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international centre for theoretical physics

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WINTER COLLEGE ON BIOPHOTONICS: Optical Imaging and Manipulation of Molecules and Cells (10 - 21 February 2003)

"Elements of the cell cytoskeleton"

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These are preliminary lecture notes, intended only for distribution to participants.

























Actin	2 GPa	ξ _p =15 μm
Tubulin	2 Gpa	ξ _p =6 mm
Silk	~5 GPa	
Elastin	0.002 GPa	
Cellulose	80 GPa	Dry ramie fibers
Cellulose	20-40 Gpa	Wet fibers
DNA	~1 GPa	ξ _p =50 nm
Spektrin	0.002 GPa	ξ ₀ =10-20 nm

Source: table 2.2 in D. H. Boal: "Mechanics of the Cell", and table 8.4 in J. Howard: "Mechanics of Motor Proteins and the Cytoskeleton".







Elasticity of 2D networks Symmetry important. Two relevant cases: Square symmetry. Four-fold connectivity Triagonal symmetry. Six-fold connectivity General elasticity theory:		
1D	2D	
Displacement, x	Strain tensor u _{ij} (relative deformation)	
Force, f	Stress tensor, σ_{ij} Stress is equivalent to pressure, force per unit area	
$f=-k_{sp}x$ k_{sp} : spring constant	$\sigma_{ij} = \sum_{k,l} C_{ijkl} u_{kl}; C_{ijkl} \text{ Elastic stiffness constants}$	
$E = \frac{1}{2}k_{\rm sp}x^2$	Density of free energy, ΔF : $\Delta F = \frac{1}{2} \sum_{ijkl} C_{ijkl} u_{ij} u_{kl}$	















A scint-billing point of solution can be take the an elastic medium at short timescales, and like a viscous fluid at longer time scales. This behaviour is characterized by "the viscoelastic properties" of the medium.
 Time-domain: relaxation modulus, G(τ)
 Frequency domain: shear moduli, G'(ω) and G''(ω)

Apply oscillating strain $u_{\alpha}(t)$ at frequency ω , the resulting stress in the material is $G^{11}(\omega)$, du_{α}

$$\sigma_{xy} = G'(\omega) u_{xy}(t) + \frac{G'(\omega)}{\omega} \frac{\partial u_{xy}}{\partial t}$$

 $\mathcal{G}'(\omega)$: role of a shear modulus $\mathcal{G}'(\omega)$ termed "shear storage modulus" $\mathcal{G}''(\omega)/\omega$: role of a dynamic viscosity \Rightarrow $\mathcal{G}''(\omega)$ termed "shear loss modulus"







































Want to learn more?

Relevant books:

- "Mechanics of the Cell" by D. H. Boal
- "Mechanics of Motor Proteins and the Cytoskeleton" by J. . Howard
- "Physics of Bio-Molecules and Cells", Les Houches lecture notes, session LXXV, ed. By H. Flyvbjerg, F. Jülicher, P. Ormos and F. David (e.g. Lecture by M. Dogterom) •
- (A very small selection of) papers:
 "Mechanism of Actin-Based Motility" by D. Pantaloni et al, Science 292, 1502-1506 (2001).
- "A Mechanism for Nuclear Positioning in Fission Yeast Based on Microtubule Pushing", by P. T. Tran et al, J. Cell Biol. 153, 397-411 (2001). .