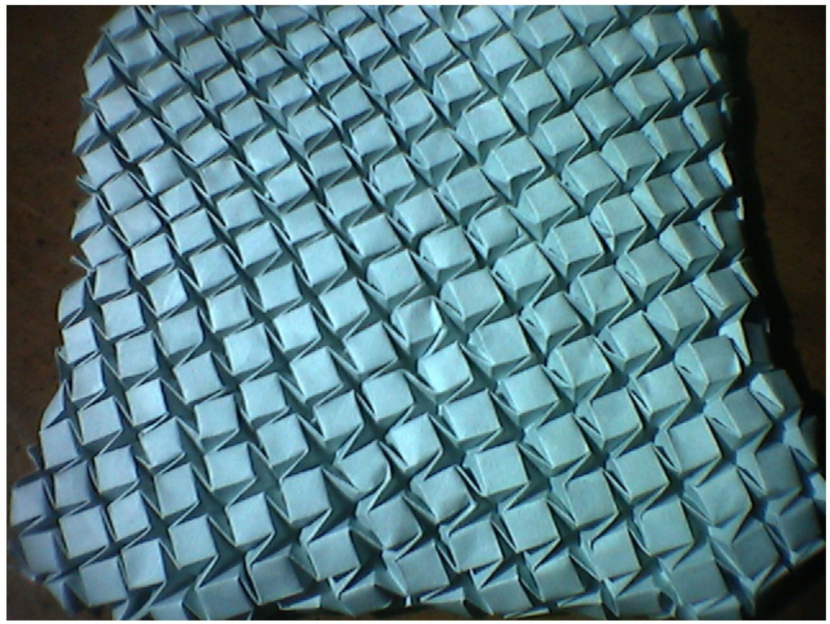
Self-Folding Membranes



Galen T. Pickett
Physics and Astronomy
CSU Long Beach

- **Folded structures**

- **Proteins... knots.**
- **Membranes**

http://cellbio.utmb.edu/cellbio/mitoch1.htm

- **Crumples**

Nojima, JSME, 45, 2002, 364

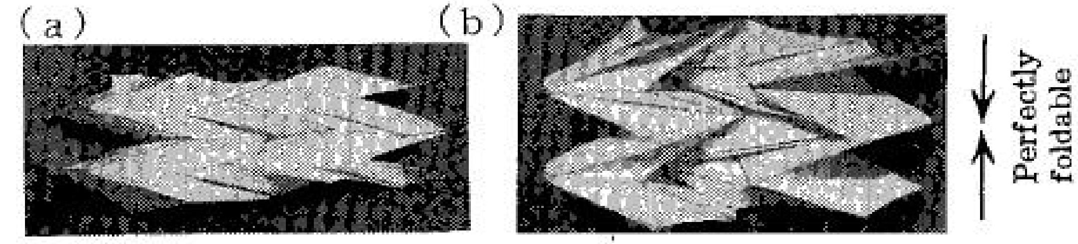


Fig. 4 Appearances of folded samples ((a) and (b) correspond to the fold patterns in Figs. 3(a) and (b))

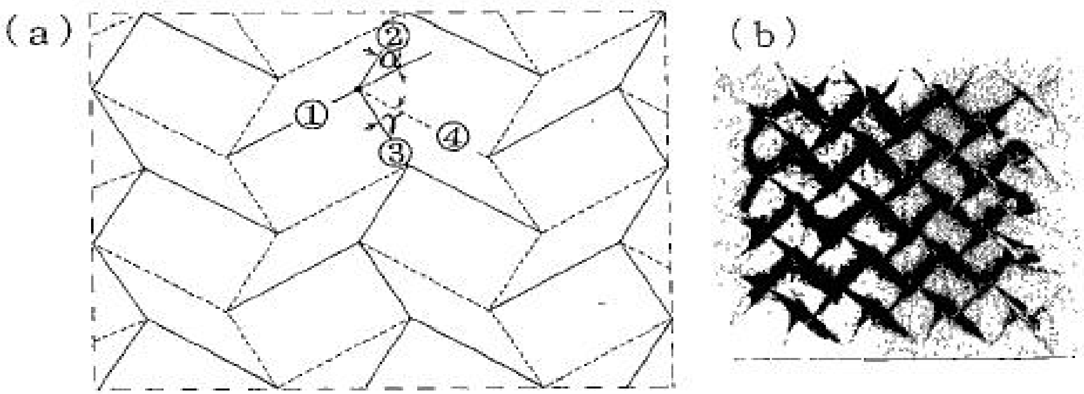
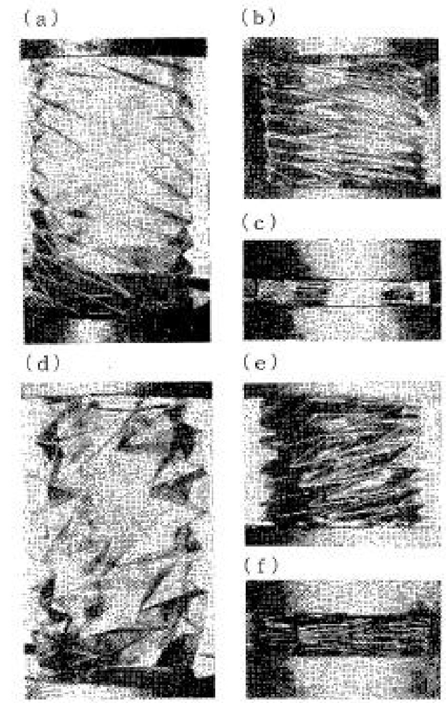


Fig. 5 Zig/zag type 1-4 folding (a), imperfectly folded polypropylene sheet to form a rigider plate (b)

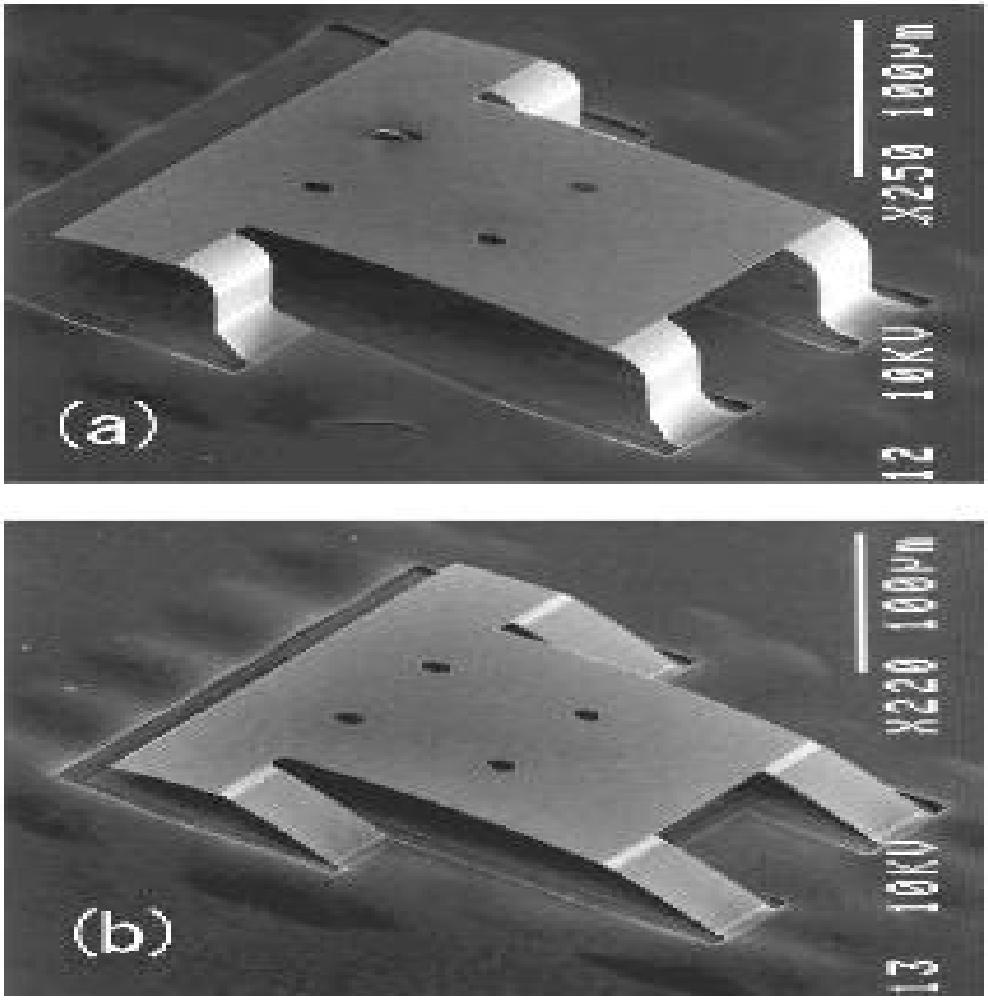


- **Packaging:**

Package designs by Paul Jackson

http://www.origami-artist.com/pages/mainpages/thumbs/images/pjpack10.jpg

● Engineered creases



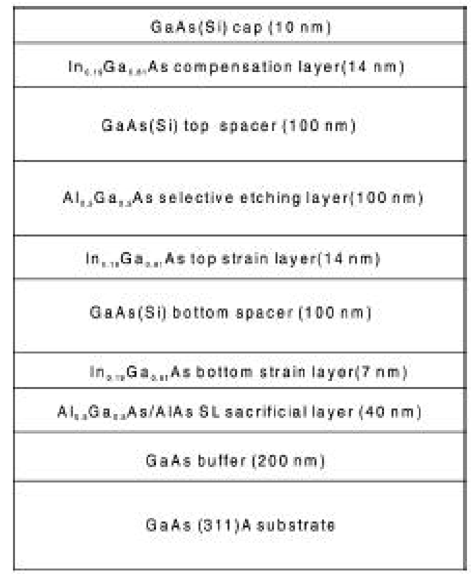
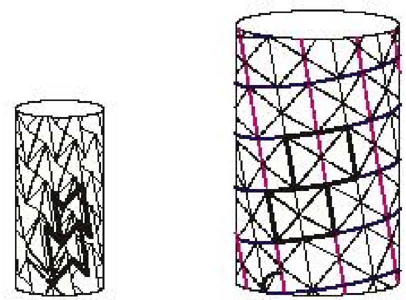


Fig. 1. Cross-section of the epitaxial structure grown by MBE for making valley- and mountain-folds.

- **Engineered origami**

- **Arterial stent:**

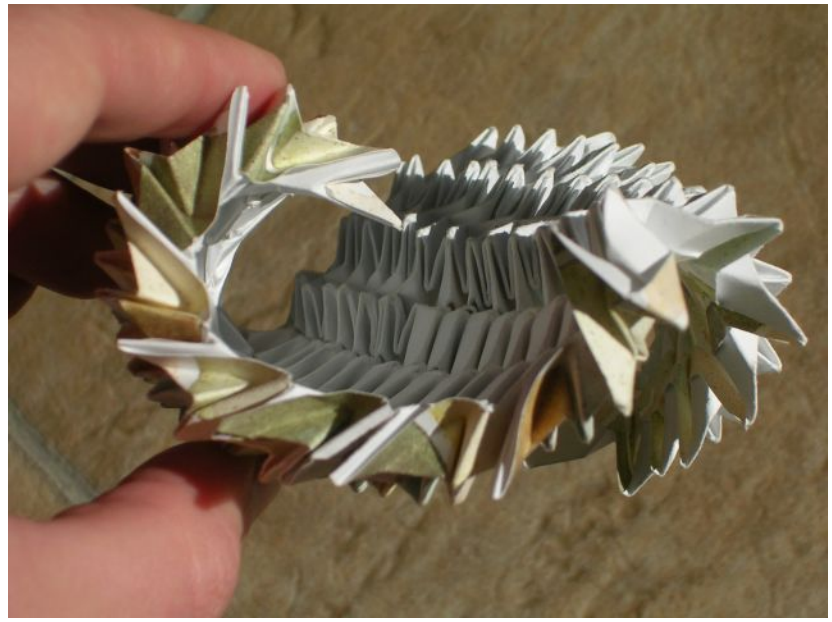
Buckling pattern of a thin-walled tube under torsion.



A origami stent with helical folds when it is folded and fully expanded.

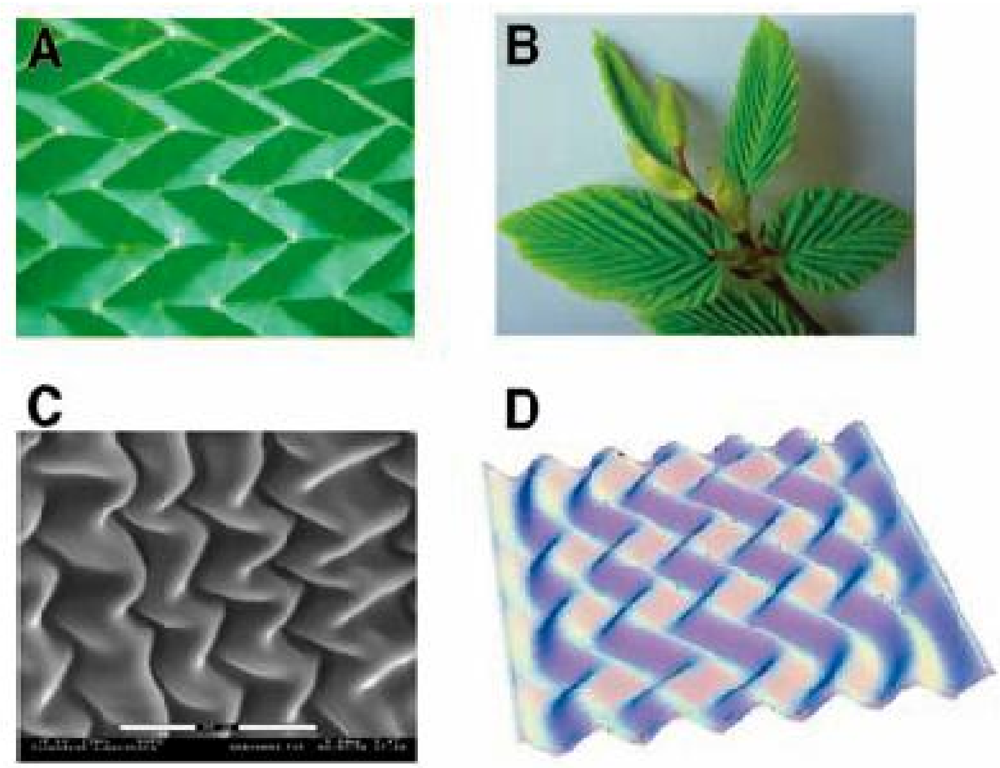
You, Z. and Kuribayashi, K.. A novel origami stent.
Proceedings of the 2003 Summer Bioengineering Conference,
Key Biscayne, FL, USA, June 2003

- **Art:**



- **Local curvature controlled.**

- **Stiff membrane on shrinking substrate**



L. Mahadevan, S. Rica, Science 307 (2005) 1740

Add creases:

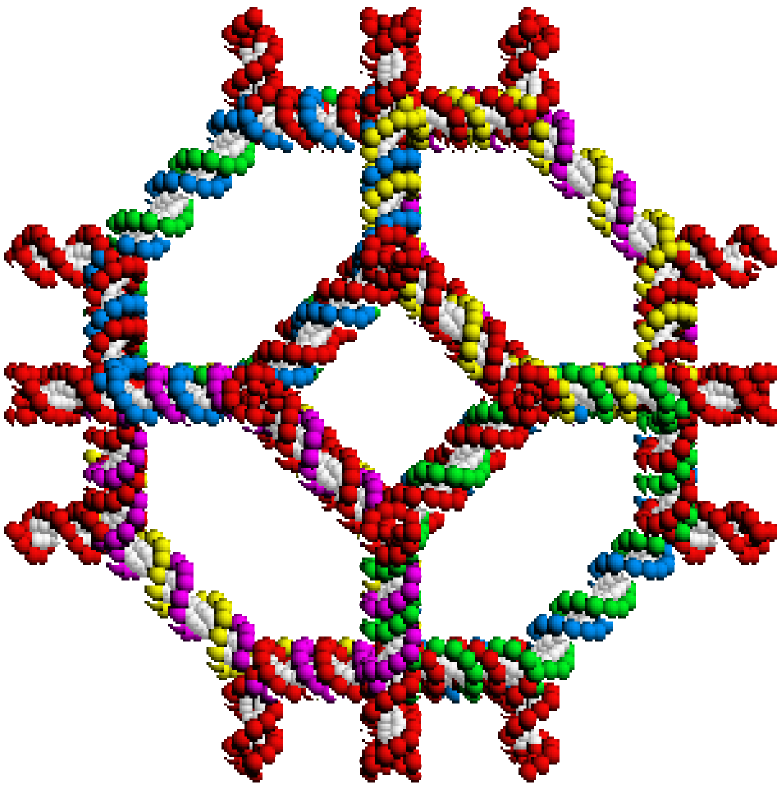
- **Space Engineering**

“Eyeglass”, Robert J. Lang

“Spirit” rover

- **DNA-Origami**

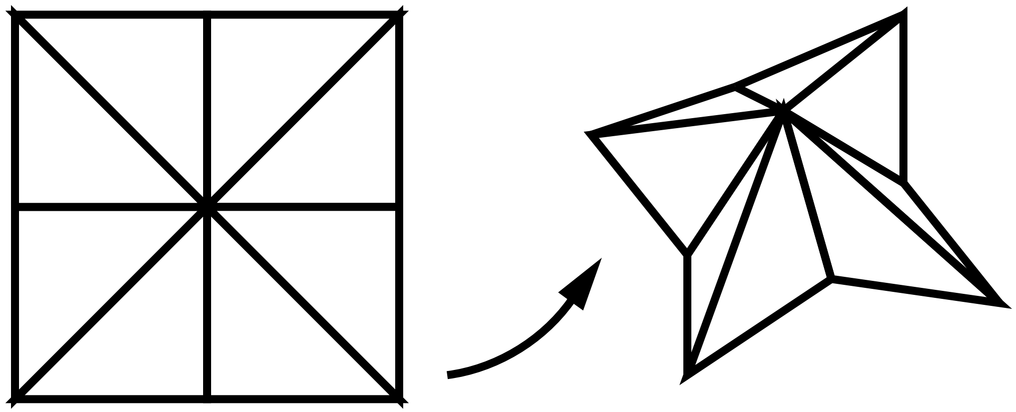
WILLIAM M. SHIH, JOEL D. QUISPE & GERALD F. JOYCE
Nature 427, 618-621 (2004);



Paul Rothemund, Nature Physics, 2006

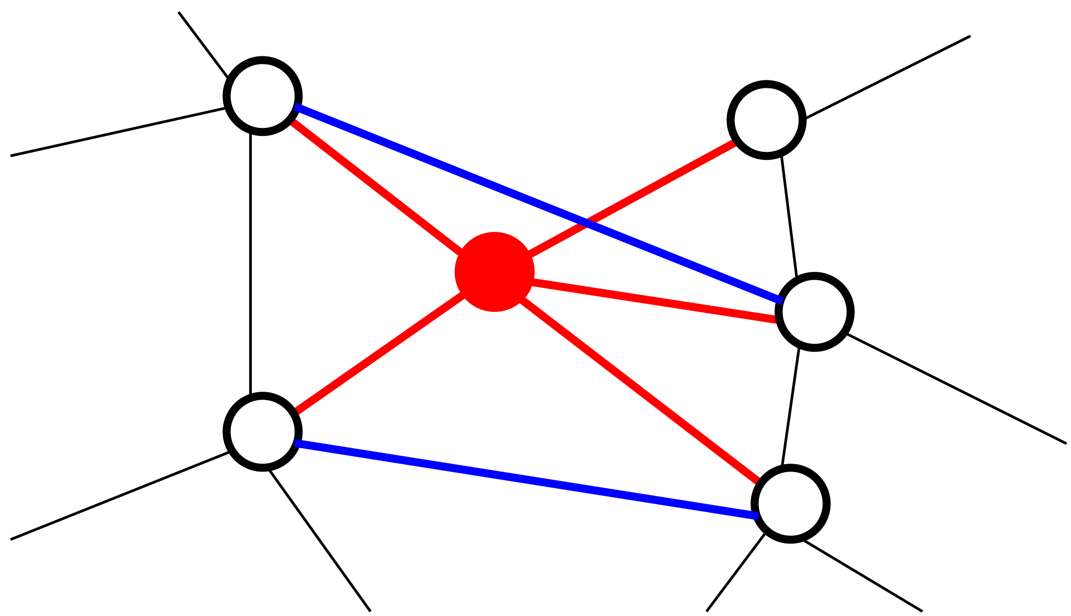
Model

- “Scored” stiff membrane in a poor solvent:



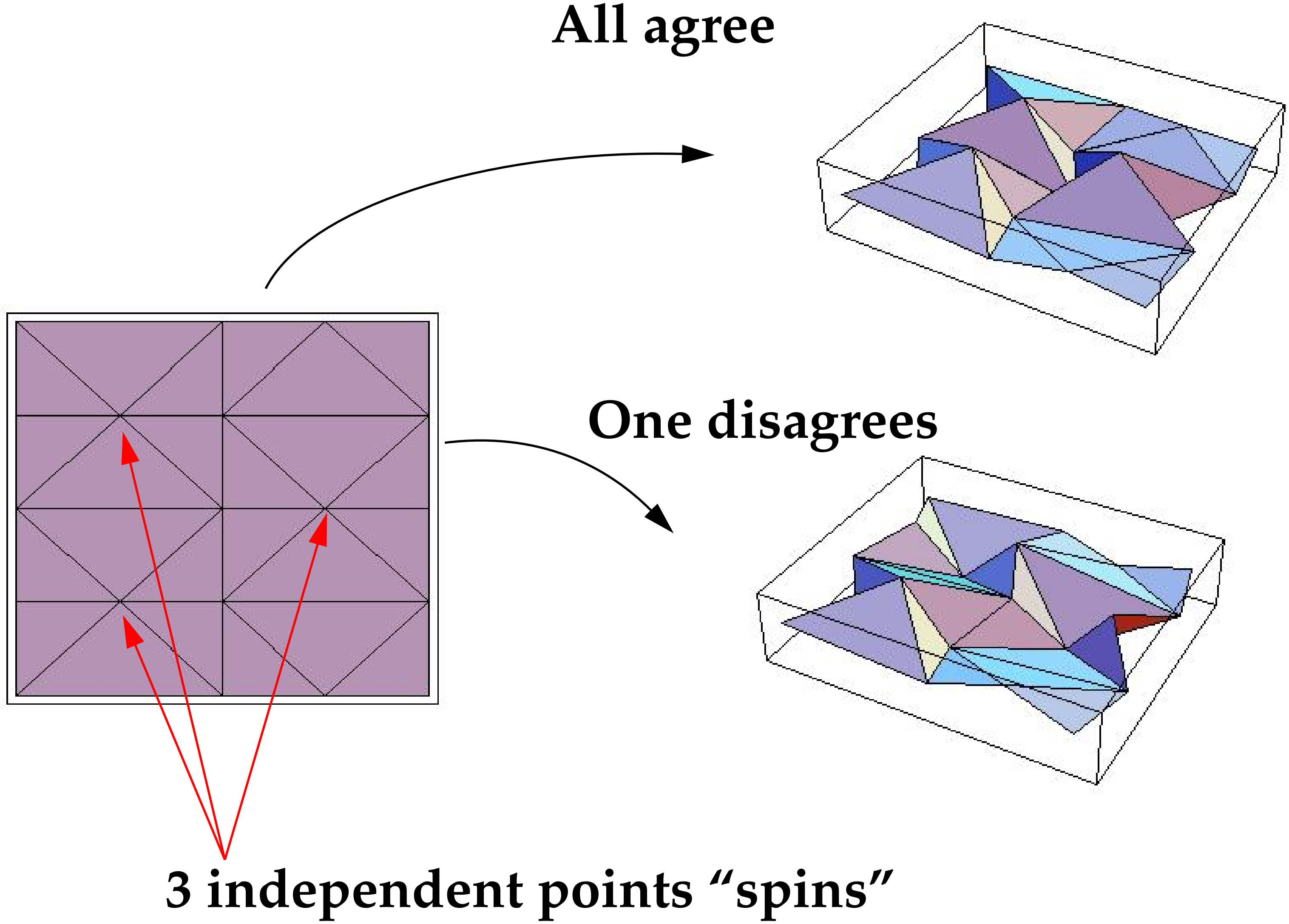
- Rigid plates connected by free joints
- Short ranged attractive forces between plates.
- Simpler to focus on vertices of an effective model

- **Vertex Model**

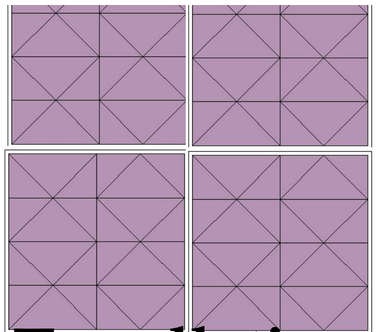


$$\overrightarrow{dr}_i/dt = \overrightarrow{bonds + attractions + noise}$$

- **Structures**

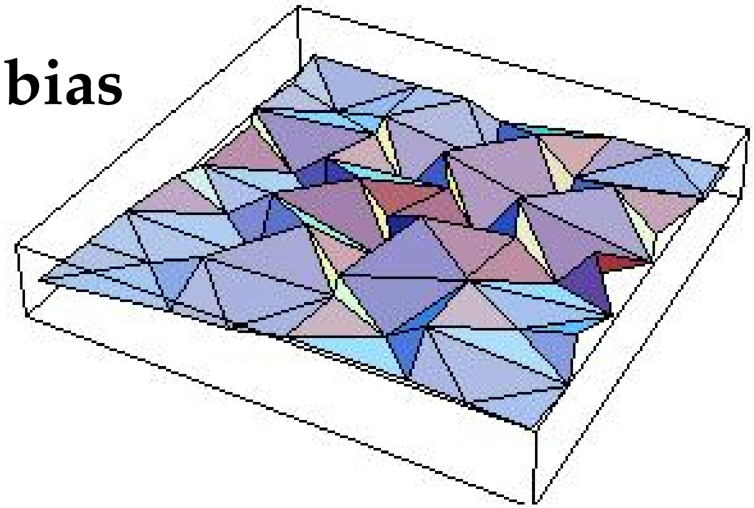


- **Bigger Structures:**

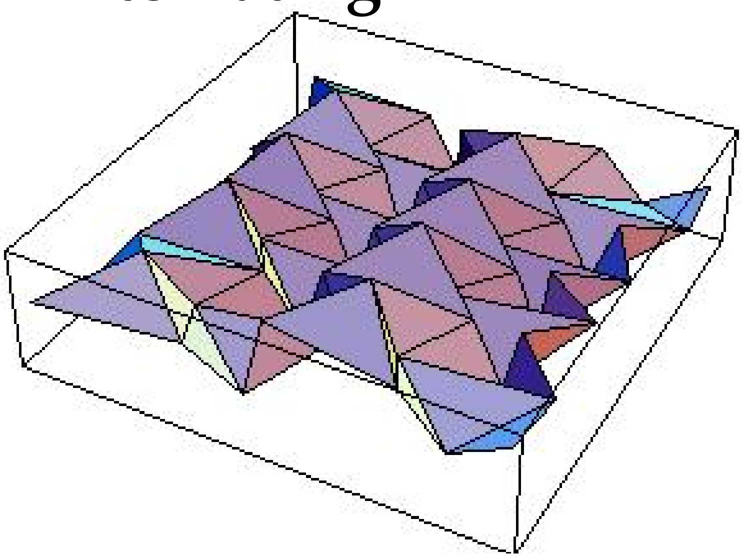


Tessellation of 4 copies

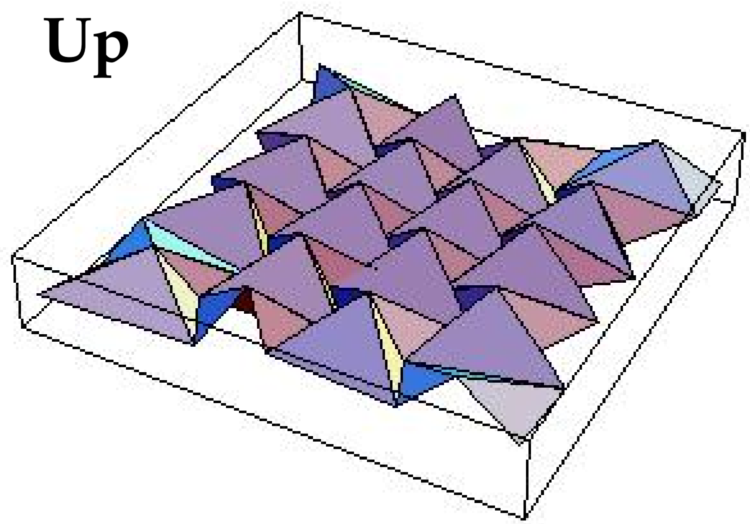
No bias



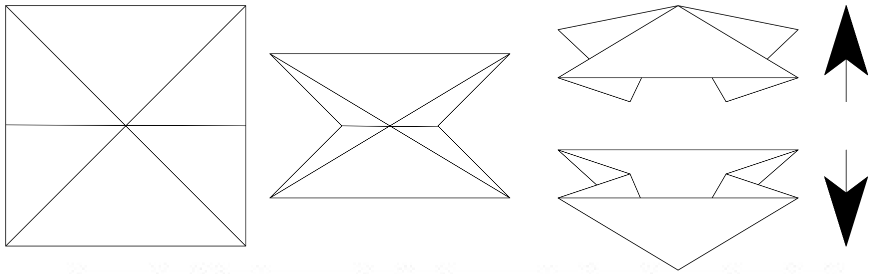
Alternating

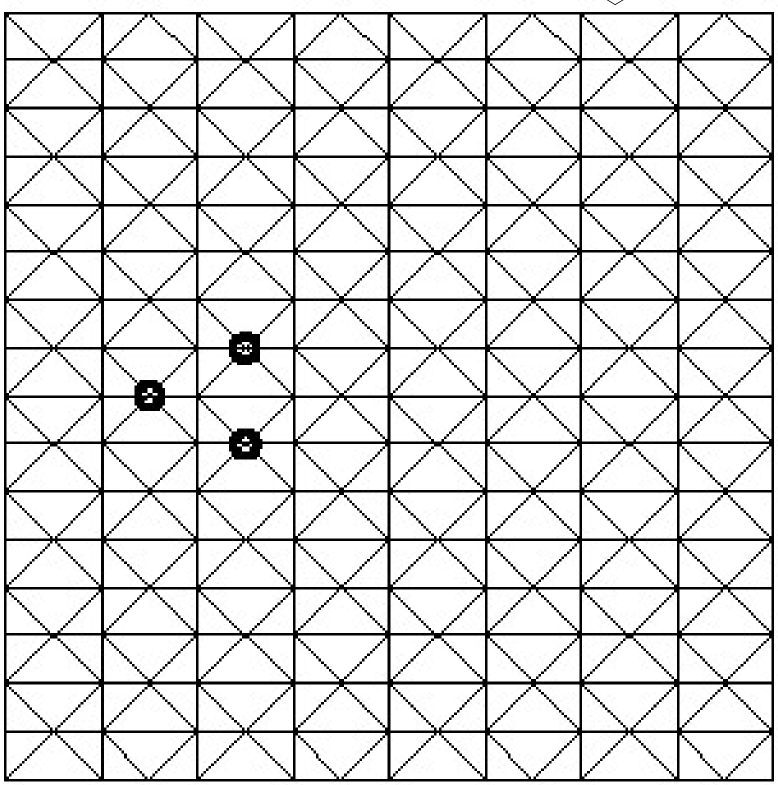


Up

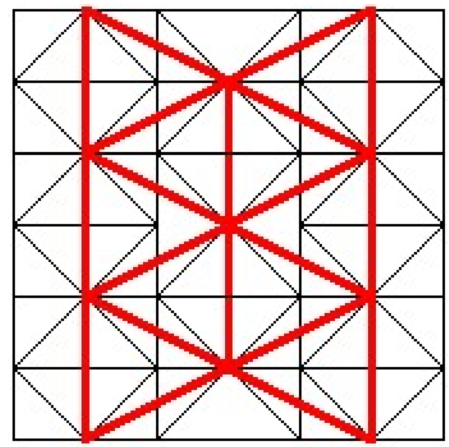


- **Extra Interactions**

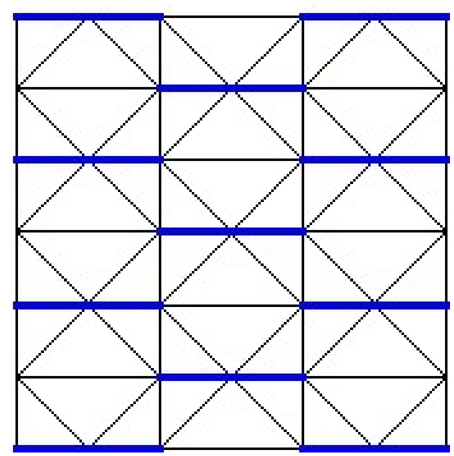




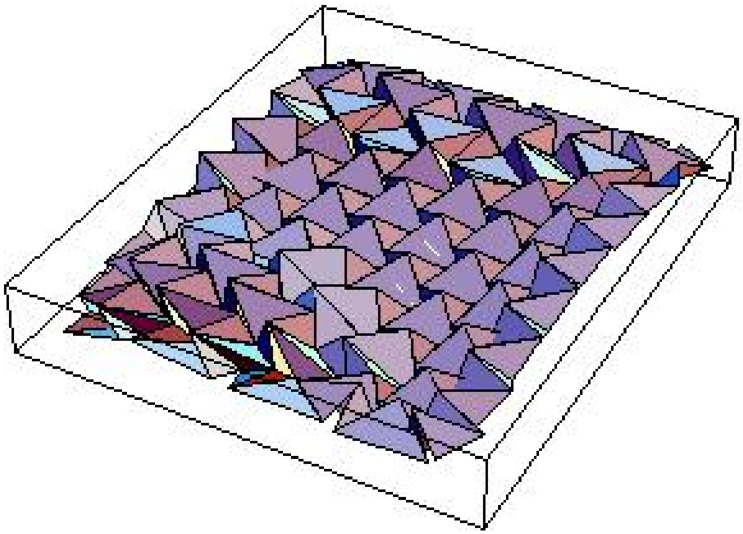
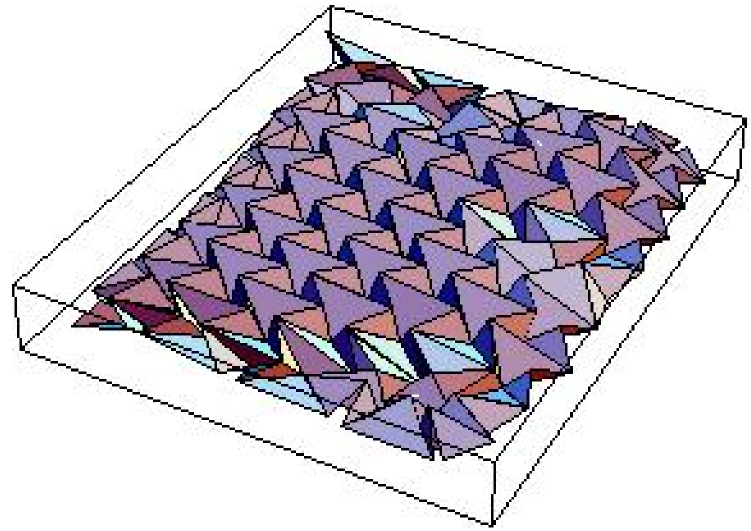
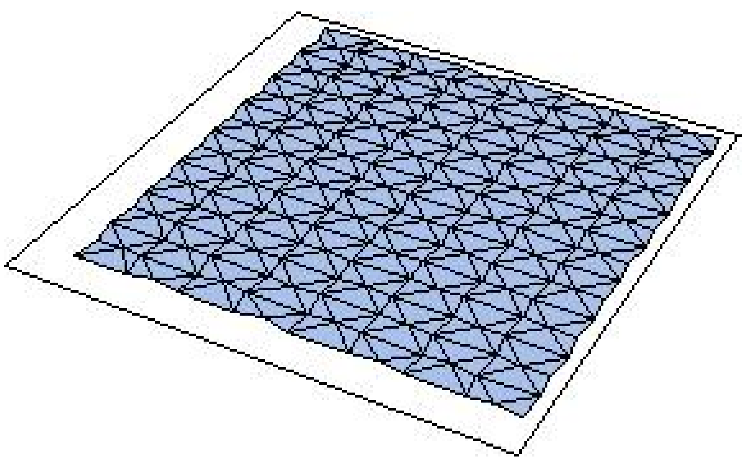
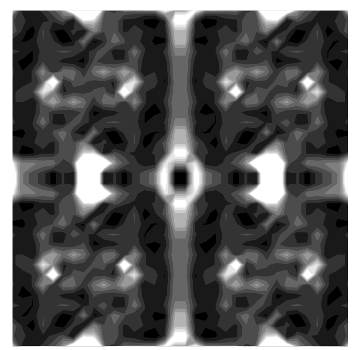
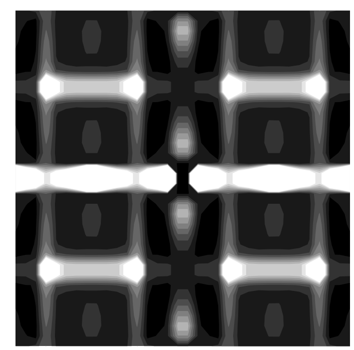
"Bring points together"



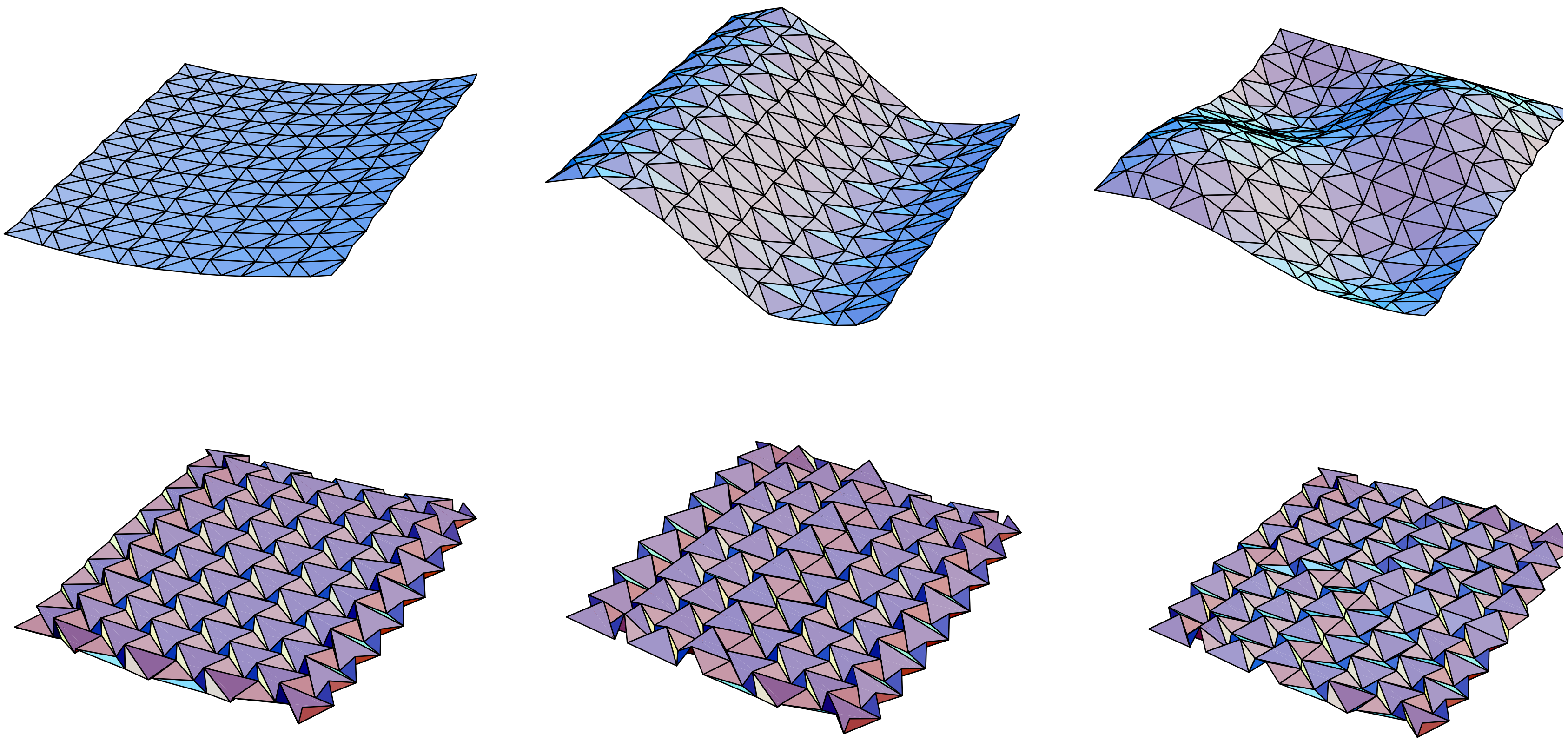
"Collapse waterbombs"



- **Defects, Long-lived flat states.**

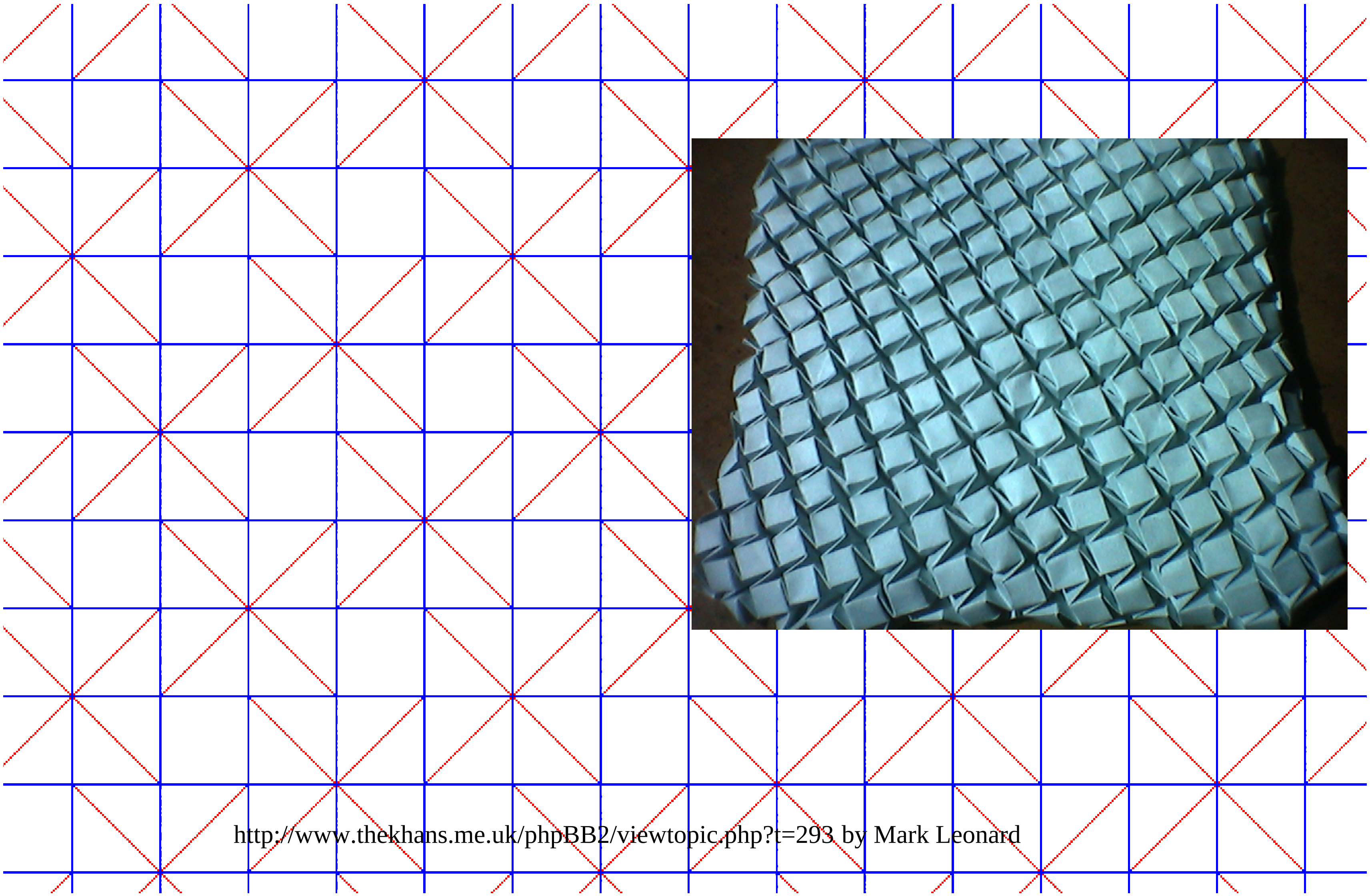






- **Controlled Collapse**



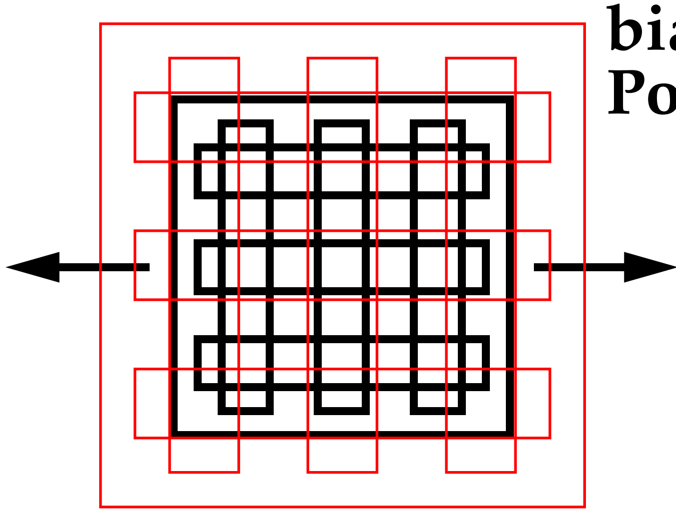
- **Initial curvature controls collapse.**

• Other crease patterns

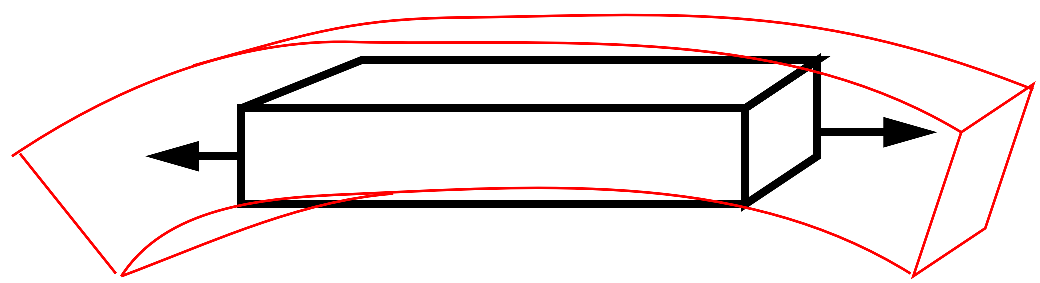


http://www.thekhans.me.uk/phpBB2/viewtopic.php?t=293 by Mark Leonard

- **Mechanical properties of films**



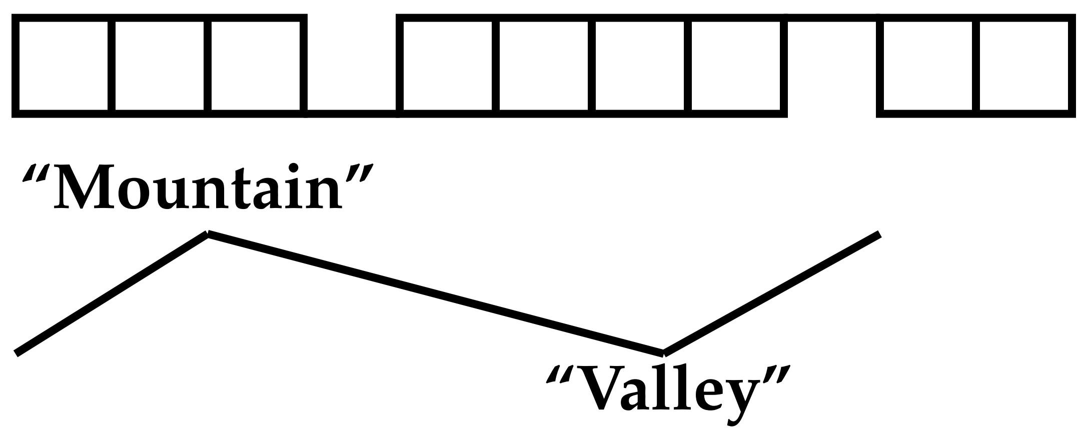
Uniaxial strain, biaxial response: Poisson's Ratio =-1.



Spontaneous traction-induced curvature

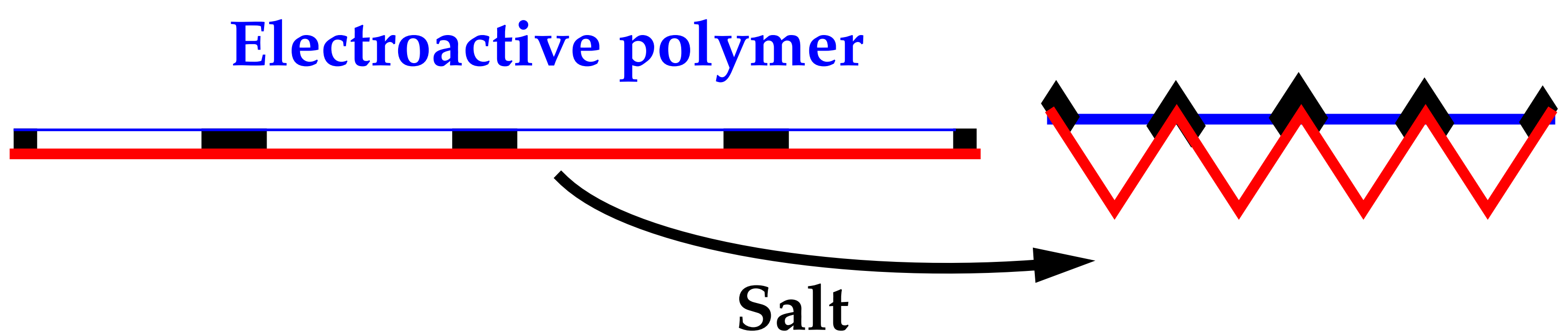
CONCLUSION

- **Scoring can help guide spontaneous folding patterns**
- **Vertex control is key... how to link neighboring vertices.**
- **Give creases “mountain” or “valley” nature**
  - DiDonna: cond-mat/0108312v1:



- **Speculation**

- **Controlled collapse**



- **Perforation**

- **Combine the two ... selective ion pump.**