

## Efficiency and Optimization of Biomaterials



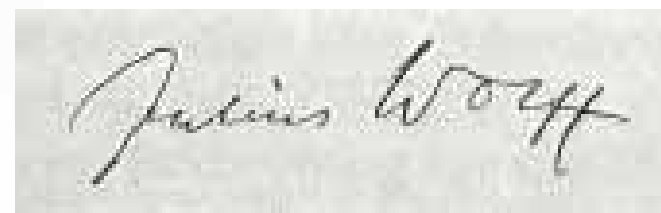
Helmut Kirchner

[www.inm-gmbh.de](http://www.inm-gmbh.de)

Pierre L.M. Maupertuis, 1698-1759



Julius Wolff, 1832-1902





Weissensee, Berlin



1892, 1991

Reihe:  
„Reprints Medizinhistorischer Schriften“  
Hrsg.: Dieter Wessinghage  
– Nr. 4 –

JULIUS WOLFF

DAS GESETZ

DER

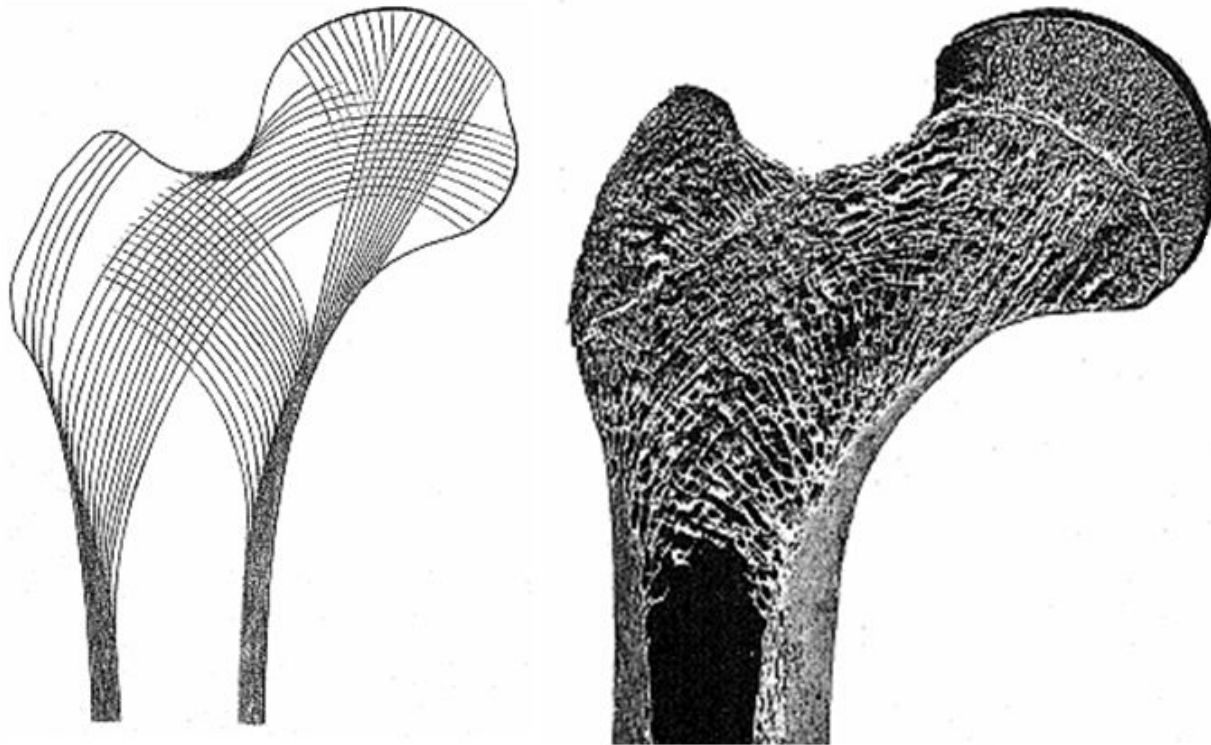
TRANSFORMATION DER KNOCHEN

Herausgabe und Bearbeitung des Reprints:  
D. Wessinghage

mit einem Vorwort  
von  
H. Mittelmeier

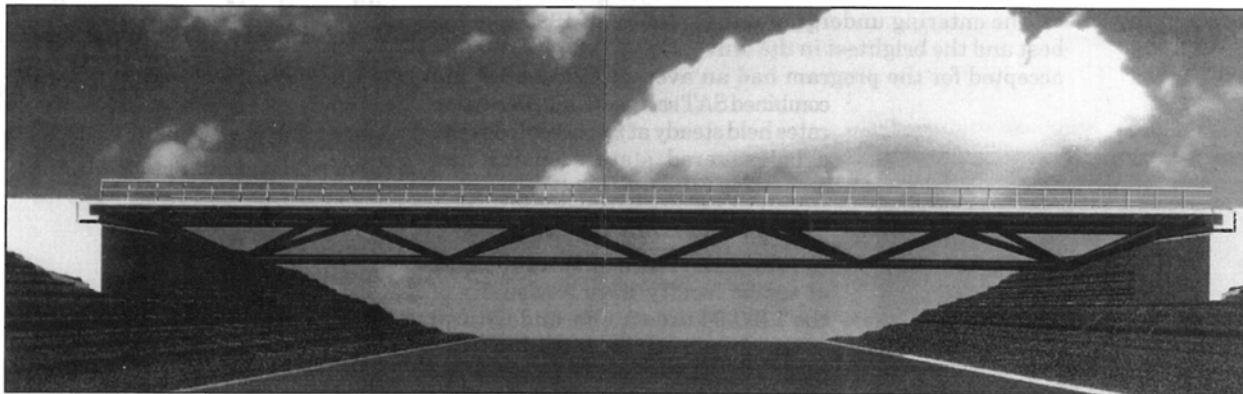


## "The Law of Transformation of Bone", 1892



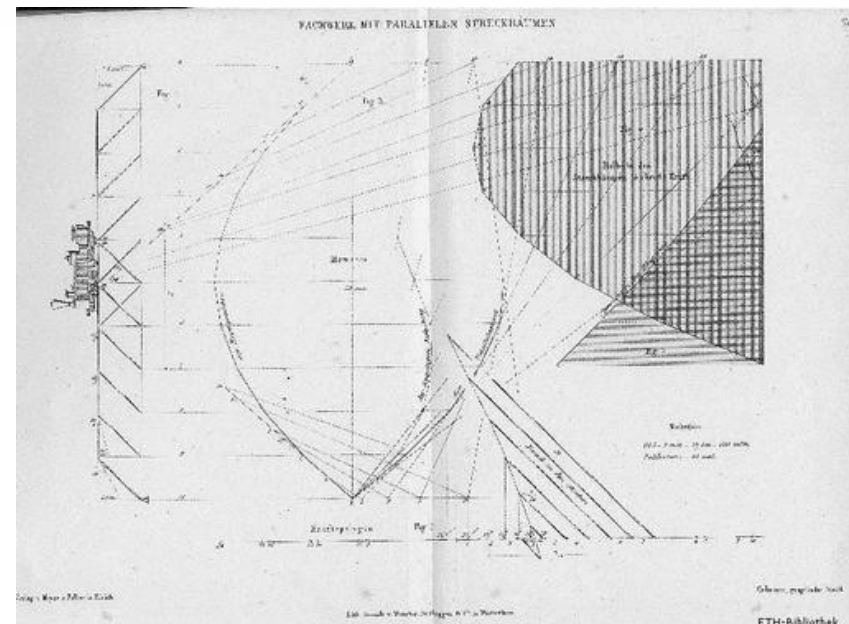
*"As a consequence of primary shape variations and continuous loading, or even due to loading alone, bone changes its inner architecture according to mathematical rules and, as a secondary effect and governed by the same mathematical rules, also changes its shape."*

# Nature builds bones as the engineer bridges



*Computer rendering of the award-winning carbon shell struss bridge designed by UCSD engineers.*

# Karl Culmann, 1821-1881





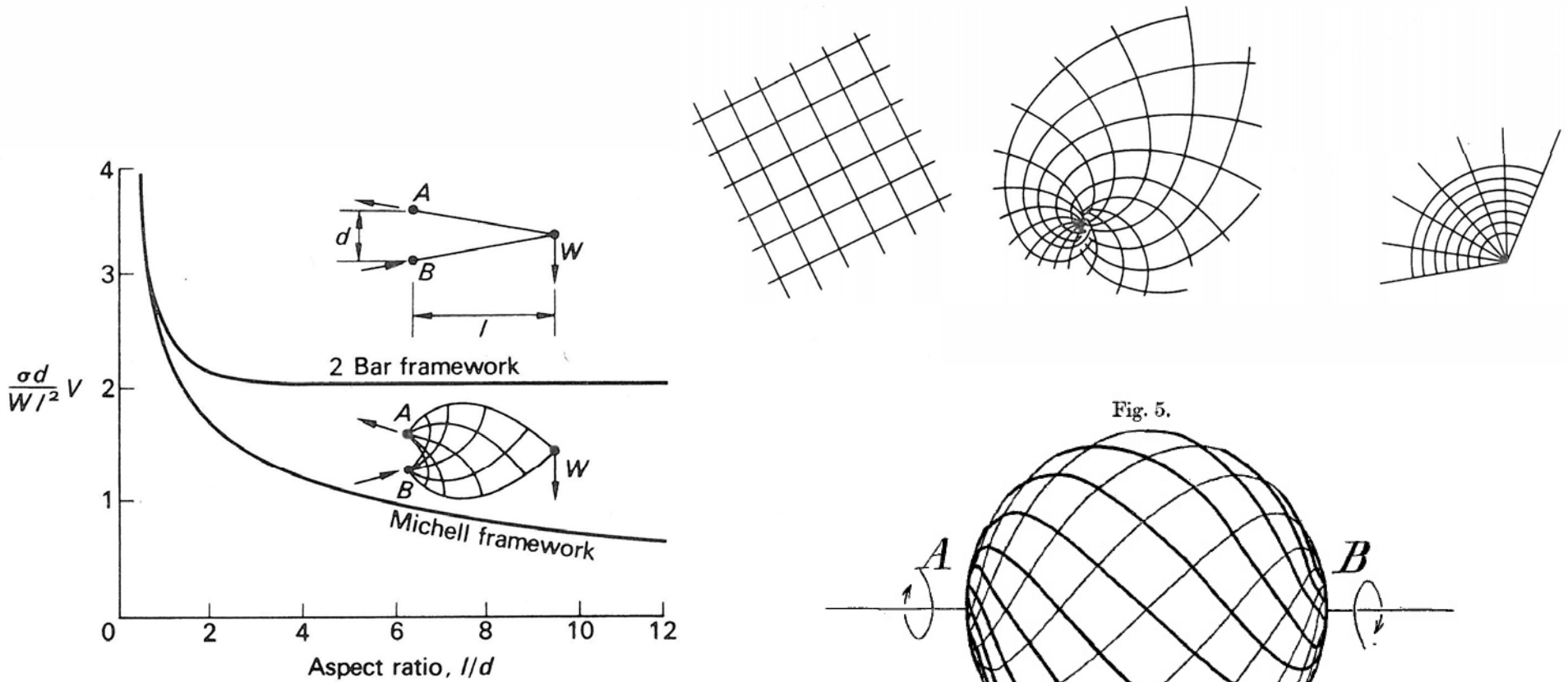
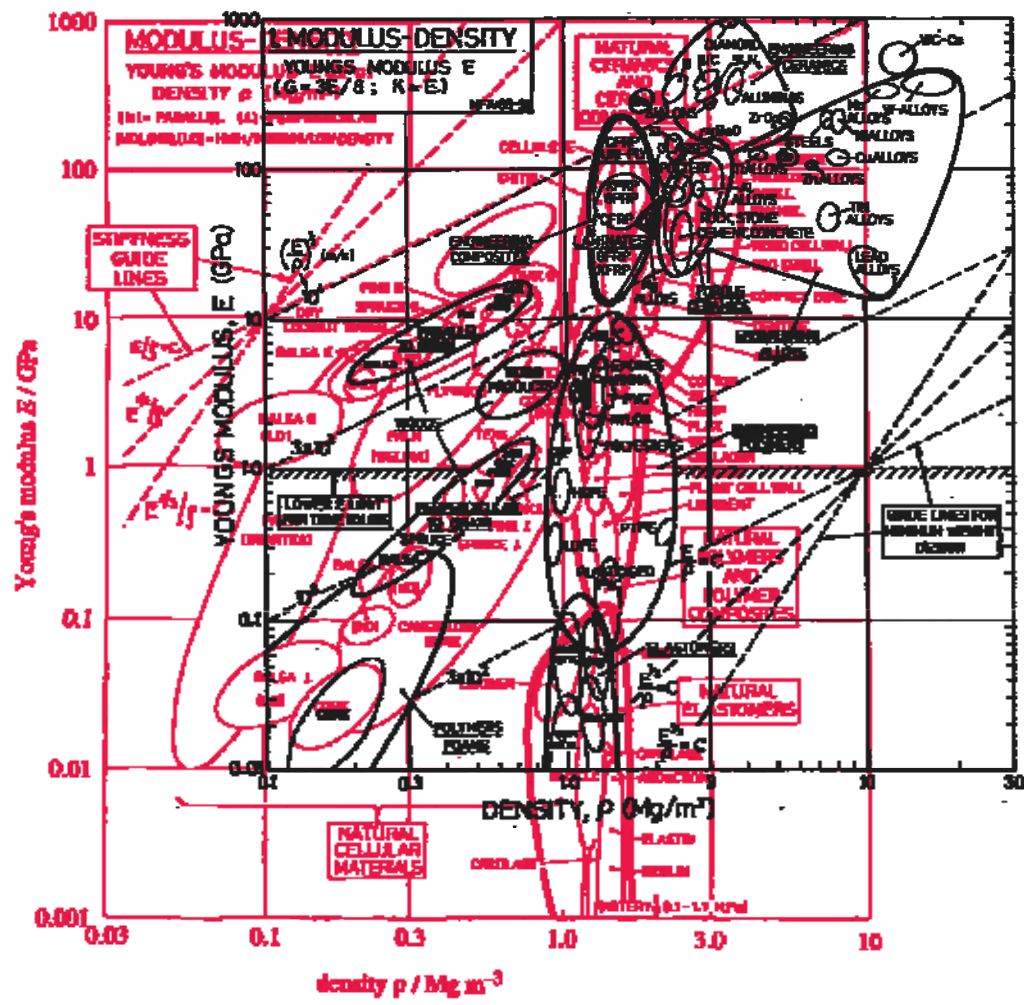


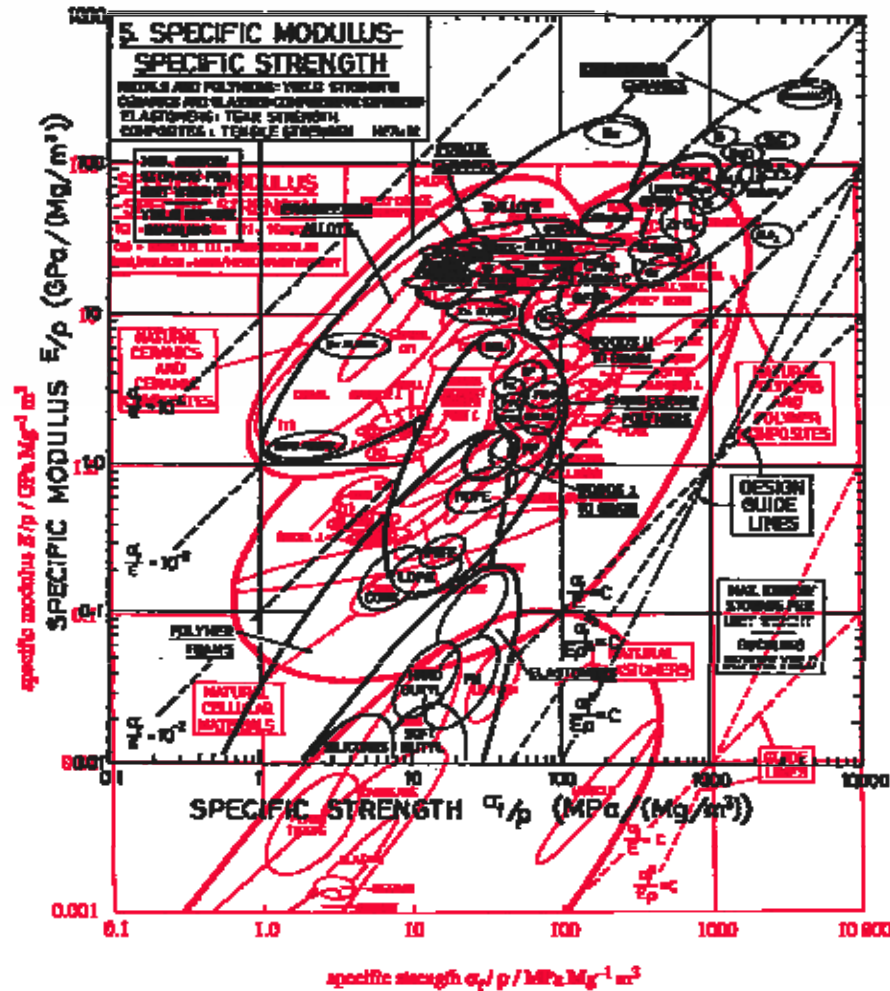
Fig. 7.4 Curves comparing a bar frame (upper curve) with a Michell framework. is a measure of volume and the abscissa is the aspect ratio of the framework. (From 1965, *Braced Frameworks*, Pergamon Press, Oxford; after CHAN, 1960).

# Modulus - Density





# Specific Modulus - Specific Strength



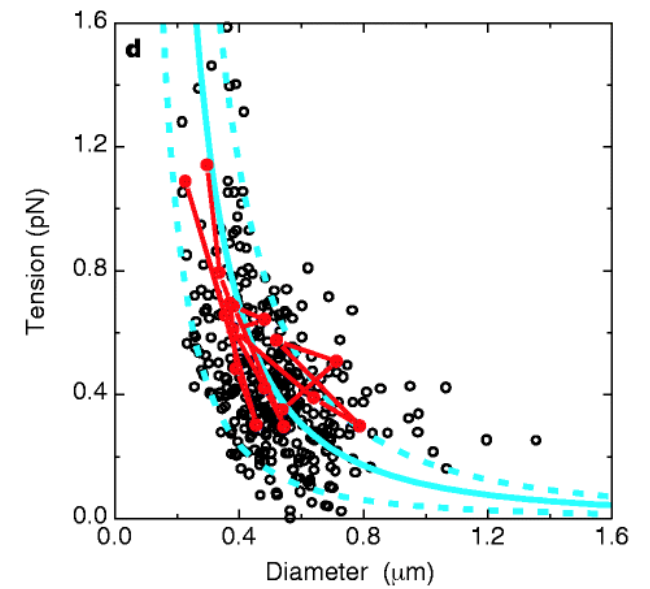
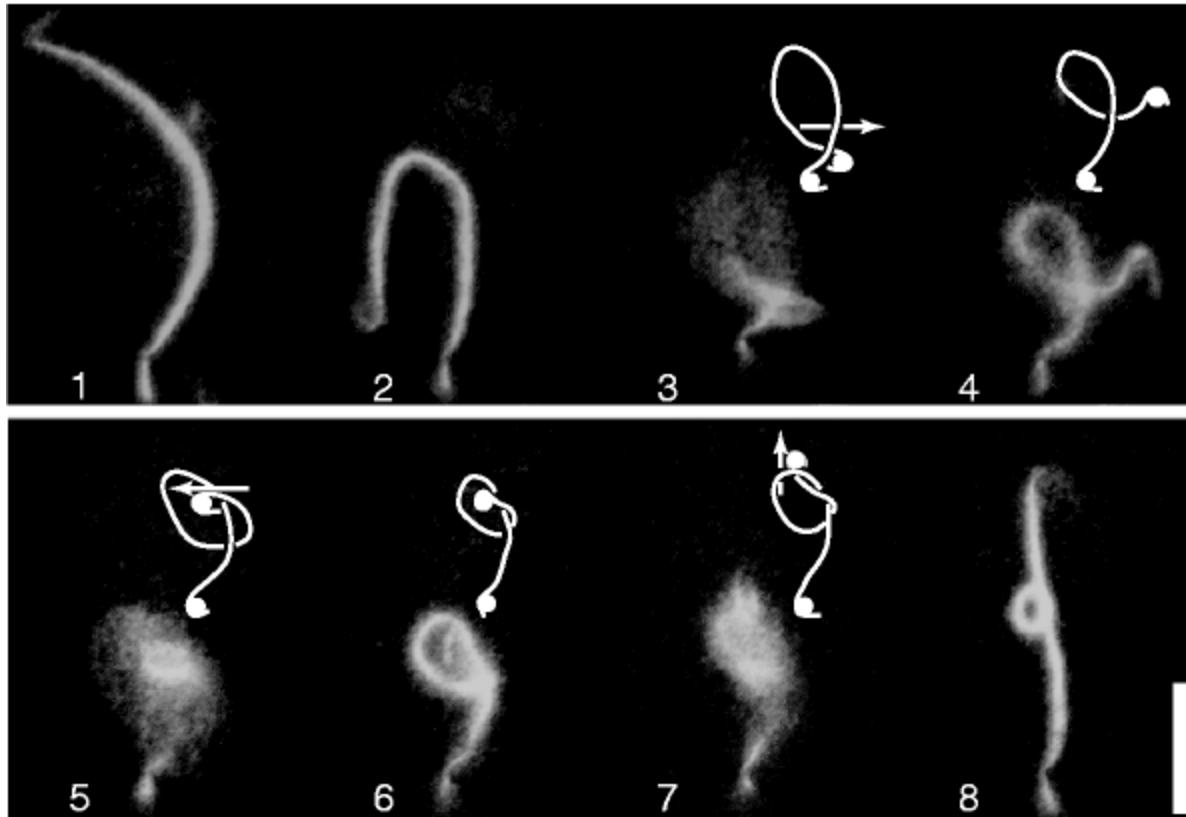
# Atomic model of the actin filament



Holmes et al. (1990) Nature 347, 44-49



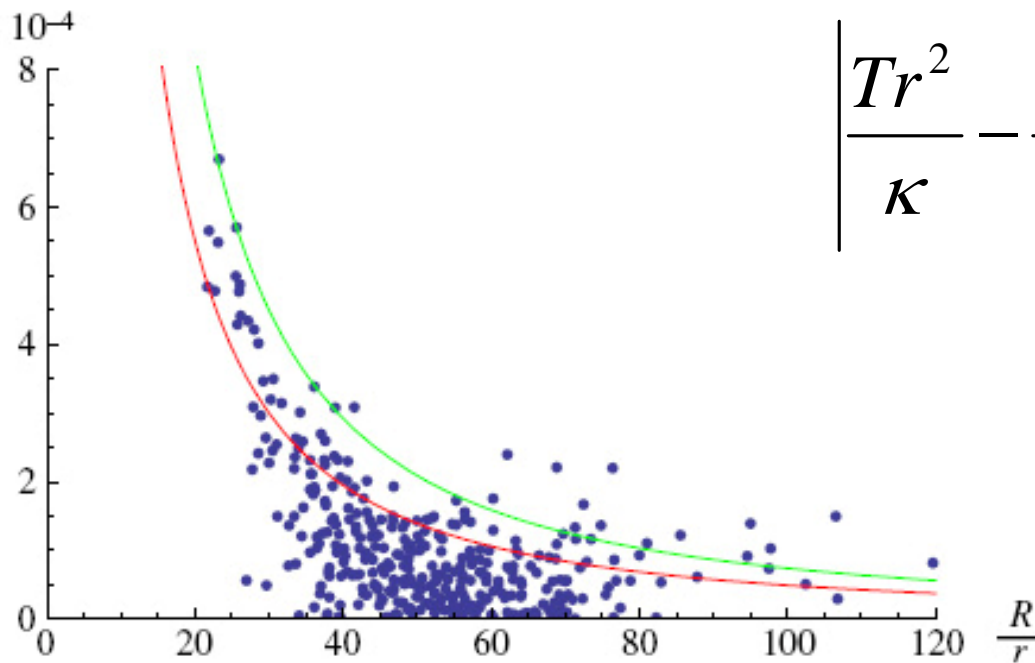
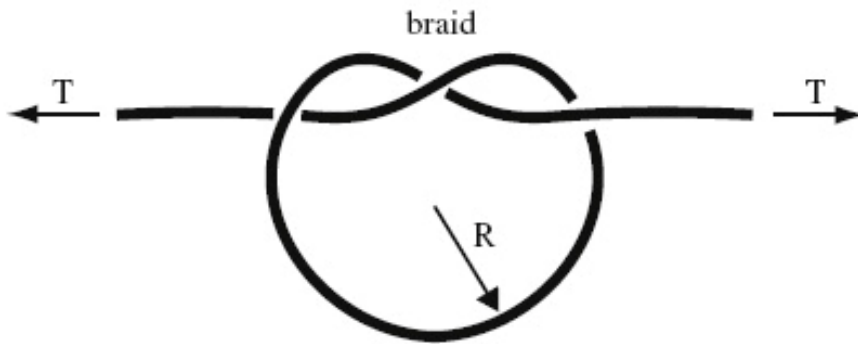
# Tying a knot in an actin filament



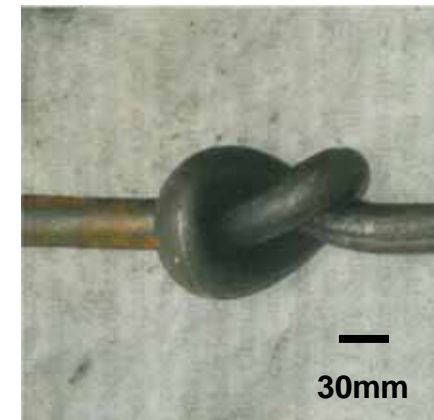
Arai et al. (1999) Nature 399, 446-448



Kirchner & Neukirch  
JMBBM 2010,3:121-123



$$\left| \frac{Tr^2}{\kappa} - \frac{1}{2} \left( \frac{r}{R} \right)^2 \right| \leq 0.49 \mu \left( \frac{r}{R} \right)^{\frac{3}{2}}$$

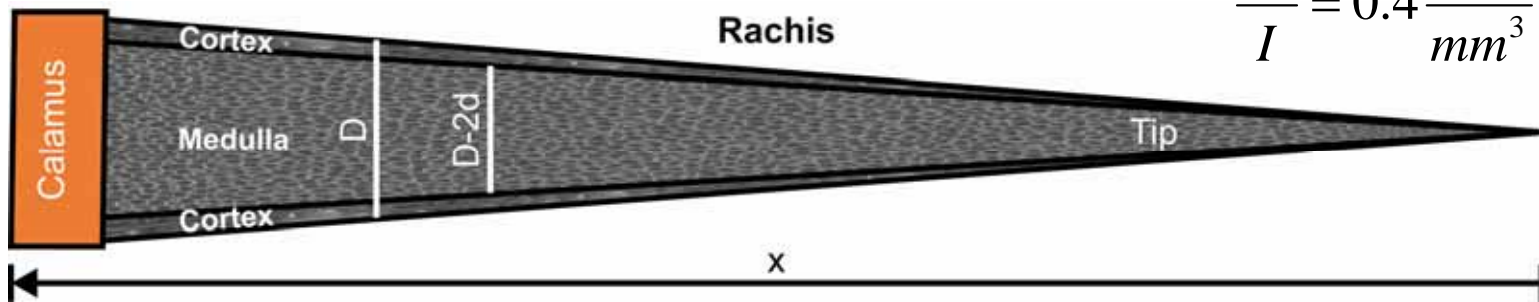


*Pavo cristatus sub. alba*



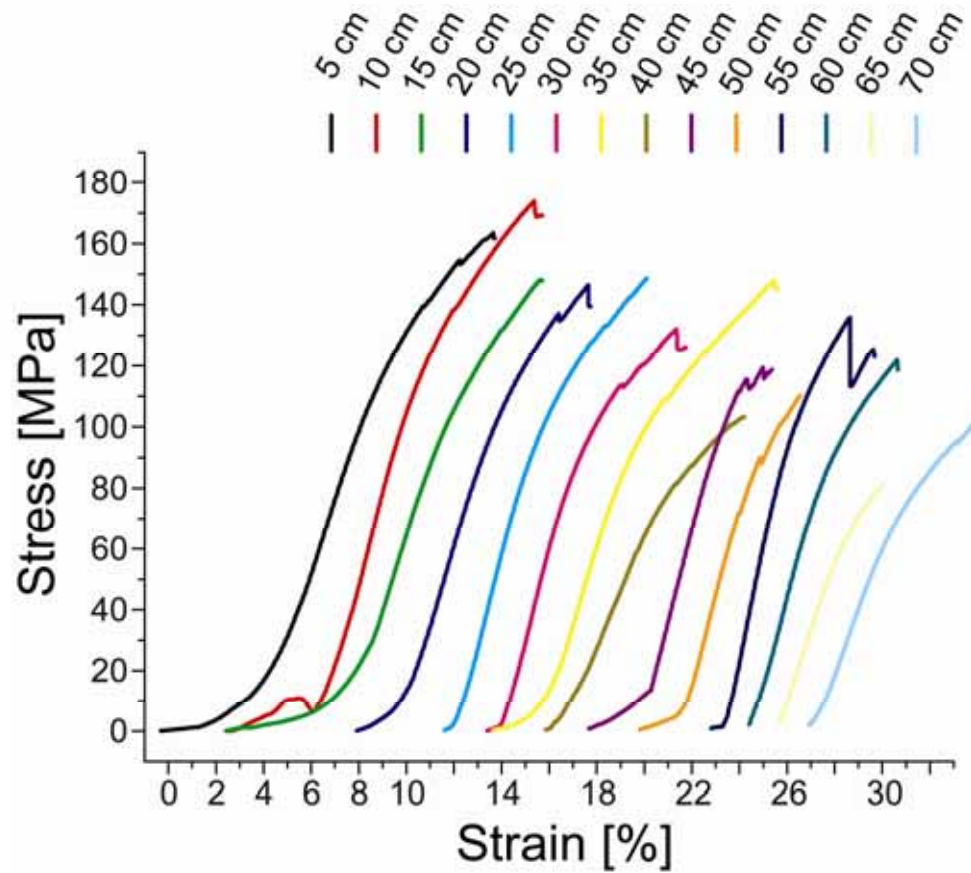


# Pavo feather



$$\frac{M}{I} = 0.4 \frac{N}{\text{mm}^3}$$

# Mechanical tests on *Pavo*



## Atlantic Puffins (*Fratercula arctica*)





Acknowledgements: Ingrid Weiss, Eduard Arzt

[www.inm-gmbh.de](http://www.inm-gmbh.de)