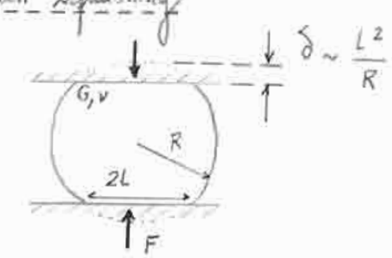
last time : - structural elements of the cytoplasm (cytosol , cytoskeleton)
- dimensional analysis & scaling
- cell mechanics experiments : cell indentation (elastic analysis not perfect : hysteresis)

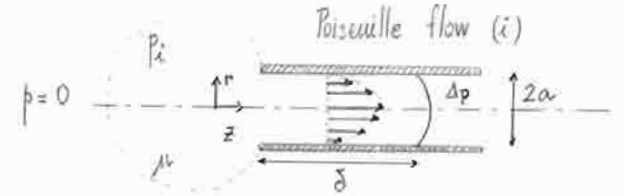
This time : micropipette aspiration
microbead manipulation
- microstructural models Brownian motion of microbeads
- mechanotransduction

• cell squashing



energy $U \sim F\delta \sim G\left(\frac{\delta}{L}\right)^2 L^3$, hence $F \sim G\,\delta^{3/2} R^{1/2}$

• micropipette aspiration (dynamic case : $\Delta p > \Delta P_c$ critical pressure)



assumptions neglect surface tension N $p_i = 0$
neglect shear or bending effects in membrane
treat interior of cell as viscous fluid
neglect inertia

Two scenarii (i) no-slip boundary condition at pipette wall $v_z(r = a) = 0$
(ii) membrane slides without friction inside pipette $v_z = \frac{d\delta}{dt}$ = uniform

(i) no-slip model (viscous drop) $\Delta p \longleftrightarrow \frac{d\delta}{dt}$ or $\delta(t)$?

$\nabla p = \mu \nabla^2 v_z$
pressure ~ shear

$\frac{\partial p}{\partial z} \sim \frac{\mu}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) \sim \frac{\mu}{a^2}\frac{d\delta}{dt}$ (radial gradient dominates)

$\frac{\Delta p\, a^2}{\mu}\, dt \sim \delta\, d\delta$ yields the relation $\boxed{\delta \sim \sqrt{\frac{\Delta p\, a^2\, t}{\mu}}}$

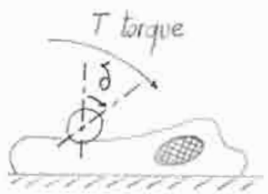
(ii) no-friction model

$\frac{\partial p}{\partial z} \sim \frac{\Delta p}{a} \sim \mu \frac{\partial^2 v_z}{\partial z^2} \sim \frac{\mu}{a^2}\frac{d\delta}{dt}$ (axial gradient at the entrance of the pipette)

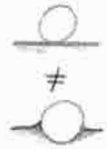
$\frac{\Delta p\, a}{\mu}\, dt \sim d\delta$ yields the relation $\boxed{\delta \sim \frac{\Delta p\, a\, t}{\mu}}$

(thin lubricating layer)
Dembo at BU

• microbead manipulation : magnetic twisting cytometry



relationship between T and δ ? for homogeneous elastic continuum



get $G^* = G' + i\,G''$ (soft glassy material ≡ cell , Fabry et al.)

- Laser tracking microrheometry (Brownian motion of beads)

access to G' and G" (homogeneous medium)
through mean square displacement
viscous for short time, elastic for long time

- Cell models
  - viscoelastic membrane on top of viscoelastic CSK (bending, surface tension, elasticity scales)
    Turner & Sens
    not necessarily linear dependence between force (indentation) and deformation
  - cellular solids model
    Gibson & Ashby, 1988; Satcher & Dewey 1997
    characteristic unit cell  bending of network
  - tensegrity model
    Donald Ingber

  - biopolymer model. $k_B T$ dependence