Bioinspired Morphing structures

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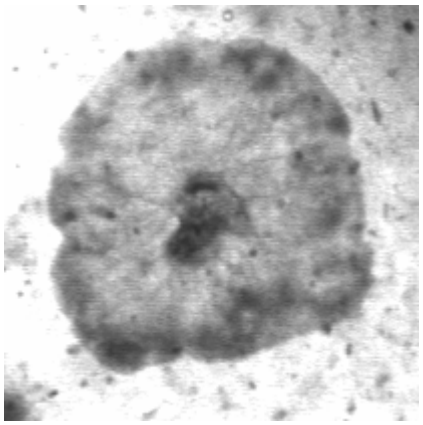
----------Agenda---------

Bat wing folding/unfolding
Plasmodial Slime Mold
Folding of leaves
Flower pedal folding/unfolding
Insect Oclosion
Free-falling of seeds
Design of free-falling UAVs

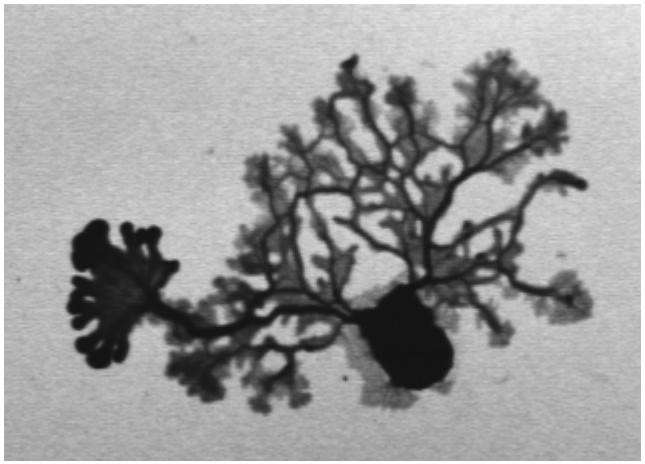
Discussion points

Large morphing of Plasmodial Slime Mold (Physarum Polycephalum)

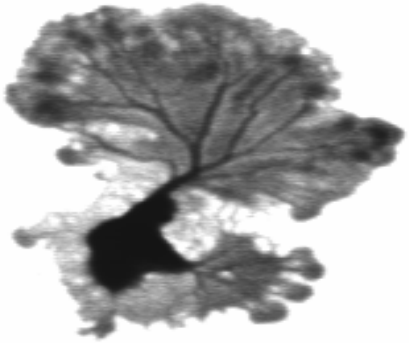
- most favorable



Hostile



moderately favorable



Large shape changes depending on environment

(Takamatsu, 2007)

Folding of leaves

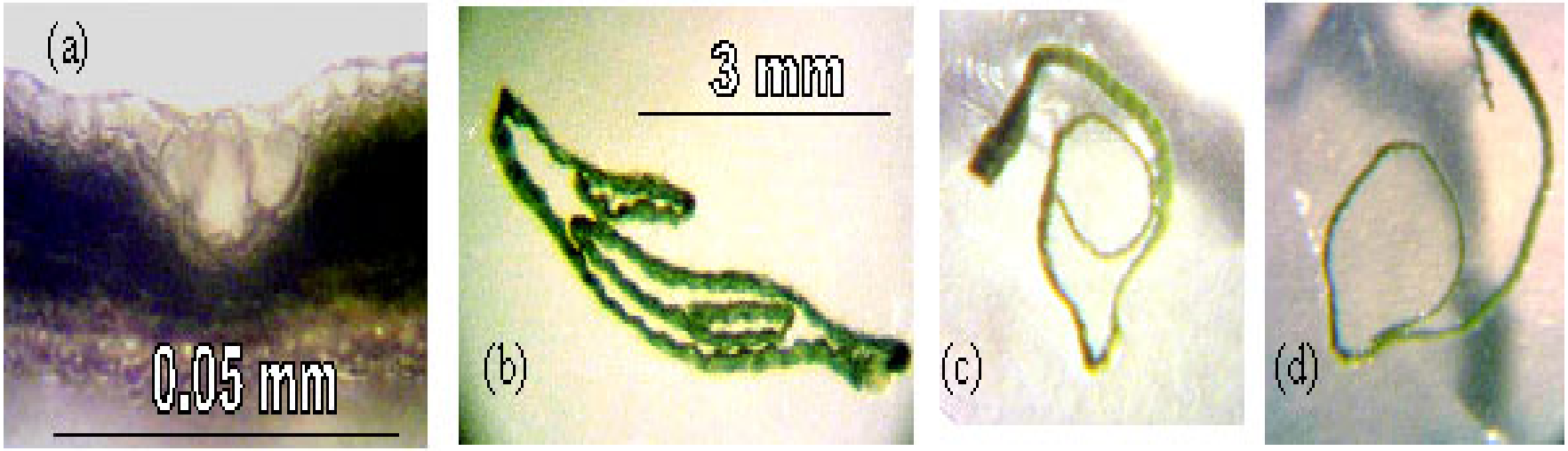
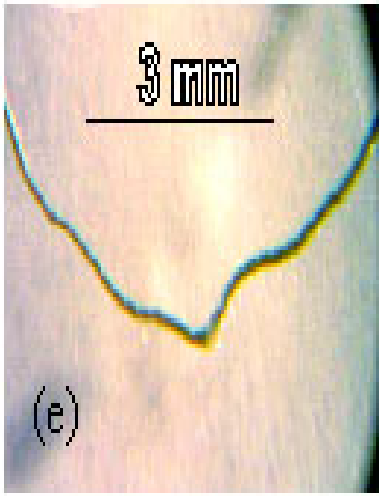


Fig. 2. How a leaf of Kentucky bluegrass *Poa pratense* (a European weed) can fold to exhibit large morphing using the concept of expansion and shrinkage of motor cells, (a) zoom up of the upper part of the leaf with expanded motor cells, (b)-(e) sequence of expansion, entire leaf showing folded in morphology by kinking at several hinges.



Folding of flower pedals

(a) morning glory (b) bindweed

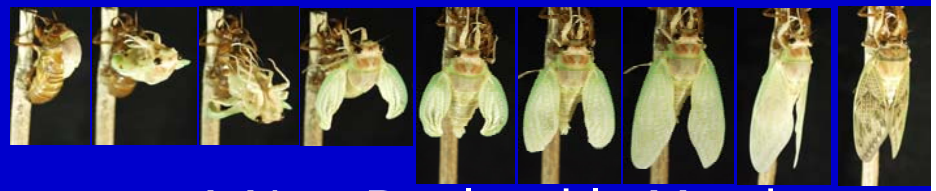
(c) helically-wound buds:
morning glory (left) bindweed (right)

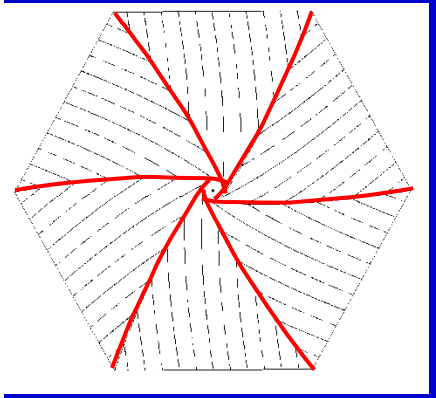
Natori et al, 2006

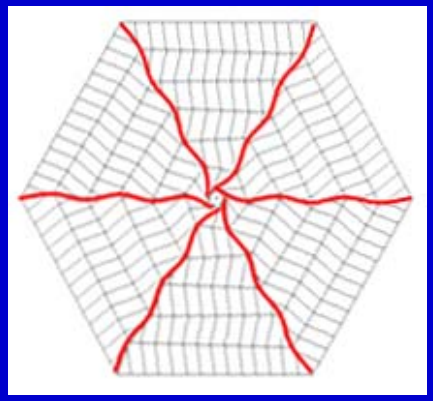
Morphological Changes in Nature

- Insects' Incomplete Metamorphosis -

Anax parthenope Julius 136 min → 30 sec







A New Deployable Membrane Concept Inspired by Insects' Eclosion

Membrane Structures with Embedded Inflatable Tubes

Kishimoto, Natori, Higuchi and Ukegawa, AIAA-2006-1898

Free-falling of seeds

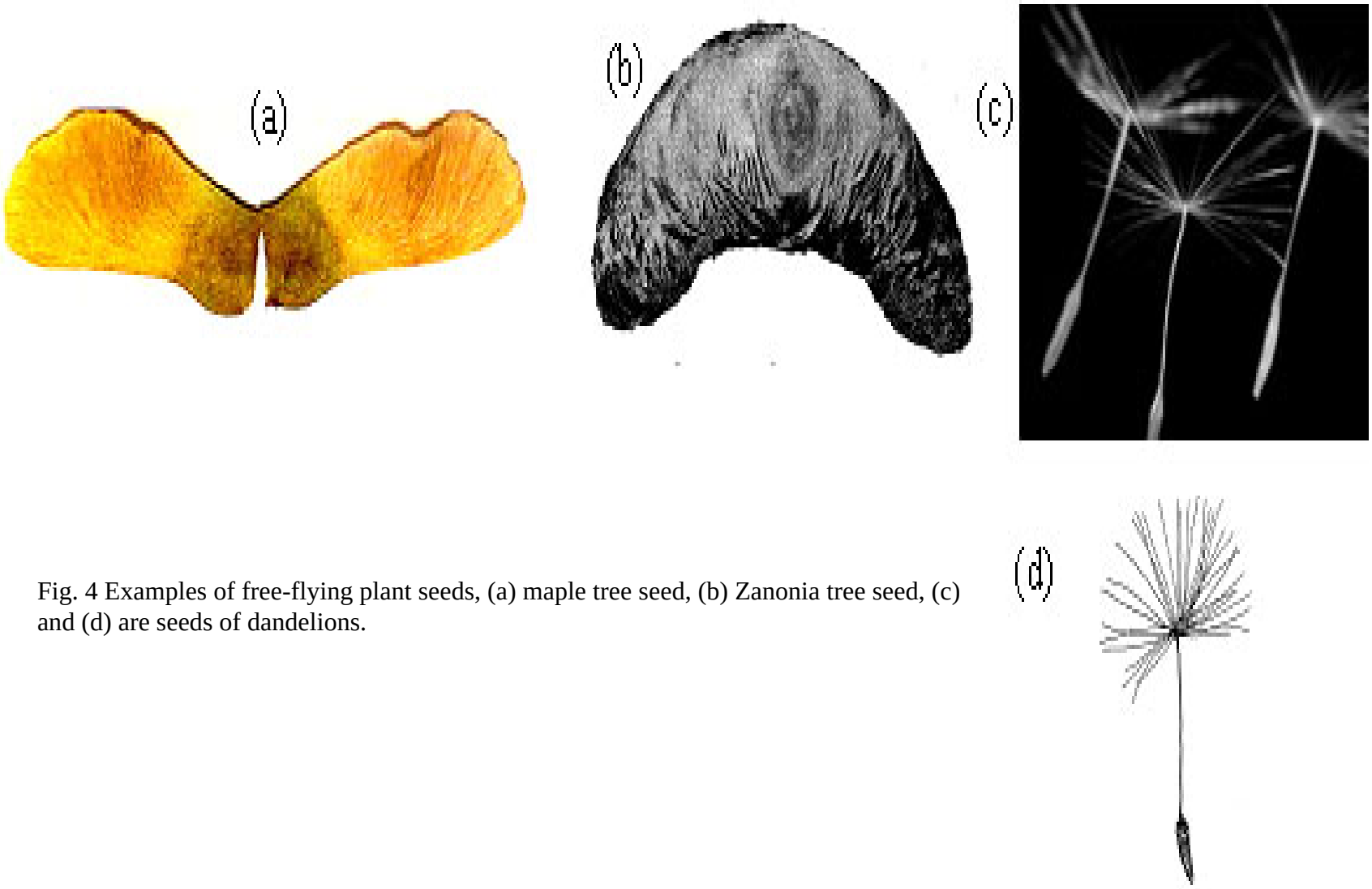
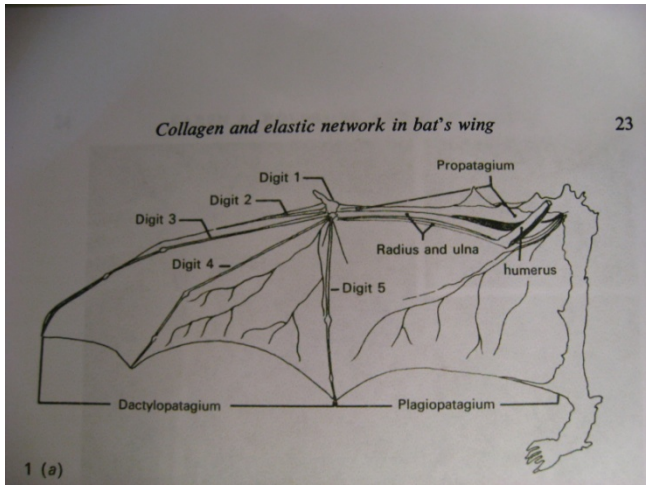
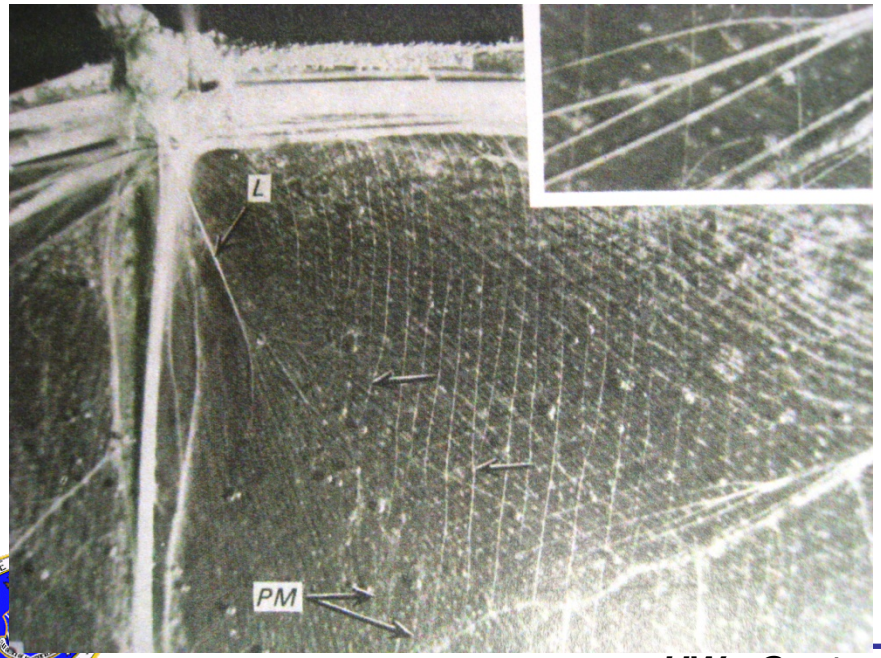


Fig. 4 Examples of free-flying plant seeds, (a) maple tree seed, (b) Zanonia tree seed, (c) and (d) are seeds of dandelions.

Bat Wing Structure and Storage

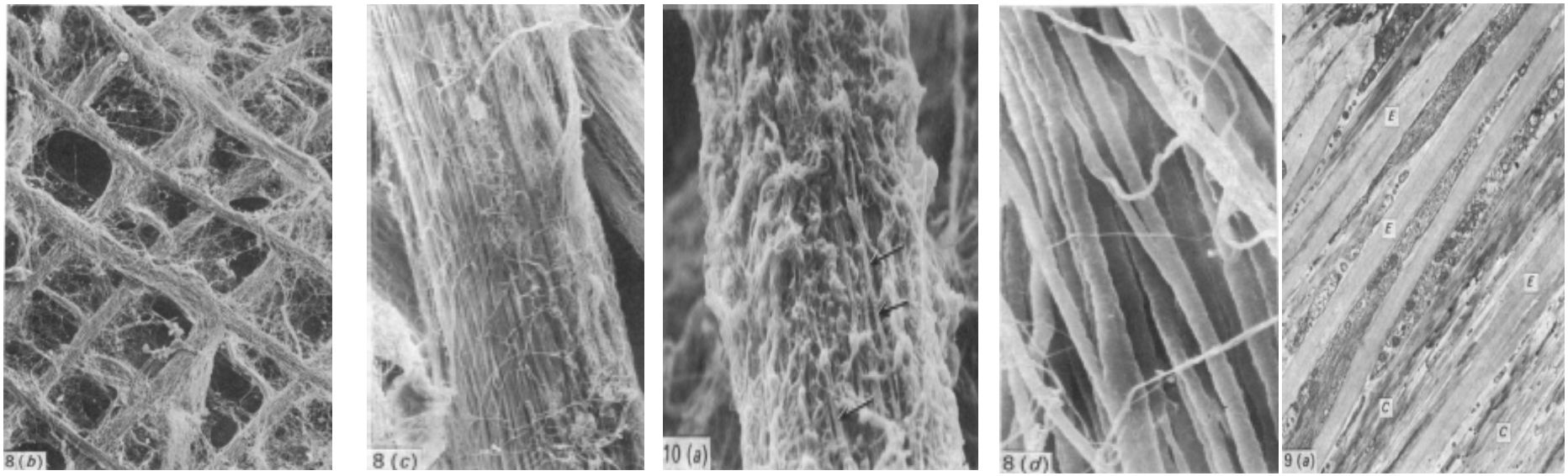


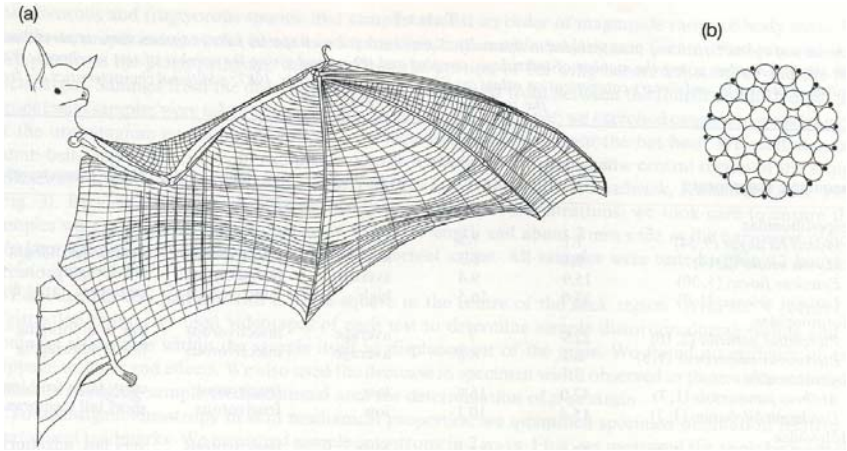


Membrane wing of a bat

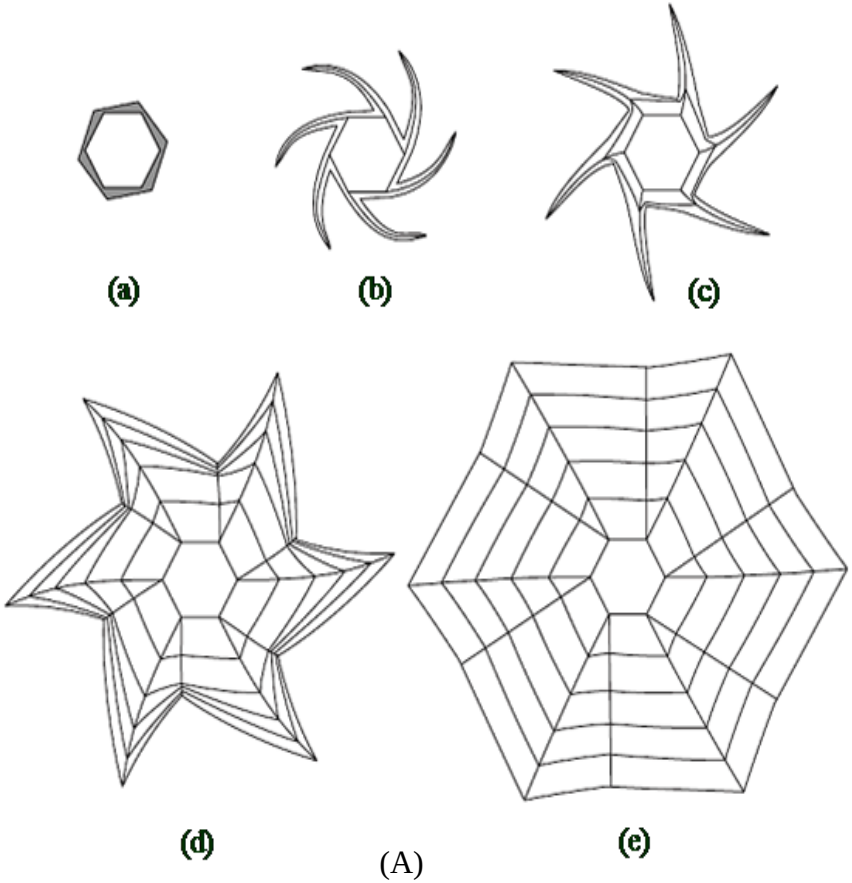
Collagen and elastin protein fibers impart strength and elasticity to the wing.

Nanofiber reinforced membrane of bat wing

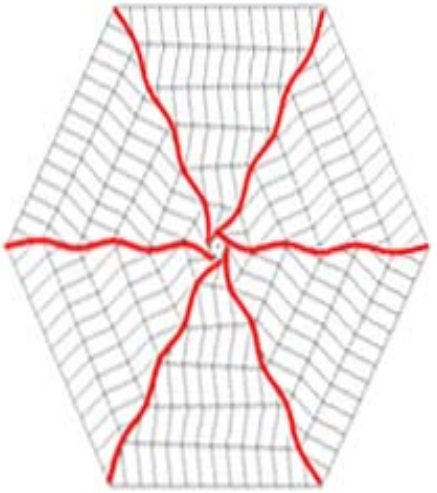




Super configurable structures

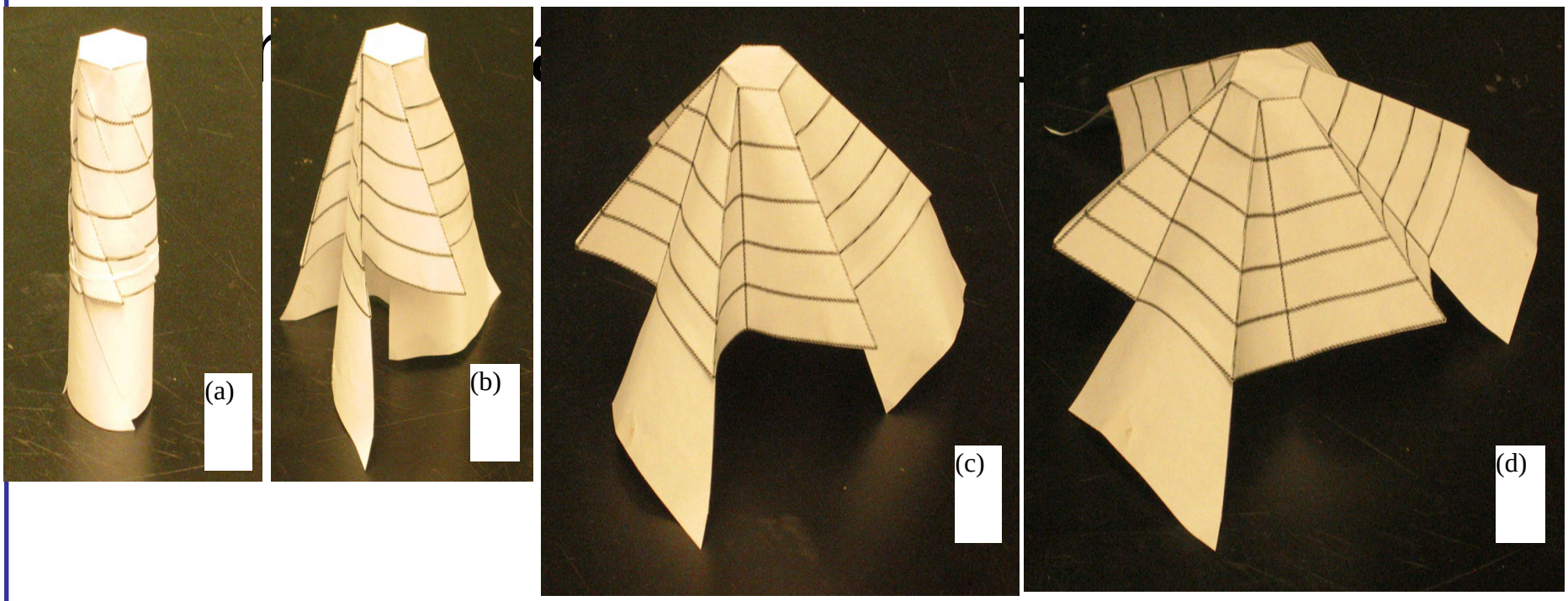


(A)

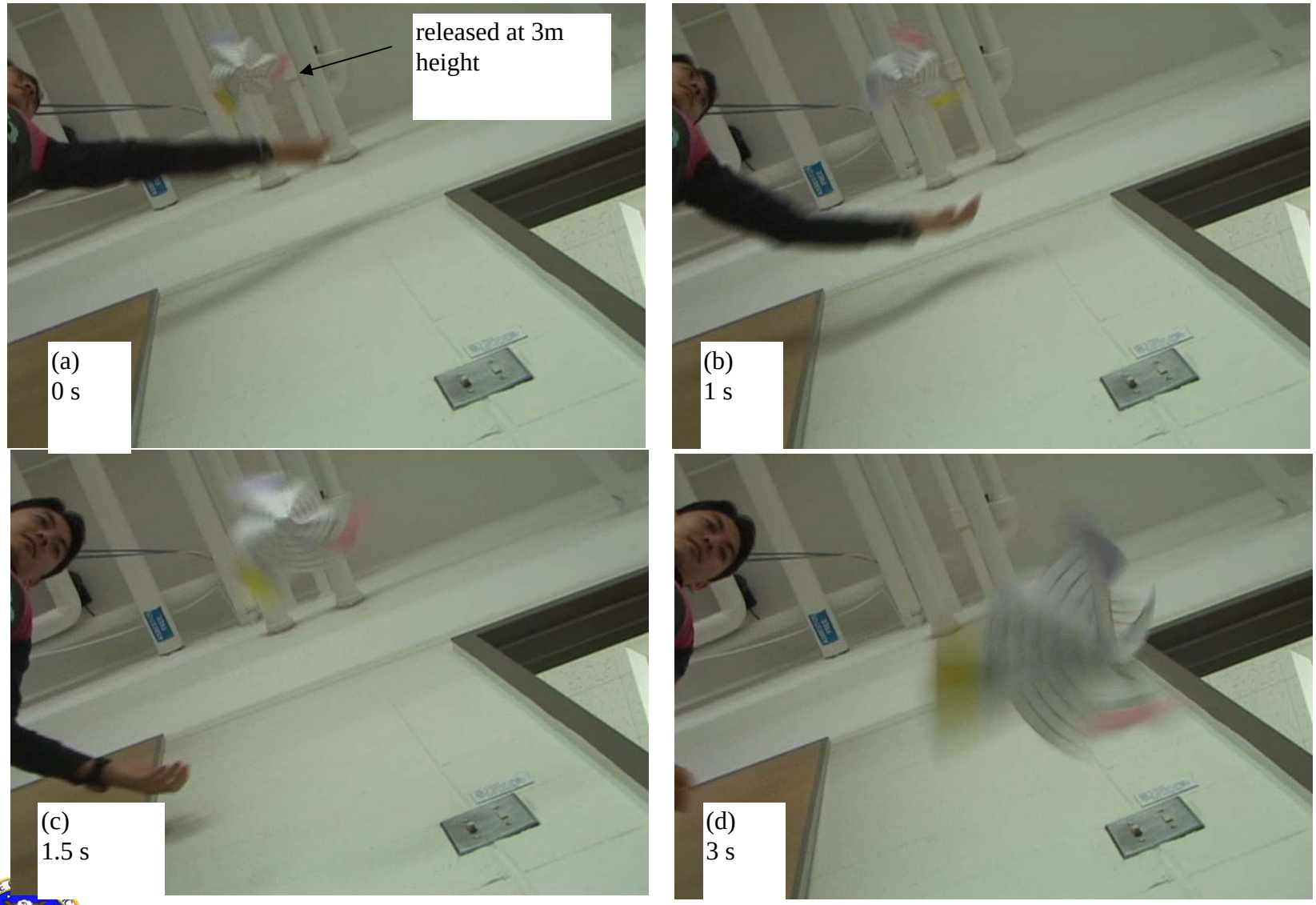


(B)

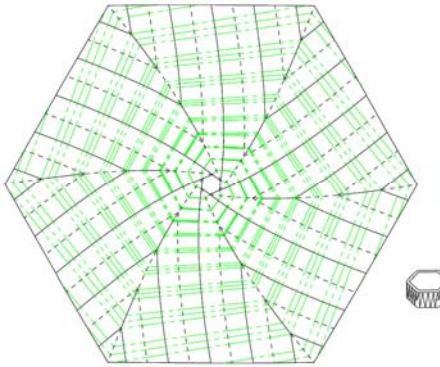
Demonstrators of free-falling

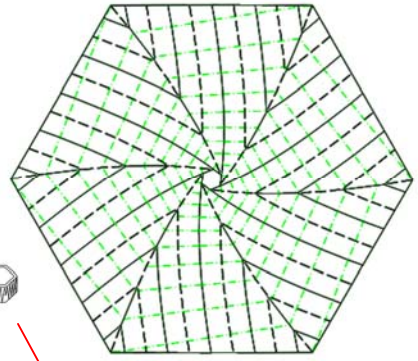


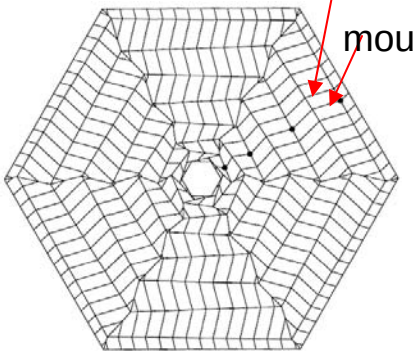
Free-falling demo



Super-configurable Design: Spiral-folds







valley

mountain

Fig. 14(a) Fig. 14(b) Fig. 14(c)

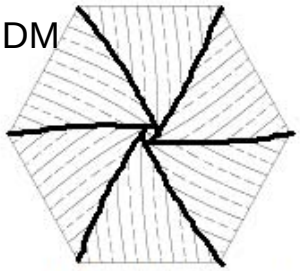
Fig. 11(a)

natori et al. ICAST

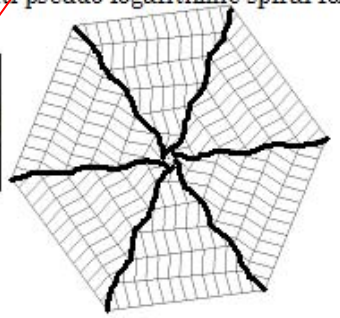
same

kishimoto et al. SDM

same

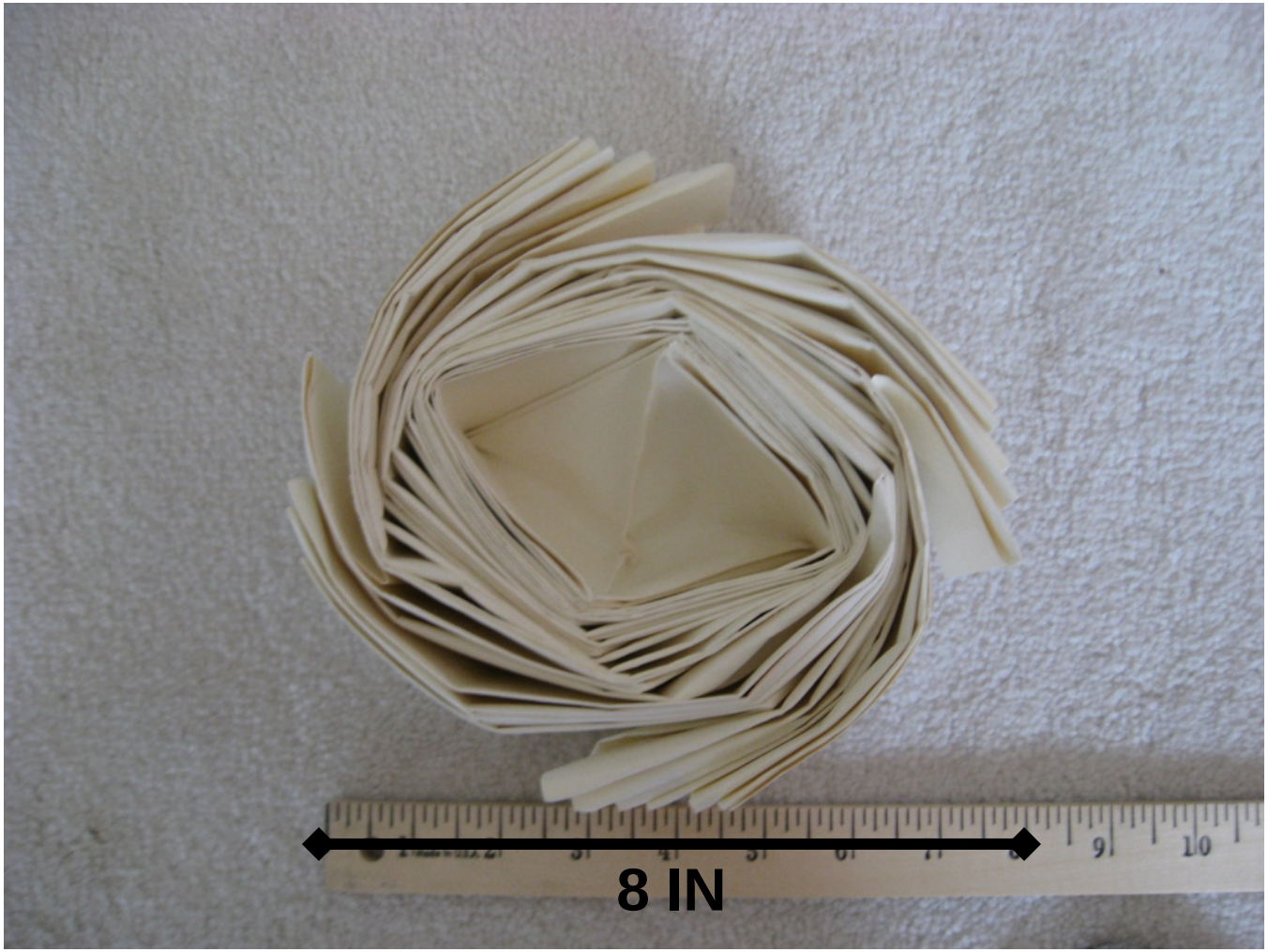


(b) multi-pseudo-logarithmic spiral folding

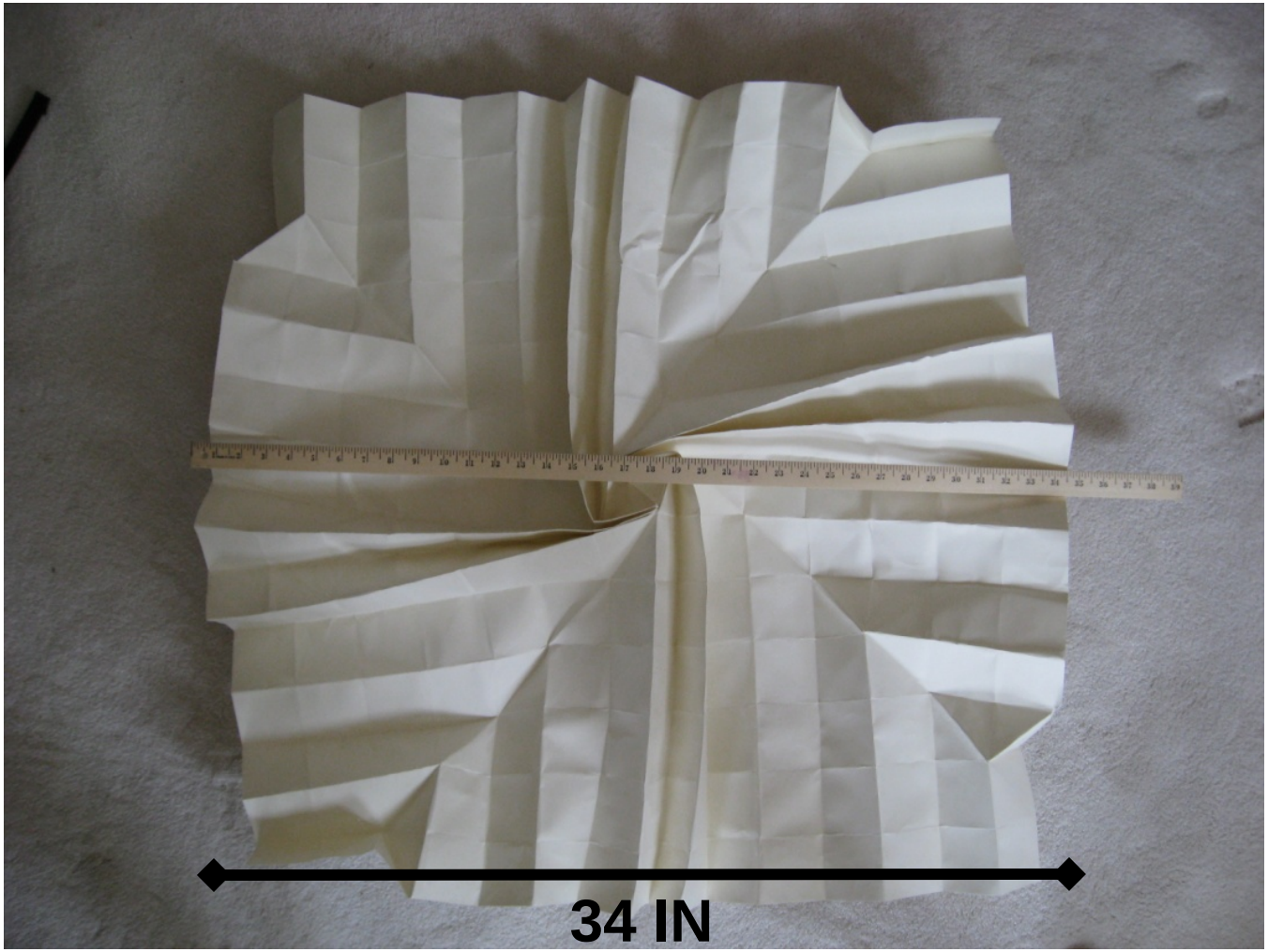


(a) pseudo-logarithmic spiral folding

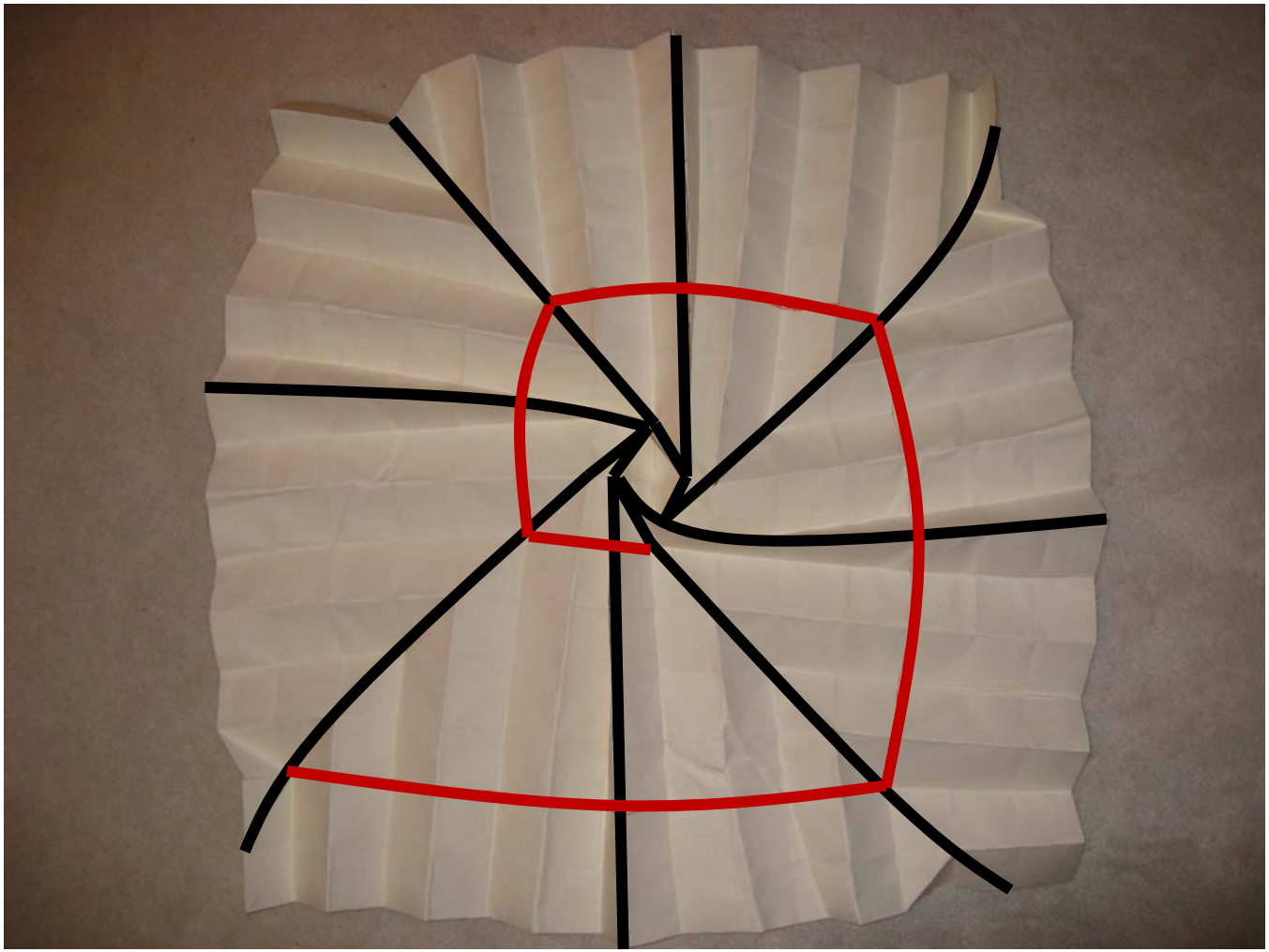
Fig. 16 Example models of proposed membrane structures.



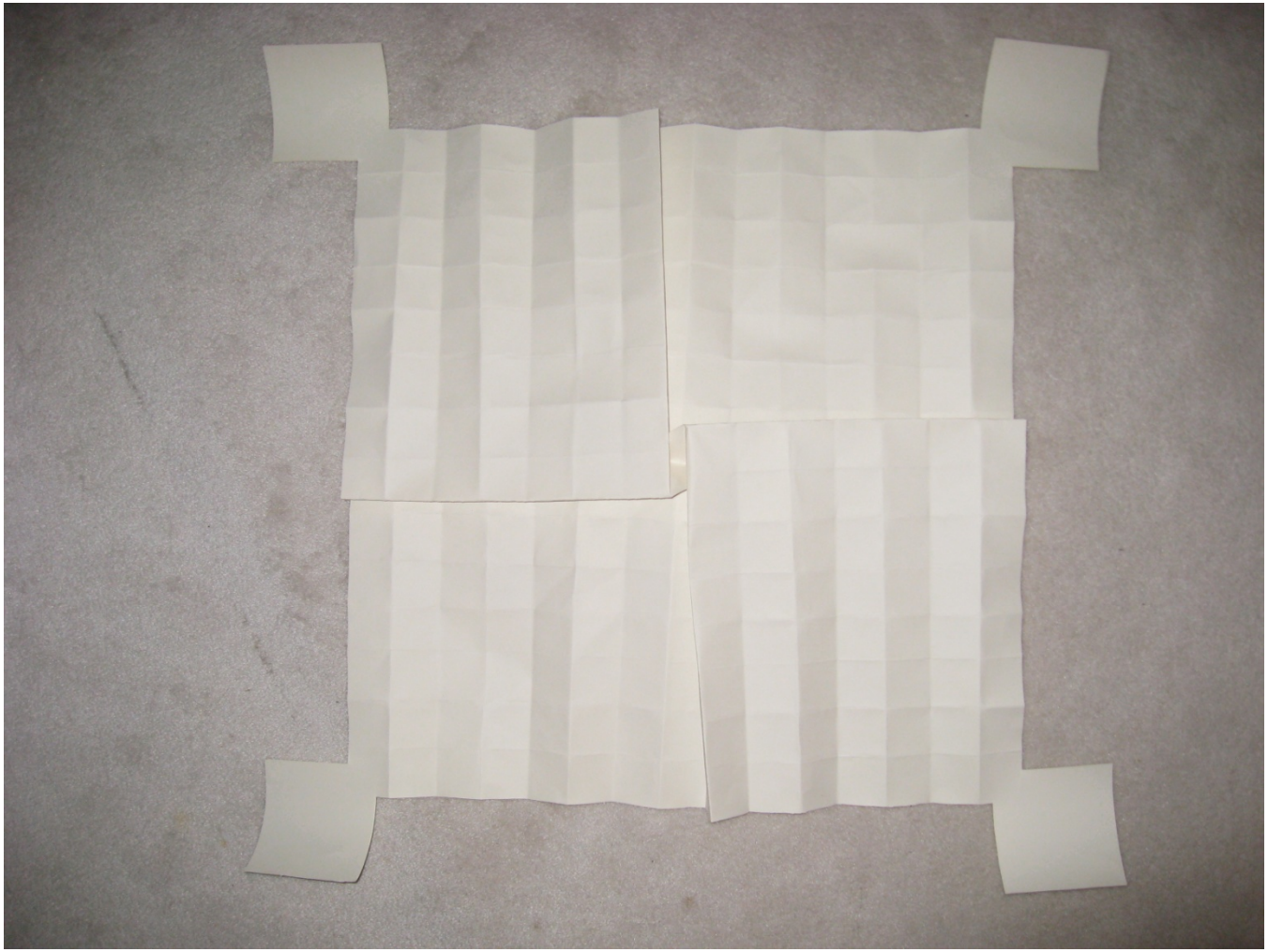
Storage mode, a spiral-folded square. Constructed out of (1) 42” x 42” Strathmore paper.



Expanded mode – yields an approximately 25 times larger area

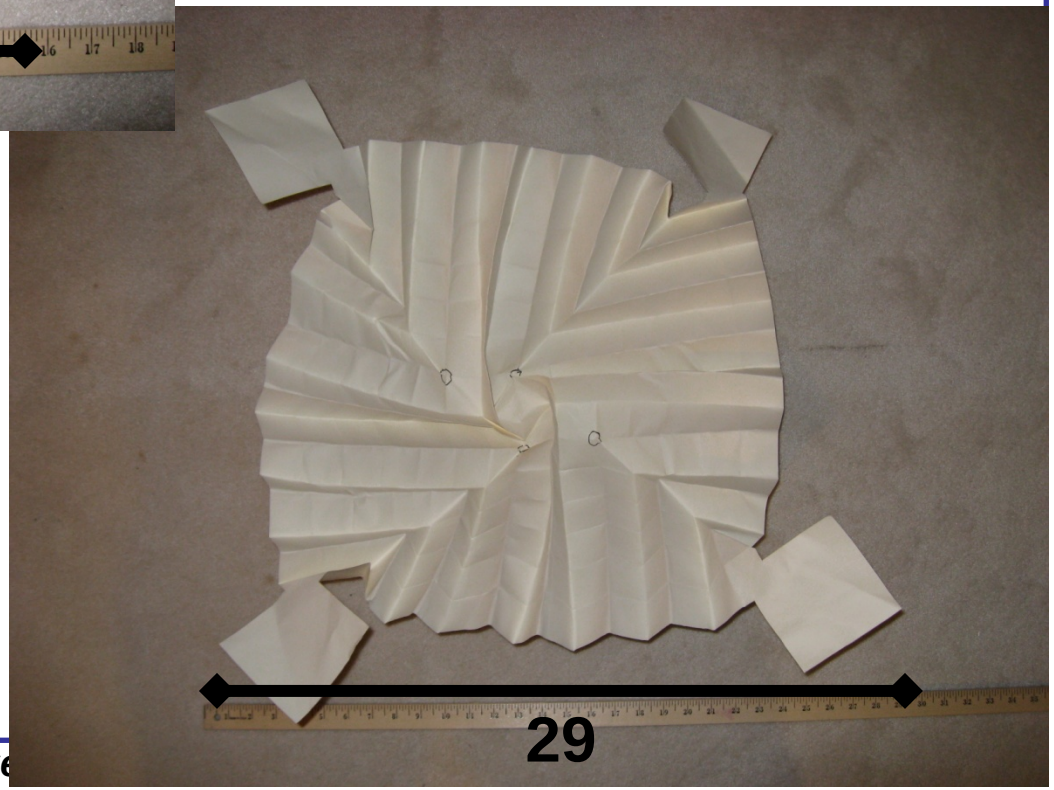


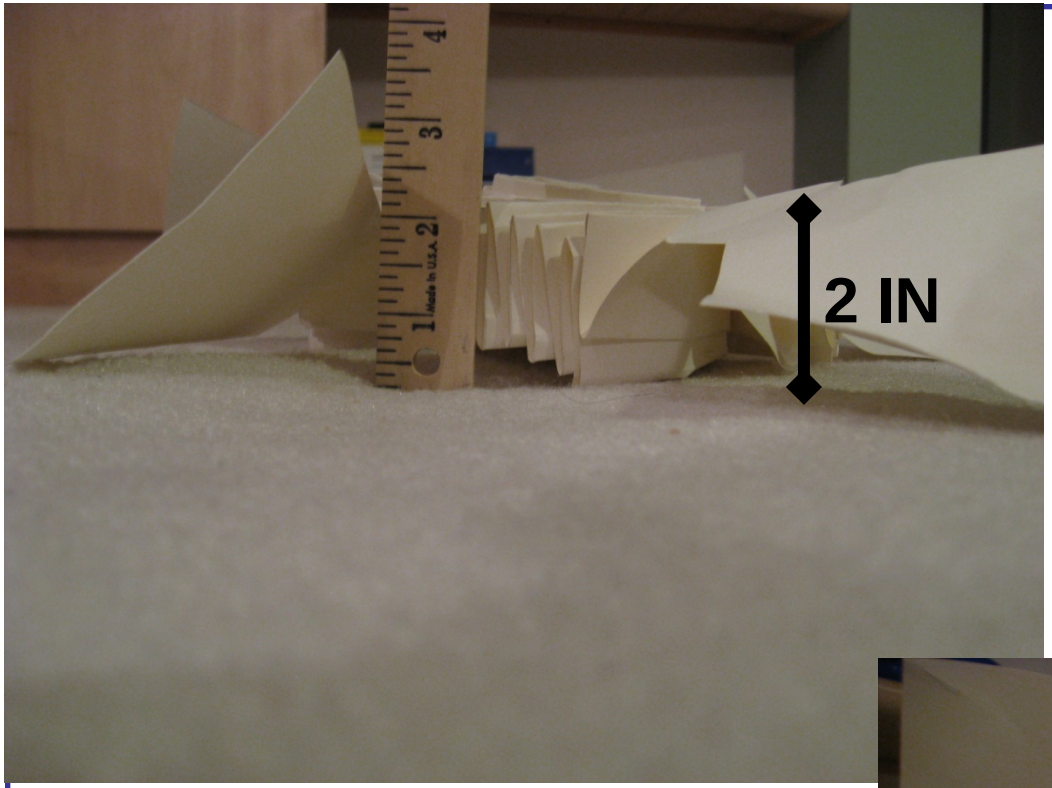
Proposed SMA lines: radial (black) and helical (red)

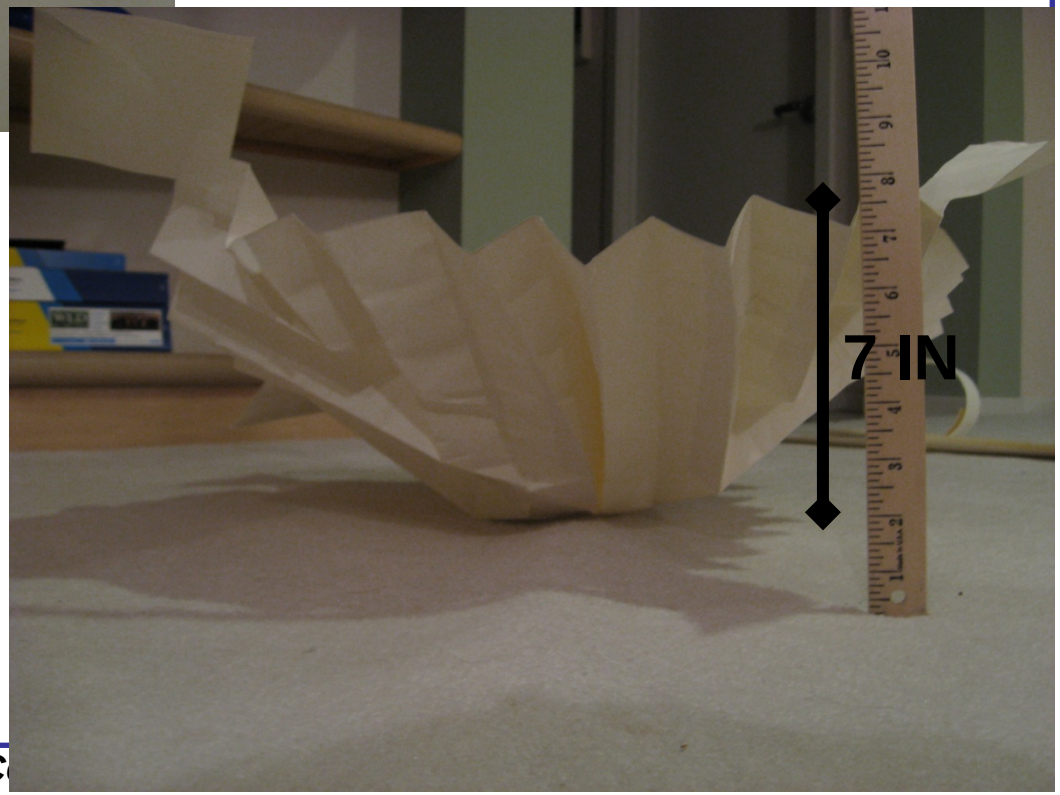


Constructing Spiral-fold square with Winglets. Notice the grid pattern of creases.

Comparisons of the Storage and Expanded modes of the Winglet Design 1 (*x*- and *y*- dimensions)







Comparisons of the Storage and Expanded modes of the Winglet Design 1 (*z* dimension).

The Expanded mode has approximately 14 times more volume than the Storage mode.

How to increase flight time

- Minimization of power expenditure by using the topology optimization of sensor networks

- Maximization of initial battery capacity and energy harvesting from flying environment, for example , use of organic solar cells

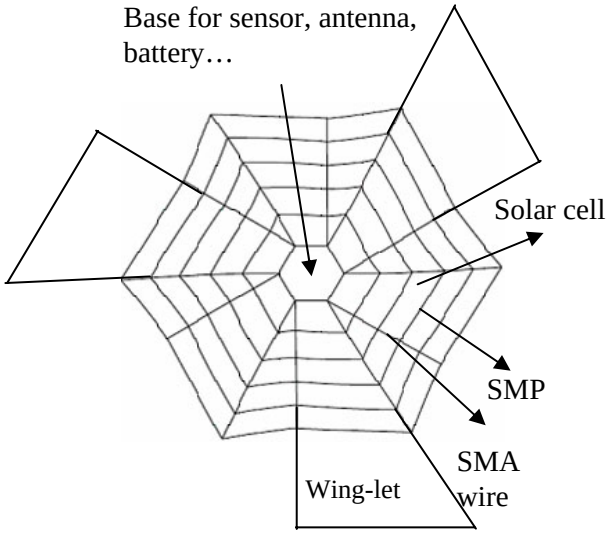
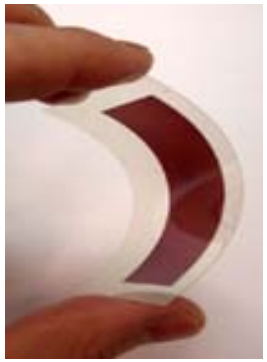


Fig. 7 Schematic of proposed MAV-1



(a)

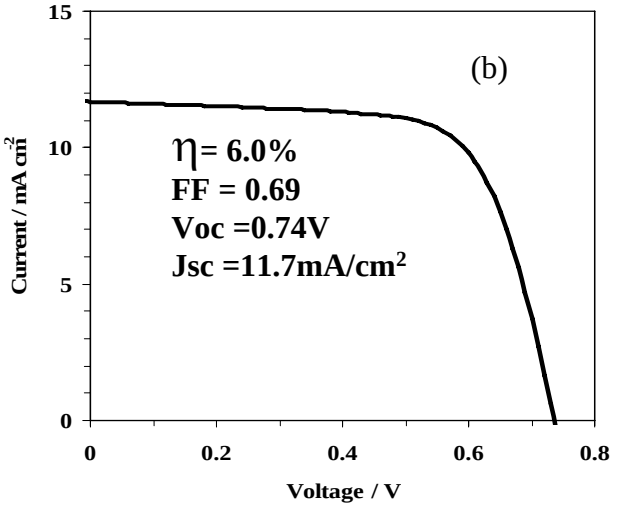


Fig. 8 (a) UW Dye-sensitized Solar cells (DSSC) and (b) its performance: energy convergent ratio η=6 %(Nagata and Taya, 2008).