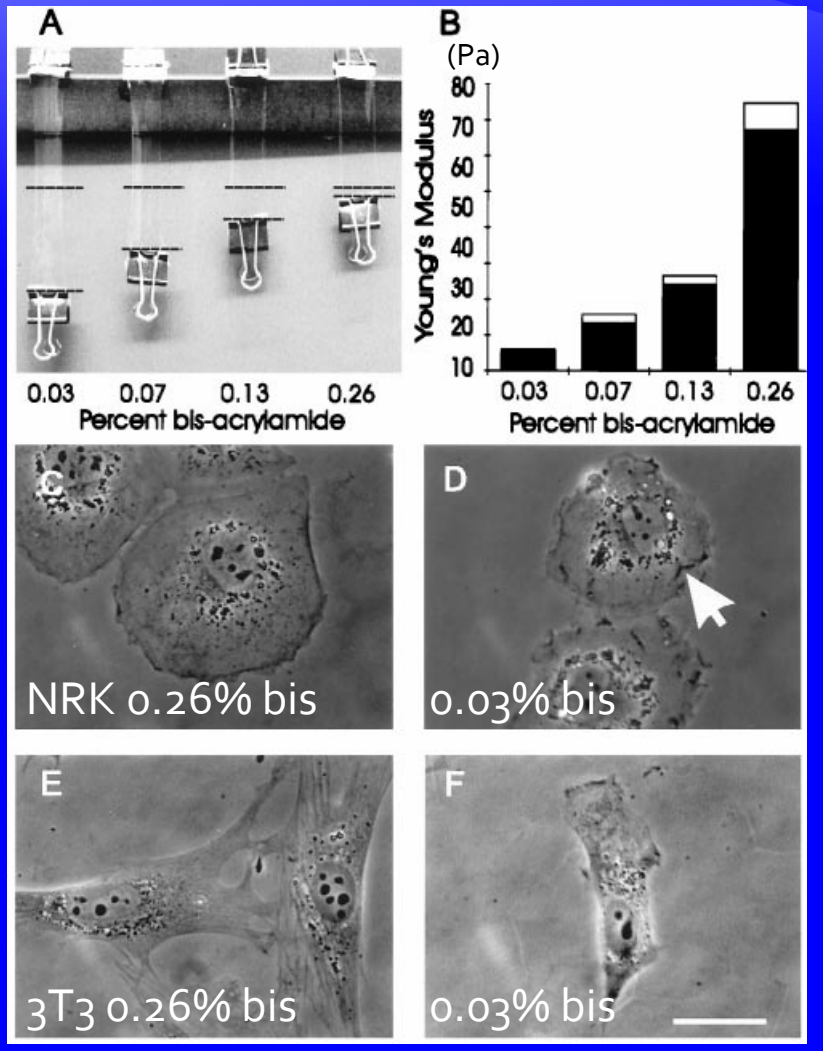
Session 20

TRACTION FORCE CONTINUA

Polyacrylamide Gels

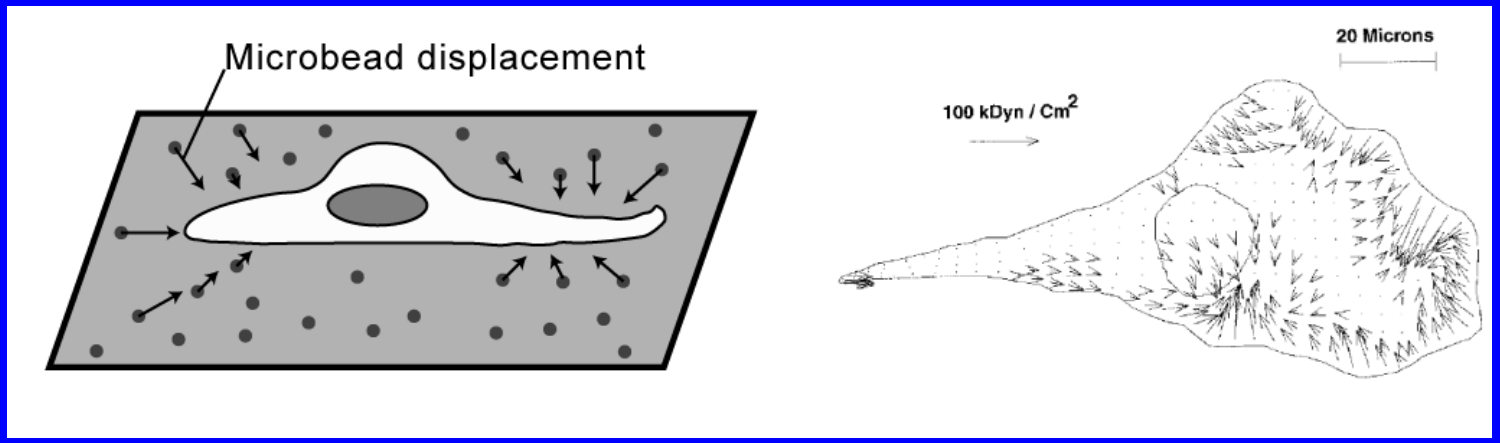
- Cells sense and respond to substrate elasticity
- Aim: vary substrate stiffness with constant chemical adhesiveness
  - Polyacrylamide gels with collagen coating
  - Bis-acrylamide cross-links gel and increases stiffness



Pelham RJ, Wang YL (1997) PNAS, 94:13661

Traction Force Microscopy

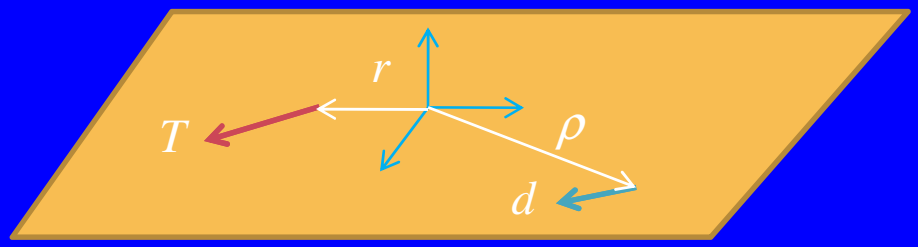
- Embed fluorescent microbeads into gel
- Observe bead positions under and around cell
- Remove cell and record cell-free positions
- Calculate the "most likely" traction forces



Bousinesq (Cerruti) Problem

- Tangential force acting on an elastic half-space
- Displacement of particle p is

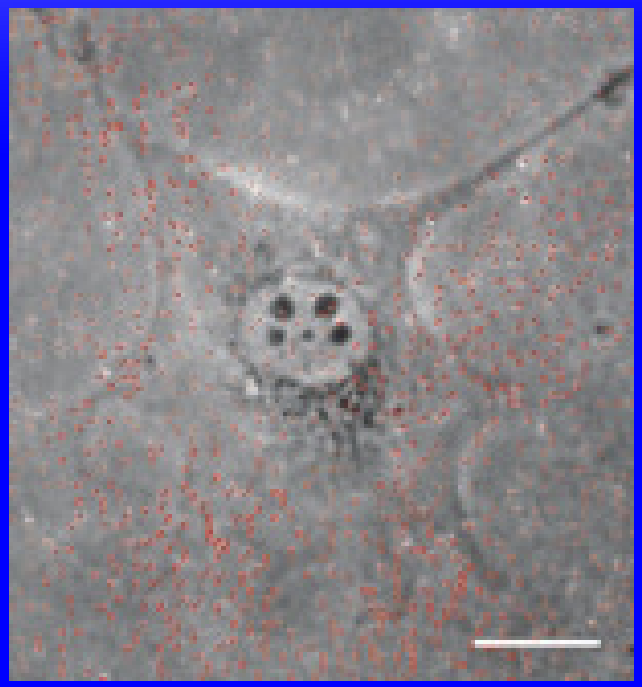
$$d_{pi} = \iint g_{ij}(\vec{\rho} - \vec{r}) T_j(\vec{r}) dr_1 dr_2$$

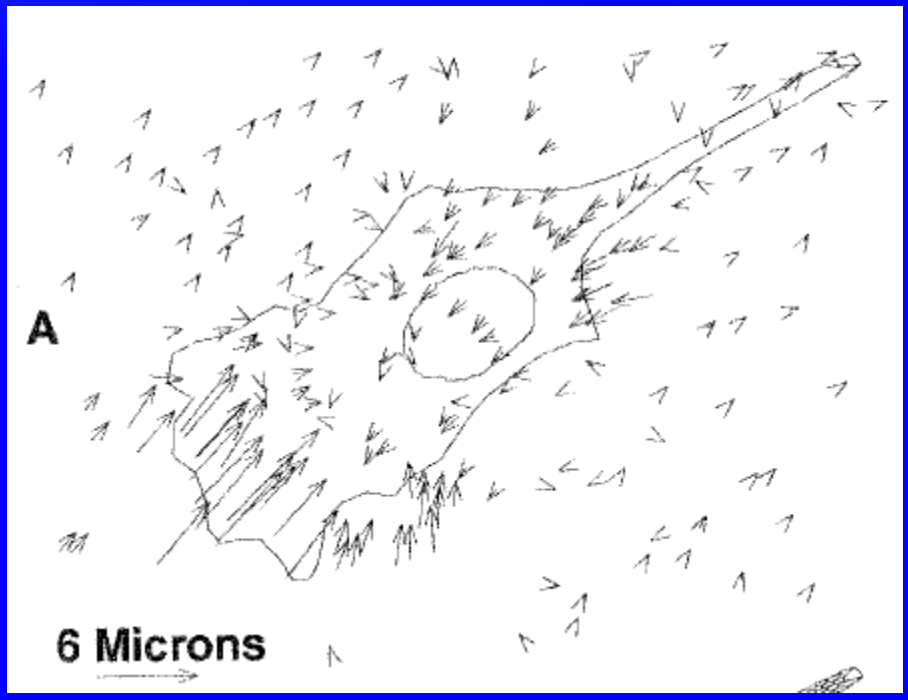


- Green's tensor g_{ij} gives displacement in i-direction at location ρ due to concentrated force T at location r acting in j-direction

Optical Imaging of Displacements

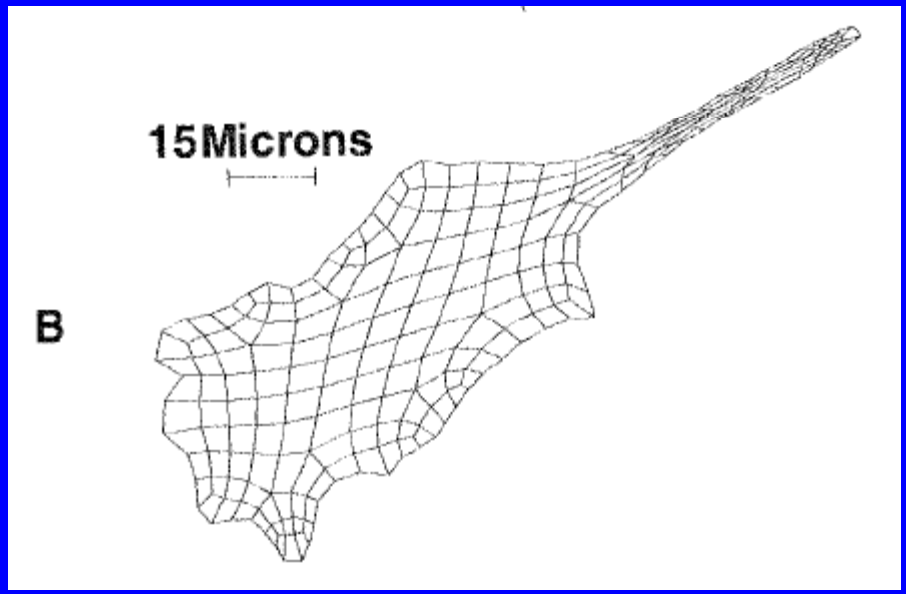
- Arrows indicate displacement of beads





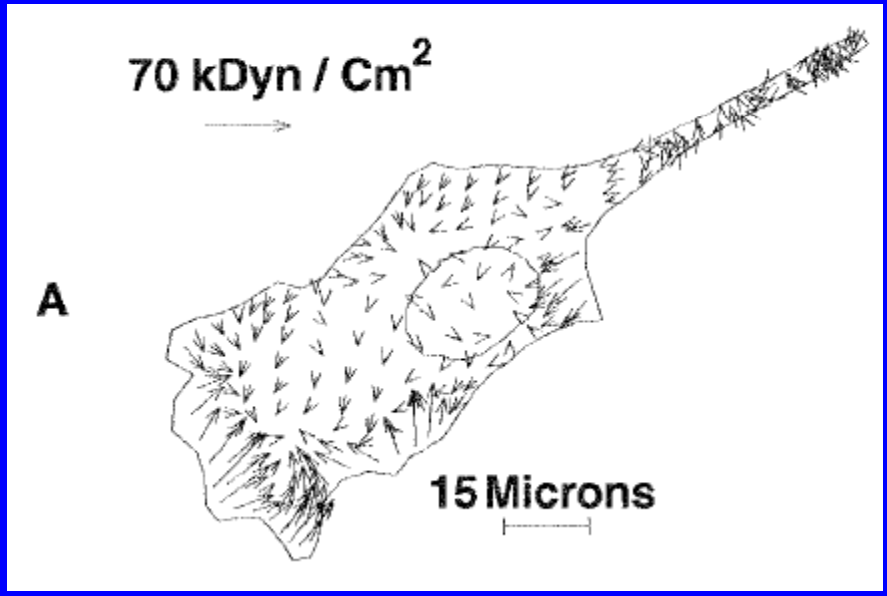
Finite Element Meshing

- Quadrilateral mesh
  - Define region where traction can exist



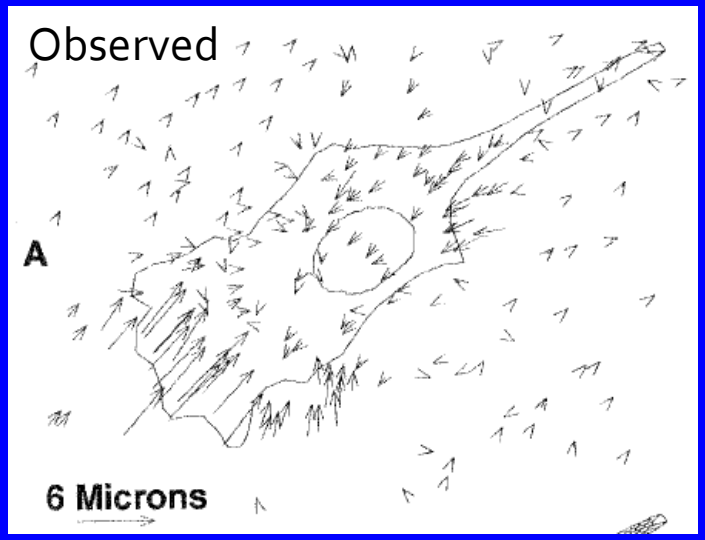
Predicted Traction Field

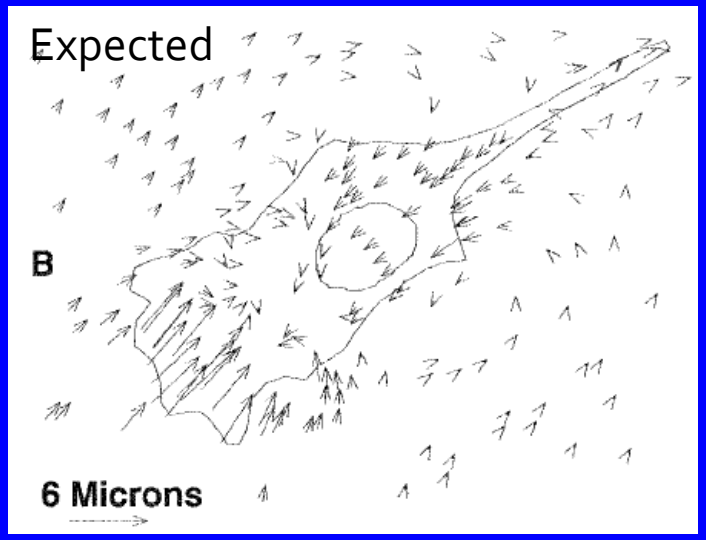
- Invert displacement equation to solve for traction field



Expected Displacement Field

- Likelihood of traction field solution
  - Minimized Chi-squared comparison
    - Lowest difference between observed and expected displacements
  - Minimized complexity
    - Lowest average traction field density



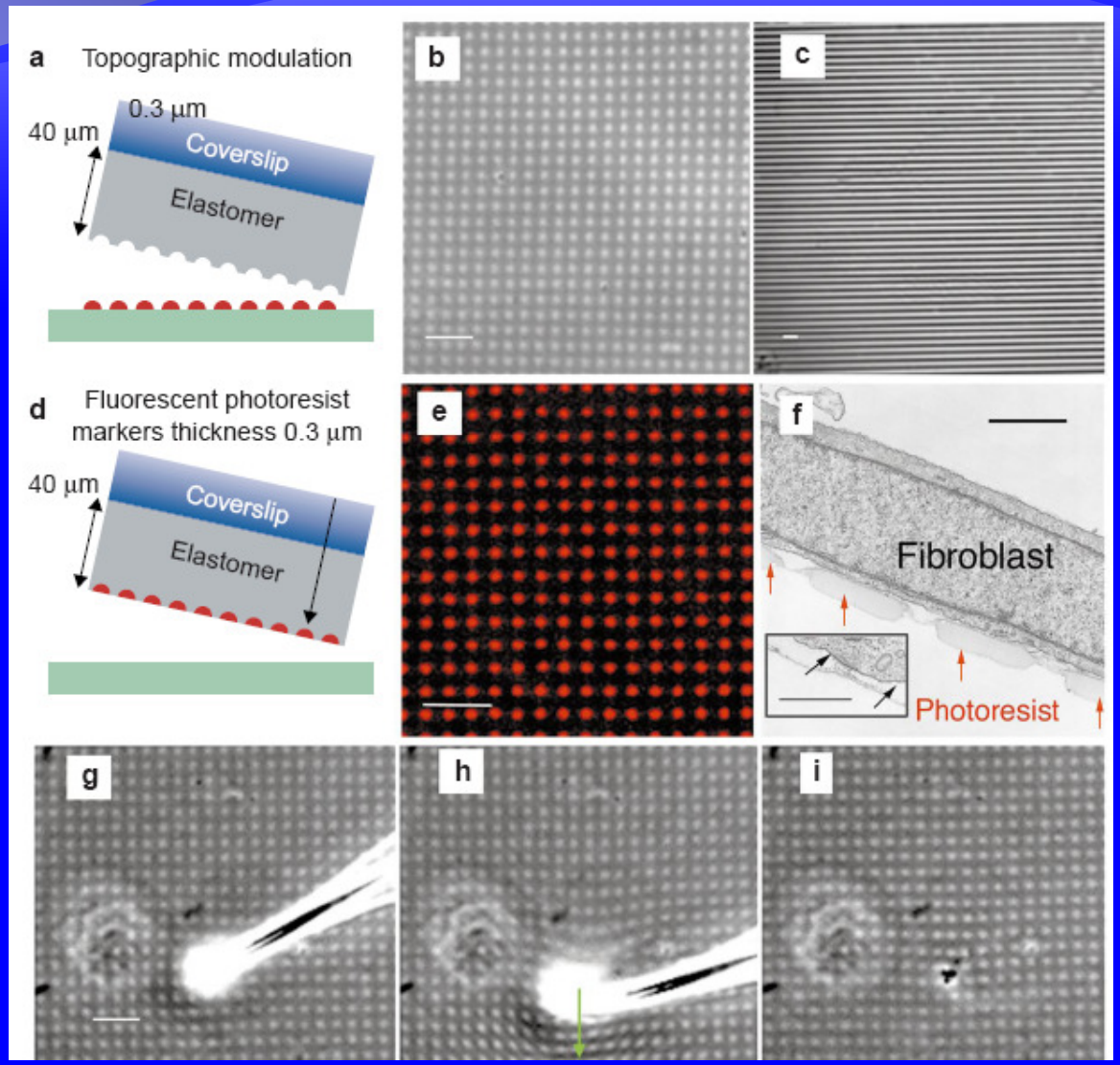


Improvements to Traction Force Microscopy

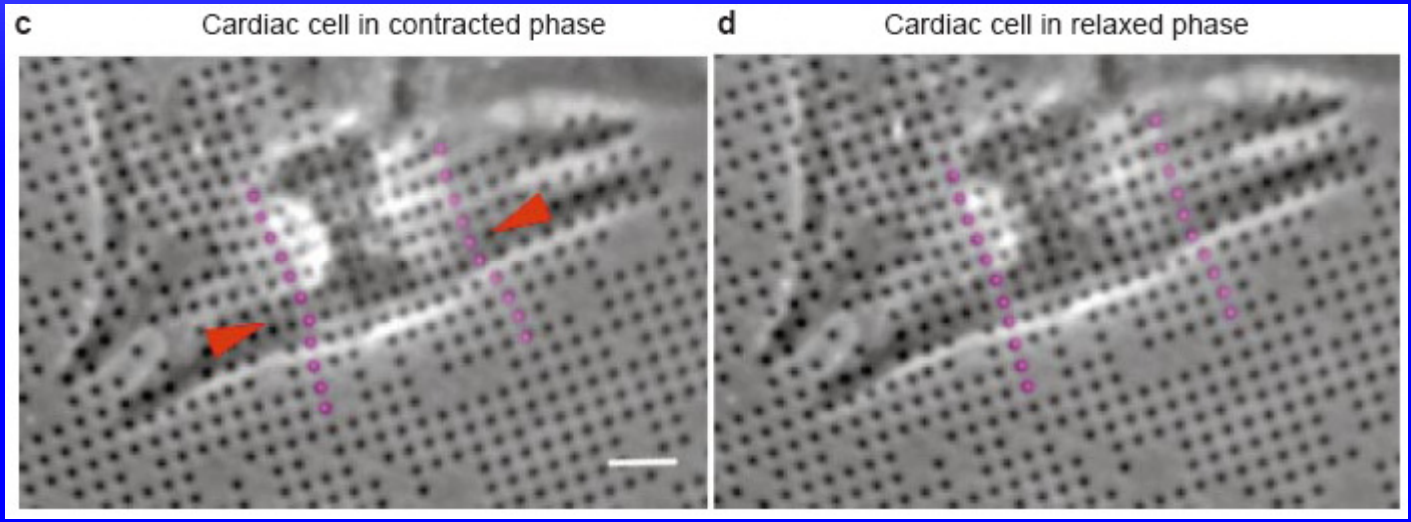
- Changes in ligand coating
- Finite thickness consideration
- New computation approaches
  - Fourier space analysis (Butler & Fredberg)
  - Exact solution to elastic half-space (Aliseda & Lasheras)

Micropatterned Substrates

- Photolithography approach
  - Marker pits
  - Fluorescent dots

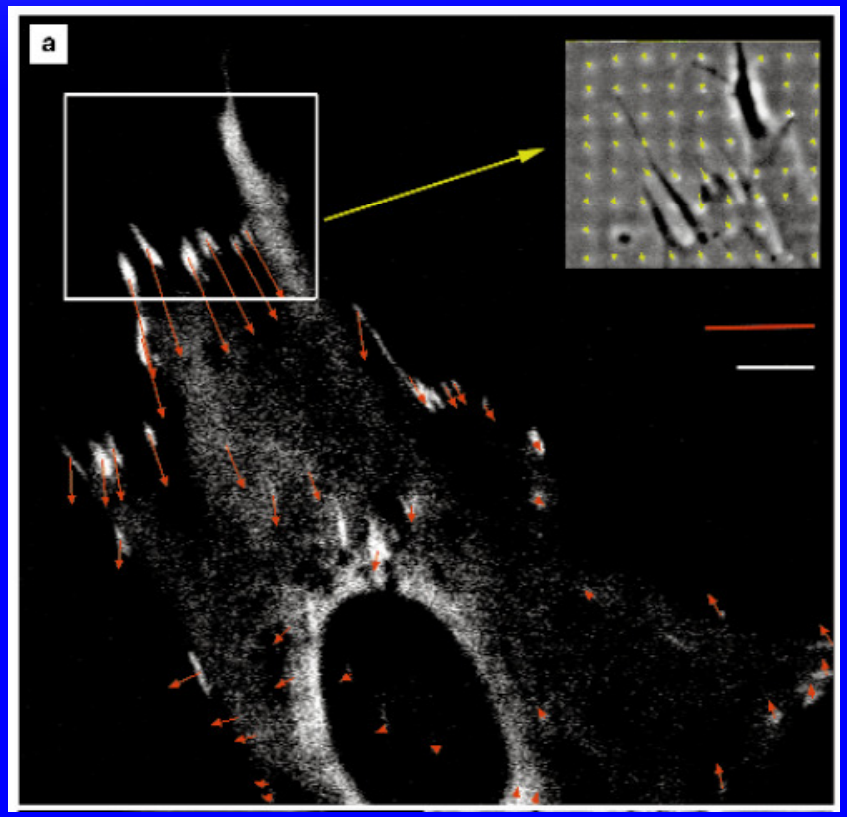


Cardiomyocyte Contraction



Force measured at focal adhesions

- Fibroblast transfected with cDNA for GFP-vinculin fusion protein



Traction Forces increase Focal Adhesion Structure: Spatiotemporal Correlation

- BDM relaxation at t=o causes decreased focal adhesion area and intensity