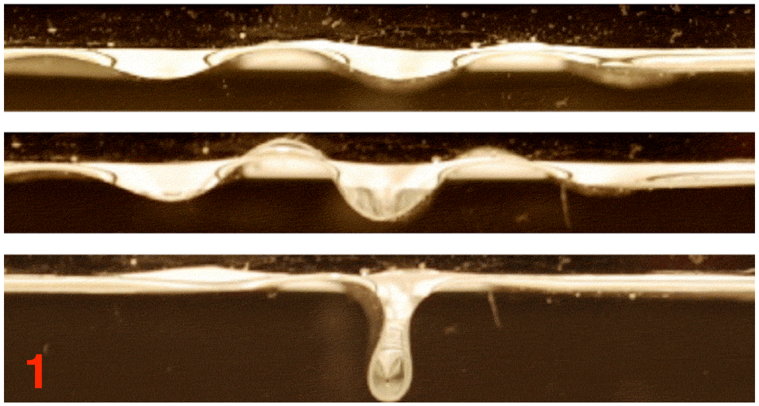
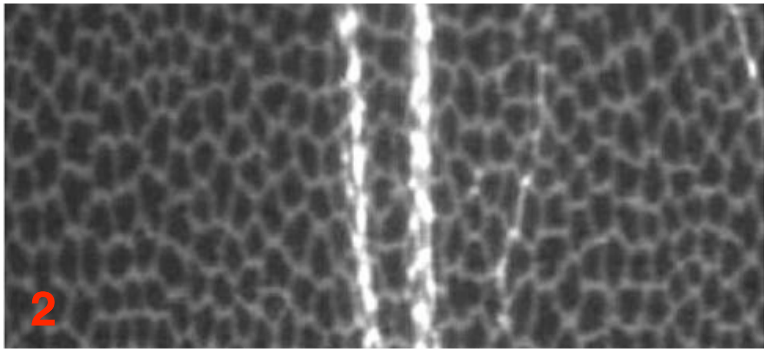
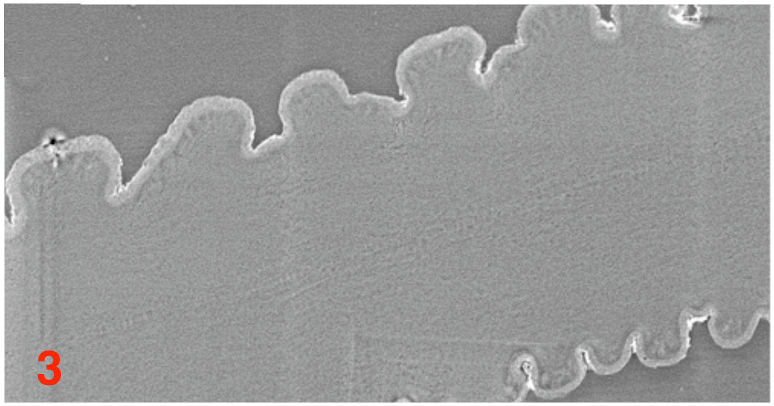
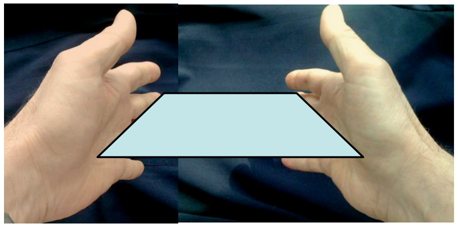
Chicago-Chile team probes molecular wrinkling/folding









A sheet of paper pushed from the sides buckles. In molecular sheets within lung sacs (2) and biological tissues (3), this buckling can take strange new forms that are important for their function. As pushing increases, the shape passes from smooth wrinkling to sharp folding, as shown in an ordinary 20 cm polyester sheet (1).

In 2006 Luka Pocivavsek, studying lung surfactants like (2) in Prof. Ka Yee Lee’s group, did an internship with Prof. Enrique Cerda in Chile to gain a deeper understanding. The result was their theory of the wrinkle-to-fold transition, demonstrated in (1) and now generalized to tissue surfaces like (3), with the help of two Chilean interns in Prof. Lee’s Chicago lab.

These biological sheets teach new ways to achieve strength and resiliency in man-made molecular sheets..

More information is in a Highlight essay in *Soft Matter **5**, 1963 (2009)*

The collaboration described here was fostered by the Chicago-Chile exchange program (`http://jfi.uchicago.edu/~tten/Chile/`), supported in part by the National Science Foundation's MRSEC Program and its office of international programs, under Awards DMR-0303072 and DMR-0807012

figure captions: All figures from
Luka Pocivavsek, Brian Leahy, Niels Holten-Andersen, Binhua Lin,
Ka Yee C. Lee and Enrique Cerda, *Soft Matter **5**, 1963 (2009)*

1. (Figure 1) Polyester film on water transitioning from an extended wrinkled state to a localized folded state. The polyester film is 10 microns thick and clamped at the boundaries. The macroscopic system is imaged from the side allowing for careful determination of amplitudes and wavelengths as well as a clear view of the wrinkle to fold transition. (a) Wrinkled state at low confinement with a wavelength l 1.6 cm. (b) Upon further compression the wrinkles increase their amplitude, but the one in the middle grows more than its neighbors. (c) The wrinkles collapse into one fold in the middle where all the excess of length is stored. The film becomes flat except for this localized defect.

2. (Figure 2d) Fluorescence image (750 microns across) of a model lung surfactant system of 2 nanometer thickness, composed of a 7 : 3, mol : mol mixture of 1,2-dipalmitoylsn-glycero-3-phosphocholine (DPPC) and 1-palmitoyl-2-oleoyl-sn-glycero-3-[phospho-rac-(1-glycerol)] (POPG)25 at an air/water interface. Folds (appearing as bright lines running perpendicular to the direction of compression) are easily visualized with fluorescence due to the high density of surface lipids and dye pulled into a given fold. The amount of material pulled into a given fold has been previously carefully measured. We used the size of the folds and our scaling law to extract out the bending stiffness of the lung surfactant monolayer to be on the order of 10 kT in agreement with previous work.

3. Figure 3(b) Cross-sectional scanning electron microscopy images of thread filament used by mussel shellfish to adhere to rock. Prior work has shown that the fiber is composed of a softer collagenous core covered by a harder protective cuticle