Living Microlenses

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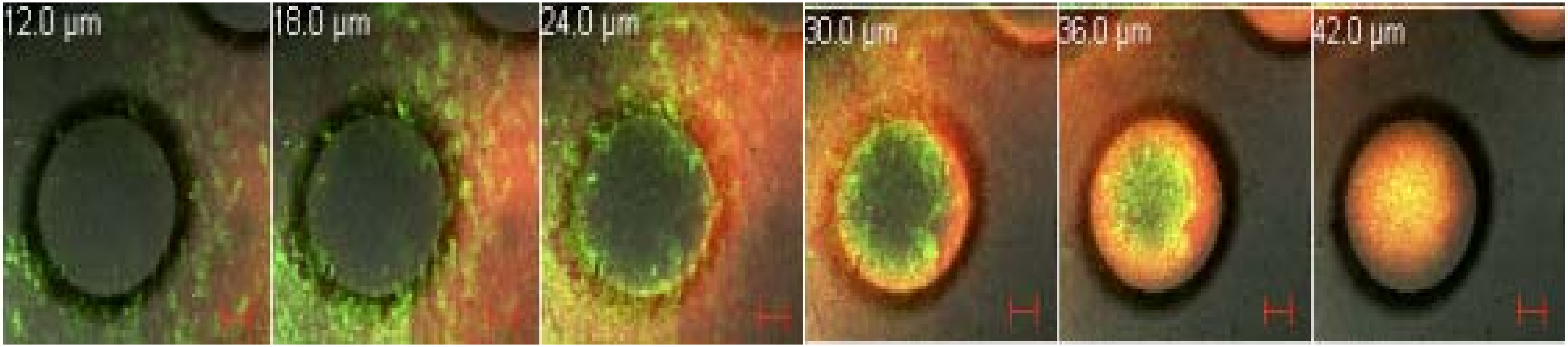
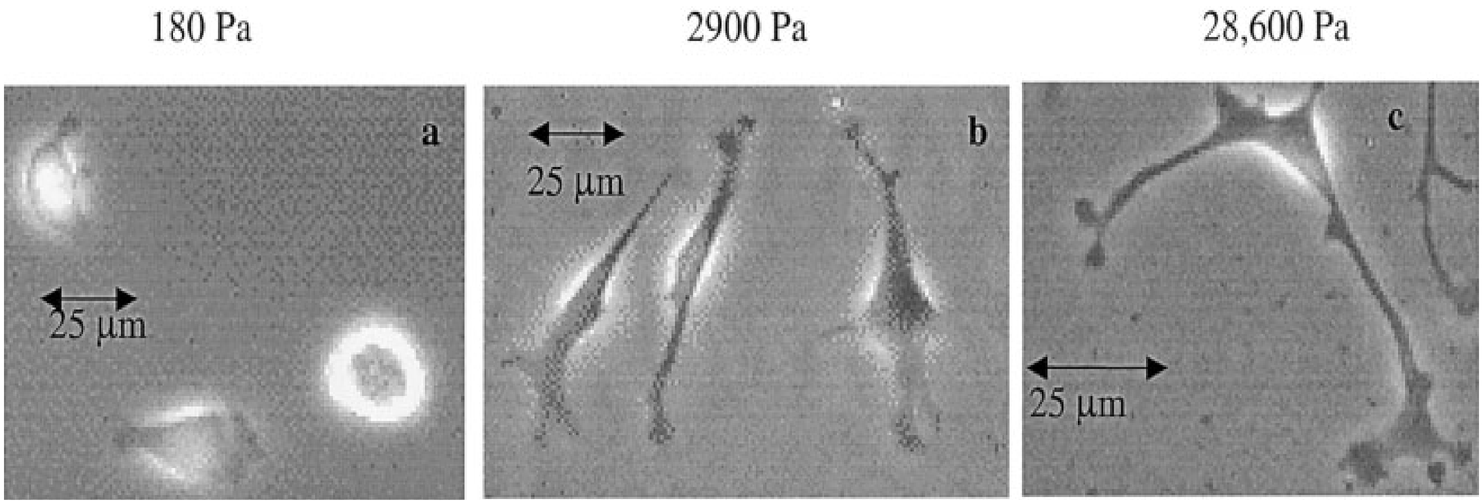


Mechanics of Cell Sheets



Janmey et al., *Cell Mot. & Cyto.*, 60, 24, **2005**

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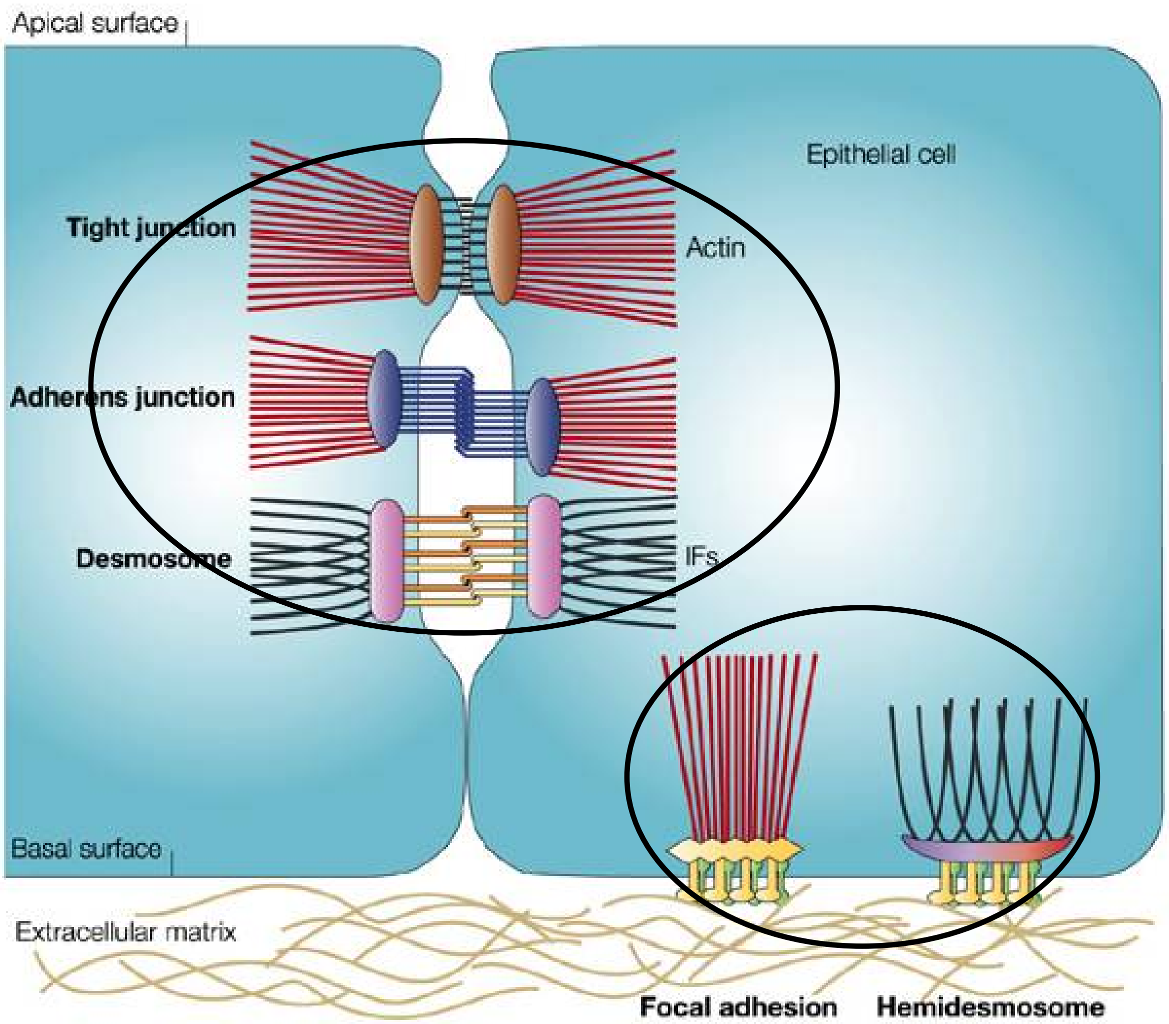
Cell Junctions

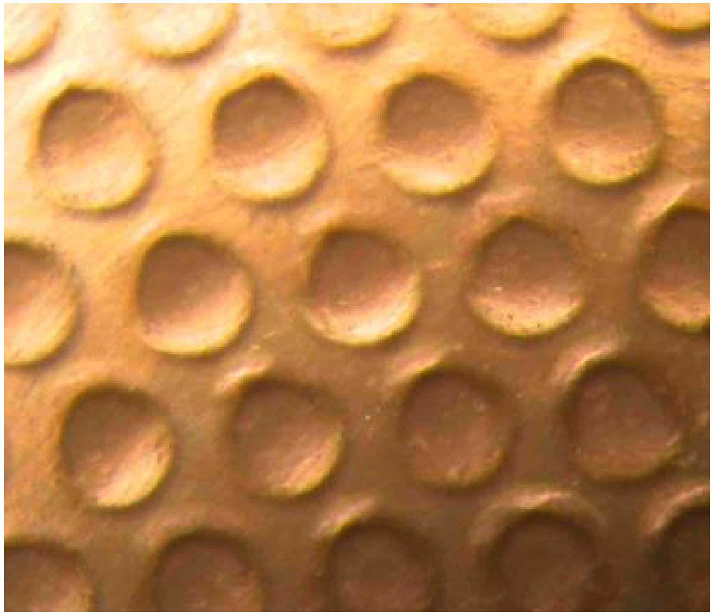


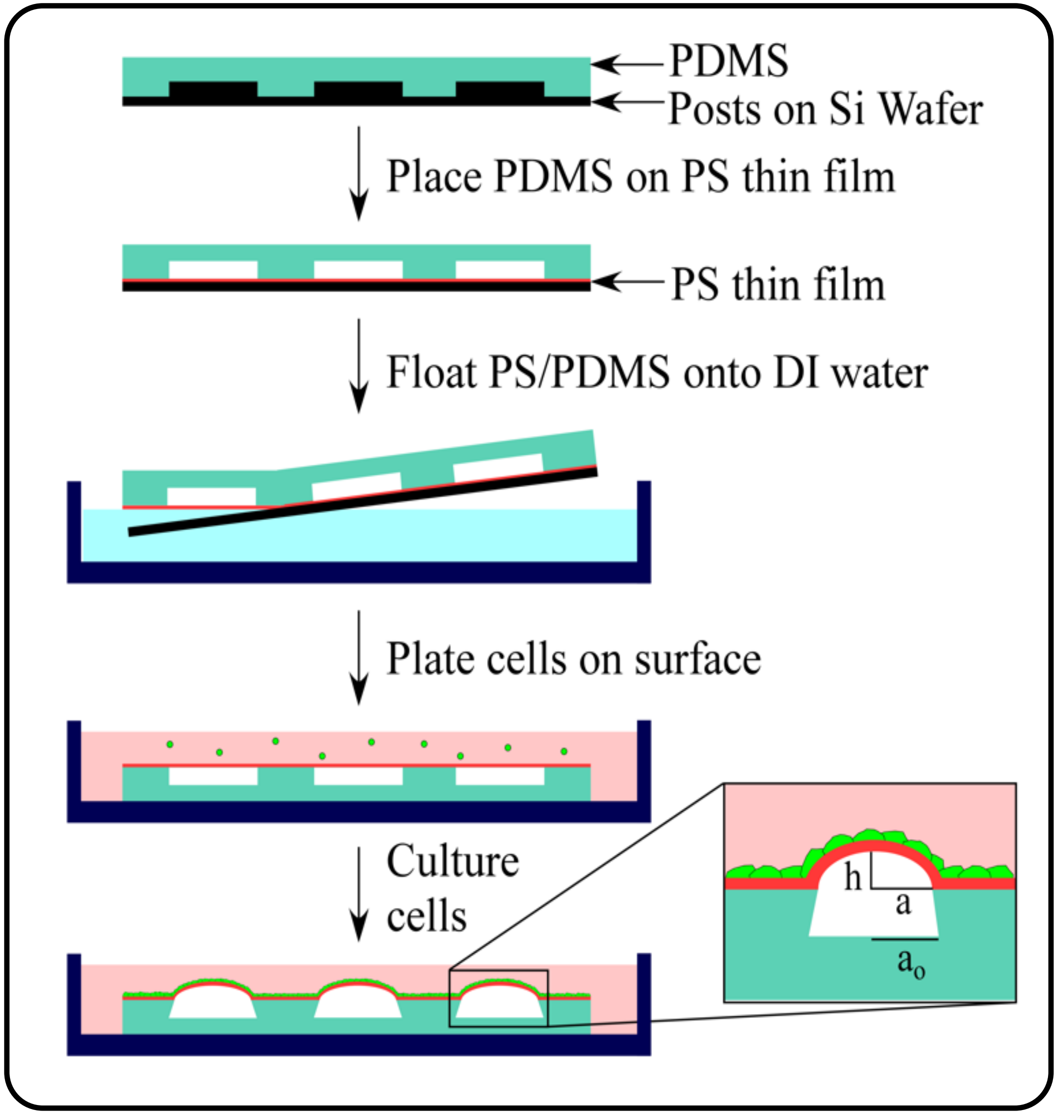
- Connects ECM to actomyosin network
- Point through which traction forces are exerted

Nature Reviews in MCB (2004) 5, 542

Living Microlenses

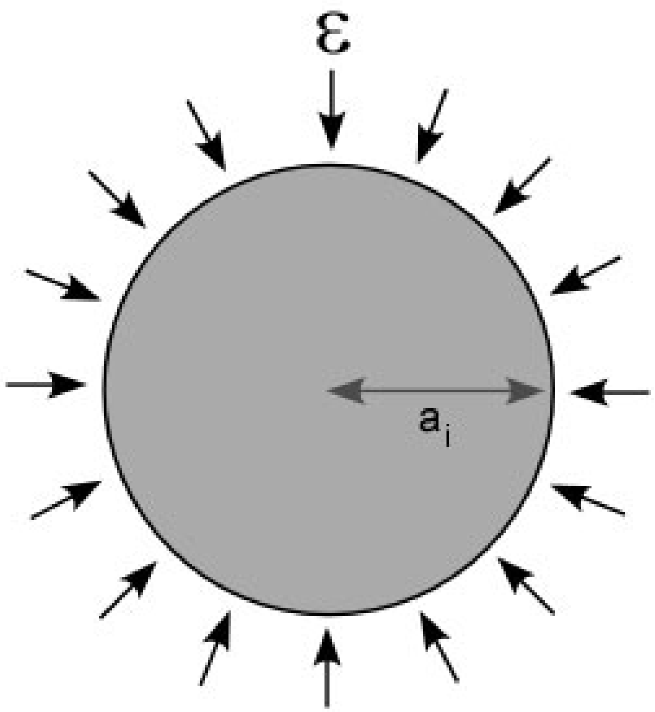
- Look at development of stress of multiple cells
- New substrate geometry of microlens arrays

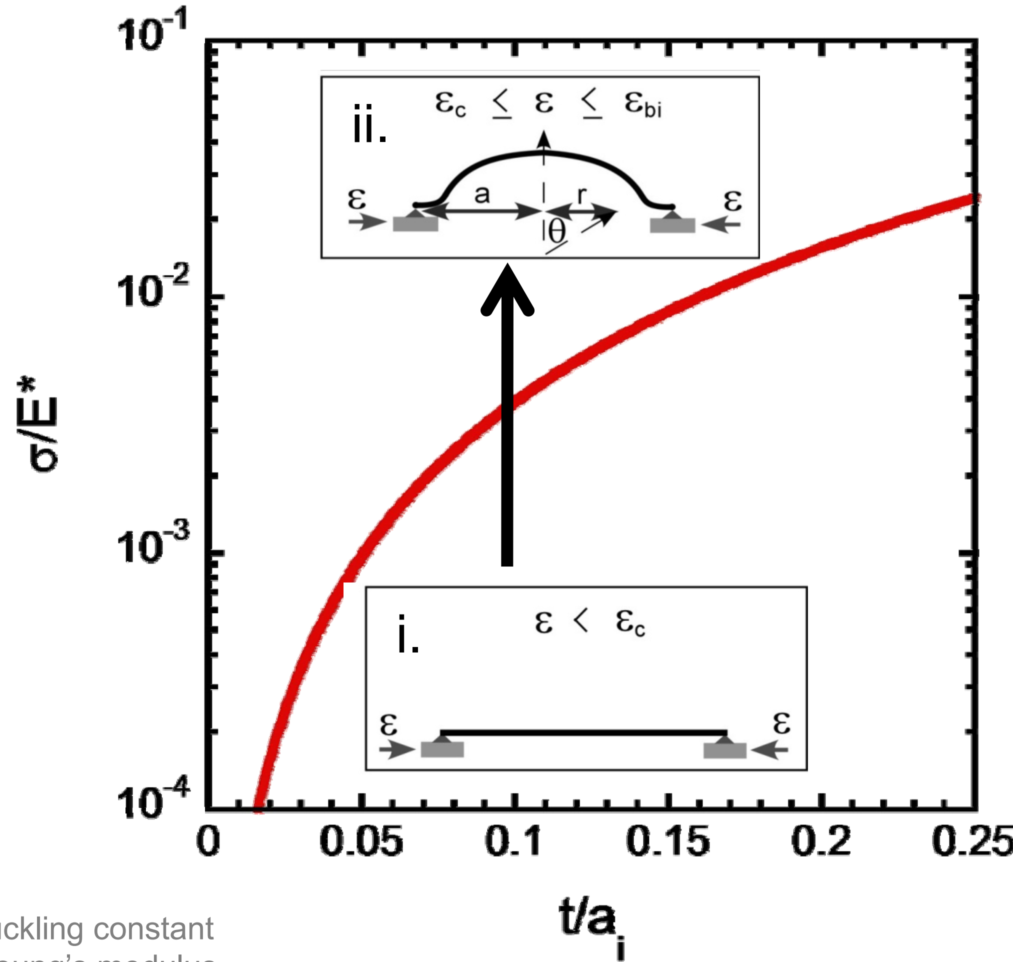




Zimberlin, Wadsworth, Crosby (2008) *Cell Motility & the Cytoskeleton*

Plate Instability





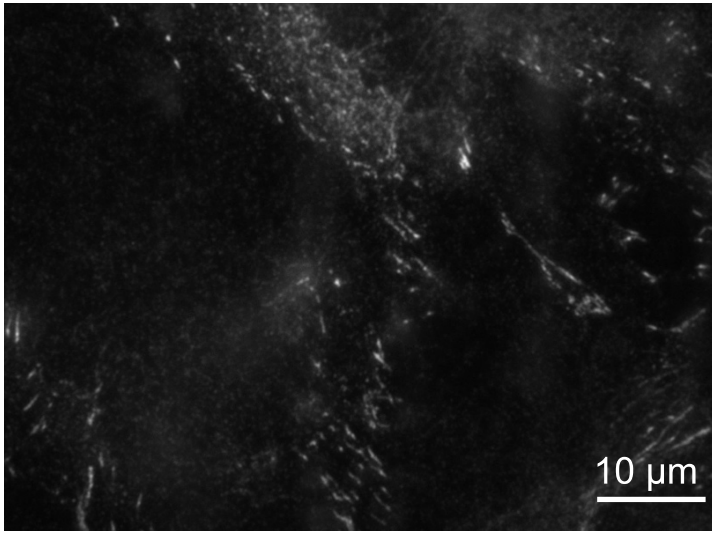
$$\sigma_c = \frac{k^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{a_i}\right)^2$$

k = buckling constant
E = Young's modulus
t = plate thickness
a = plate radius
ν = Poisson's ratio

Cell Types Used

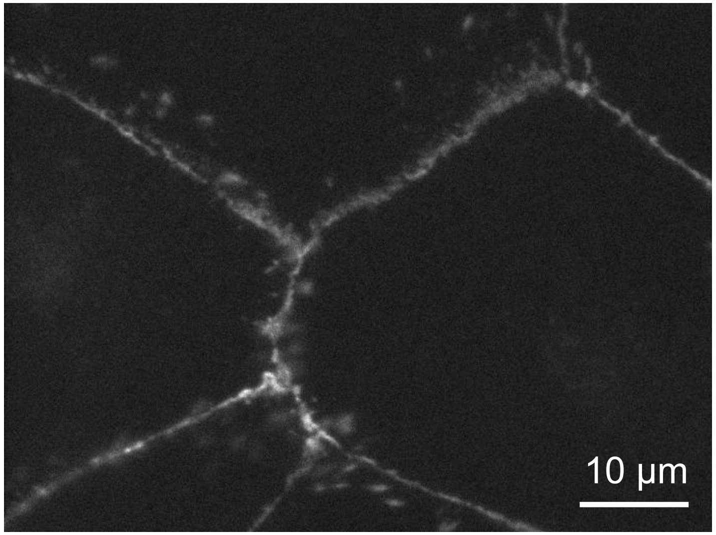
Fibroblasts: NIH/3T3

- Found in connective tissues
- Active in wound healing
- Low density of intercellular junctions



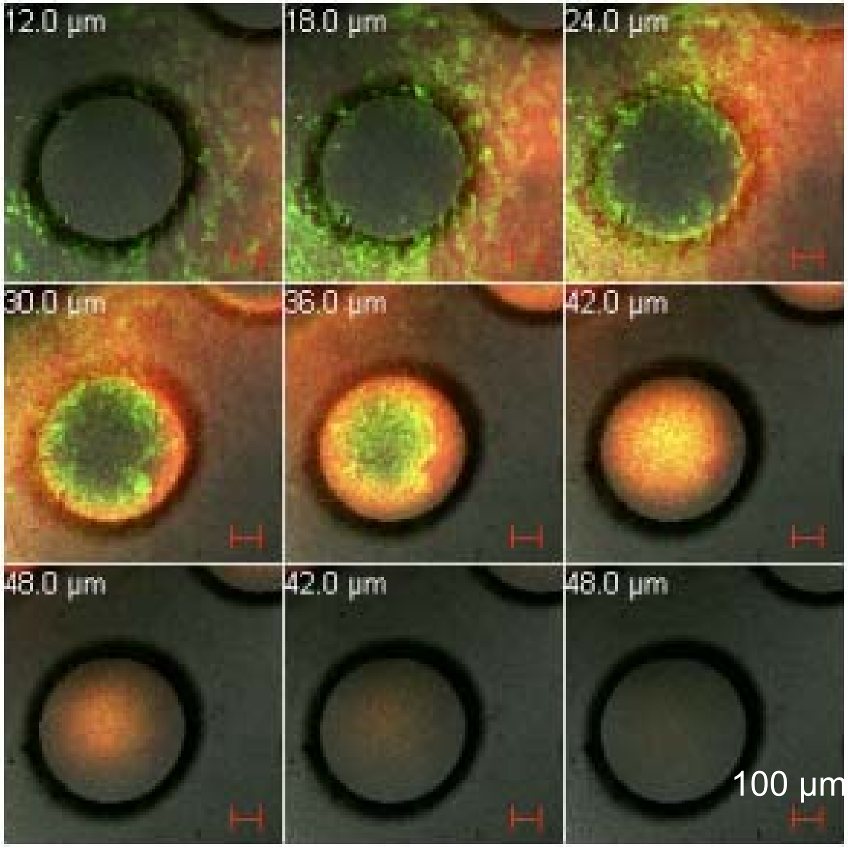
Epithelial: LLC-pK1

- Form flat/connected monolayers
- Form lining of body structures
- High density of intercellular junctions

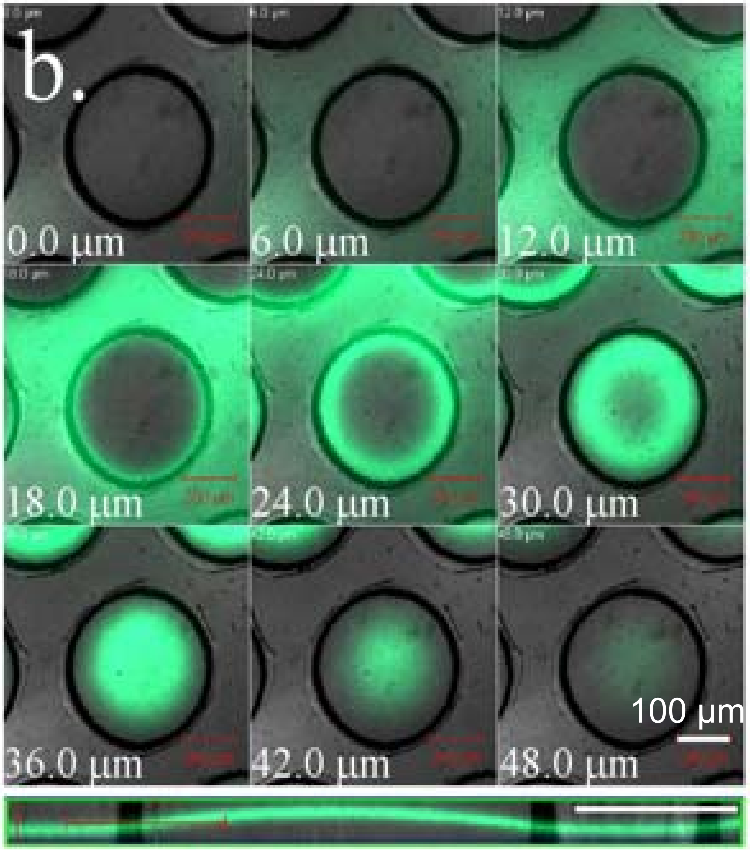


Microlens Confocal Z-Stacks

Epithelial: LLC-Pk1
GFP actin tagged



Fibroblasts: NIH/3T3
Rubrene doped PS



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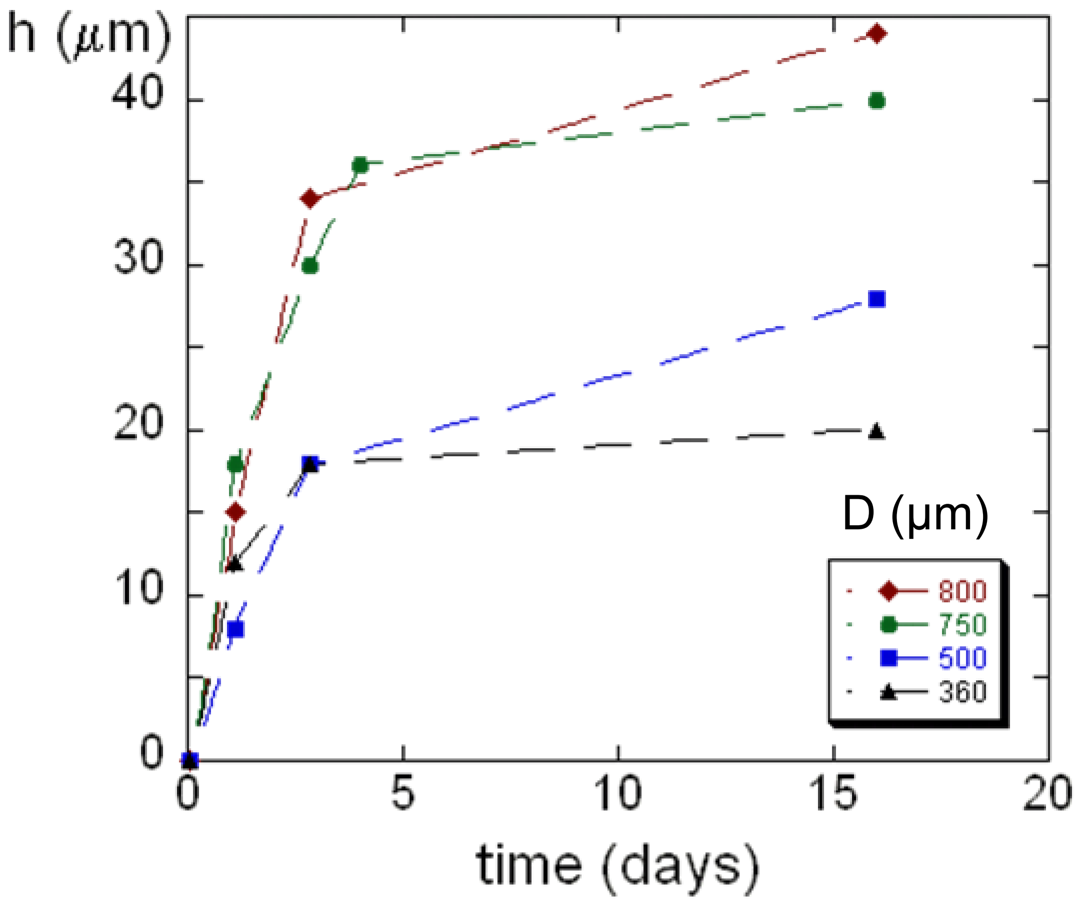
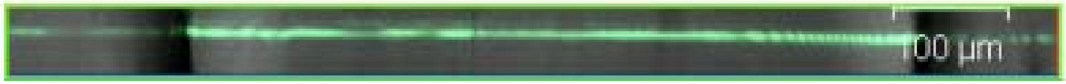
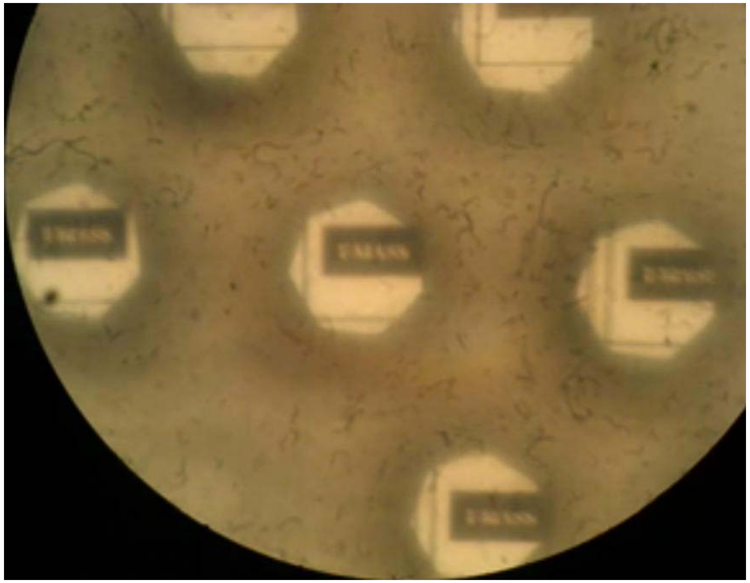
Microlens Height Development



- Presence of merely a few cells causes the plate to buckle
- When cells are removed from surface, the lenses return to their planar state





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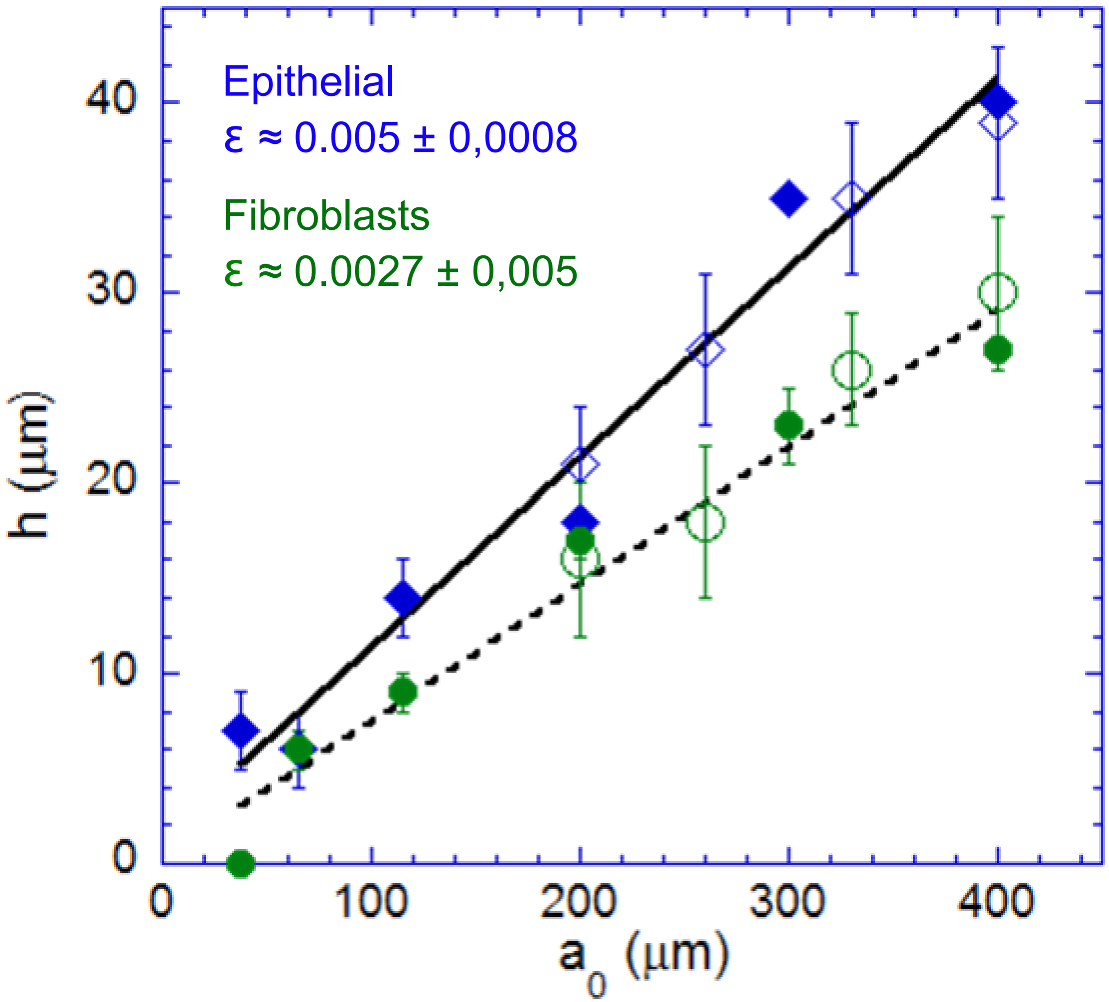
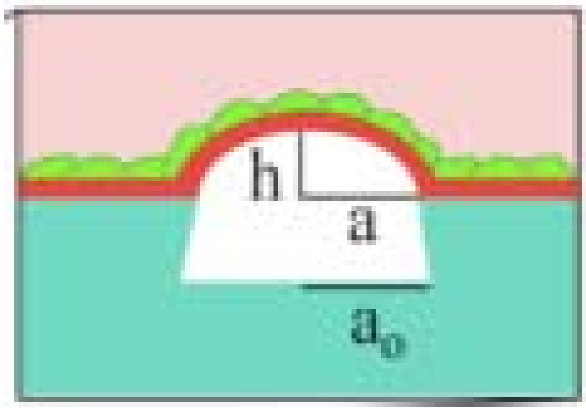
Strain Measurement



Assuming conservation of area:

$$\frac{h}{a_o} = \sqrt{\varepsilon(2+\varepsilon)}$$



Epithelial cells collectively exert more strain on the surface

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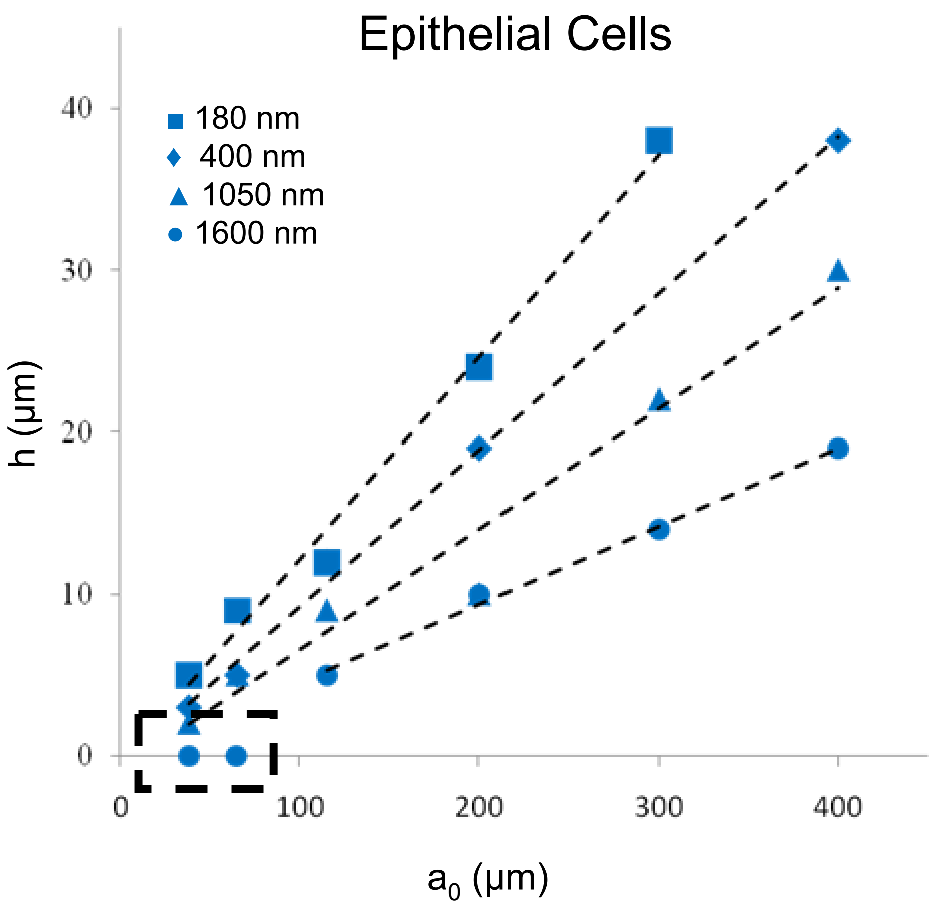
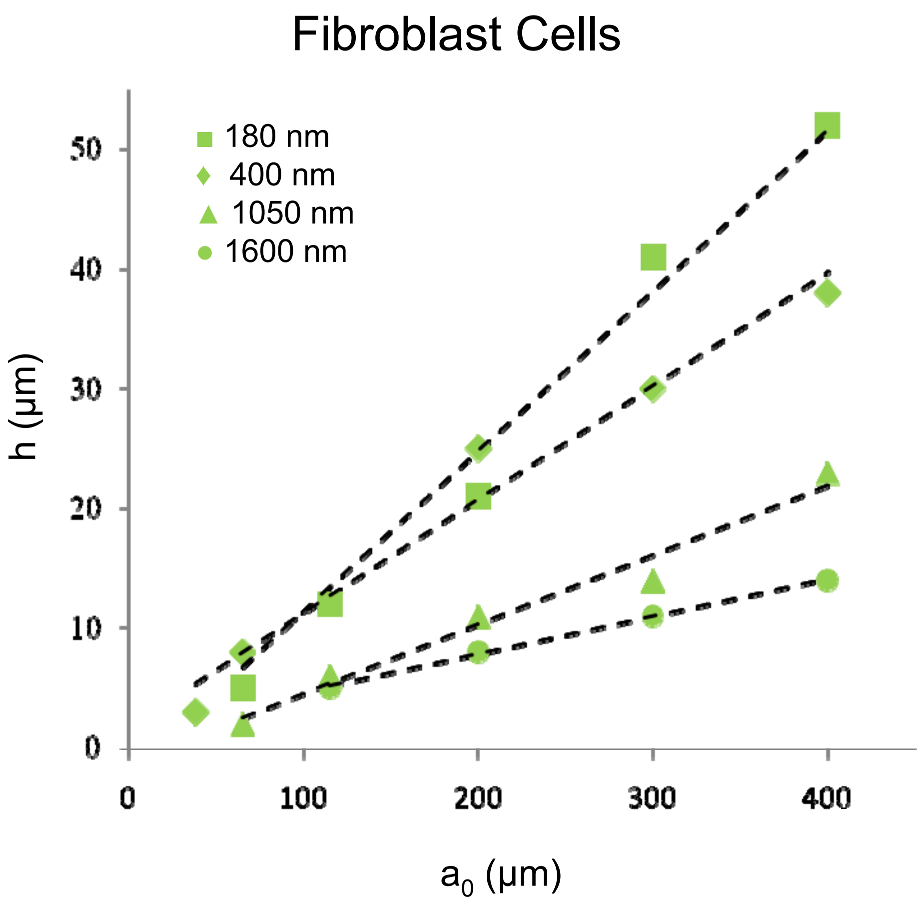
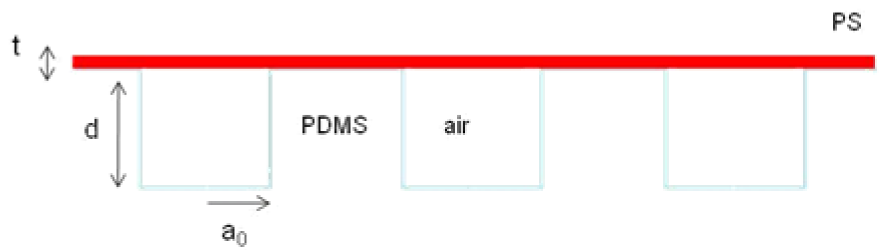
Film Thickness

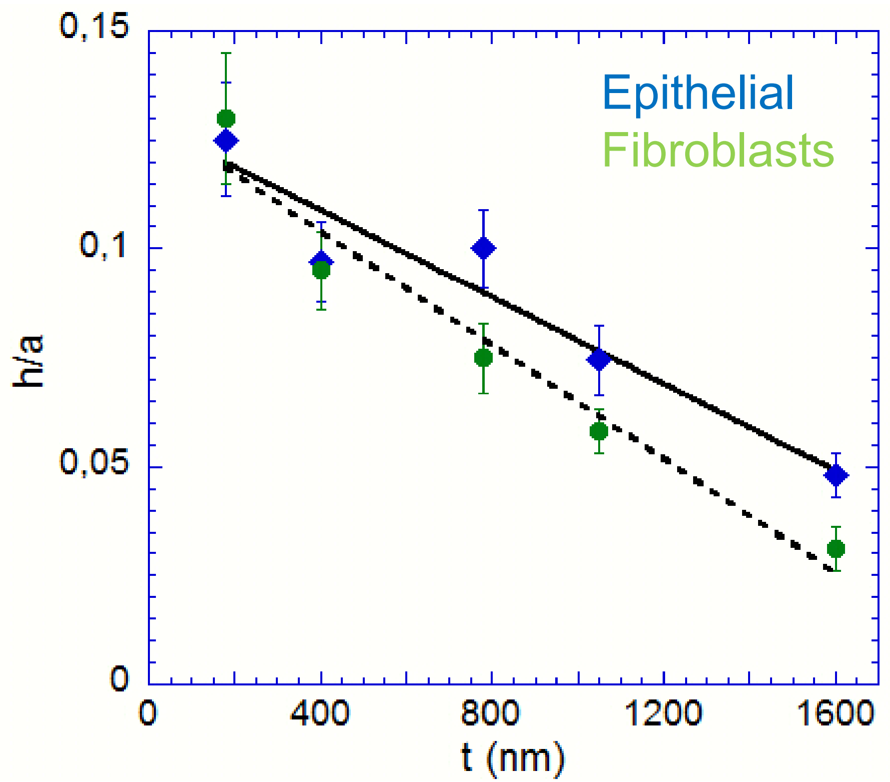


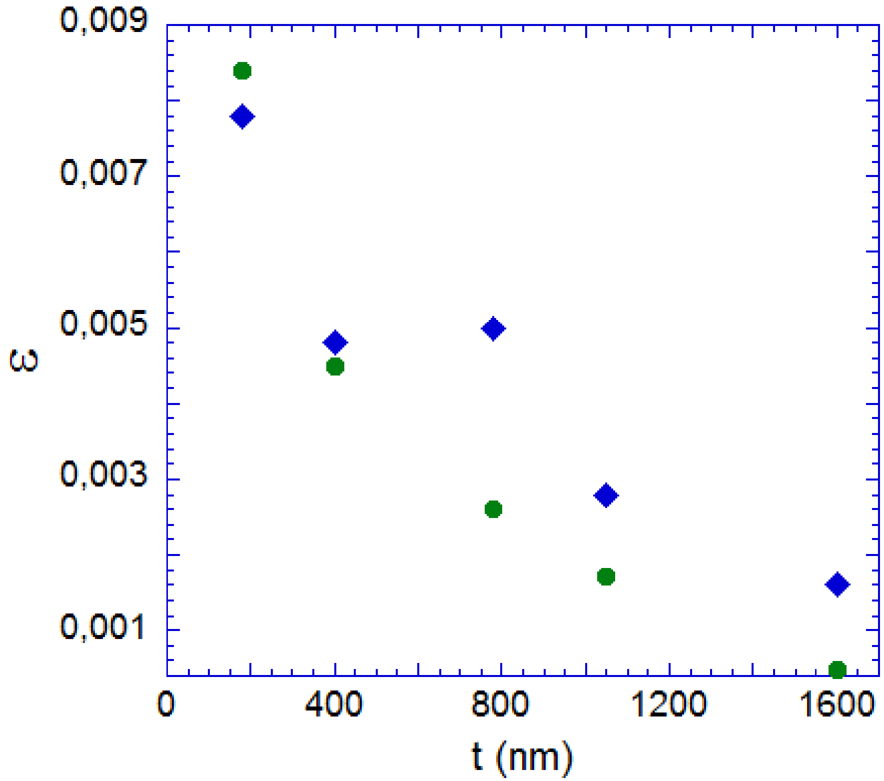




Miquelard, Zimberlin, Wadsworth, Crosby (2009) *in preparation*

Cell Sheet Strain

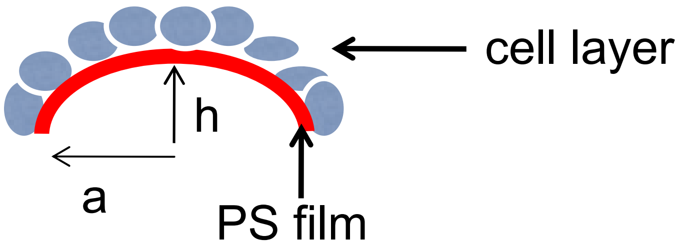




$$\frac{h}{a_o} = \sqrt{\varepsilon\left(2-\varepsilon\right)} \approx \sqrt{2\varepsilon}$$

Miquelard, Zimberlin, Wadsworth, Crosby (2009) *in preparation*

Cell Sheet Stress

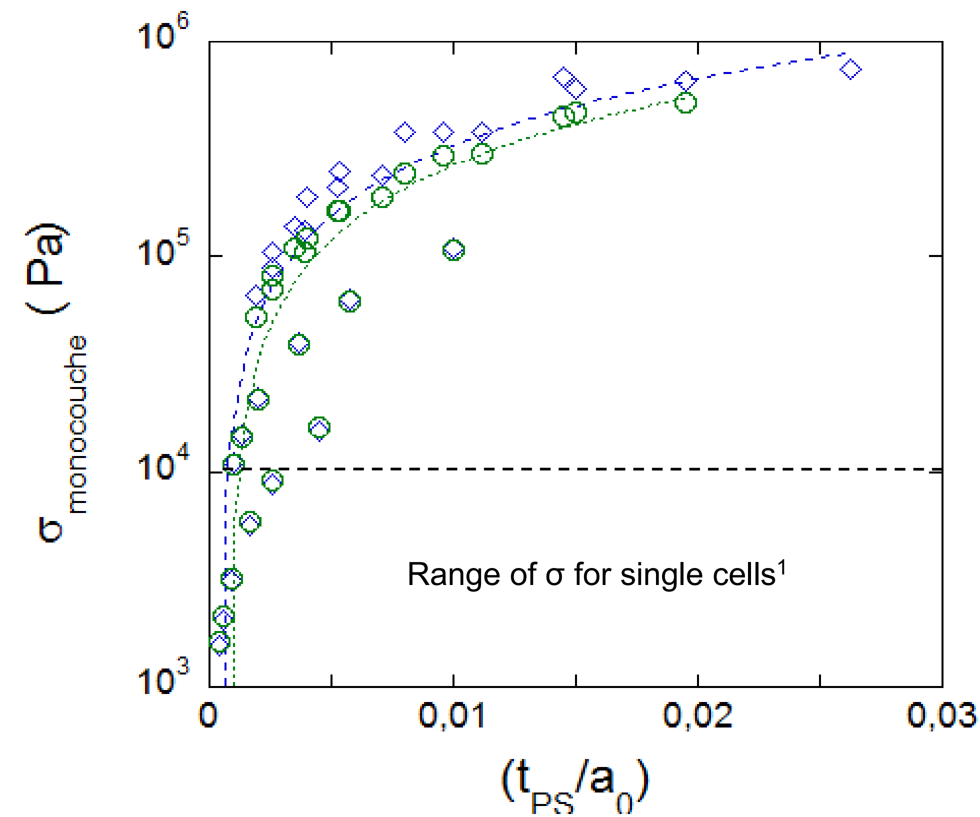


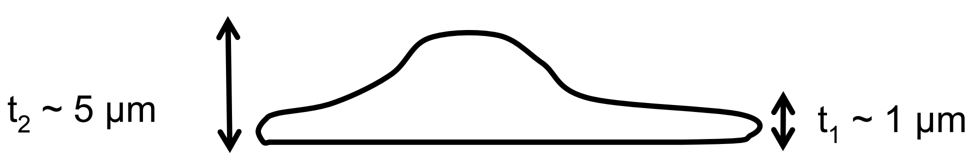
$$\sigma_{St} = \frac{E_s}{3(1-\upsilon)}\left(\frac{t_s}{t_{cell}}\right)\left(\frac{h}{a}\right)\left(\frac{t_s}{a}\right)$$

$$\sigma_{cells} = \sigma_{St}\left(\frac{1+\gamma\delta^3}{1+\delta}\right)$$

$$\delta = \frac{t_{cell}}{t_s}$$

$$\gamma = \frac{E_{cells}(1-\nu_s)}{E_s(1-\nu_{cells})}$$





Stoney, Proc. Roy. Soc., A82, 172, 1909
Freund, 1999
Klein, 2000

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Summary

- Adaptive surfaces combine living and synthetic materials for advanced applications
- Intercellular junctions play critical role in cell sheet mechanics
- Cell sheet stress increases with substrate stiffness, effect of intercellular junctions is enhanced

Acknowledgements: NSF IGERT, NSF MRSEC