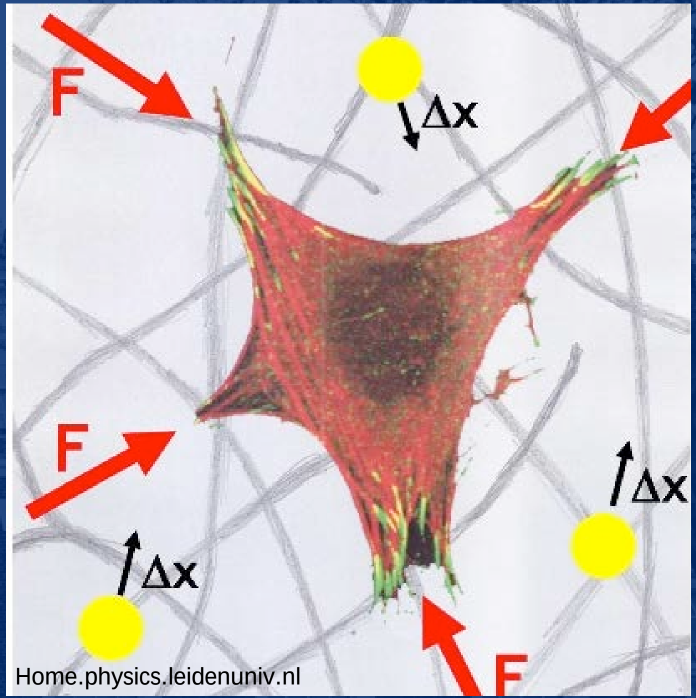
Cell and Tissue Engineering

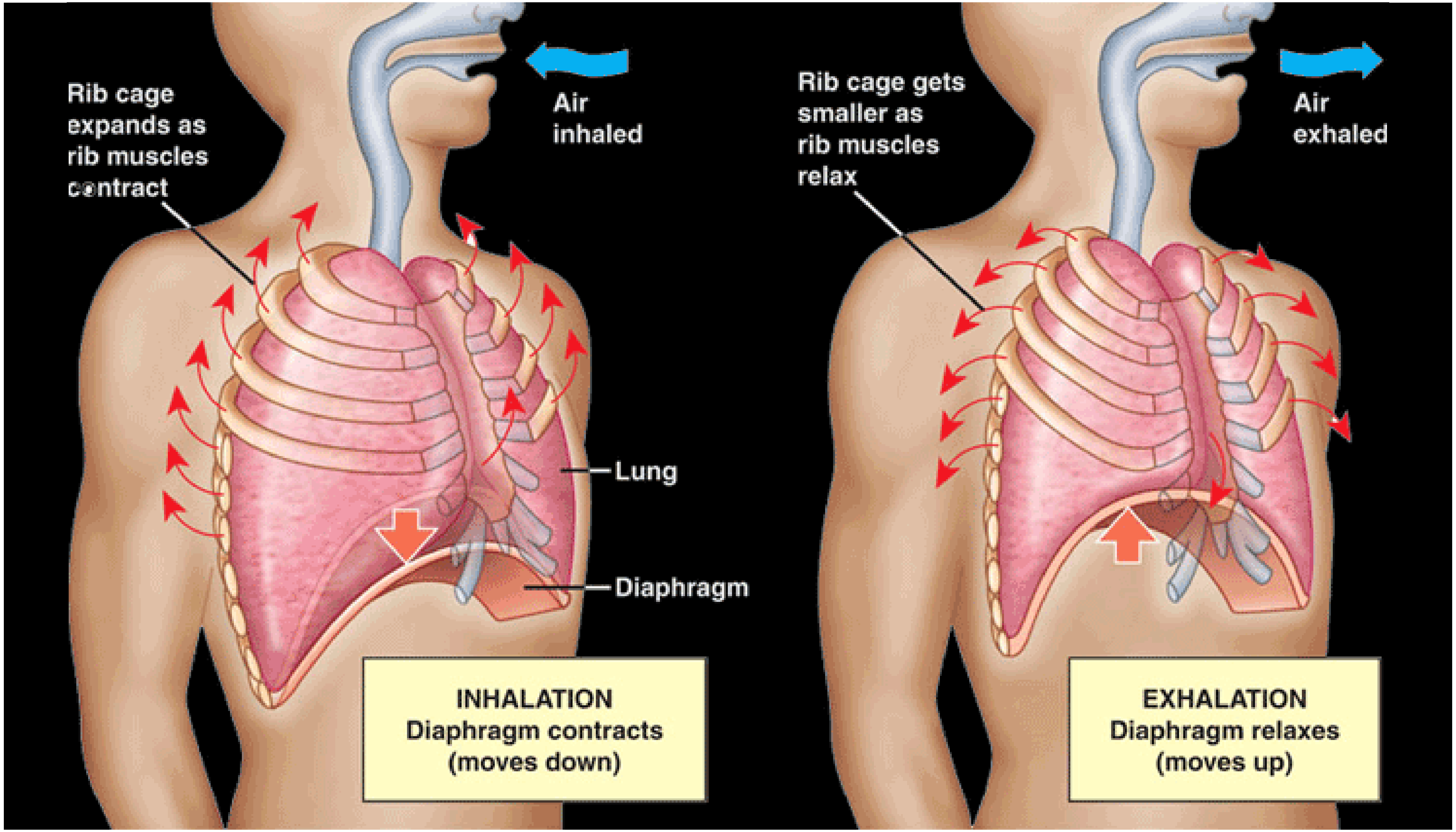
Basic Solid Mechanics



Home.physics.leidenuniv.nl

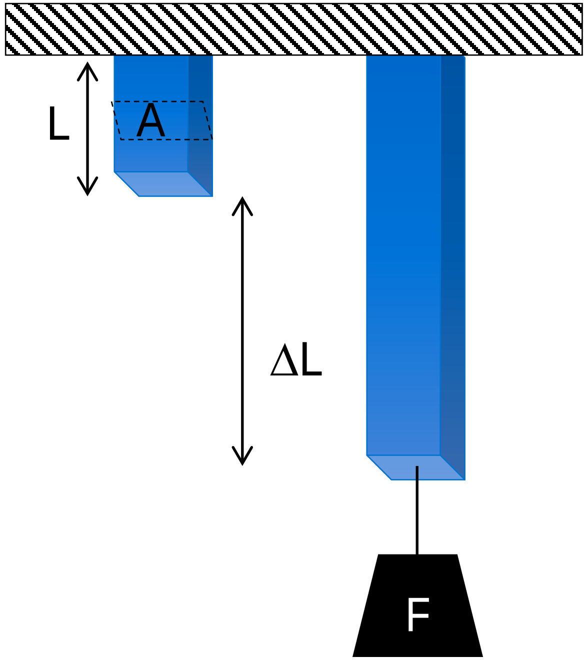
Example adapted from J. Fredberg, Harvard; Mindfulmum.co.uk

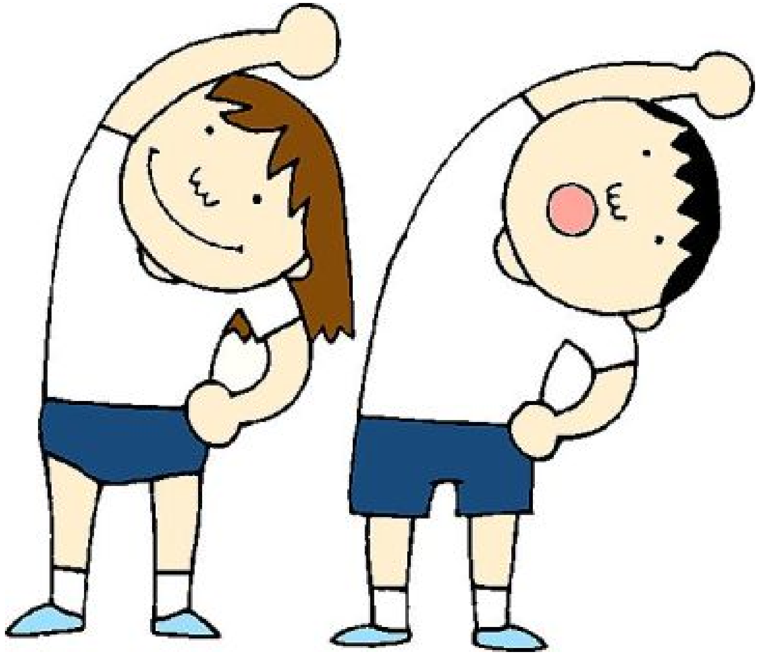
Breathing dilates and stretches cells in your lungs



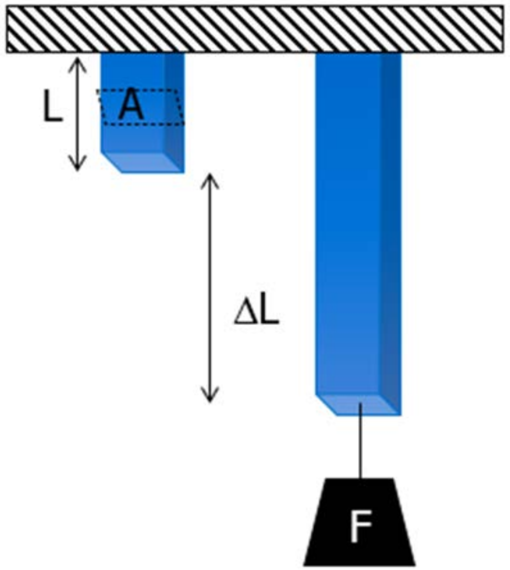
Hollister et al 2005; Mol et al 2006; Cytograft.com; Medgadget.com

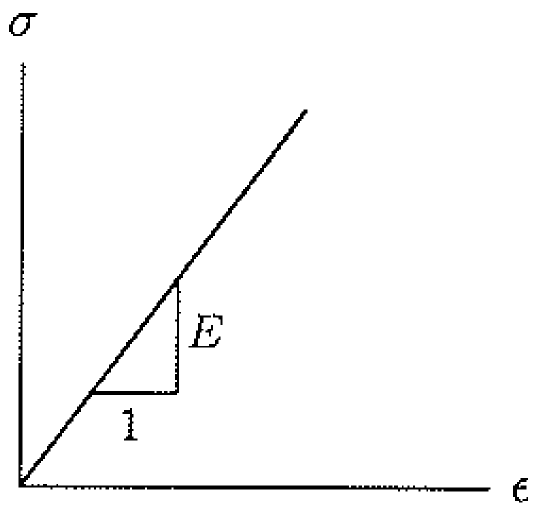
Elementary solid mechanics...





Elastic deformation



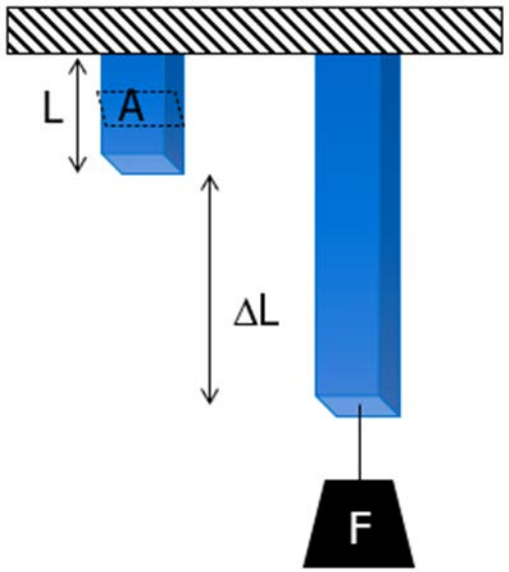


$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

Hooke's Law

σ = stress
F = force
A = area
E = elastic or Young's modulus
ε = strain

Young's modulus is a material property



E = Elastic/Young's modulus

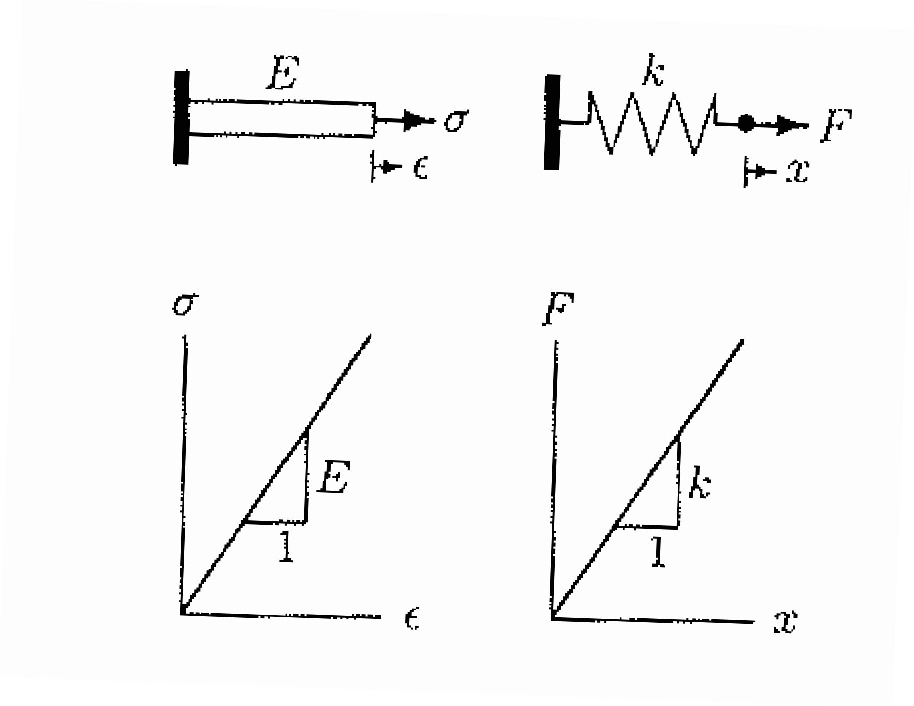
Material	Modulus (MPa)
Long bone	15-30,000
Skull bone	6,500
cartilage	1-10
tendon	1-2,000
skin	0.1-2
brain	0.067
polystyrene	2,300-3,300
Stainless steel	210,000

$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

Hooke's Law

Elastic materials behave as springs

$$\sigma = E\varepsilon \qquad F = kx$$



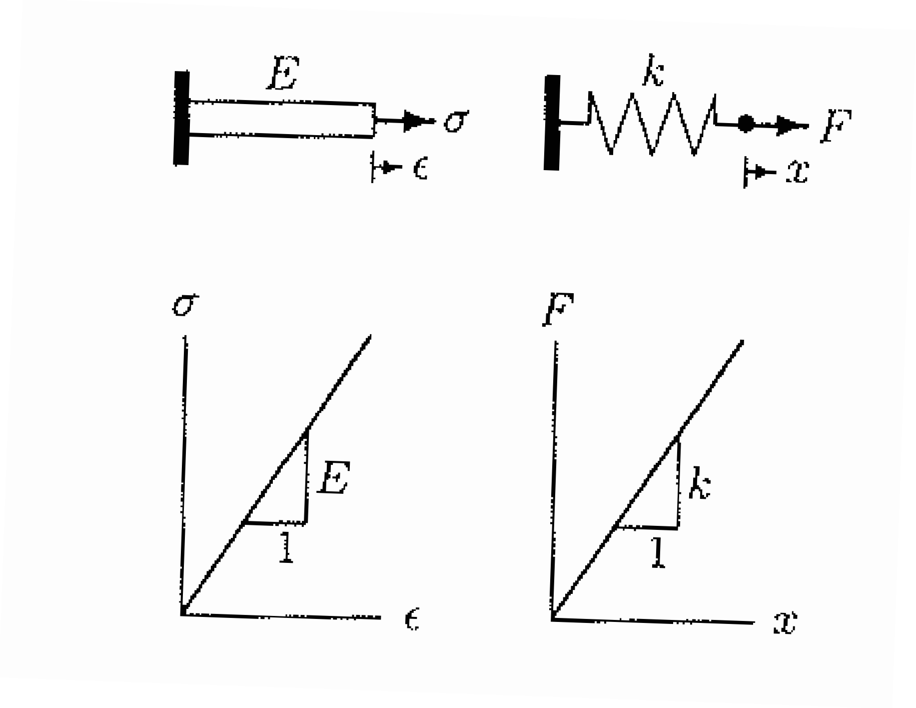
σ = stress
E = elastic or Young's modulus
ε = strain
F = force
x = displacement
k = spring constant

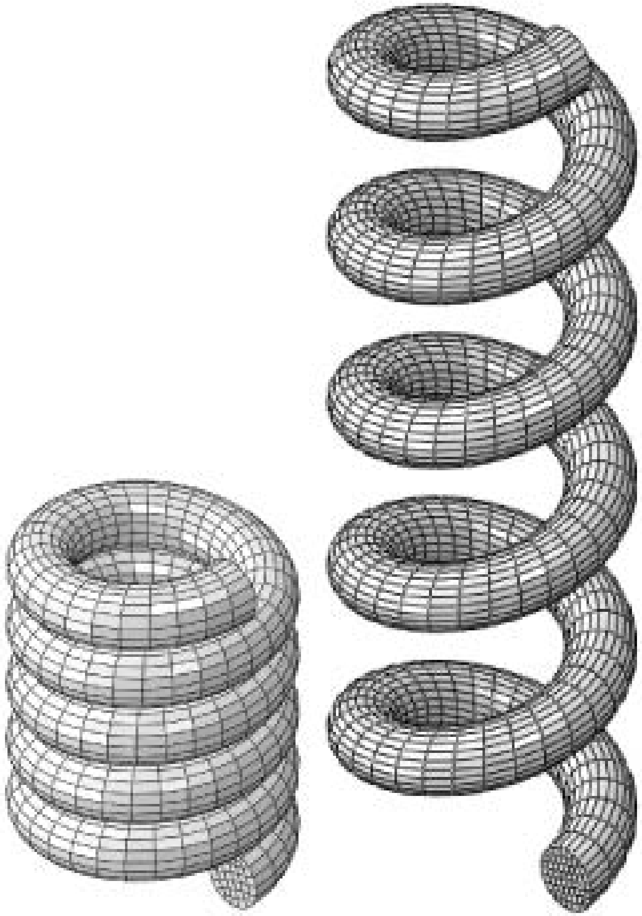
$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

Hooke's Law

Elastic materials behave as springs (cont.)

$$\sigma = E\varepsilon \qquad F = kx$$



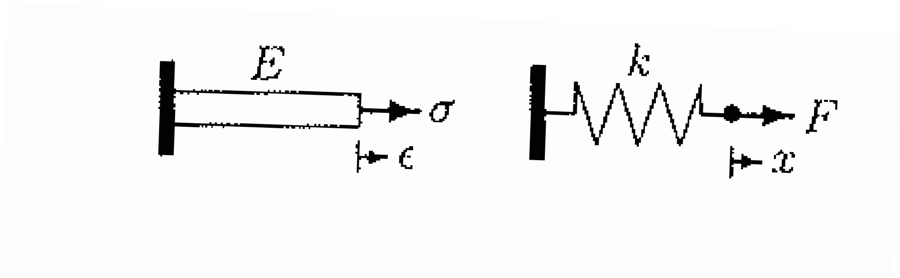


$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

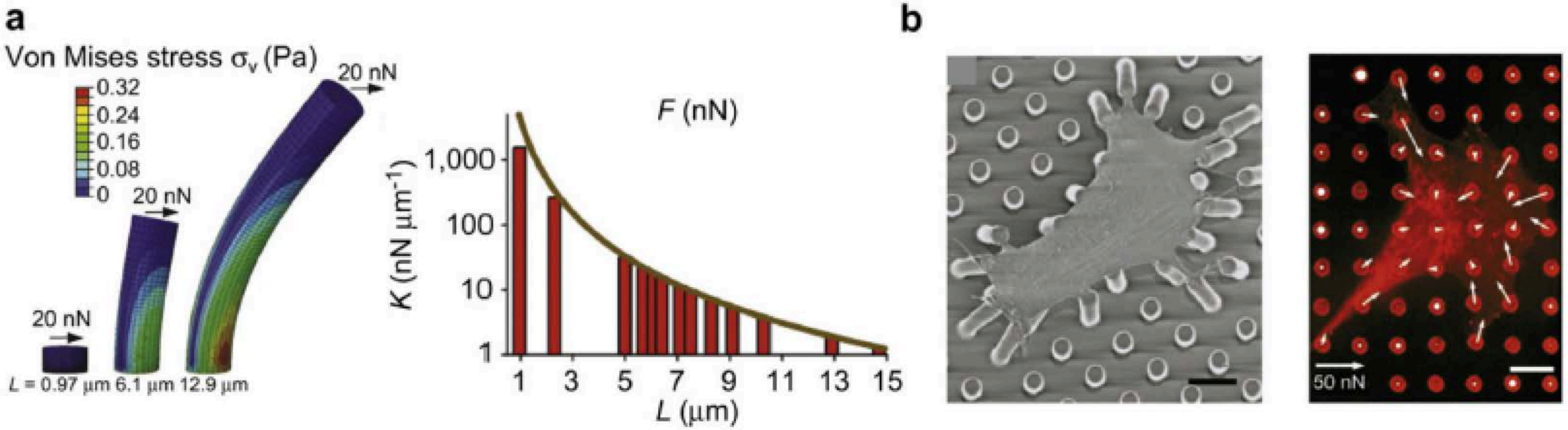
Hooke's Law

Elastic materials behave as springs (cont.)

$$\sigma = E\varepsilon \qquad F = kx$$

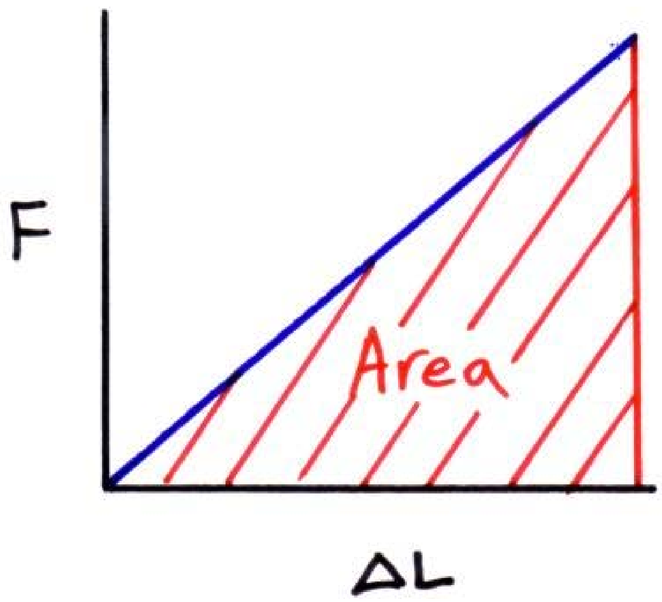


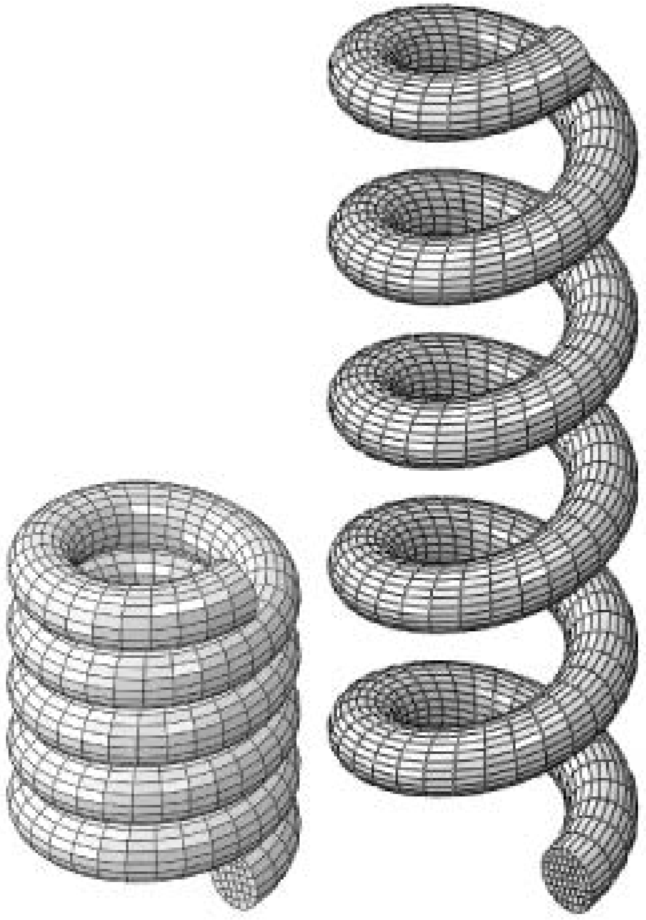
$$F = k \cdot \Delta x = \left(\frac{3}{4} \pi E \frac{r^4}{L^3} \right) \cdot \Delta x$$



Nikkhah et al, 2013

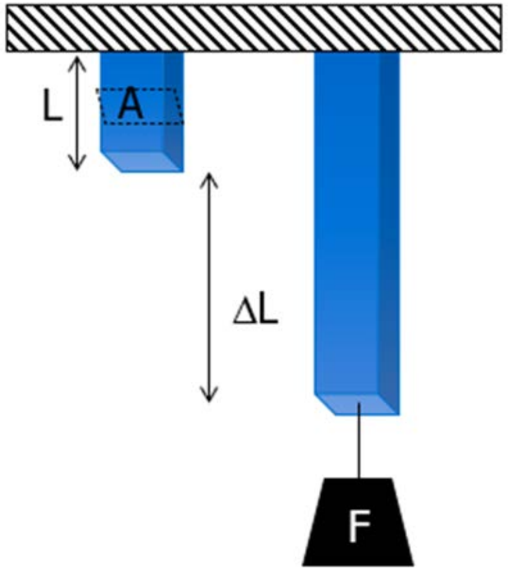
Elastic materials behave as springs (cont.)





Strain Energy $$\frac{F \cdot \Delta L}{2} = \frac{\sigma \cdot \varepsilon}{2}$$

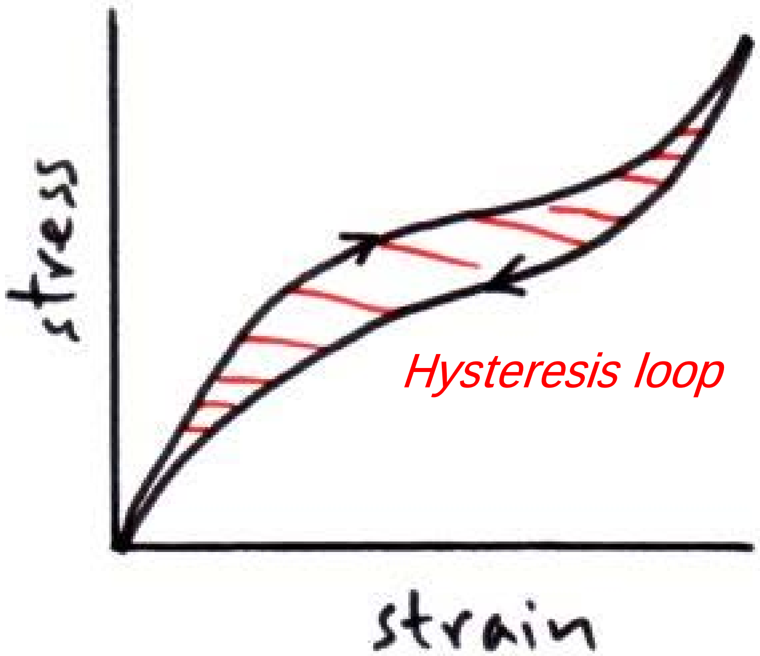
Materials can be elastic and NOT obey Hooke's law!



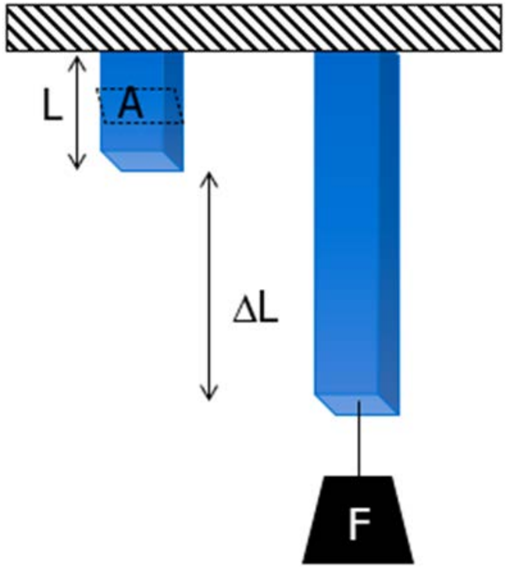
$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

Hooke's Law

RUBBER

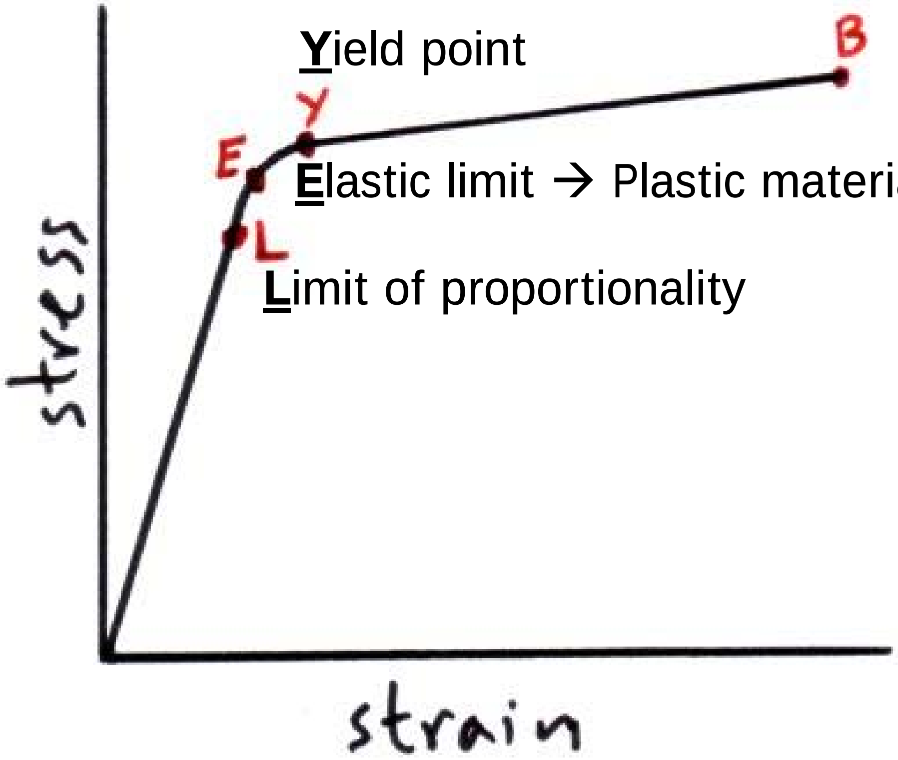


Not all materials are elastic!



$$\sigma = \frac{F}{A} = E \times \varepsilon = \frac{E \times \Delta L}{L}$$

Hooke’s Law

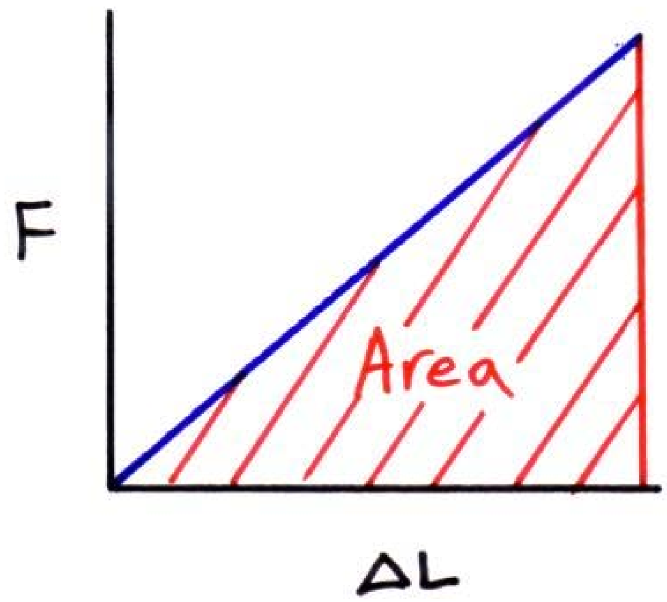


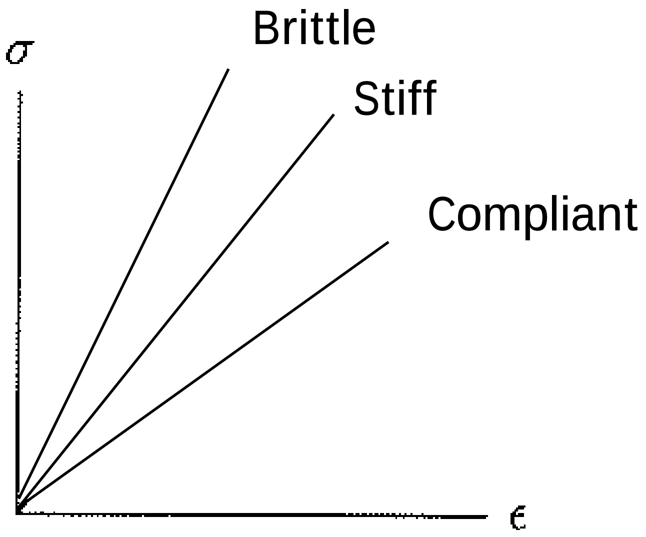
Yield point

Elastic limit → Plastic materials

Limit of proportionality

Compliant materials store the most energy

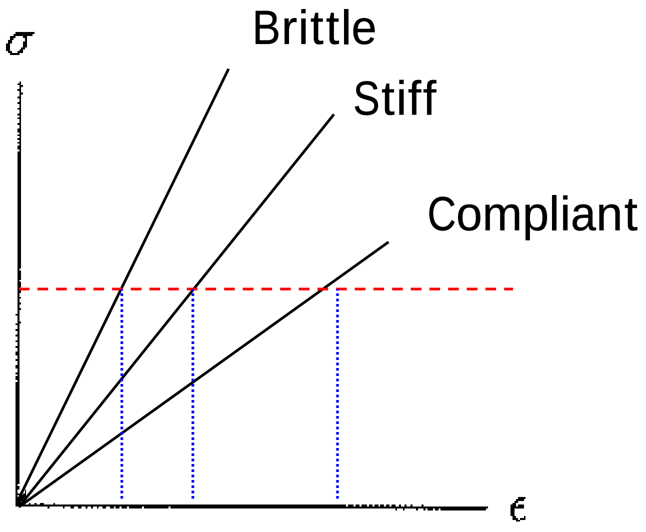




Strain Energy $$\frac{F \cdot \Delta L}{2} = \frac{\sigma \cdot \varepsilon}{2}$$

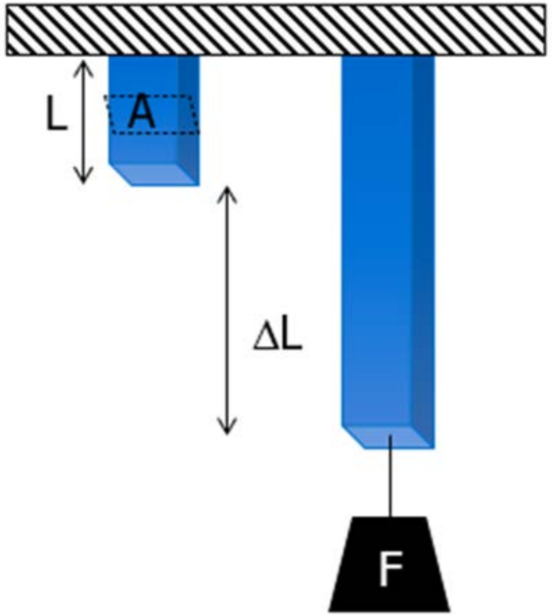
Compliant materials store the most energy (cont.)

Clock springs store energy through mechanical deformation

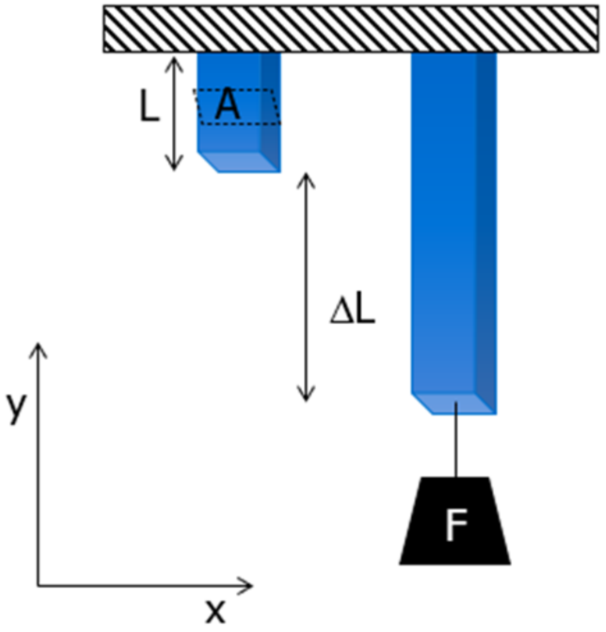


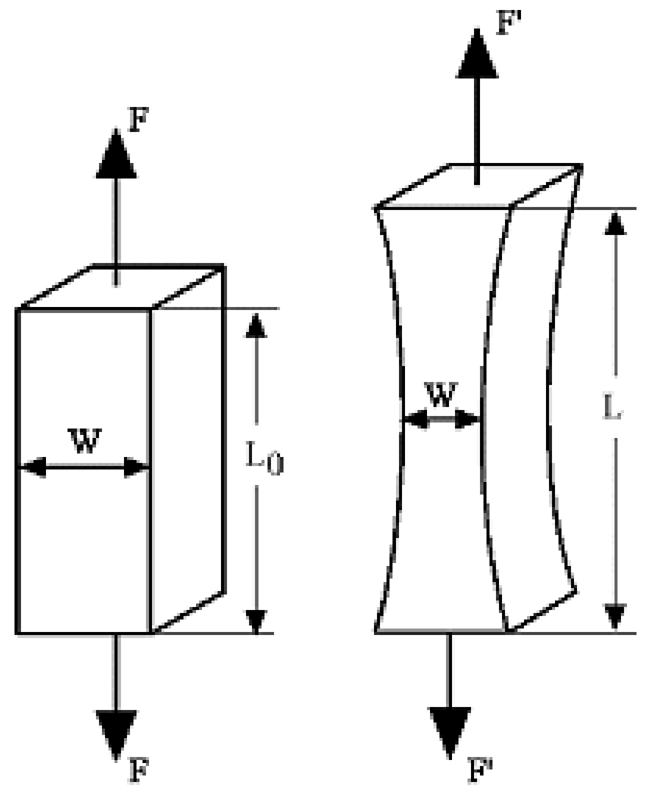
Atomictoasters.com; Wikipedia.org

Materials elongate in the direction of force



Poisson's ratio tells us about deformation perpendicular to force application

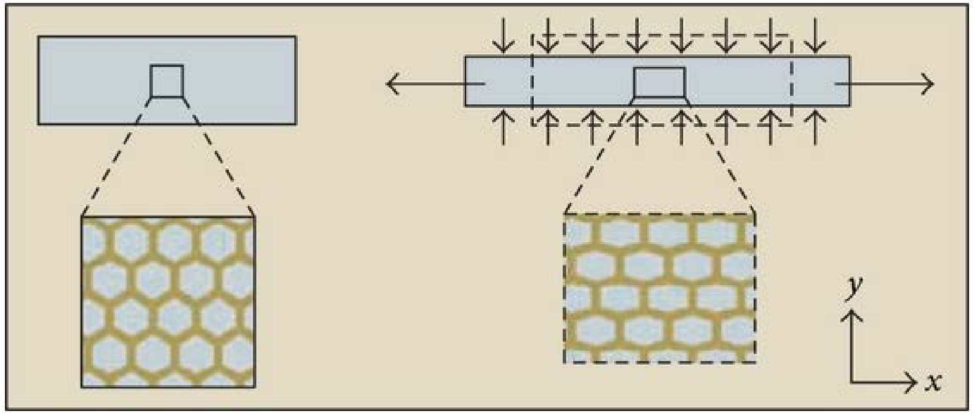




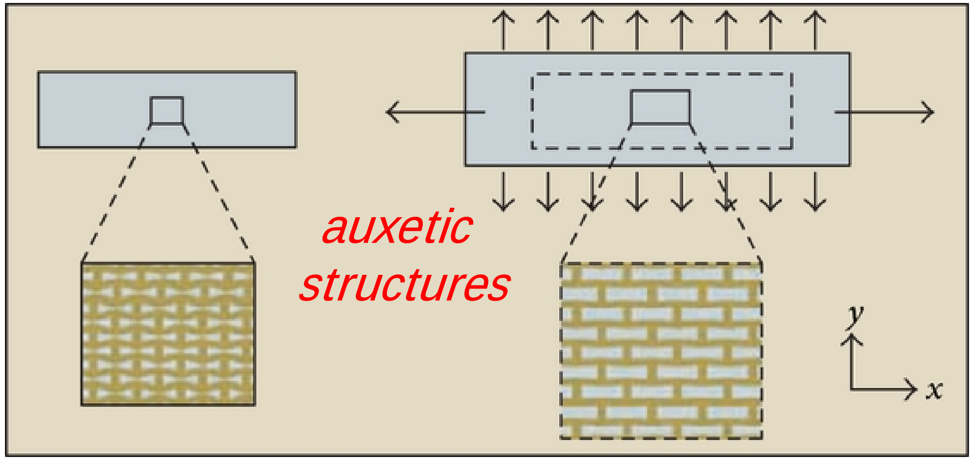
Positive Poisson's ratio $\nu_{xy} = -\dfrac{\varepsilon_x}{\varepsilon_y}$ or z (transverse) (axial)

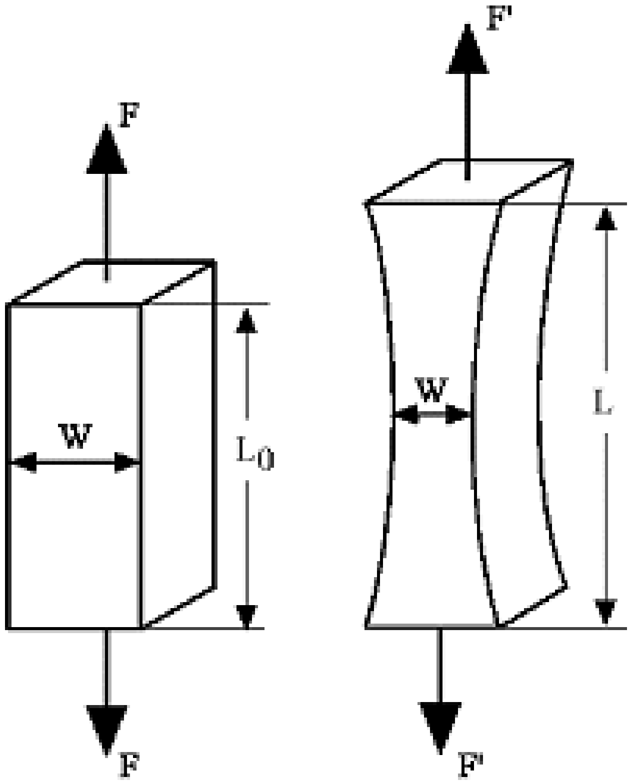
Poisson's ratio tells us about deformation perpendicular to force application (cont.)

Positive Poisson's ratio



Negative Poisson's ratio





$$\nu_{xy} = -\frac{\varepsilon_x}{\varepsilon_y}$$

or z (transverse)

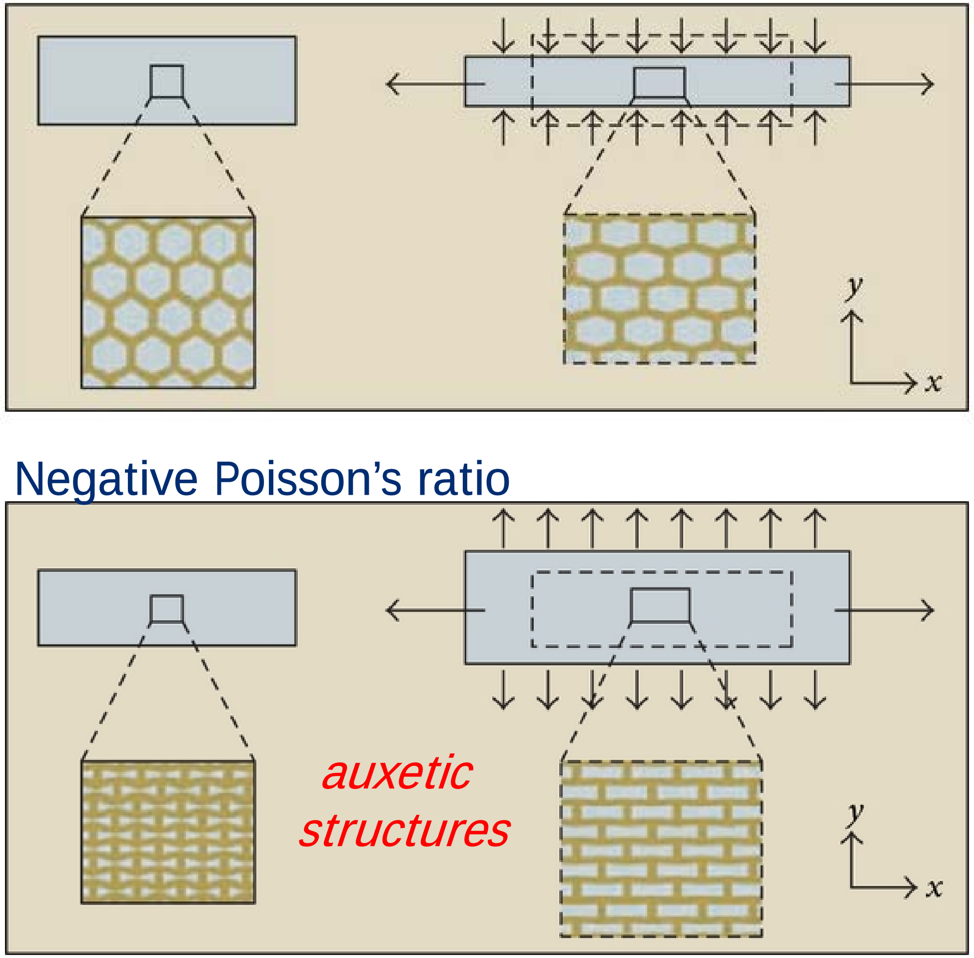
(axial)

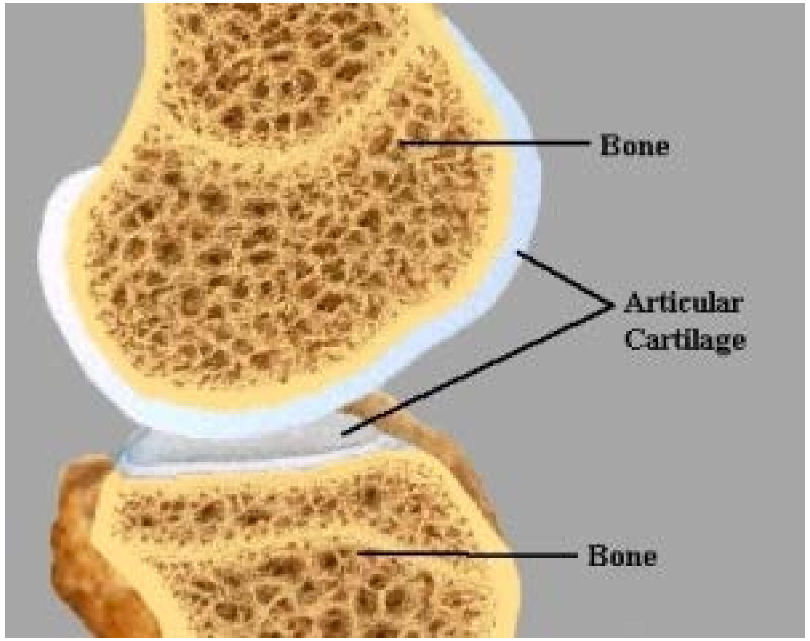
Positive Poisson's ratio

Poisson's ratio tells us about deformation perpendicular to force application (cont.)

Positive Poisson's ratio

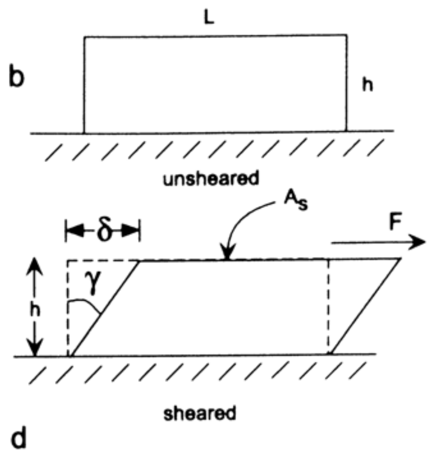
Negative Poisson's ratio

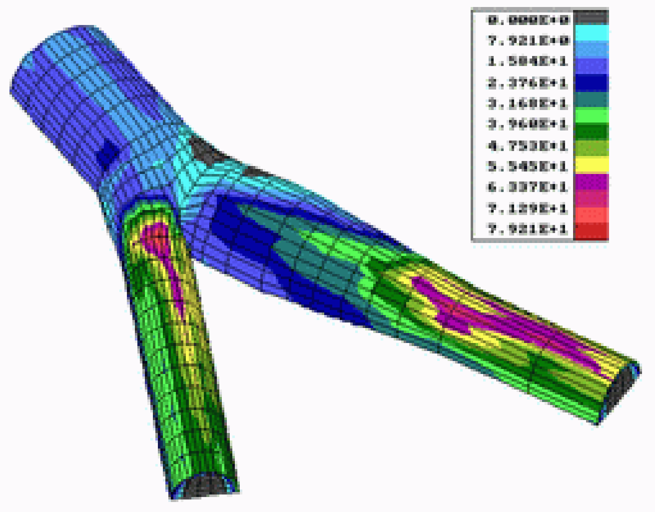




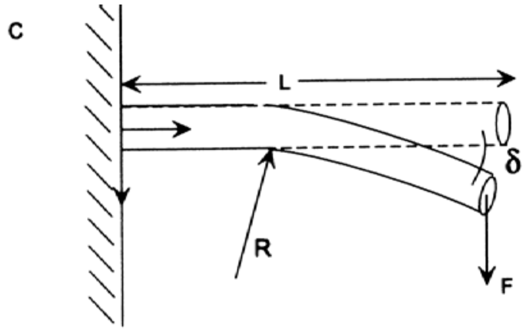
$$\nu_{xy} = -\frac{\varepsilon_x}{\varepsilon_y}$$

Quantifying deformation in other geometries

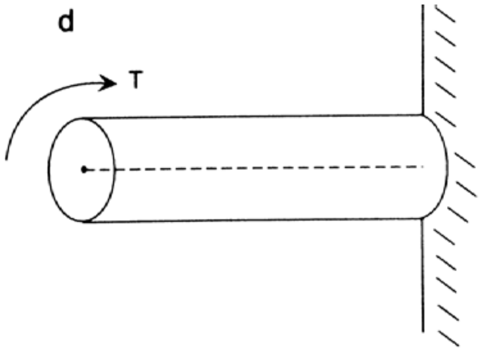




Shear stress



Bending

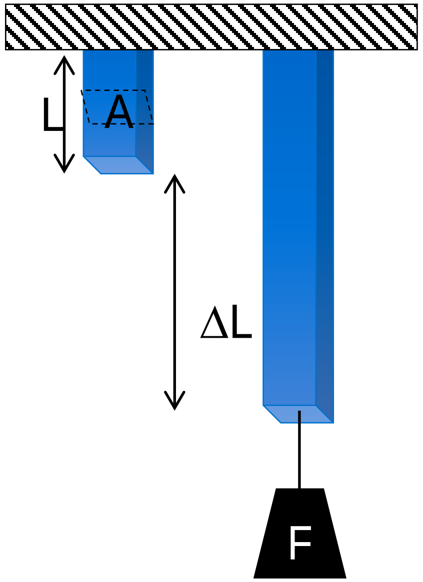


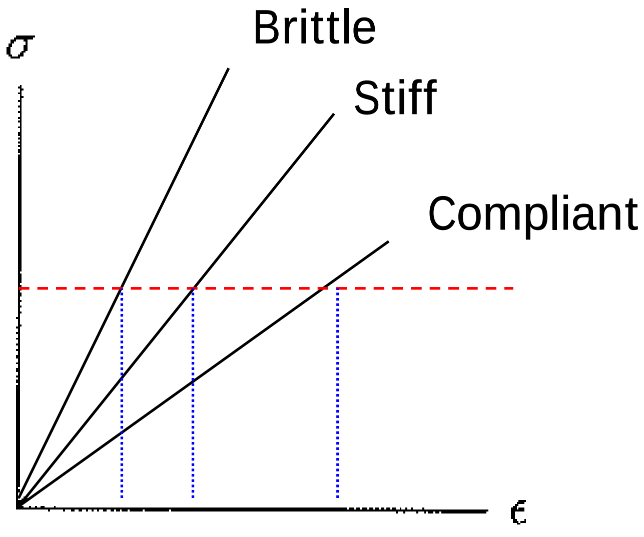
Torsion

Angelfire.com, ripley.za.net; Tissue Engineering, Saltzman

Review and rewind

Elastic solid mechanics





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Hooke's Law

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Poisson's ratio


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