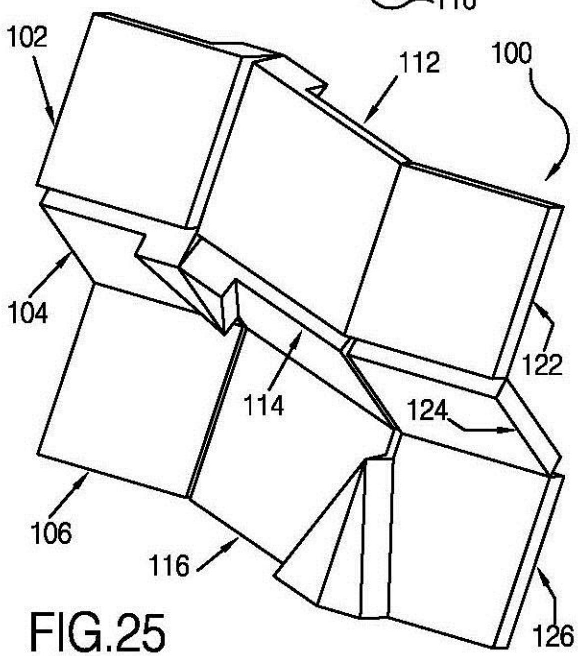


FIG.25

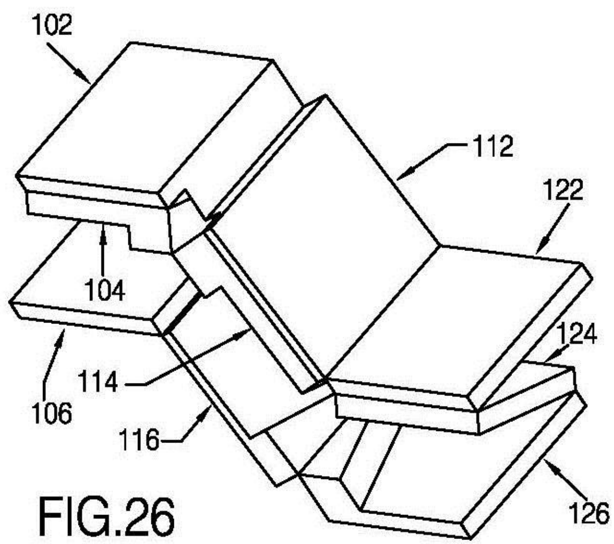


FIG.26

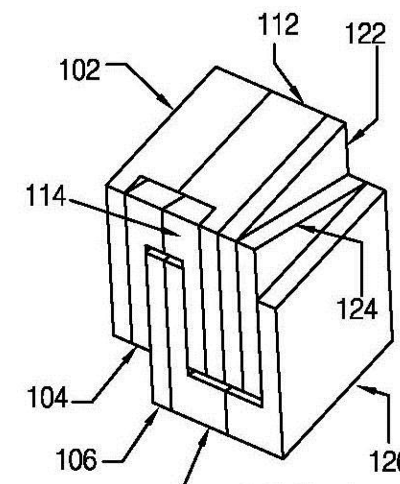
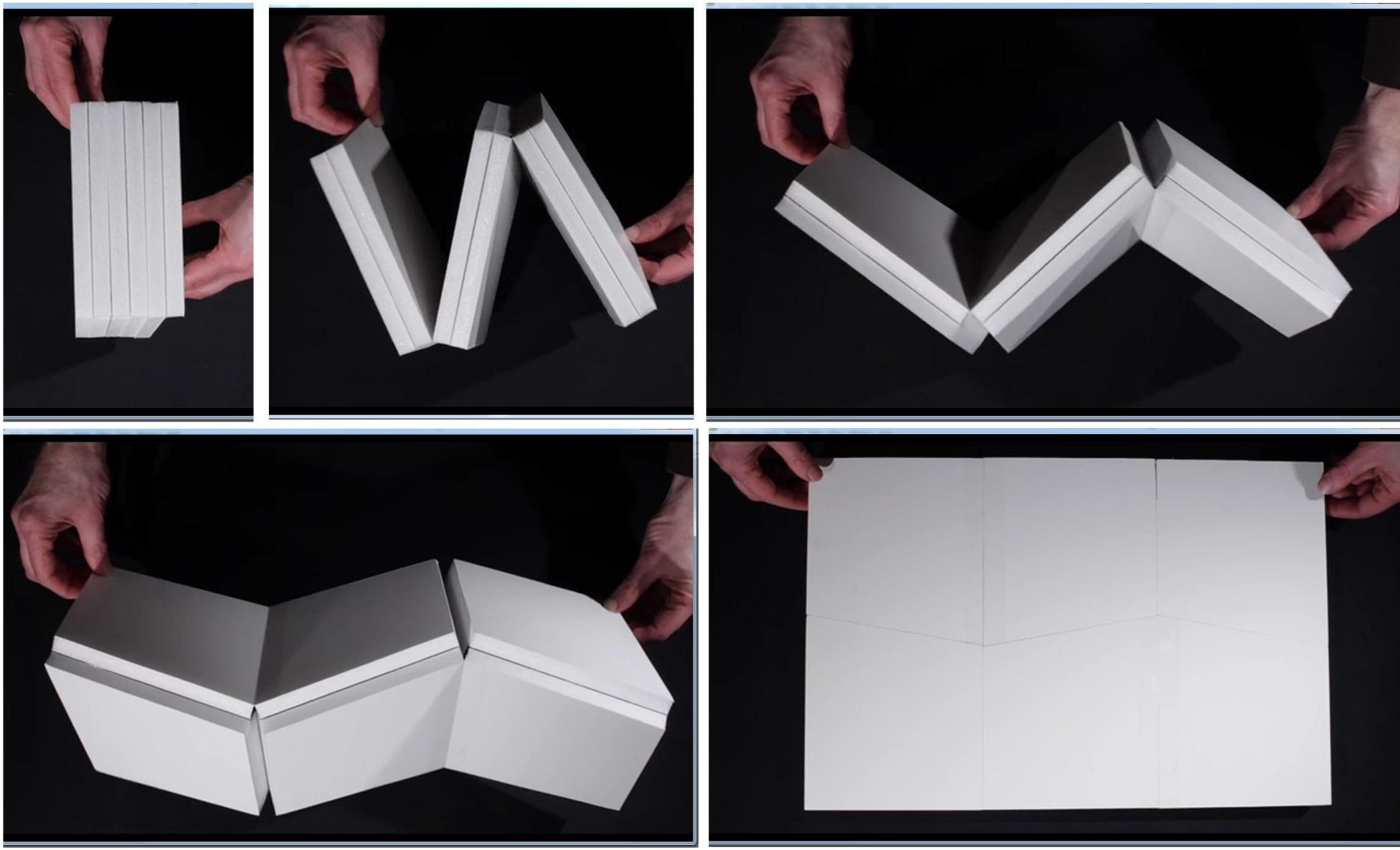
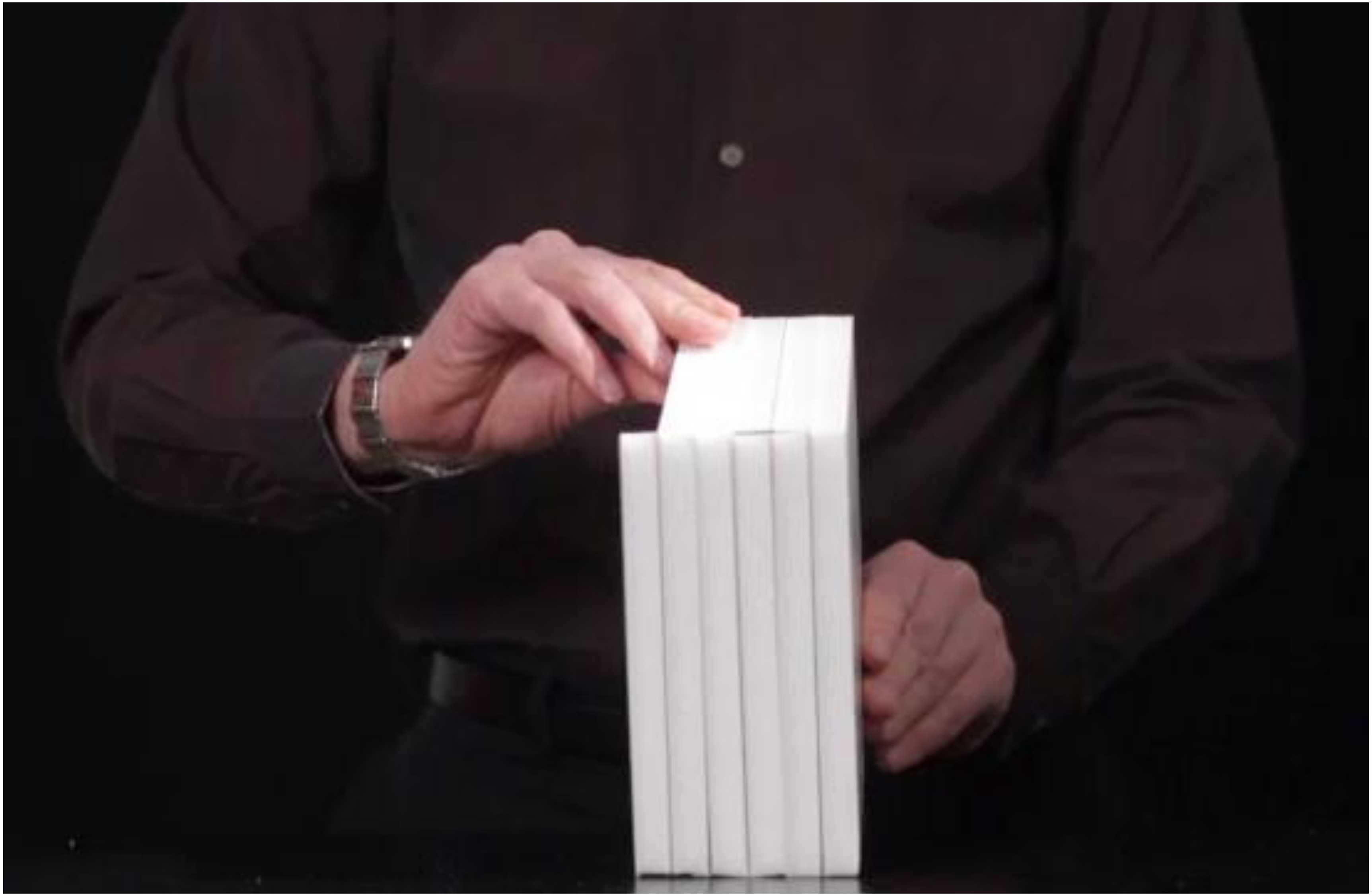


FIG.27

Kinetic Origami



Thick Origami



Kinetic Origami

Kinetic Origami

FIG. 47

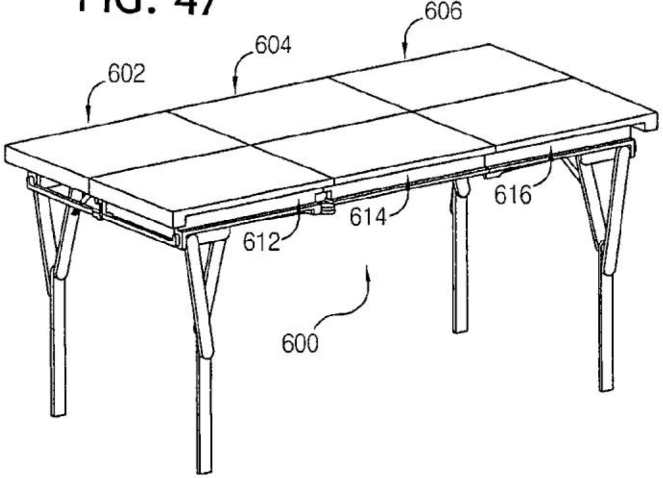
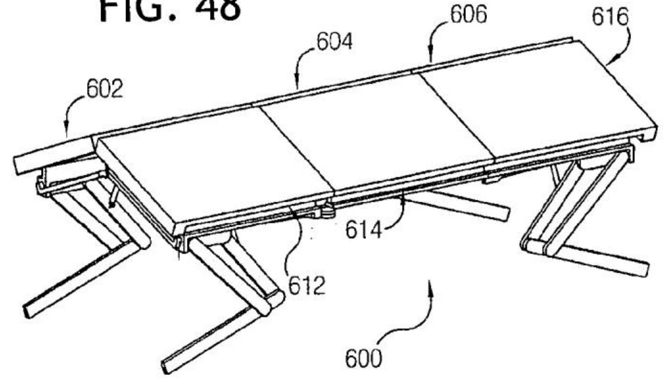


FIG. 48



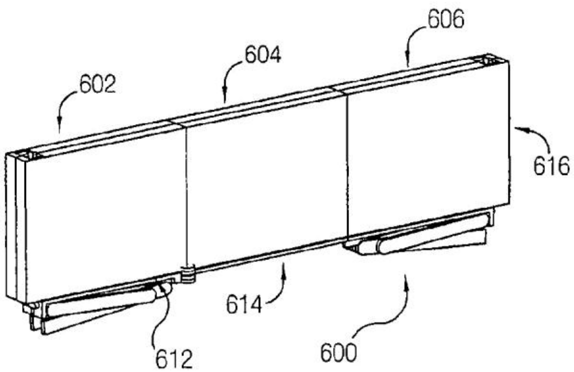


FIG. 49

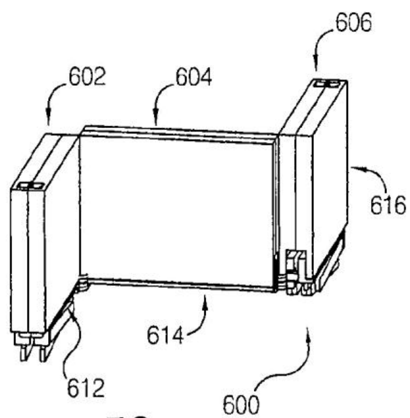


FIG. 50

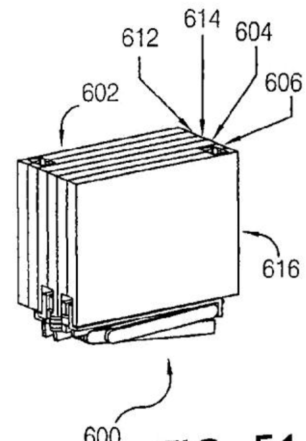


FIG. 51

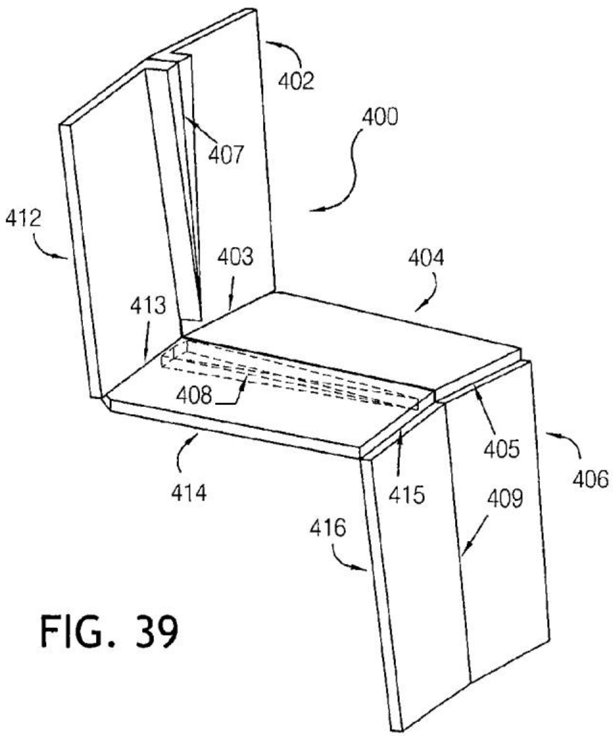


FIG. 39

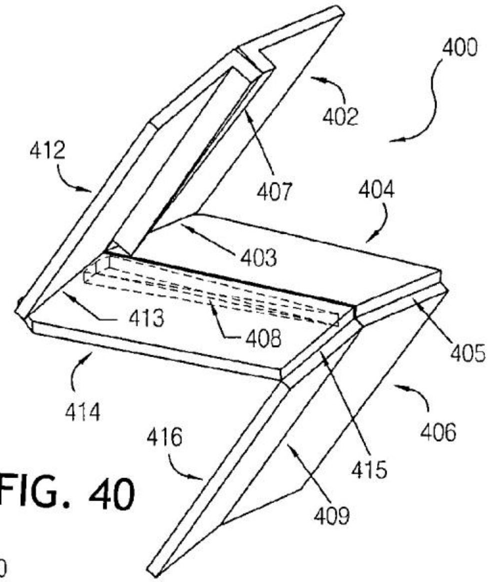


FIG. 40

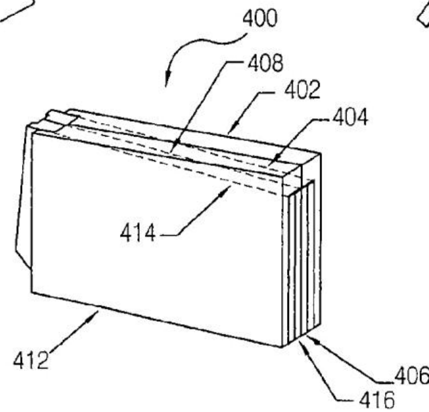


FIG. 41

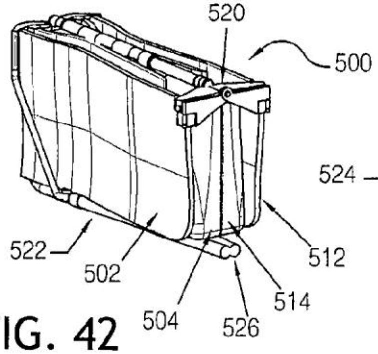
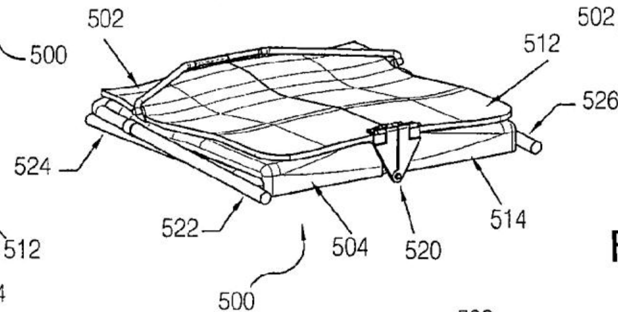


FIG. 42

FIG. 43



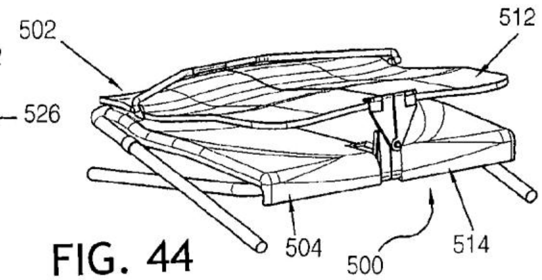


FIG. 44

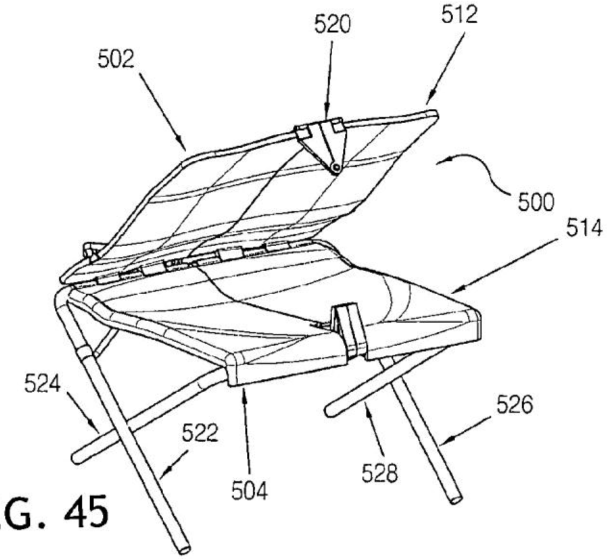


FIG. 45

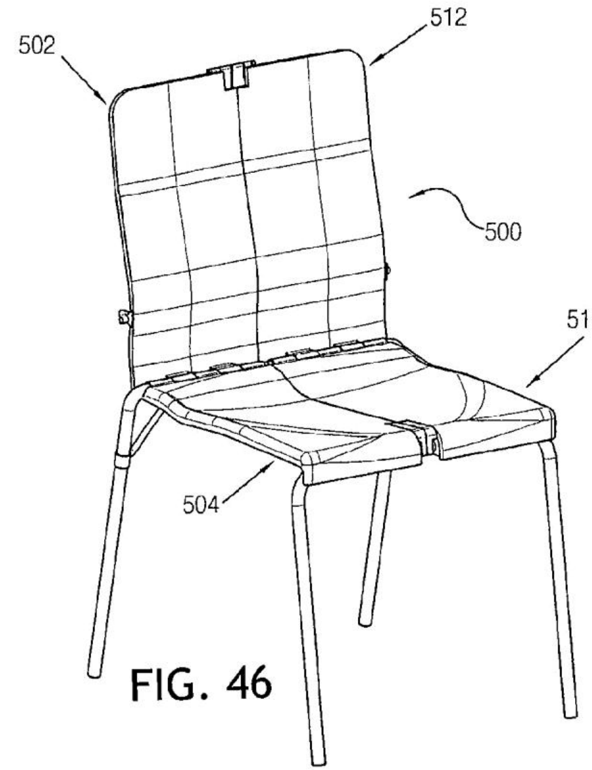
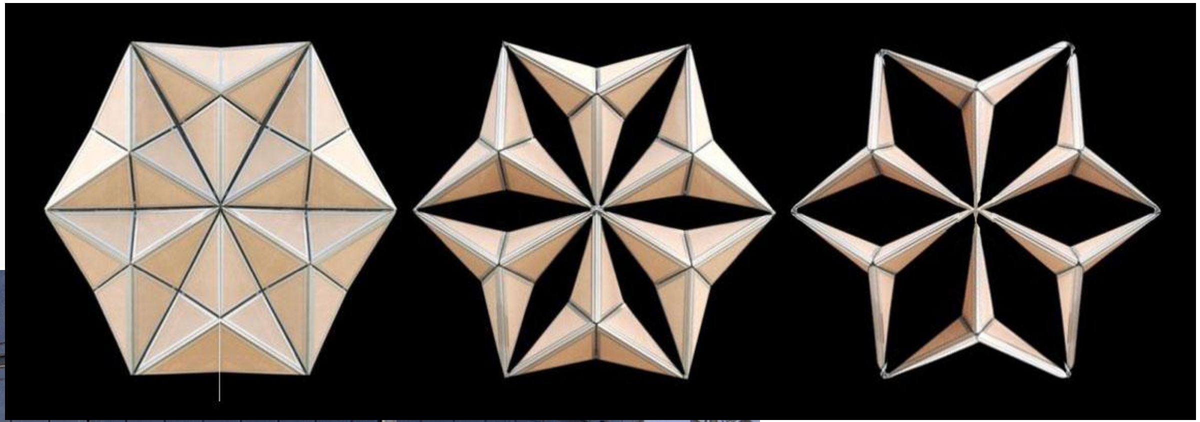


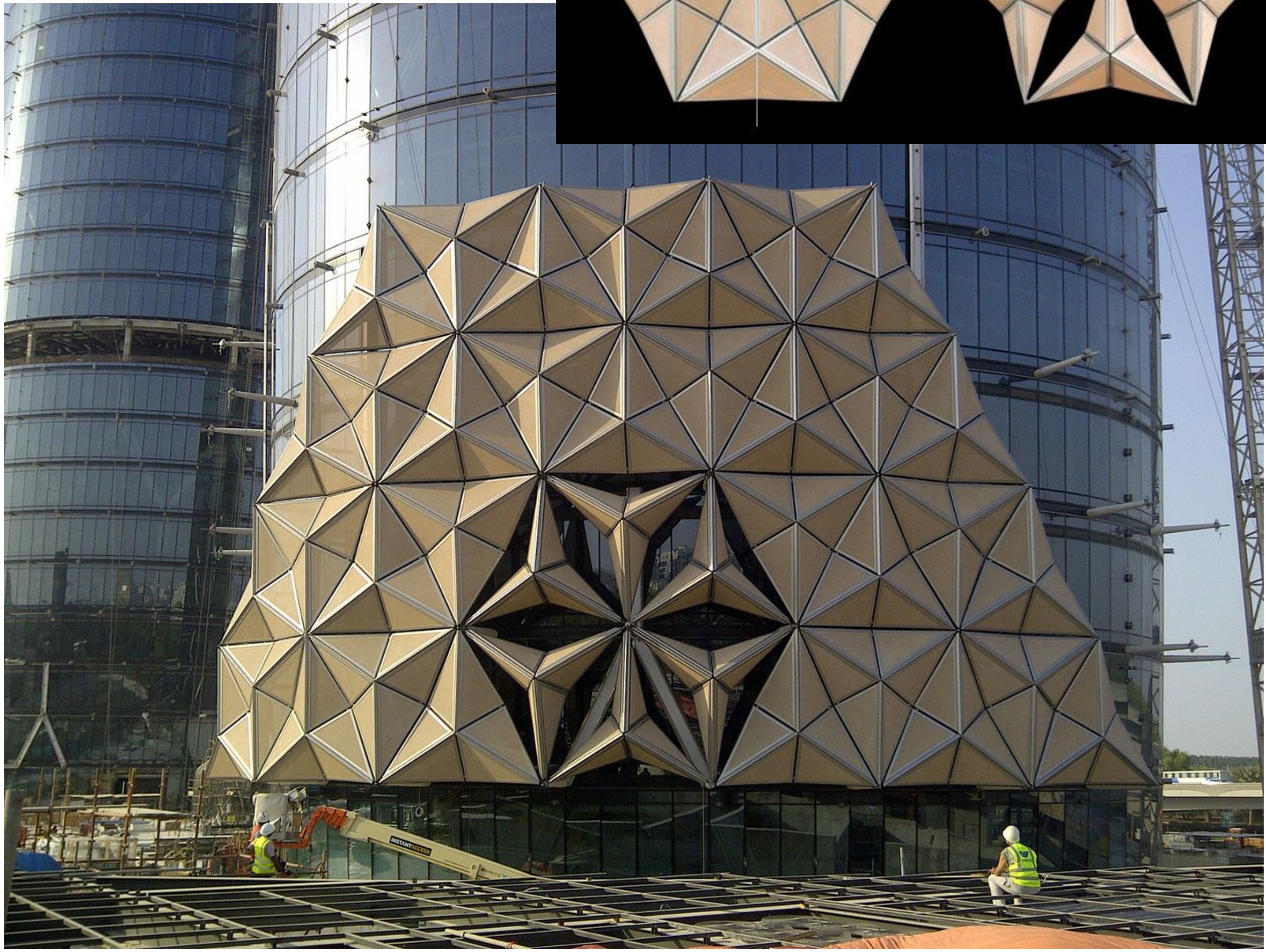
FIG. 46

Kinetic Origami

Kinetic Origami

Abu Dhabi Investment Council Headquarters
Architect: Aedas

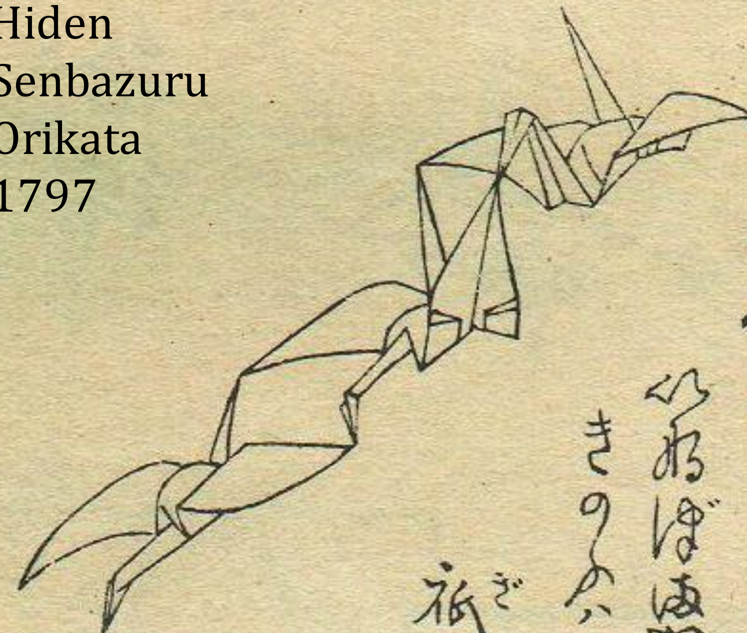




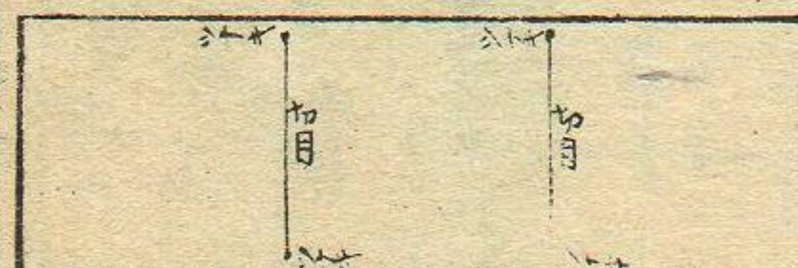
Custom Kinetic Facades:

Abu Dhabi Investment Council Headquarters
Architect: Aedas

Hiden
Senbazuru
Orikata
1797



稲妻



Modern Origami

Cerberus & **Ryujin**

Satoshi Kamiya

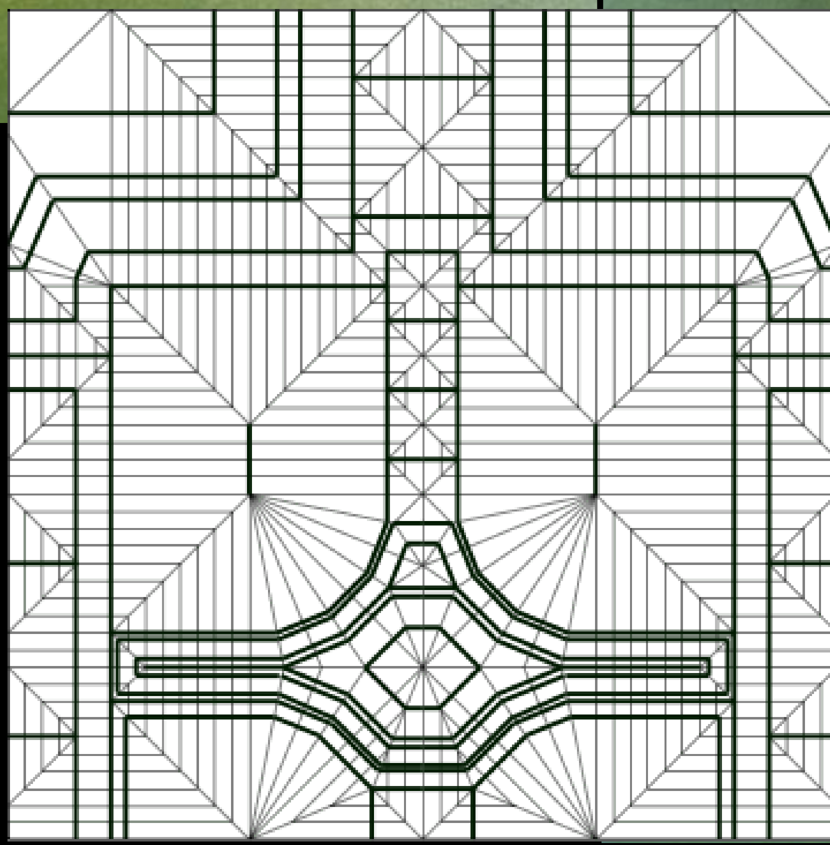
2005


2006 Design Challenge
Photos by Brian Chan
Jason Ku
Andrea Hawksley
Attack of the Kraken
Brian Chan
6-27-2006
Giang Dinh
Brian Chan
Robert Lang


Origami USA
Convention
2009
Brian Chan
Joel Cooper
Goran Konjevod

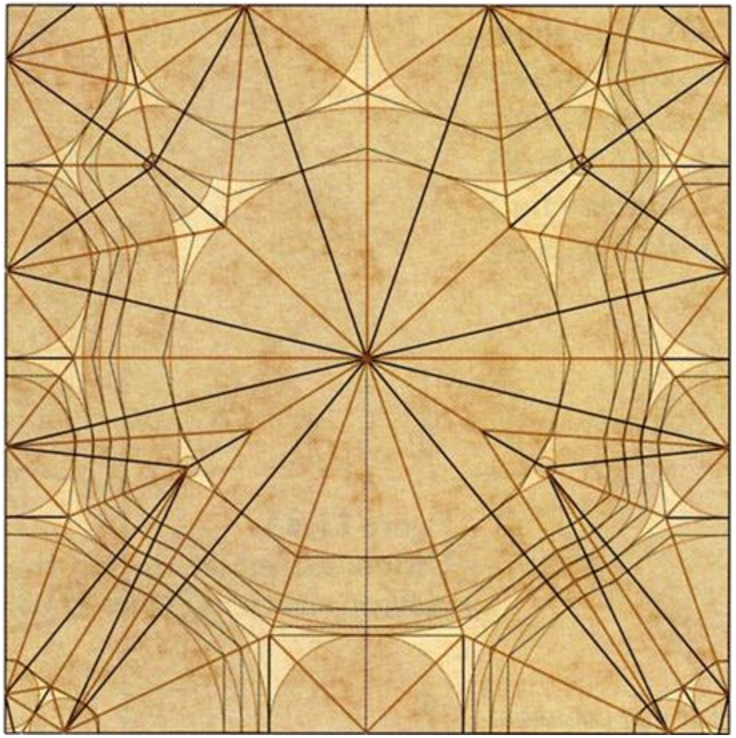
Butterfly 2.2

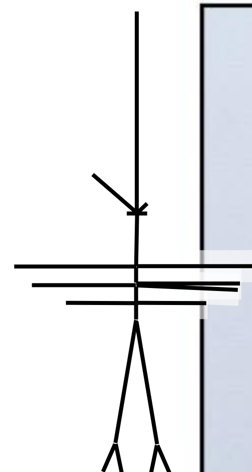
Jason Ku

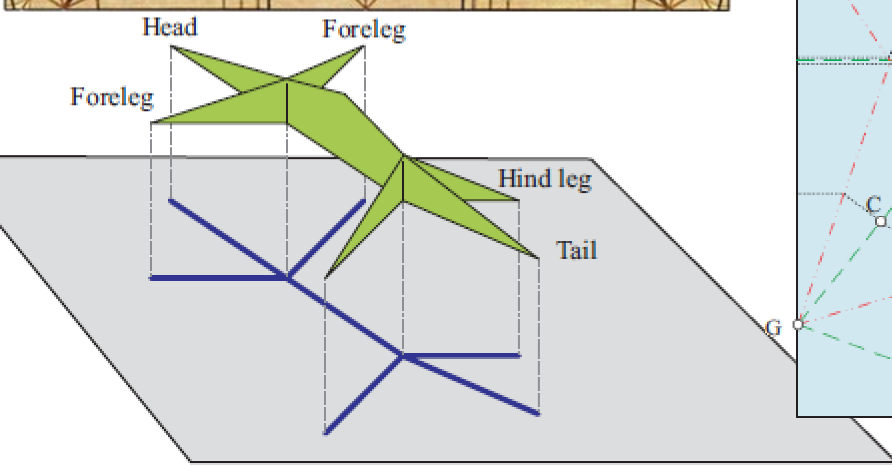


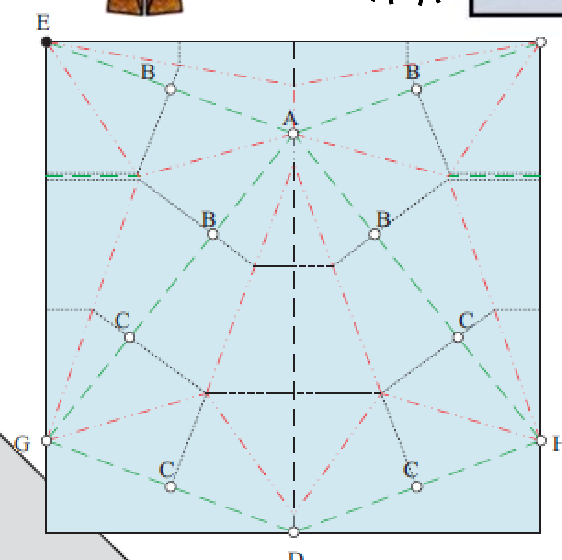
Tree Method of Origami Design

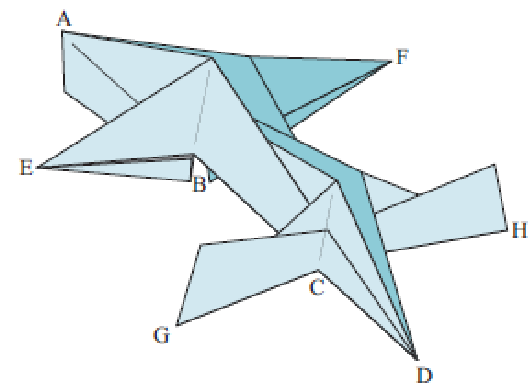
[Fujimoto, Kamiya, Kawahata, Lang, Maekawa, Meguro, Yoshino]
[Lang, Demaine, Demaine 2006–2012]



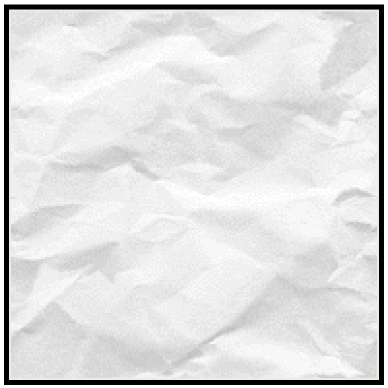


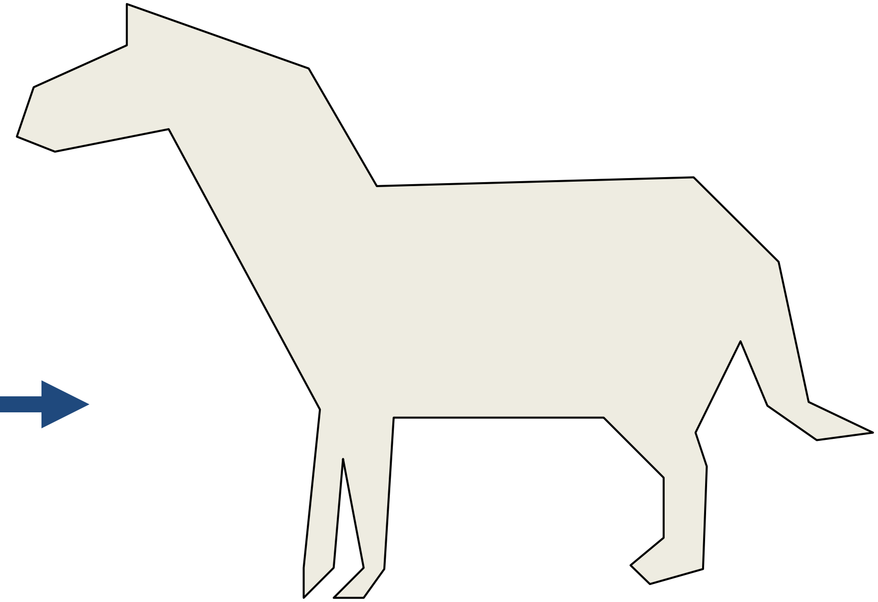


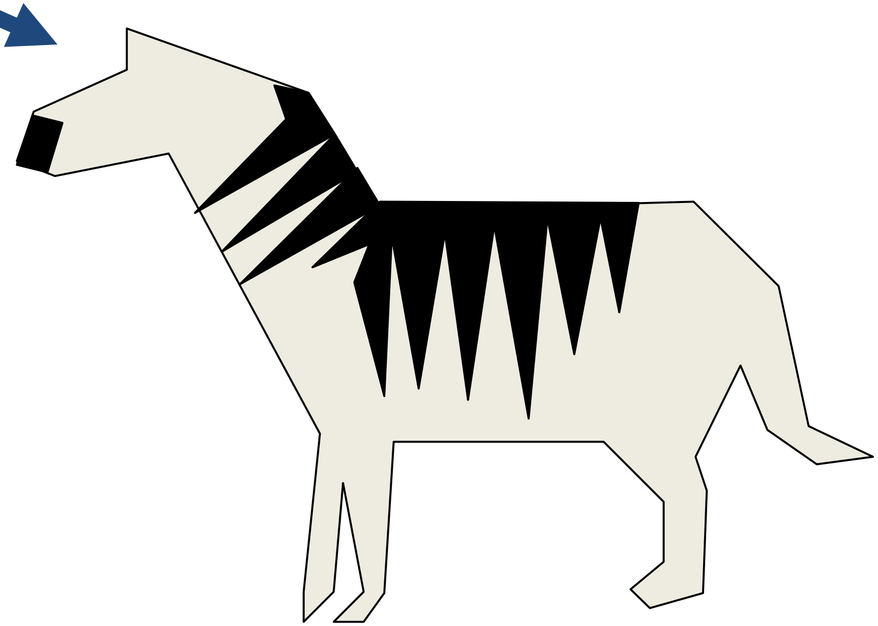


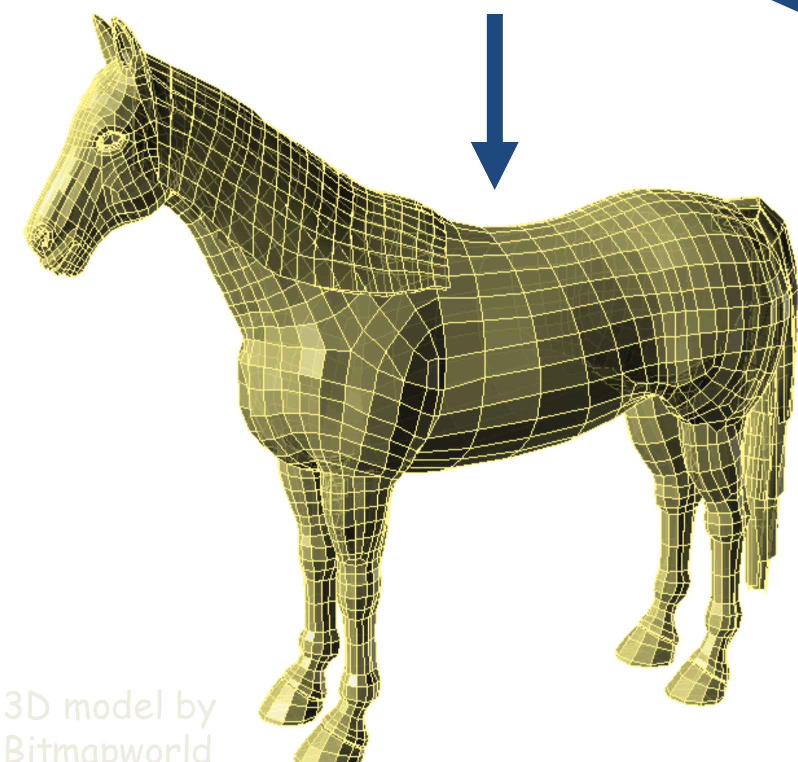


What Shapes Can Be Folded?





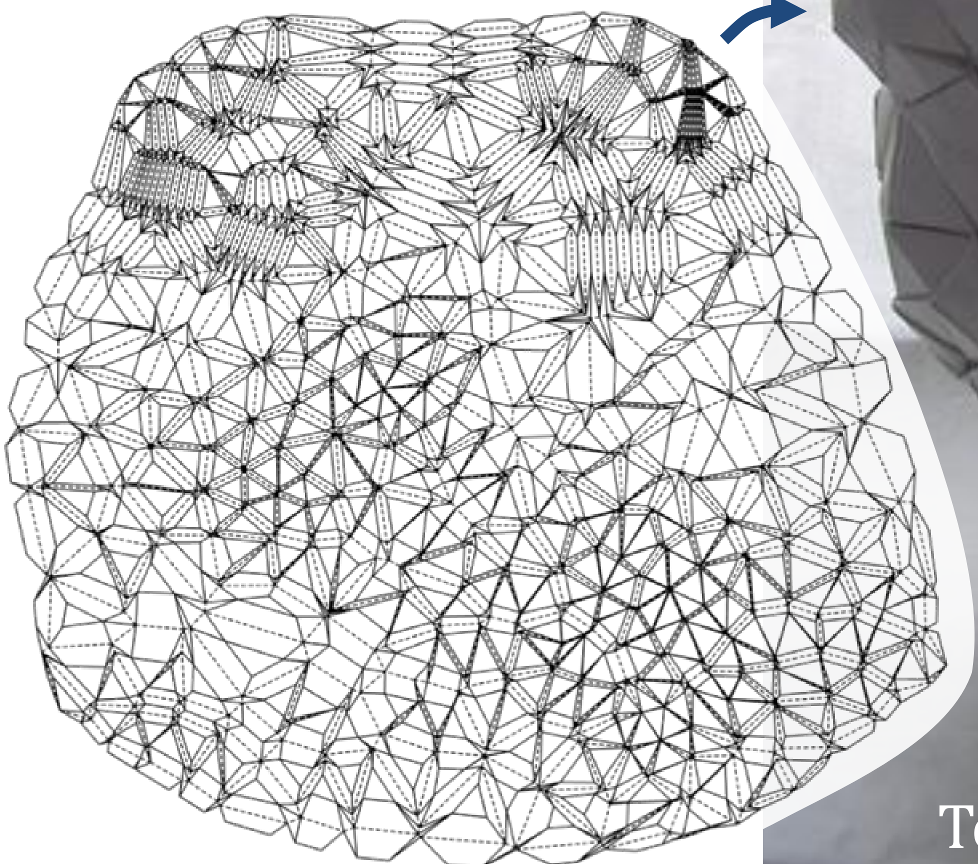


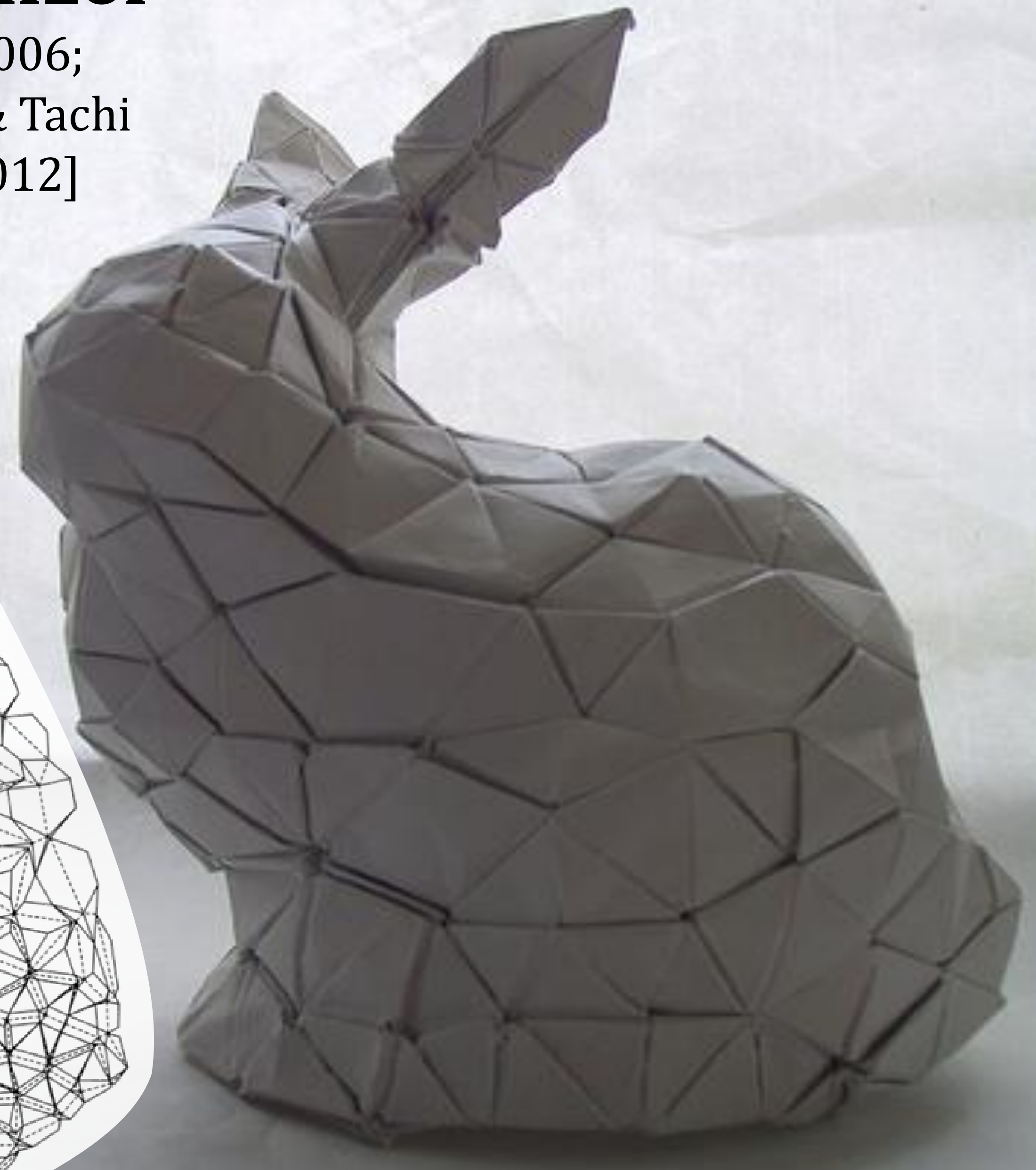


[Demaine, Demaine, Mitchell 1999]

Origamizer

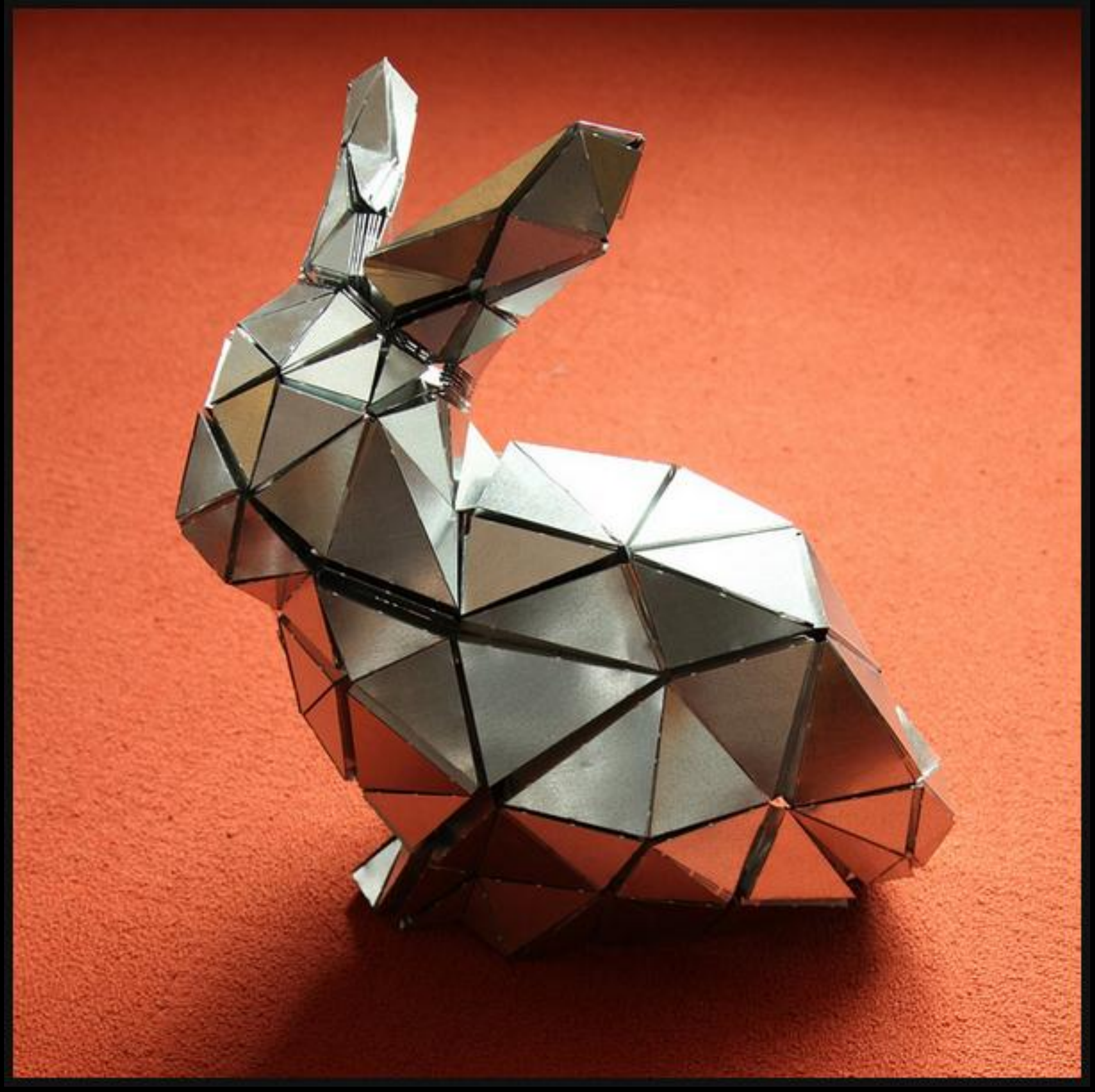
[Tachi 2006;
Demaine & Tachi
2009–2012]





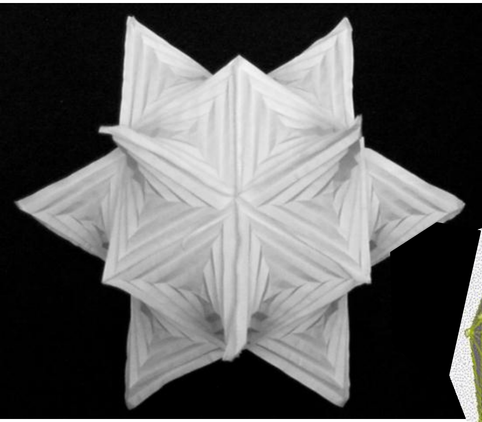
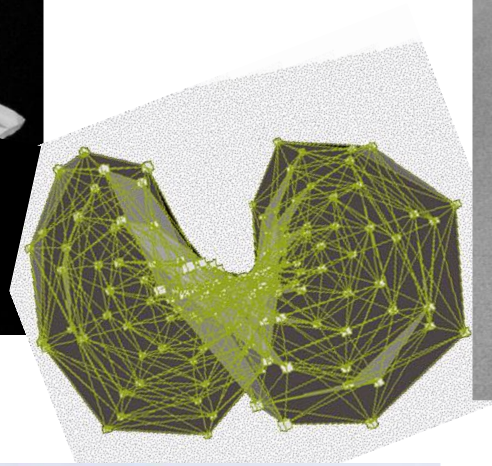
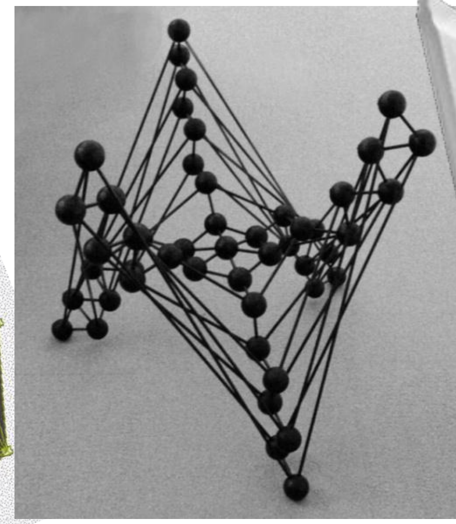
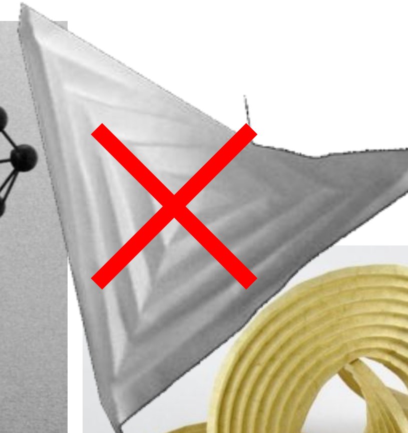
Tomohiro Tachi

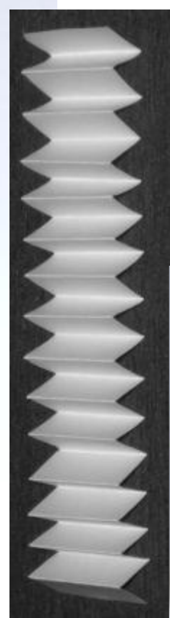
[Cheung, Demaine, Demaine, Tachi 2011]



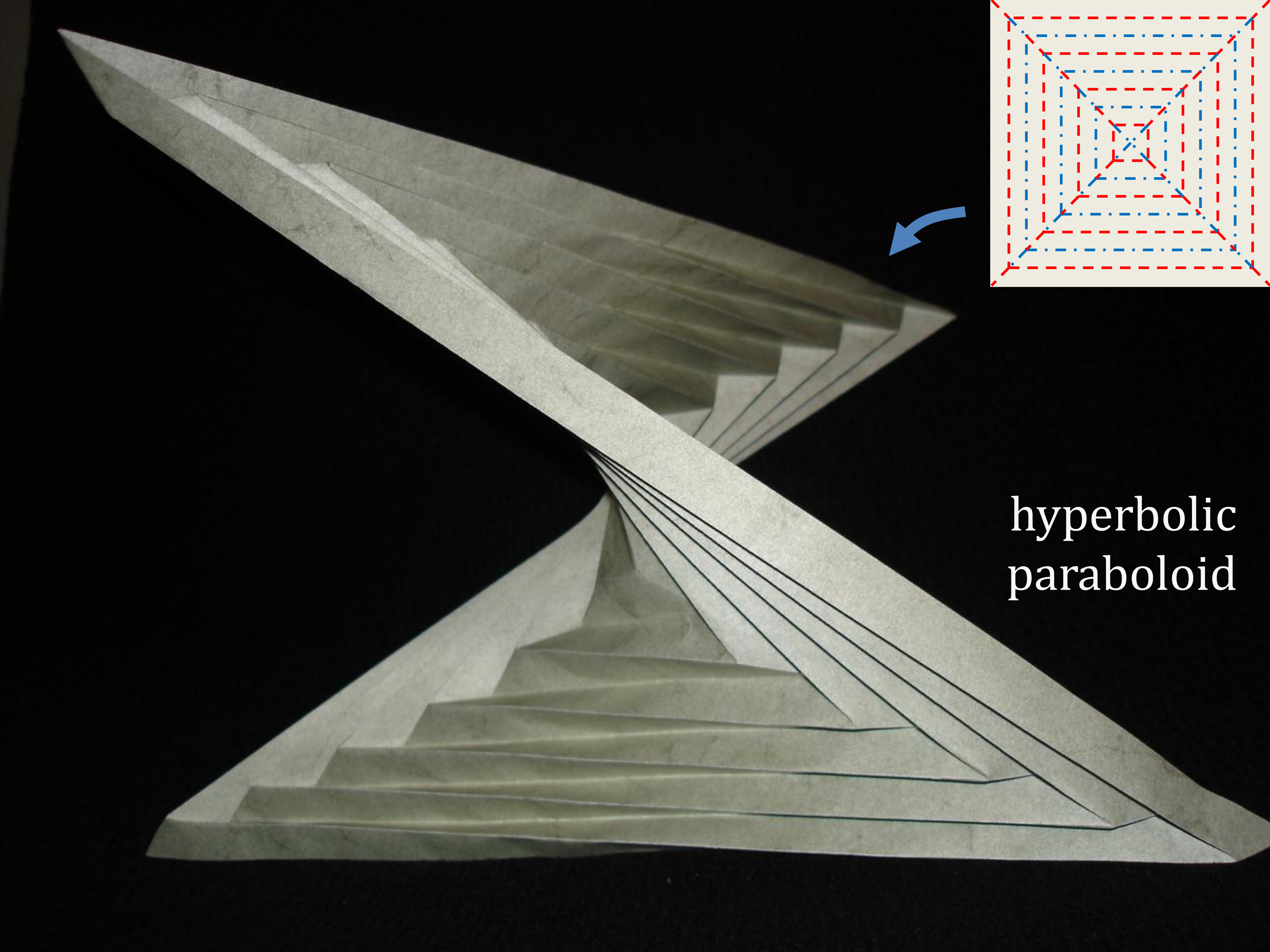
[Cheung, Demaine, Demaine, Tachi 2011]

Pleated Folding [1999–2013]

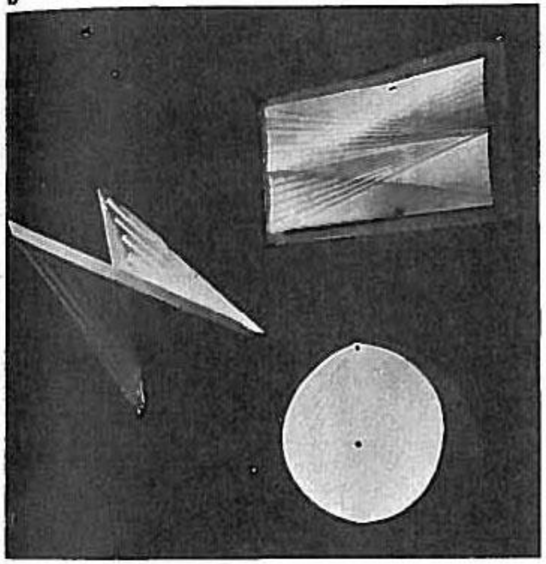





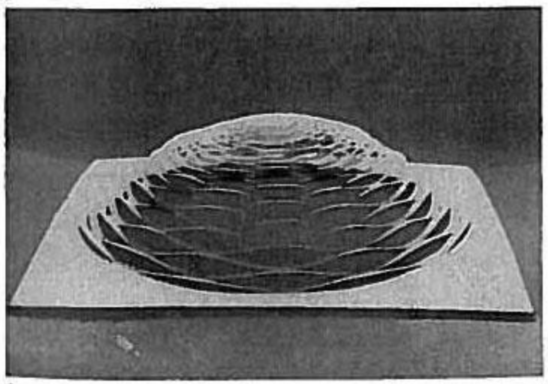


hyperbolic paraboloid

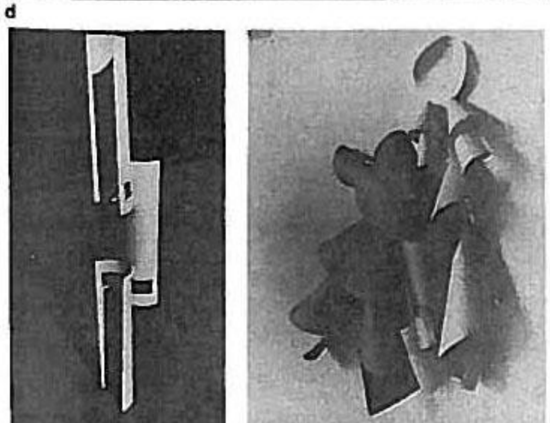
b



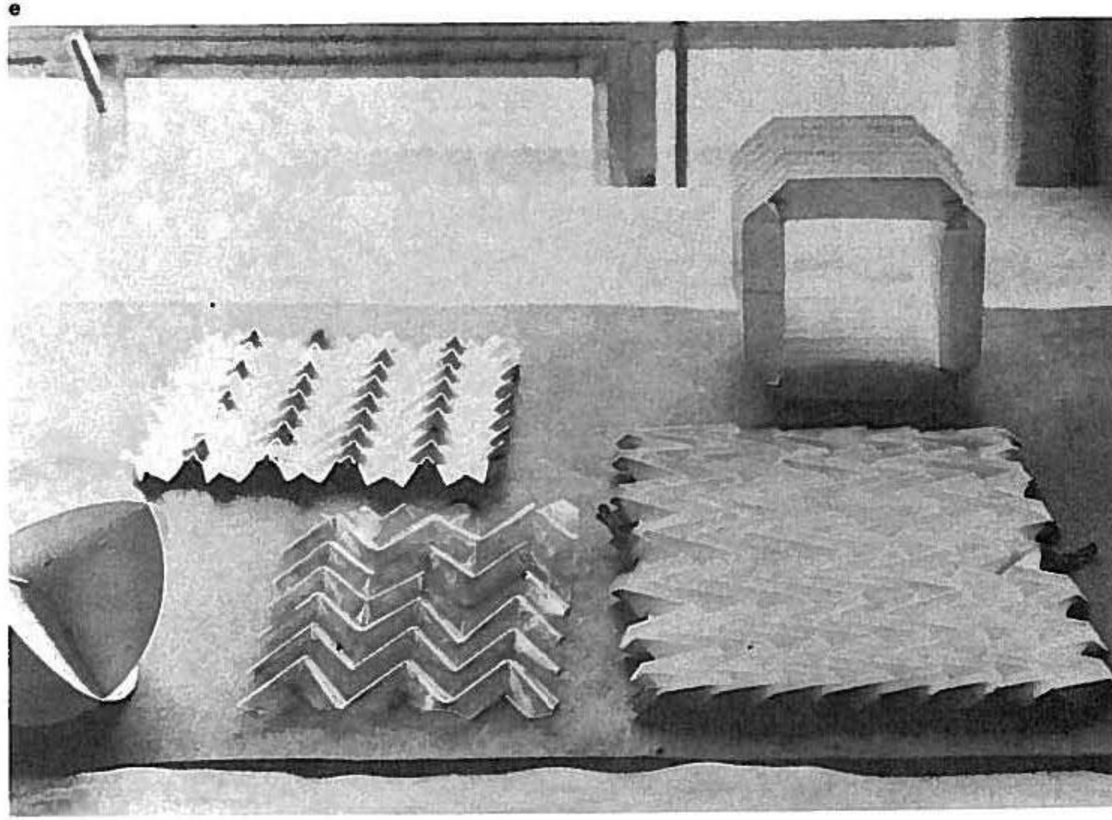
c



d



e



b
Students in Albers's preliminary course: paper study. 1927–28. Foliate construction: a circular piece of paper was folded like a fan, from two opposite points of departure. This resulted in a shrinkage which altered the periphery (form) of the sheet.—Square sheet: here too the paper was folded fanlike from two opposite sides. The folds cross each other and result in a "snake" effect—one edge curves up, the other down.
Wing form: automatic result of folding concentric squares.

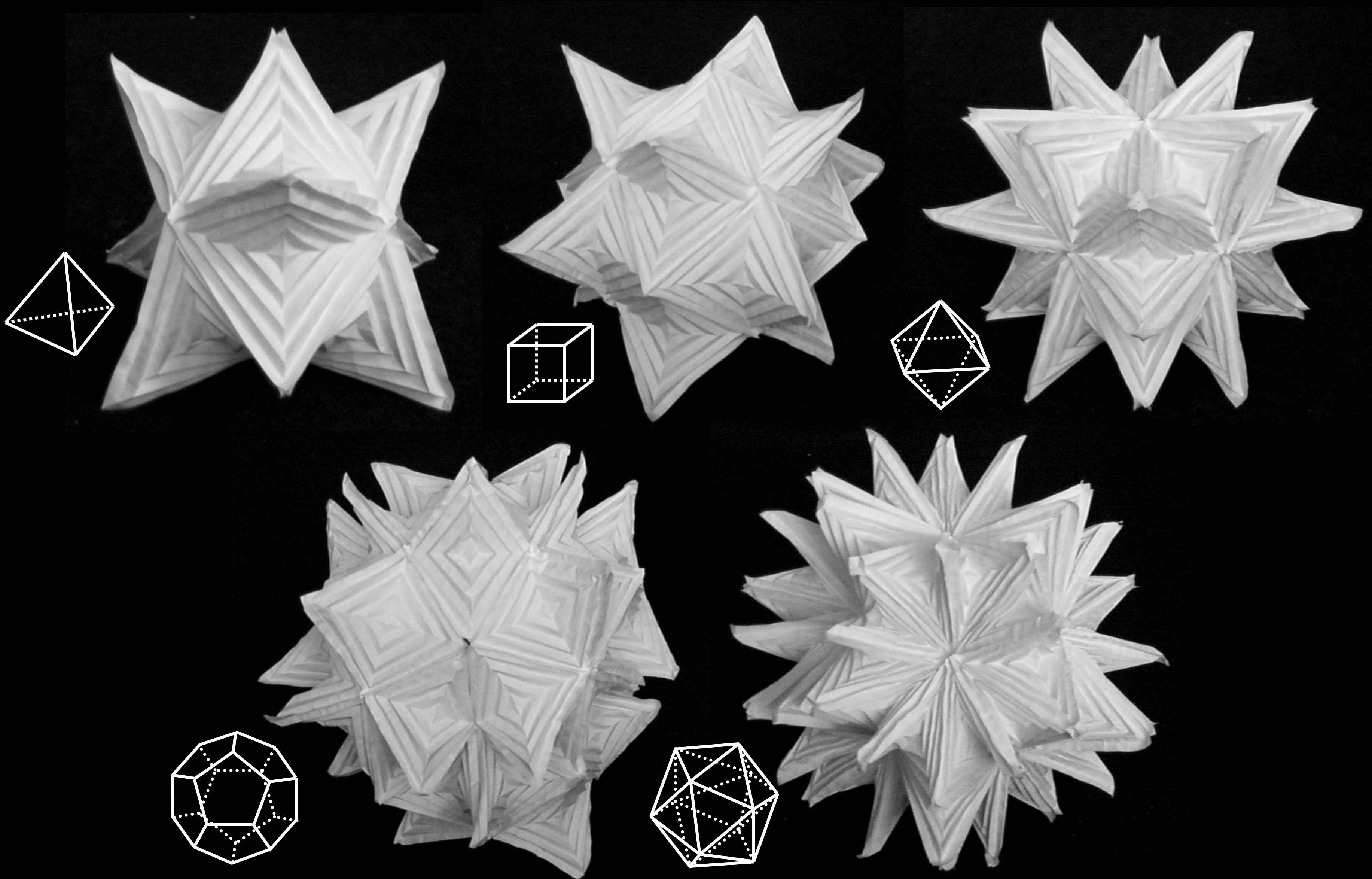
c
Students in Albers's preliminary course: paper study. 1927–28. The dome-shaped structure evolves from a flat sheet of paper by means of cuts which make extension into a dome shape possible.

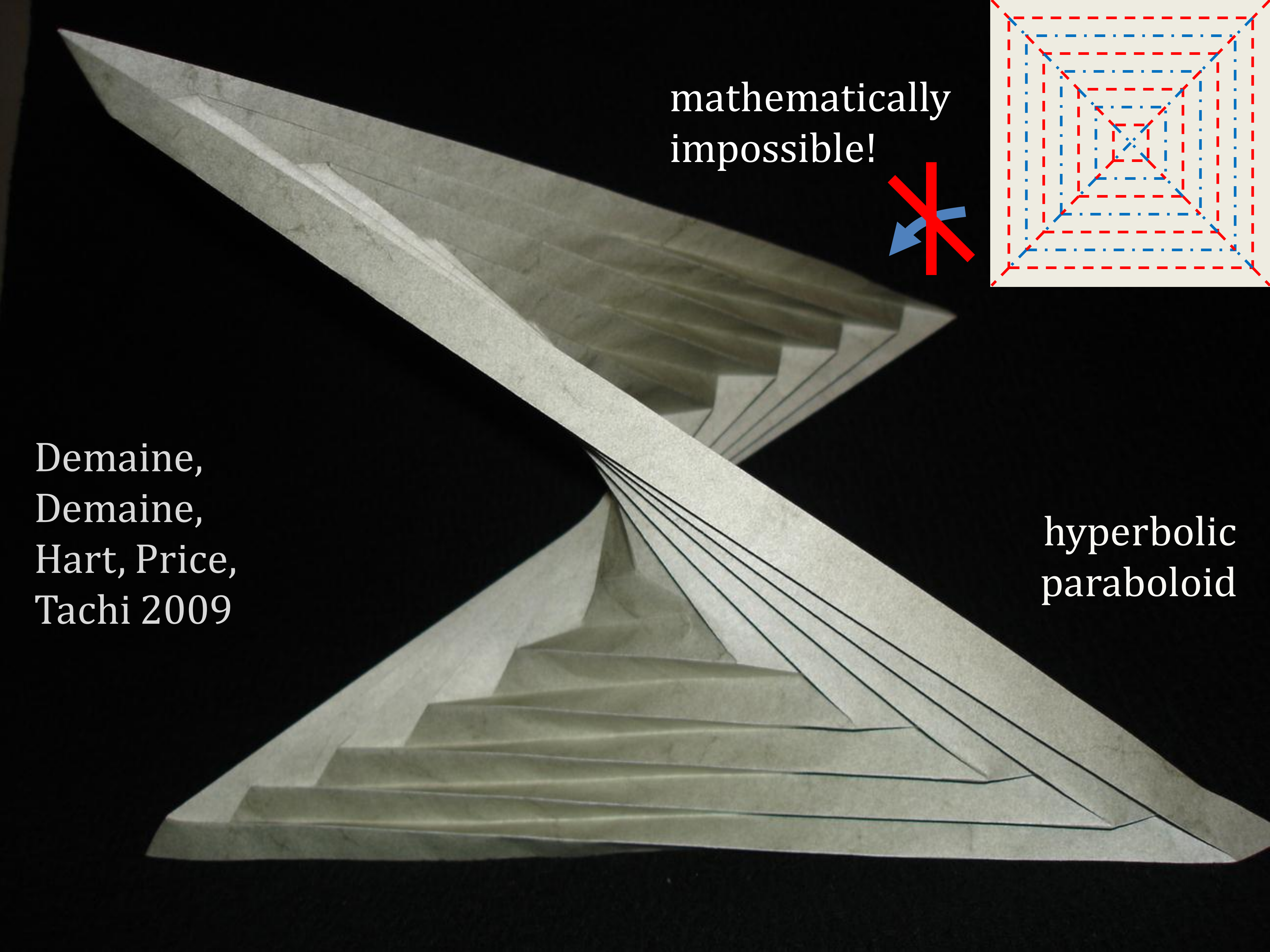
d
Students in Albers's preliminary course: paper studies. 1927–28. Both exercises took advantages of a given material quality: the paper was rolled and tended to remain rolled. The columnar form (left) resulted from cuts. The conic forms (right) derive automatically from cutting two concentric circles out of rolled paper.

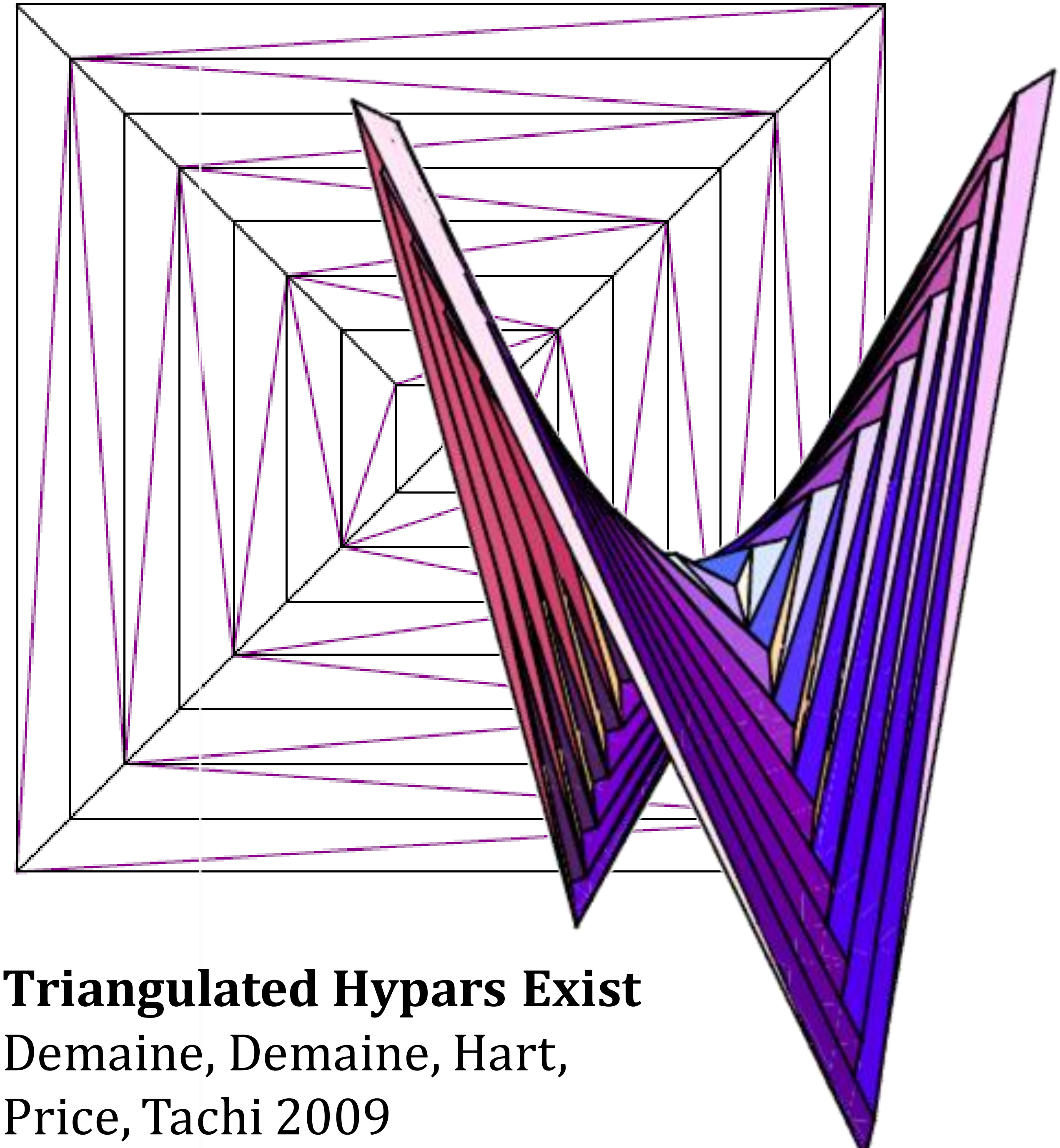
e
Students in Albers's preliminary course: studies with paper and acetate. 1927–28. Various zigzag folds—fundamental exercises. Two-dimensional shrinkage is one result of such folds in the case of flat structures. Two of these structures are made of paper; the transparent one in center foreground is made of acetate. Iridescent colors in the corners of the acetate structure indicate areas of especially high tension. The camera bellows (upper right) is the result of zigzag folds in a single direction. The corners were so rounded off that only a single overlap resulted; bevels were not permitted because otherwise the specific qualities of a camera bellows, light and air impermeability, would not be achieved. The task of constructing a camera bellows was assigned by Albers to every student; the student had to solve it entirely independently. No technical explanations were given.

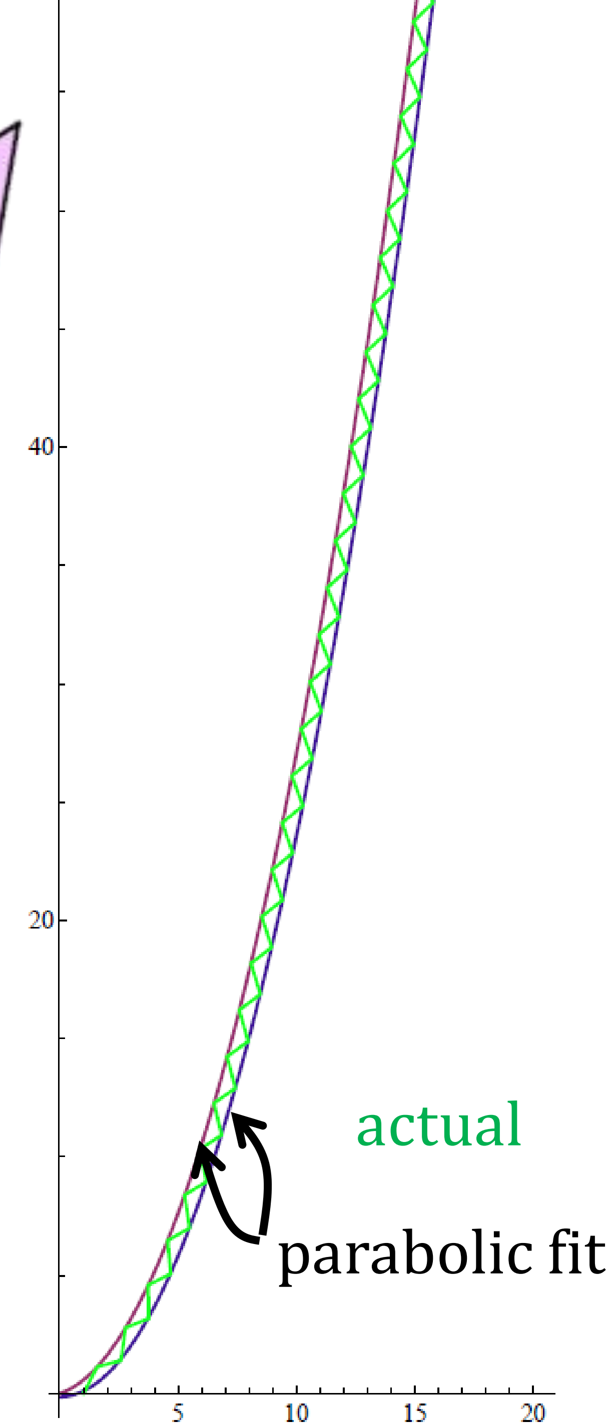
Hyparhedra: Platonic Solids

[Demaine, Demaine, Lubiw 1999]



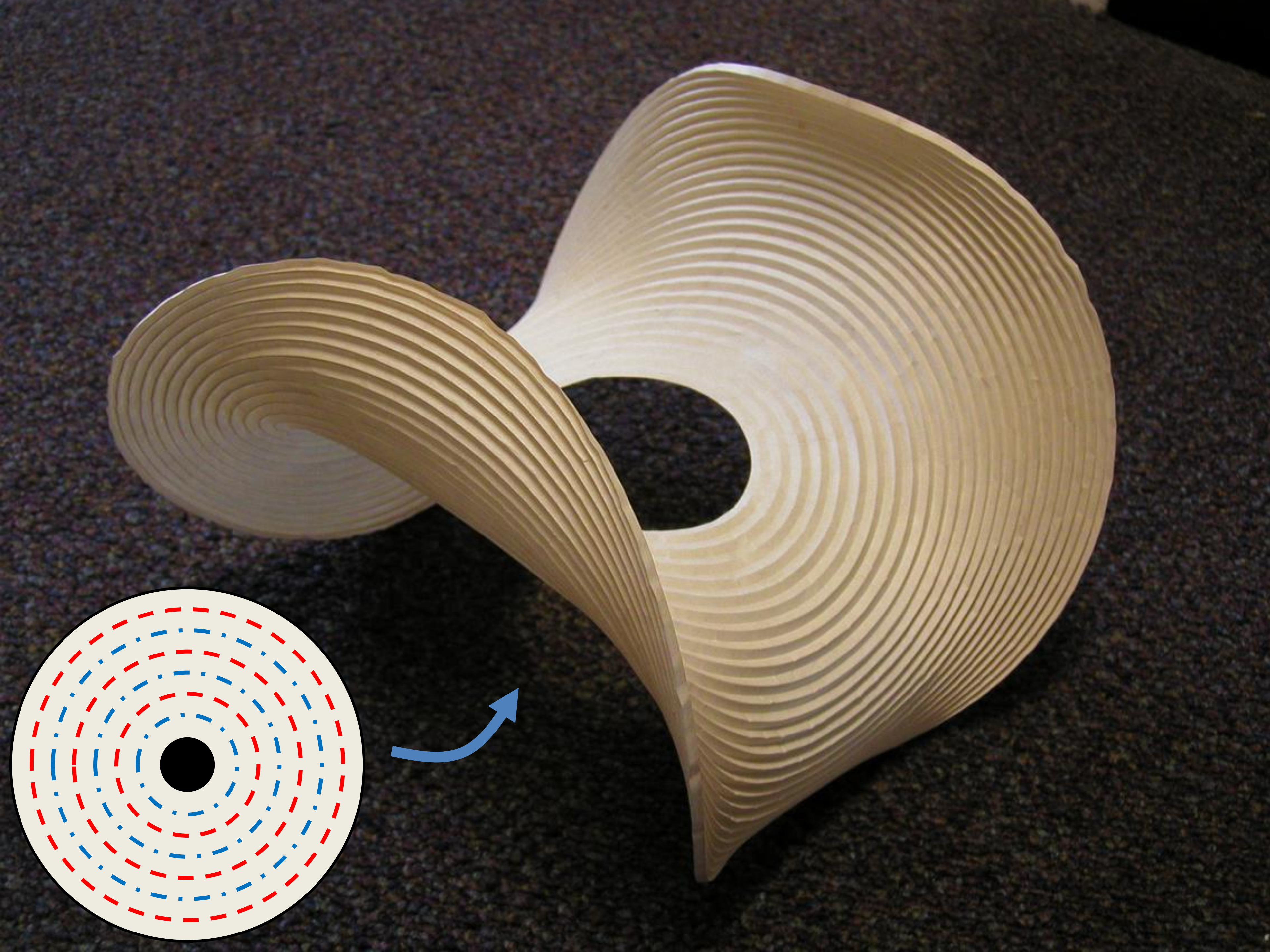

mathematically
impossible!
Demaine,
Demaine,
Hart, Price,
Tachi 2009
hyperbolic
paraboloid

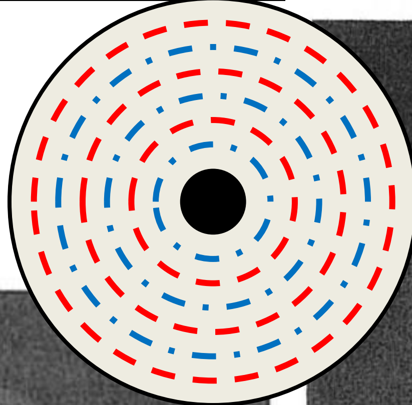


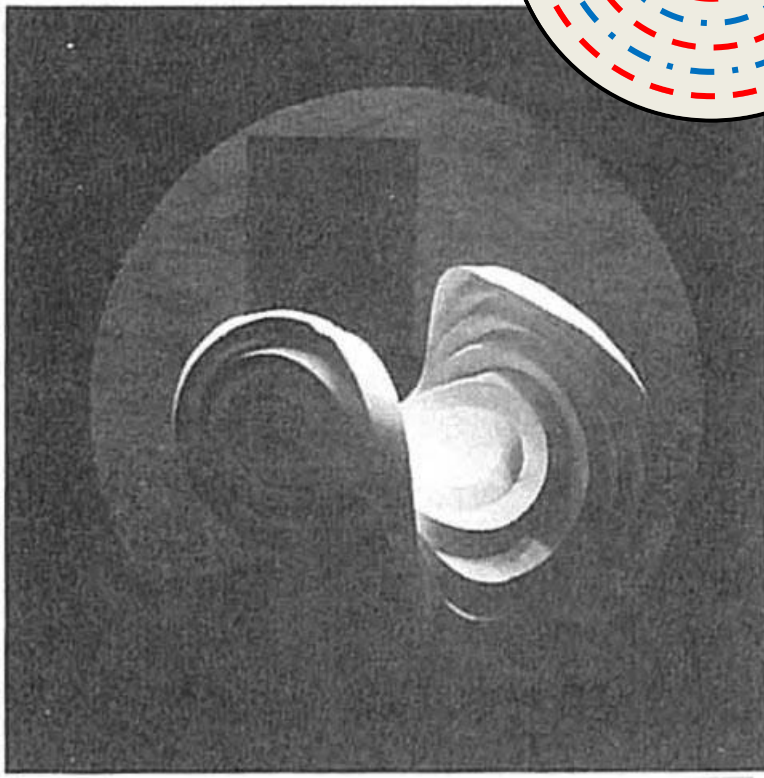


Triangulated Hypars Exist

Demaine, Demaine, Hart,
Price, Tachi 2009

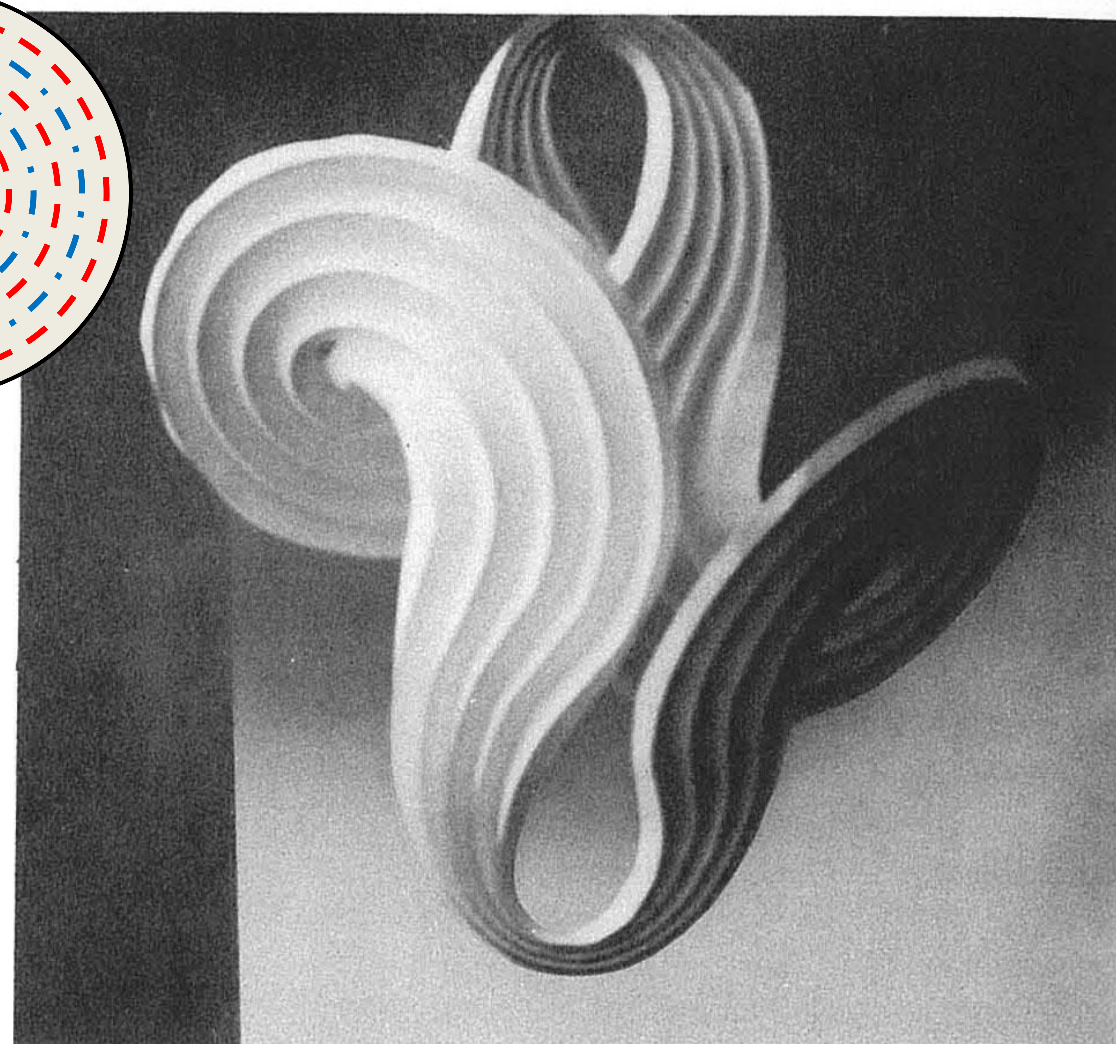






a

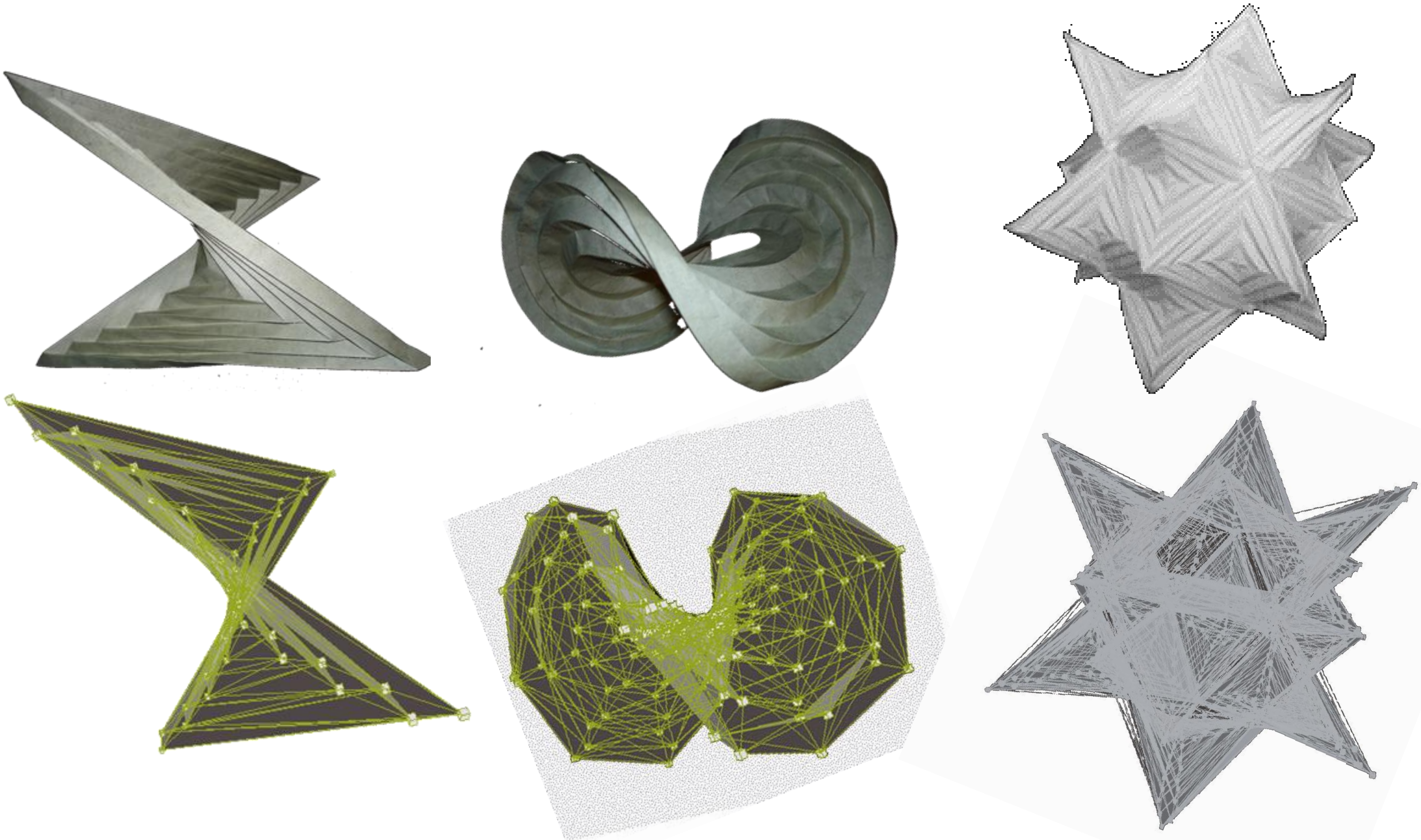
Student in Albers's preliminary course: paper study. 1927–28. The shape results automatically; it is the result of back-and-forth folds in concentric circles. One special feature of this form is its mobility. The development of the curve form is of special pedagogic value, because it provides the student with unexpected revelations concerning the material and the construction principles.

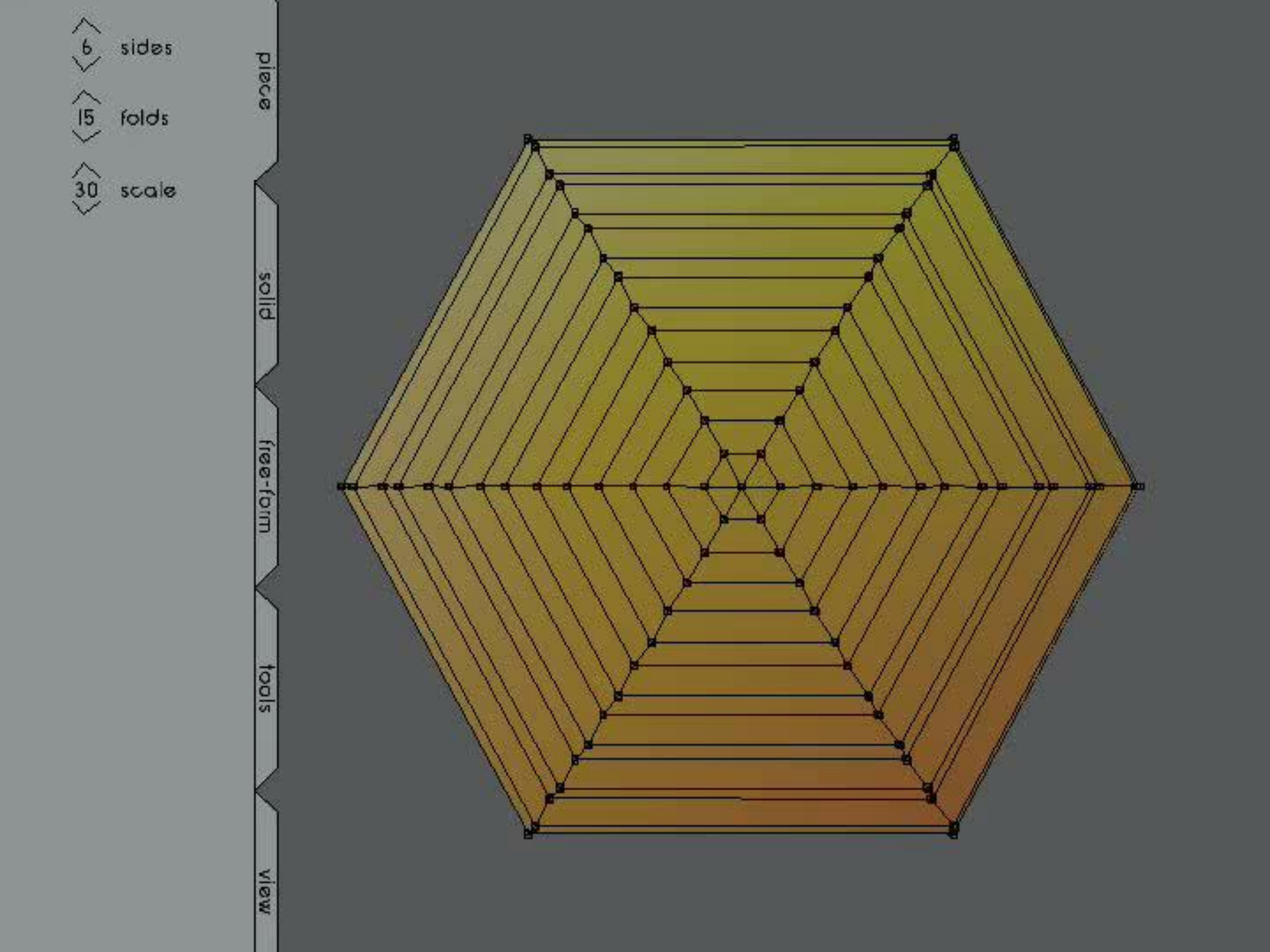


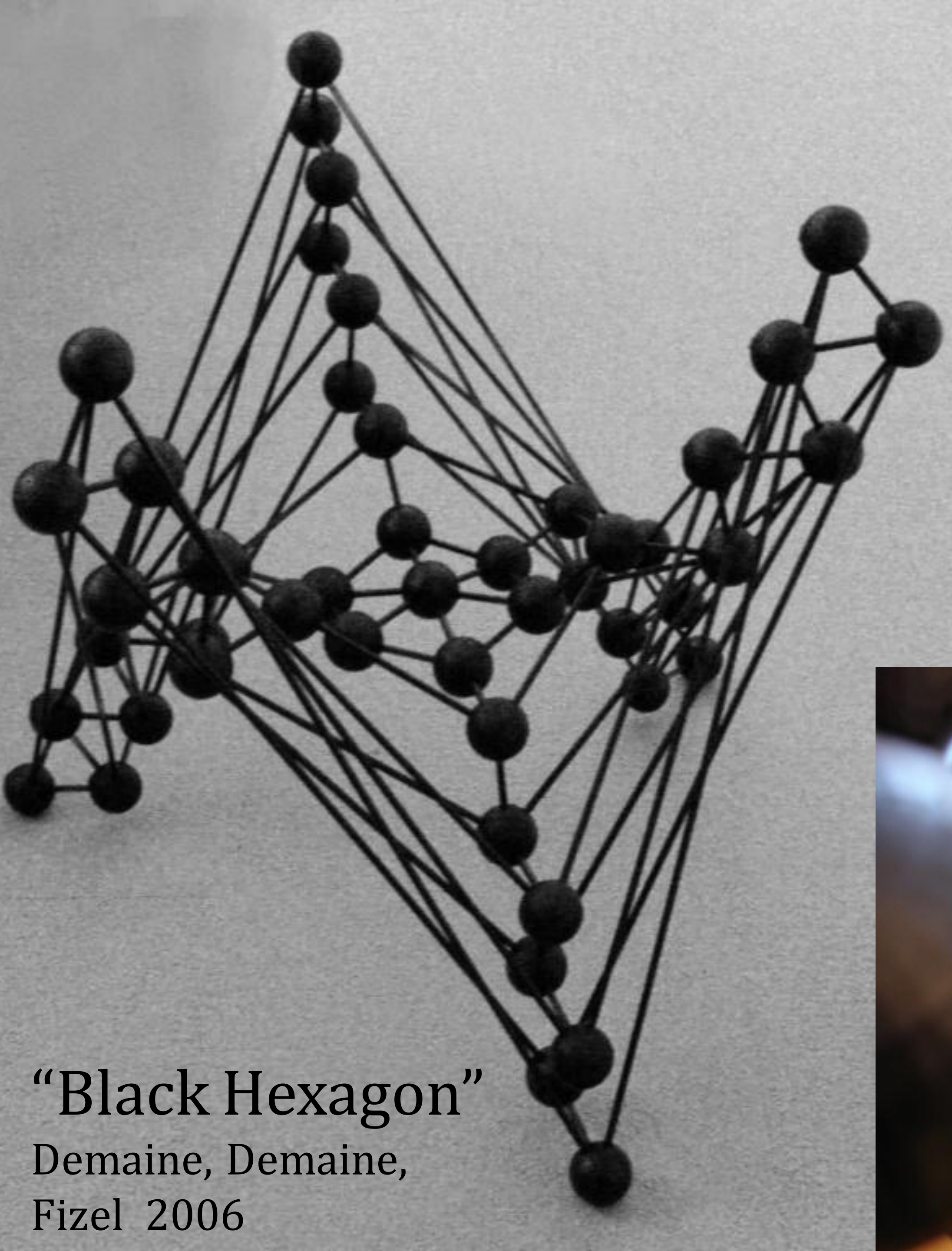
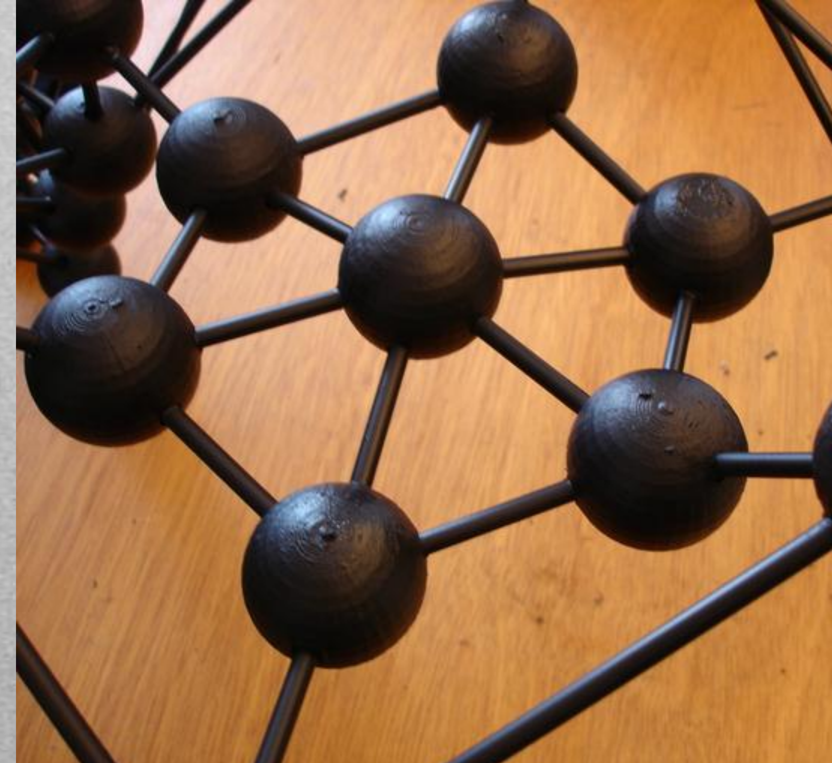
A paper sculpture abstraction by Irene Shawinsky. Photo from the Museum of Modern Art. This piece, over a yard wide, was made by cutting a "doughnut" from a very large sheet of white paper, scoring it in concentric lines, accordion-pleating it, and hanging it from wires so that it would take these convolutions of its own weight.

Virtual Origami

[Demaine, Demaine, Fizel, Ochsendorf 2006]




6 sides
15 folds
30 scale
piece
solid
free-form
tools
view


“Black Hexagon”
Demaine, Demaine,
Fizel 2006

“Computational Origami”
Erik & Martin Demaine
MoMA, 2013–2014

Elephant hide paper
~9”x15”x7”

Curved Crease Sculpture

Erik & Martin Demaine

Renwick Gallery,
Smithsonian
American Art
Museum, 2012

Feb.–Apr., 2012
Brockton, Mass.

fullerCRAFT museum™

Demaine &
Demaine
2011

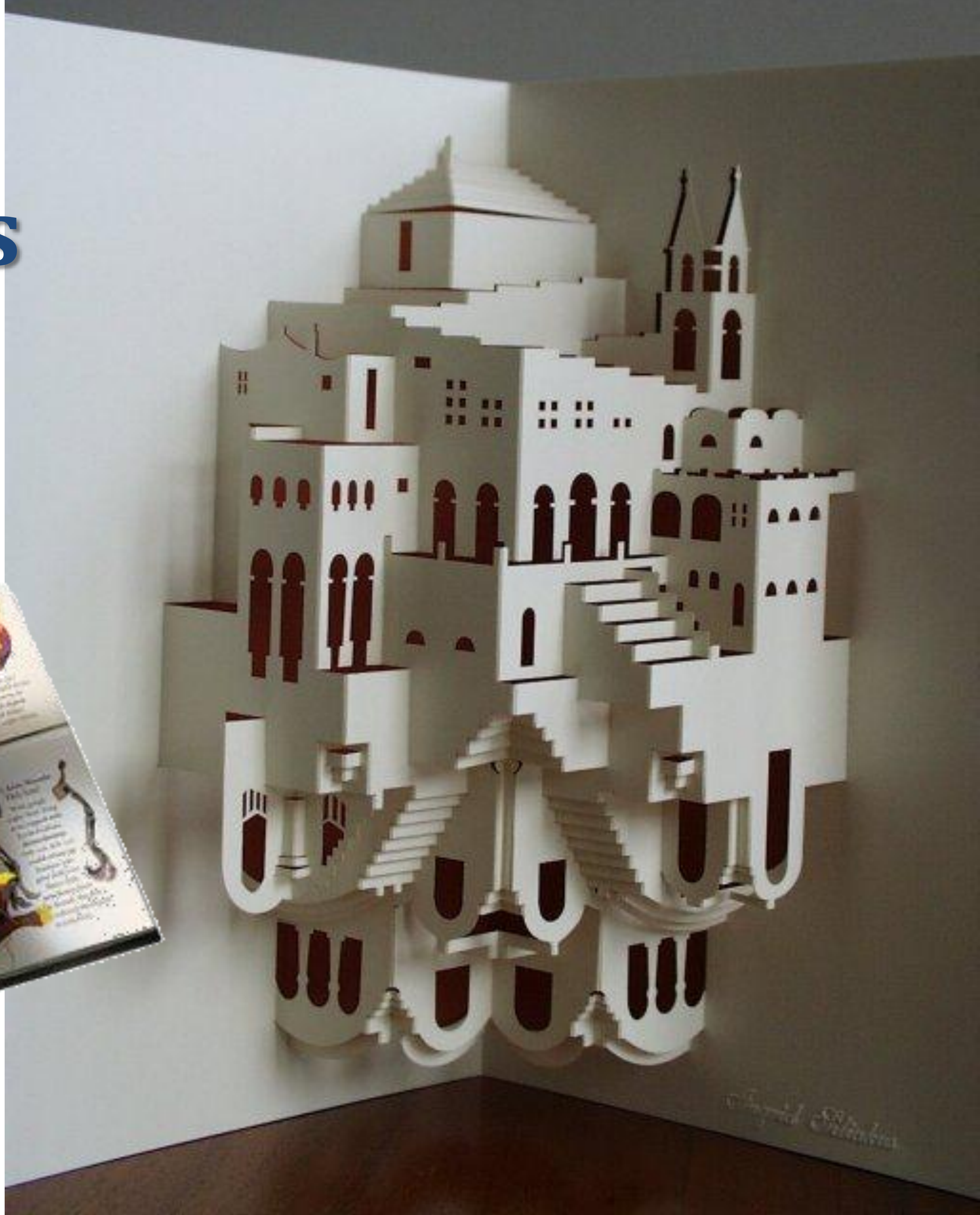
Guided By Invoices
Chelsea, New York
Jan.–Mar., 2012

Earthtone Series
Demaine & Demaine
2012

Simons Gallery
Stony Brook, NY
July–Aug., 2012

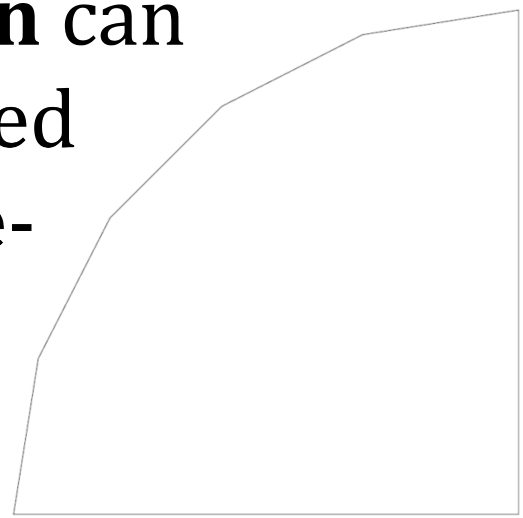
Ocean Series
Demaine &
Demaine, 2012

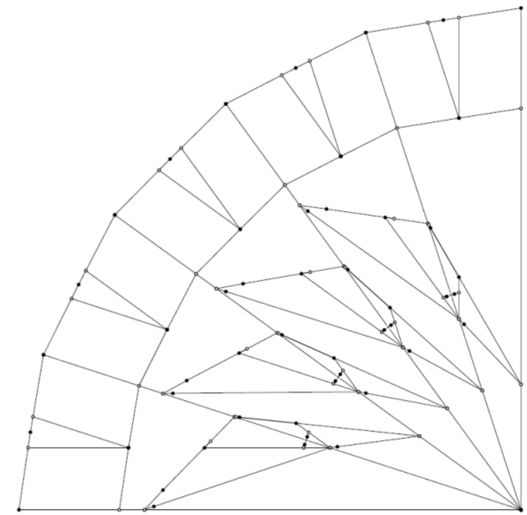
Popup Books/Cards

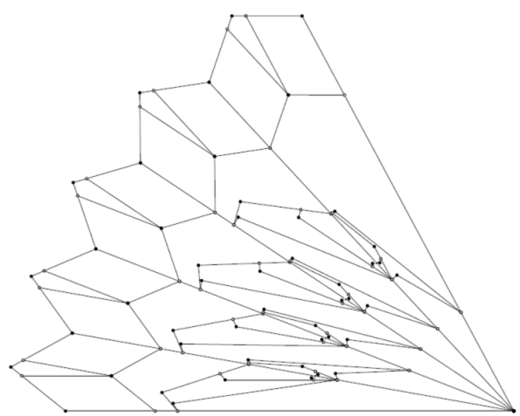


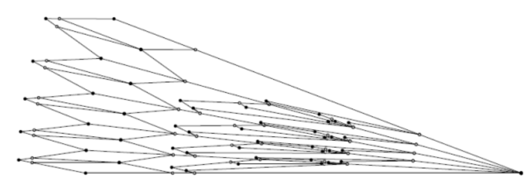
Popups [Abel, Demaine, Demaine, Eisenstat, Lubiw, Schulz, Souvaine, Viglietta, Winslow 2013]

- Any **polygon** can be subdivided into a single-degree-of-freedom popup, with specified target angle



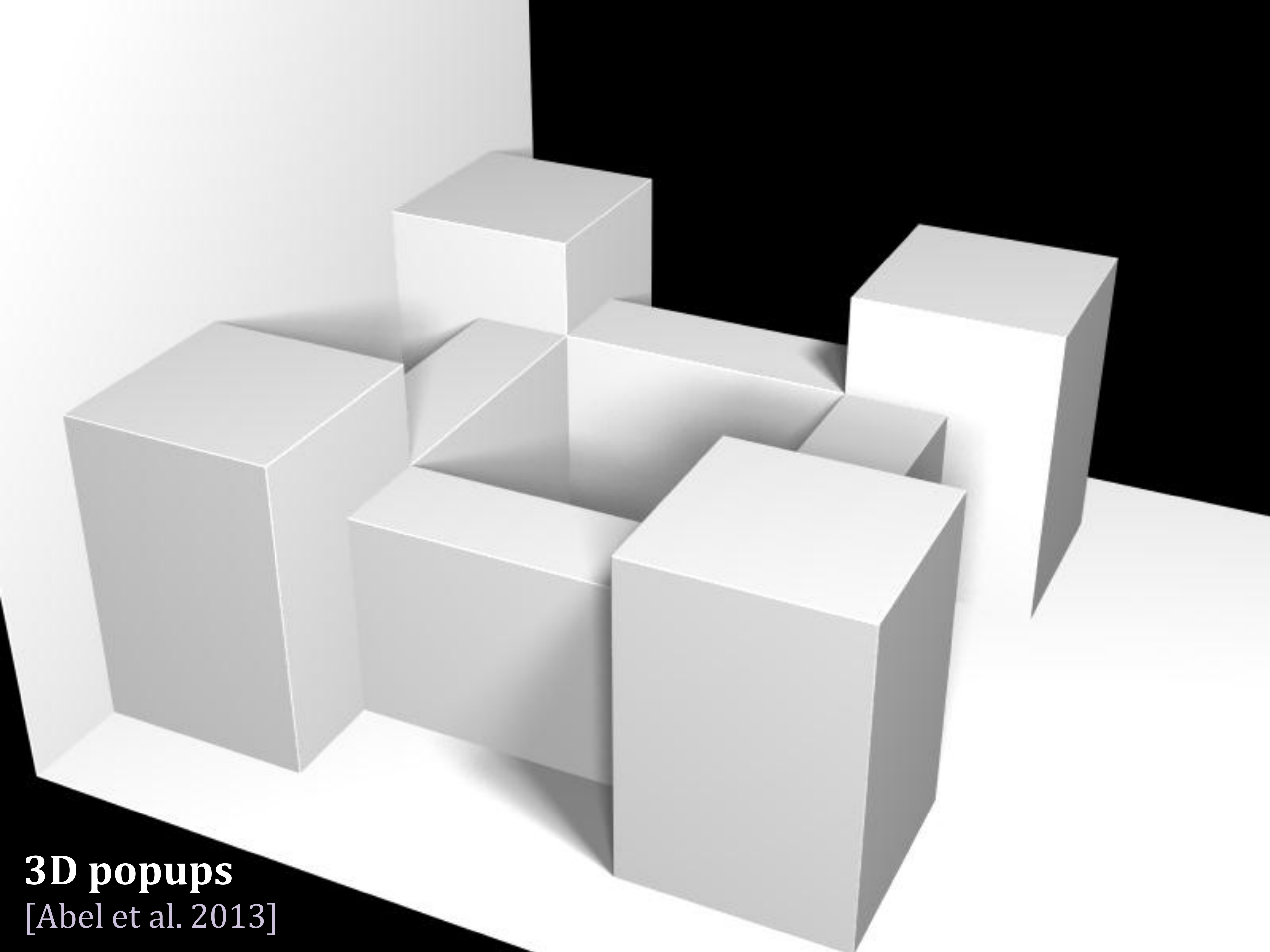






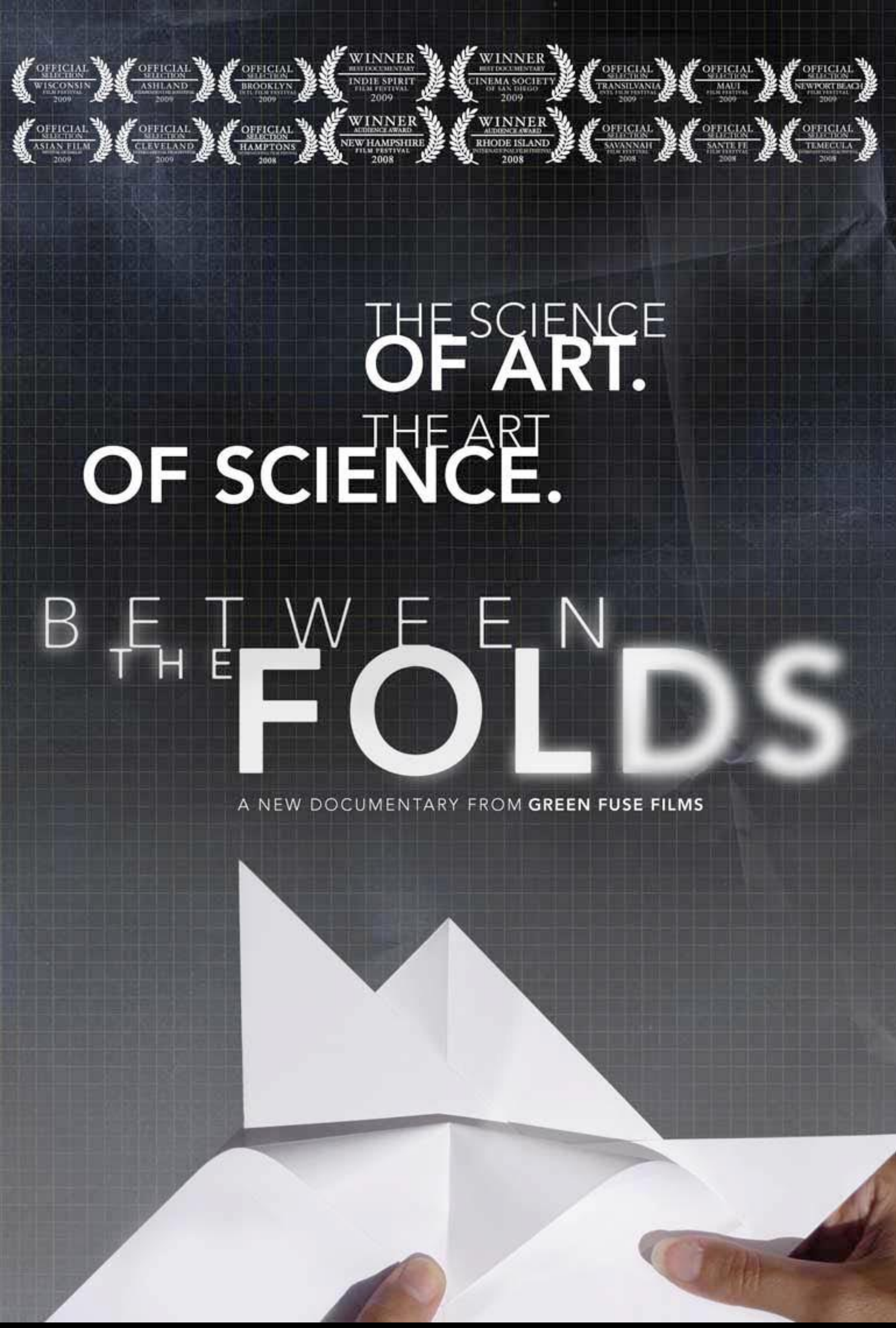
Popups [Abel, Demaine, Demaine, Eisenstat, Lubiw, Schulz, Souvaine, Viglietta, Winslow 2013]

- Any **polygon** can be subdivided into a single-degree-of-freedom popup, with specified target angle



3D popups
[Abel et al. 2013]

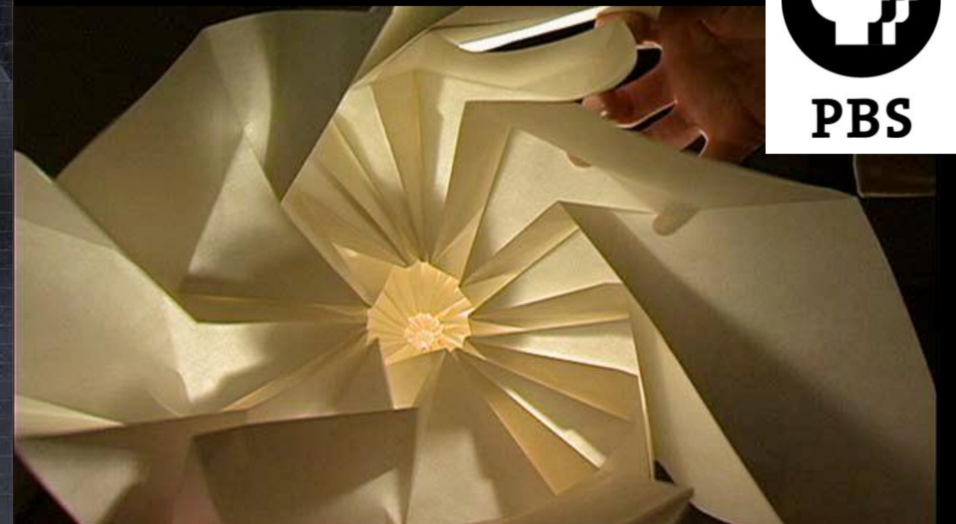
Hydro-Fold [Christophe Guberan 2012]

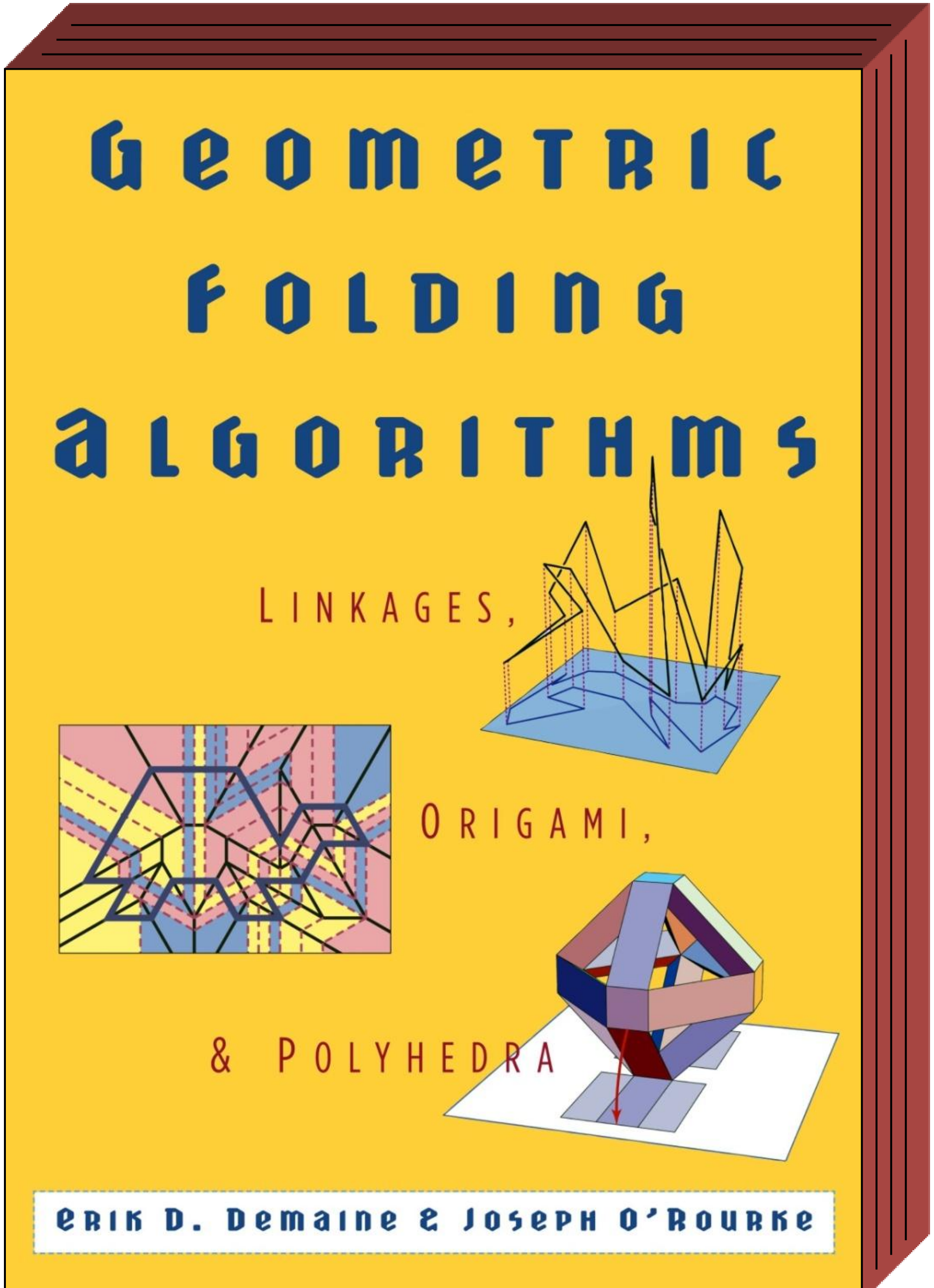


green fuse films

[i]NDEPENDENTLENS

PBS

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