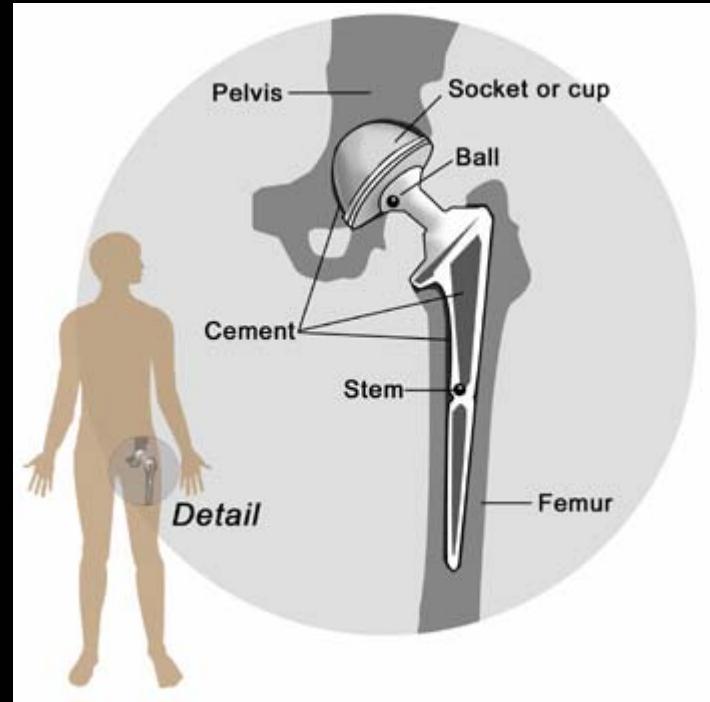


# Biomaterials

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## Biological (natural) materials



## Biomaterials

"Any substance (other than a drug) or combination of substances, synthetic or natural in origin, which can be used at any period of time as a whole or in part of a system which treats, augments or place any tissue, organ or function of the body."

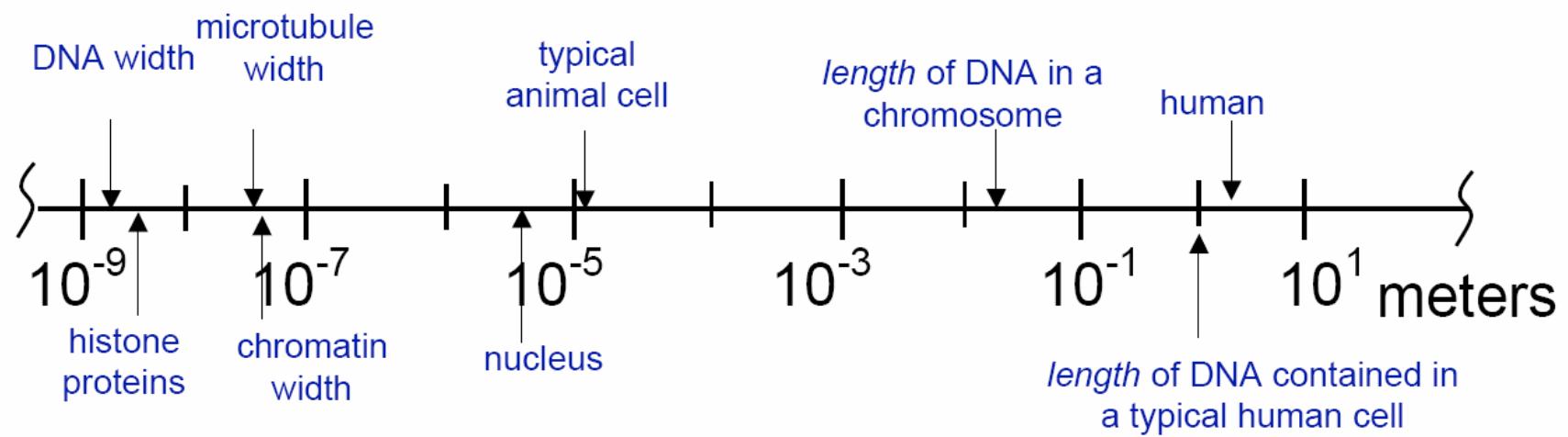
J. W. Boretos and M. Eden  
Contemporary Biomaterials, 1984

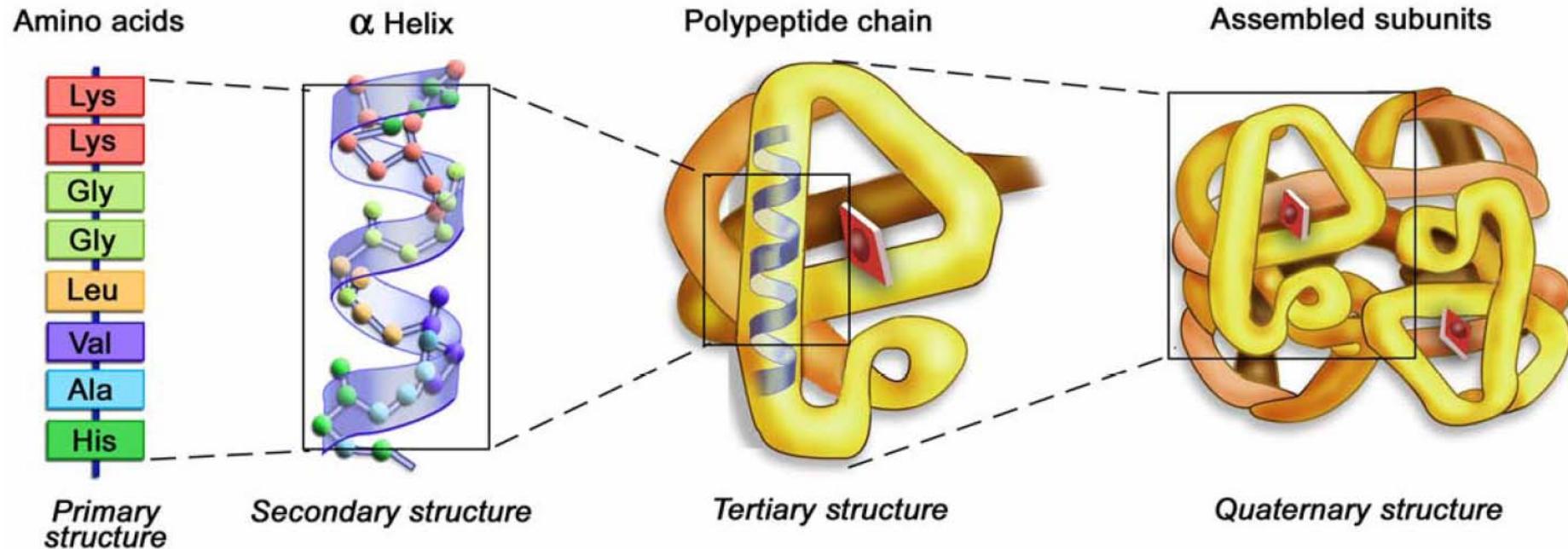
"A non-variable material used in a medical device intended to interact with biological systems."

D. F. Williams  
Definitions of Biomaterials, 1987

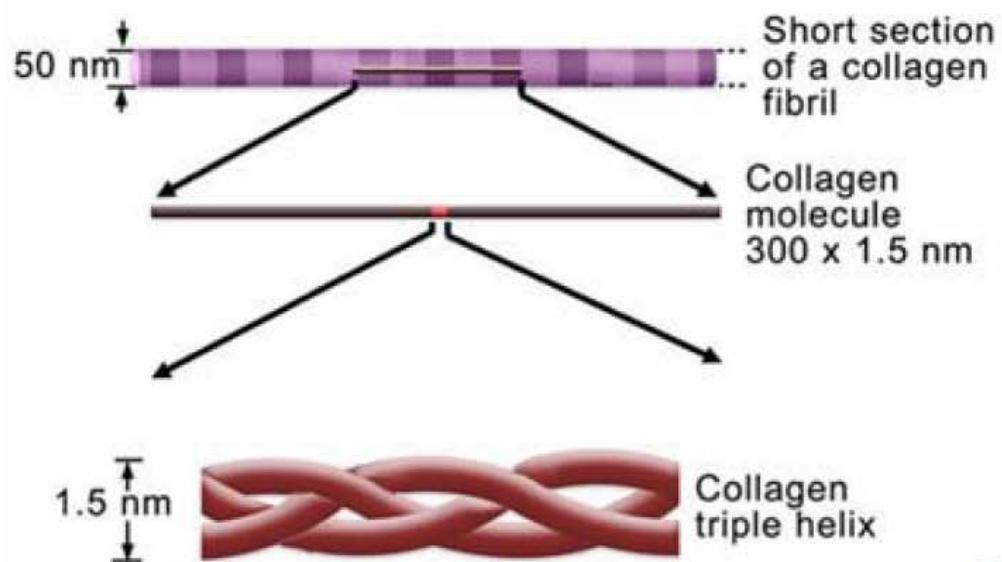
# Biological Materials

# Human materials mechanics

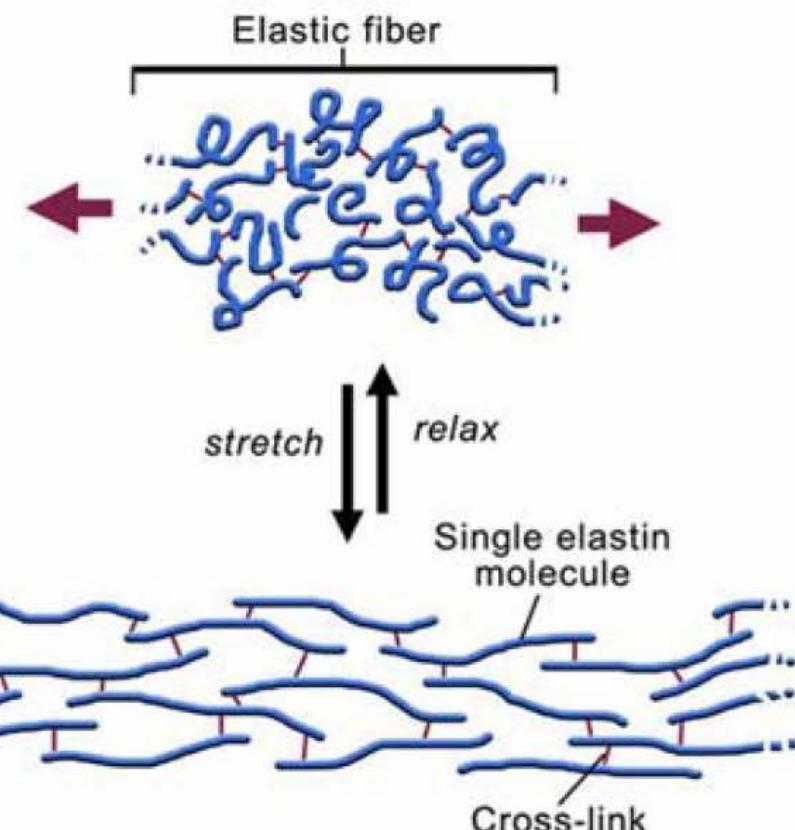




[after A. L. Lehninger, D. L. Nelson and M. M. Cox. *Principles of Biochemistry*, pg. 171.]

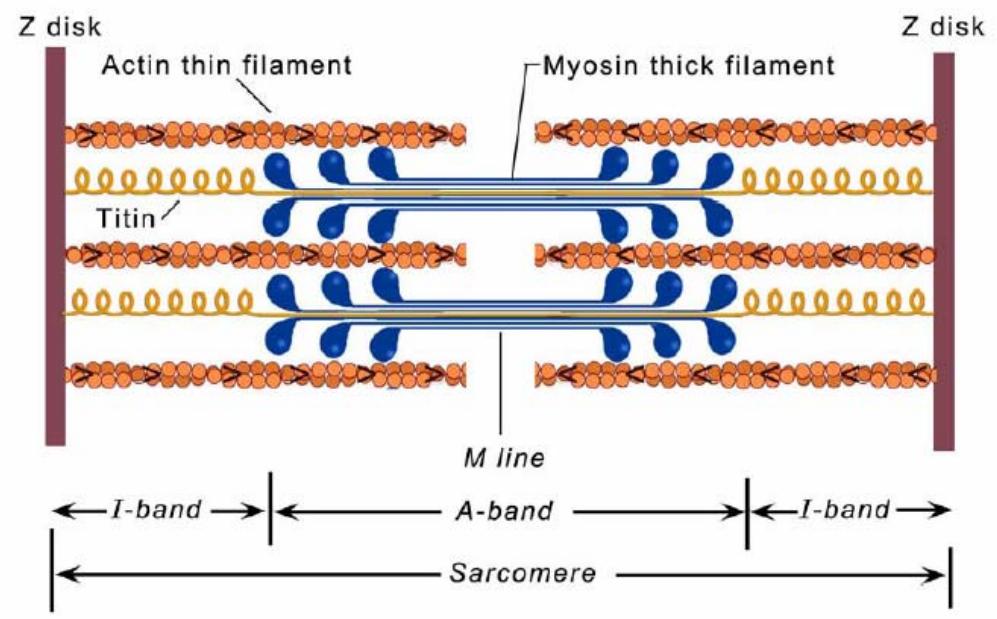
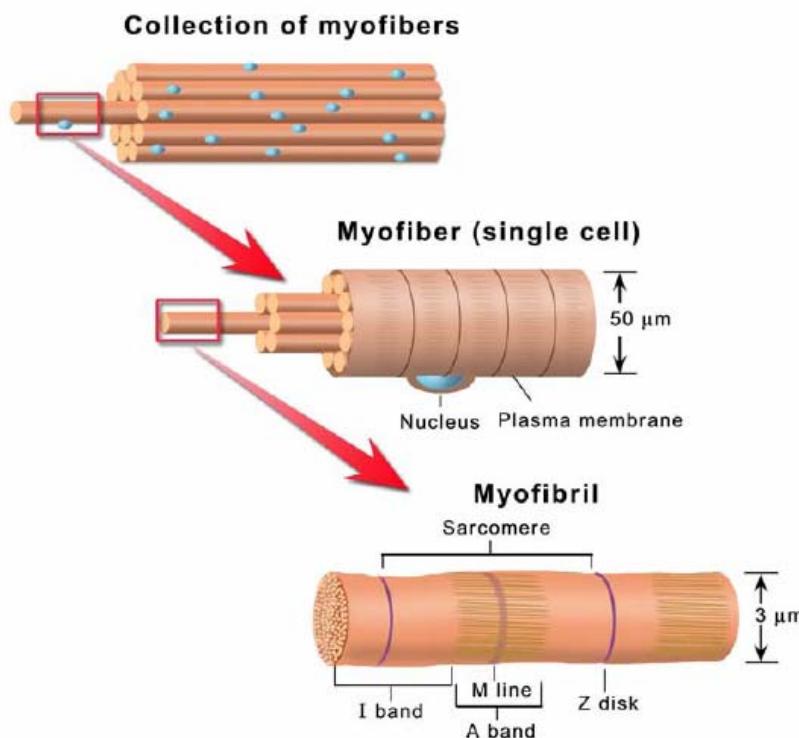


A



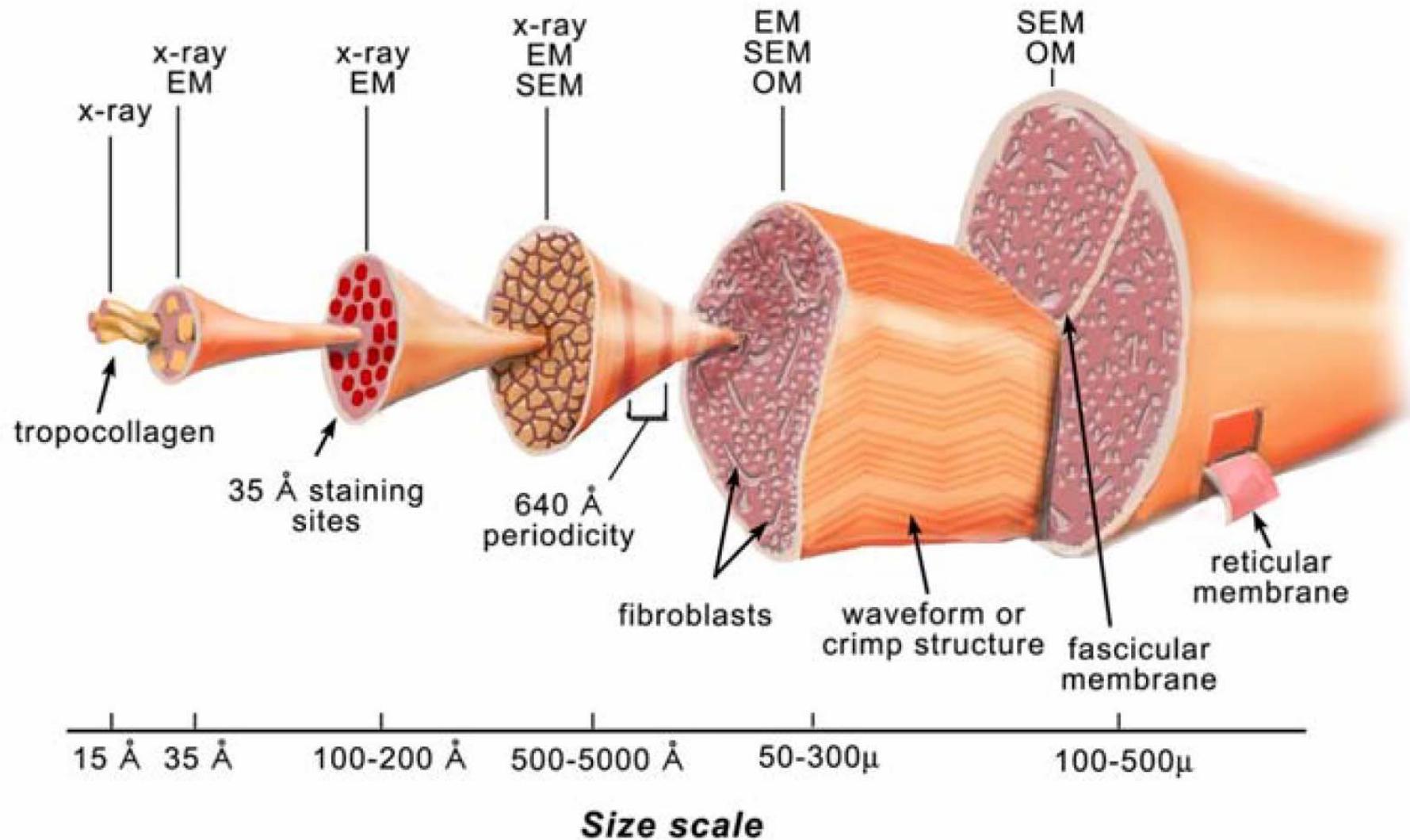
B

# Muscles: Spanning from Macro to Nano



# Tendon Hierarchy

## Evidence:



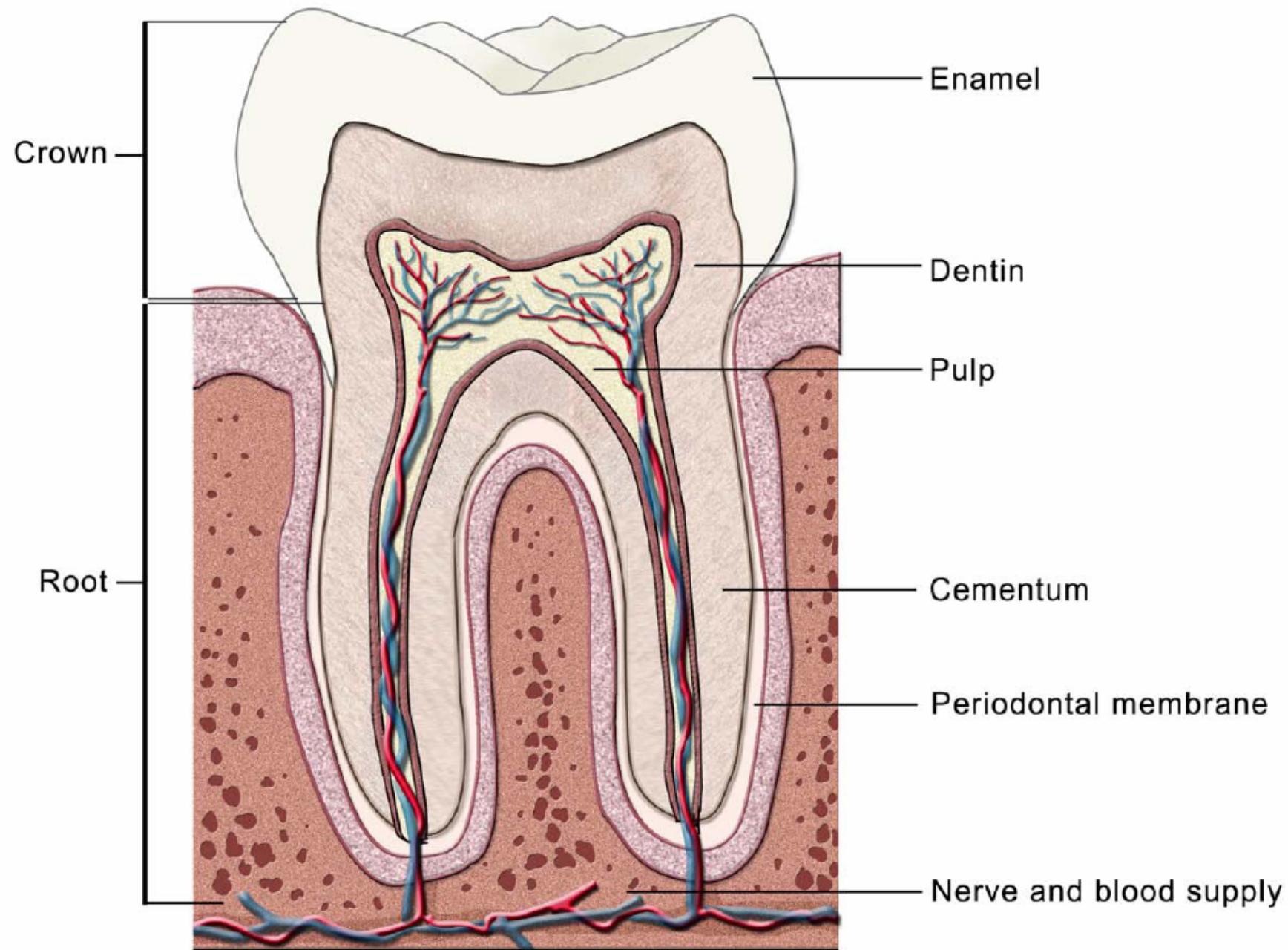
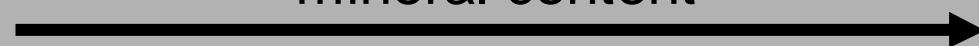


Image source: OCW

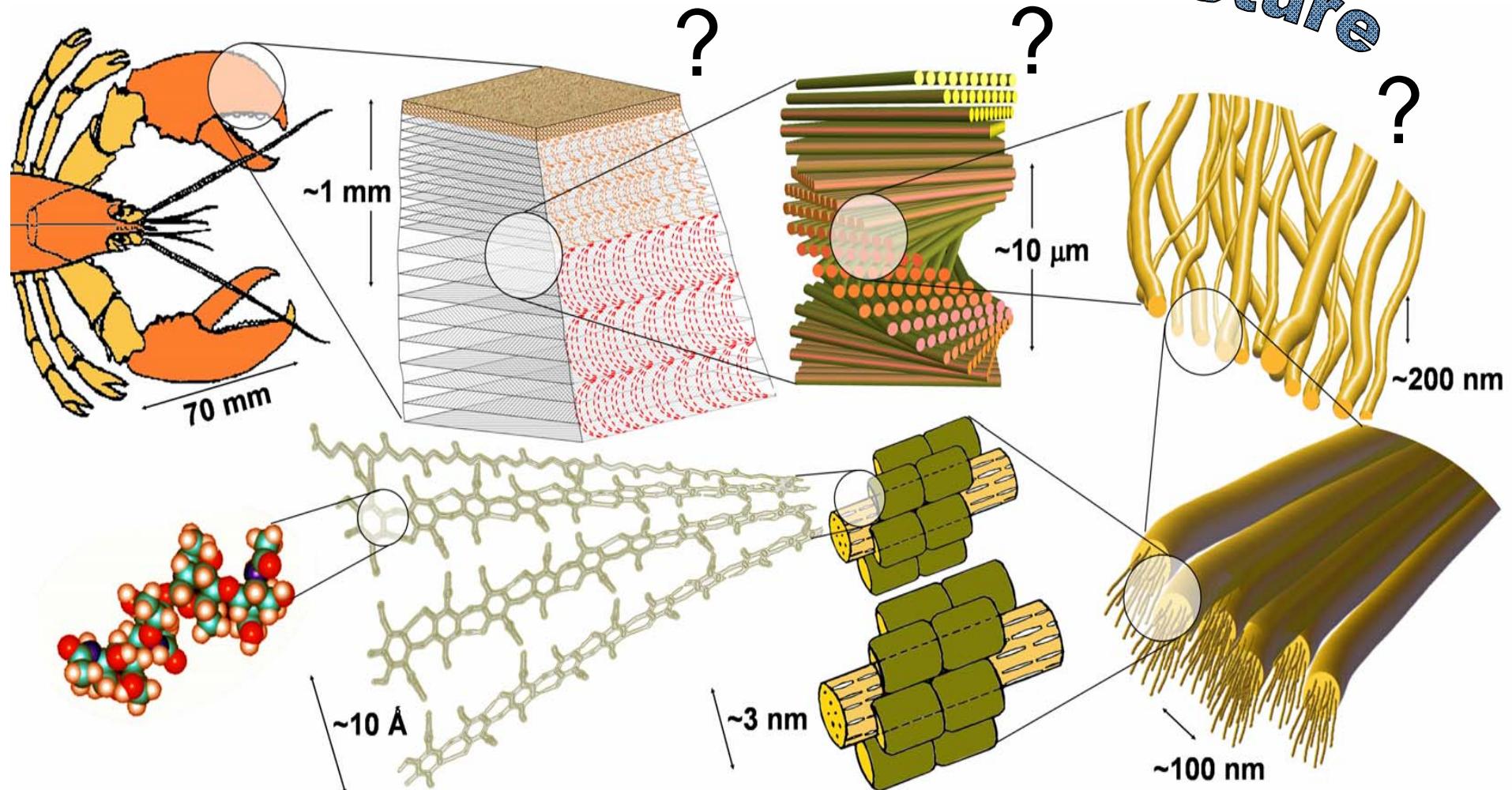


mineral content



# Schematics - structure - crustacean cuticle

## mesostructure

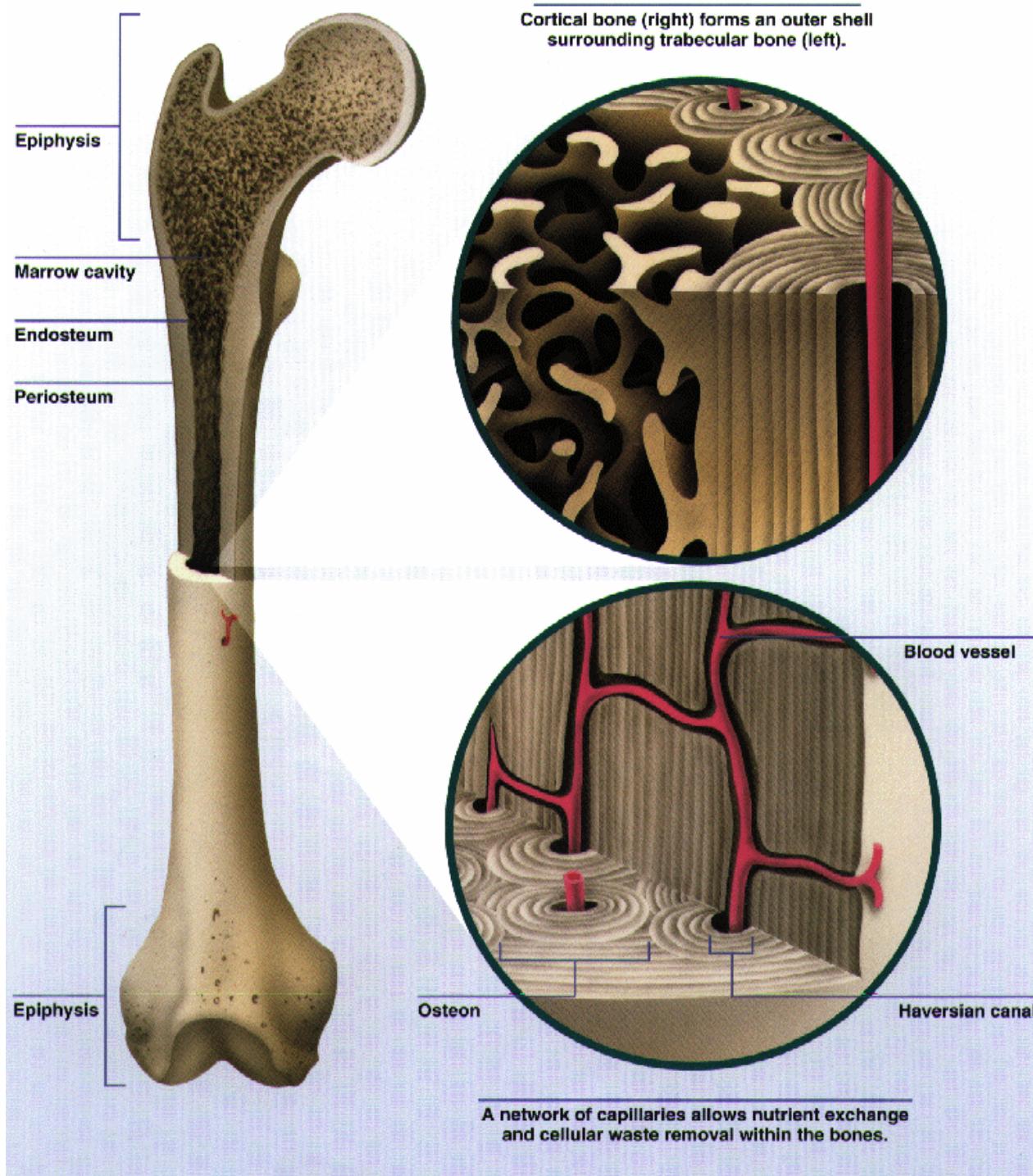


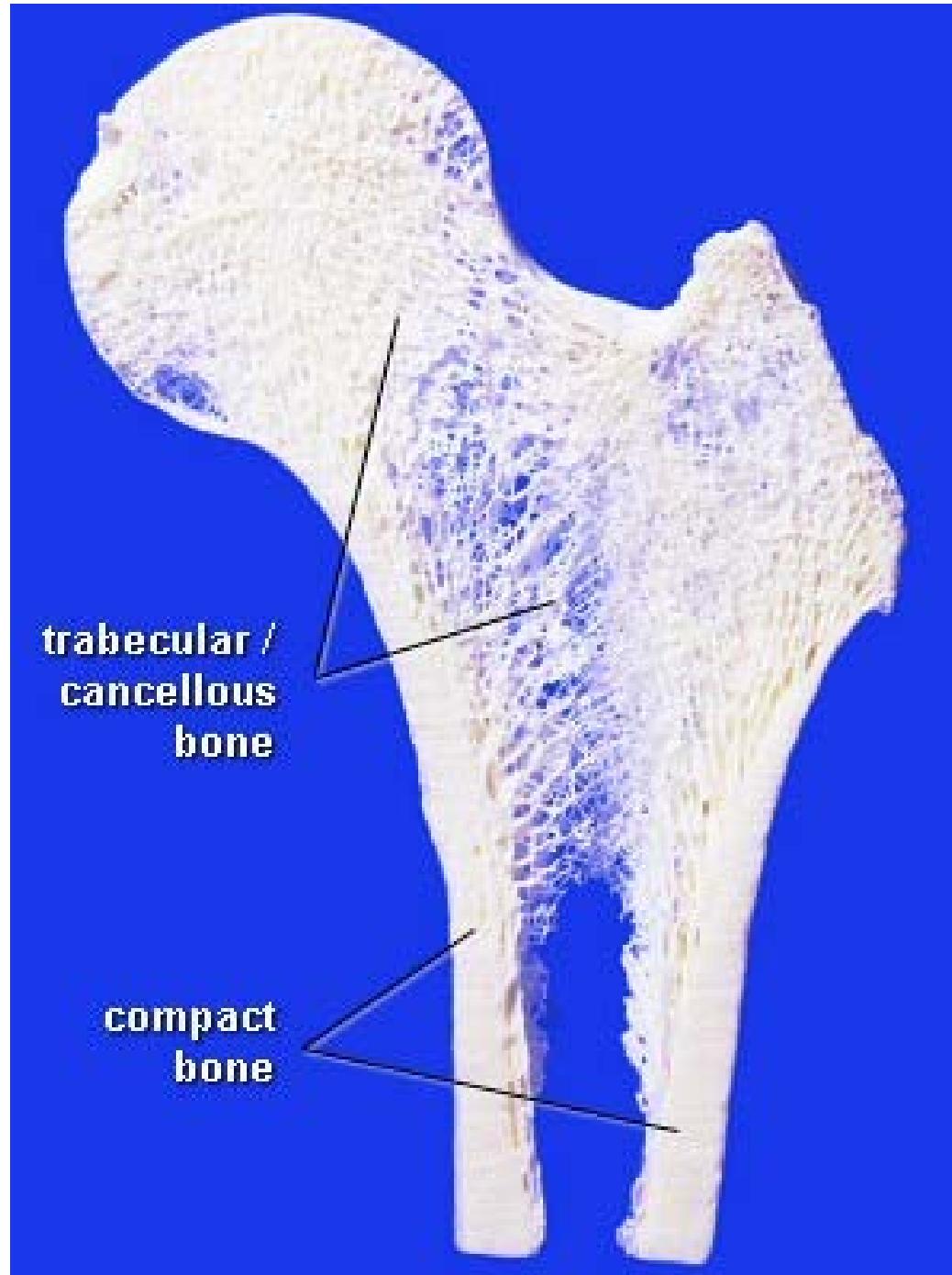
Bouligand: Twisted fibrous arrangement in biological materials and cholesteric mesophases. *Tissue Cell.* 1972; 4 : 189  
Weiner, Arad, Sabanay, Traub. Plywood structure of bone in rat: Orientations of collagen. *Bone* 1997; 20: 509

Giraud-Guille, Fine structure of the chitin-protein system in the crab cuticle, *Tissue Cell* 1984; 16 : 75

Giraud-Guille, Plywood structures in nature, *Current Opinion in Solid State & Material Science*, 1998; 3: 221

Vincent, Structural Biomaterials (Princeton University Press, USA, 1990)





# Osteonal Bone Microstructure

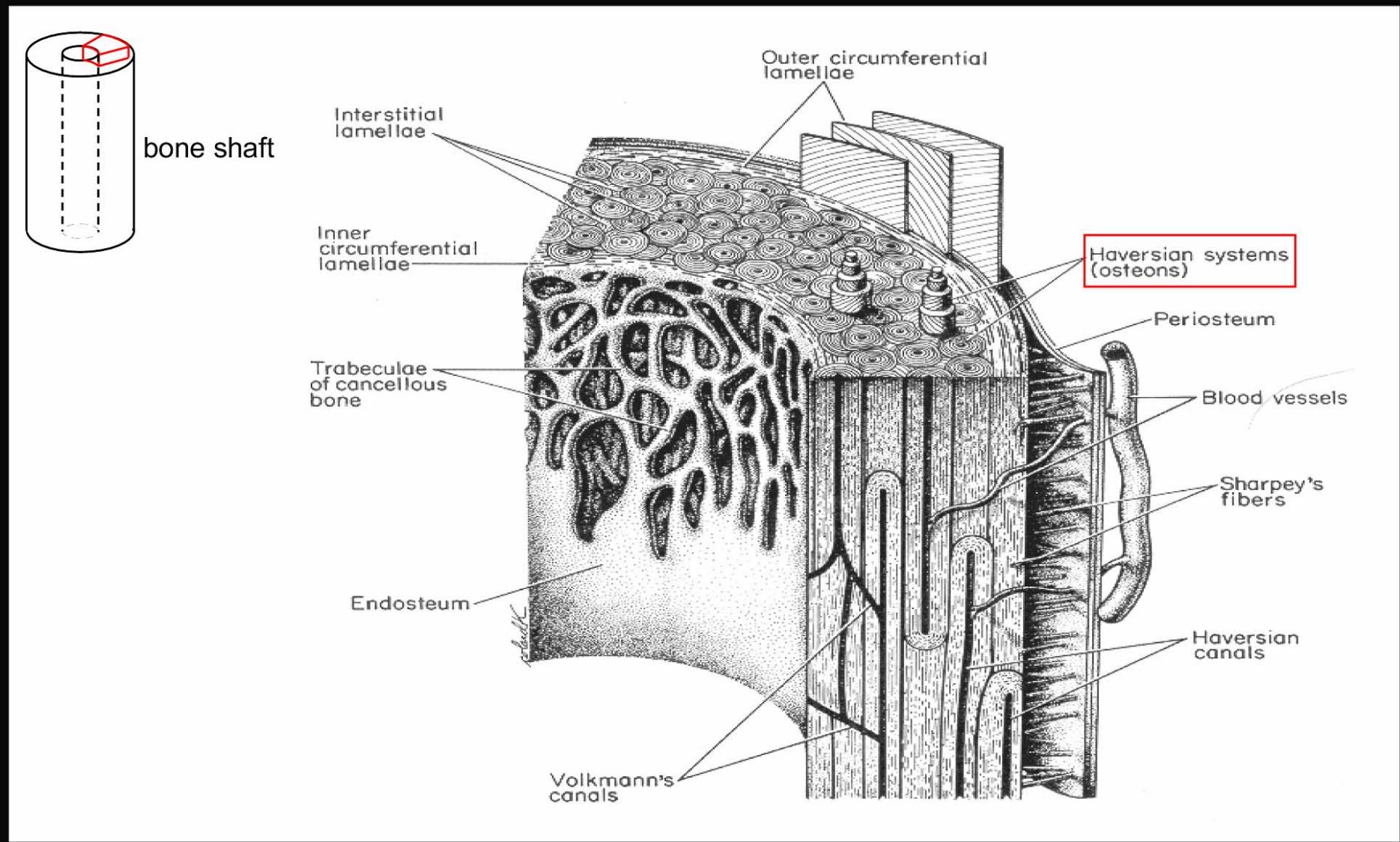
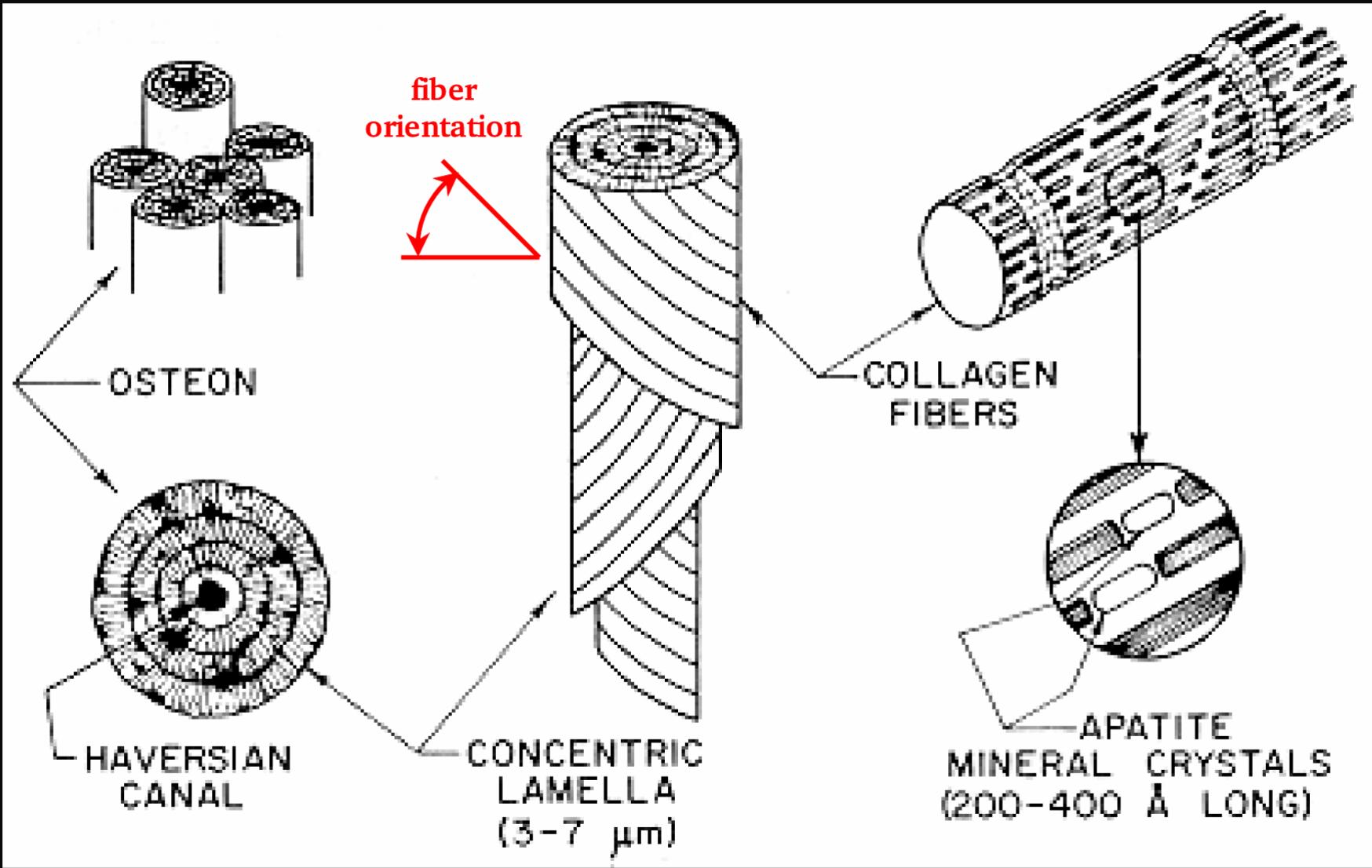


Image: Martin et al. *Skeletal tissue mechanics* 1998

# Osteon Details

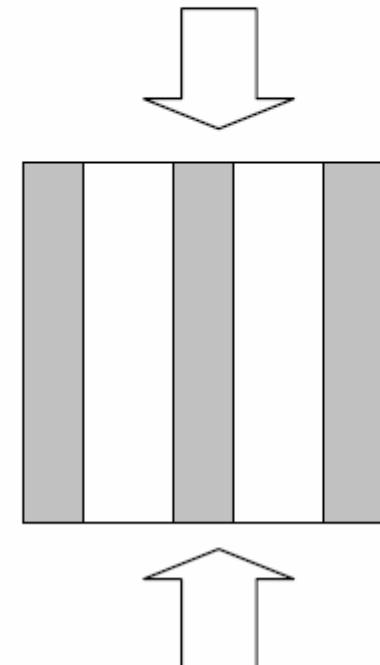


	<b>Ultimate Comp. Str. (MPa)</b>	<b>Modulus of Elasticity (GPa)</b>
<b>Cortical Bone</b>	<b>140 - 200</b>	<b>14 - 20</b>
<b>Cancellous Bone</b>	<b>5 - 60</b>	<b>0.7 - 1.5</b>
<b>Synthetic HA</b>	<b>200 - 900</b>	<b>34 - 100</b>
<b>Bone Mineral</b>  (anorganic bone)	<b>25</b>	<b>6</b>

## Modeling Anisotropic Composites

Example: a uniaxially-oriented, continuous 2-phase structure

Load along the longitudinal axis:



*Voigt model: equal strains  
(parallel strain model)*

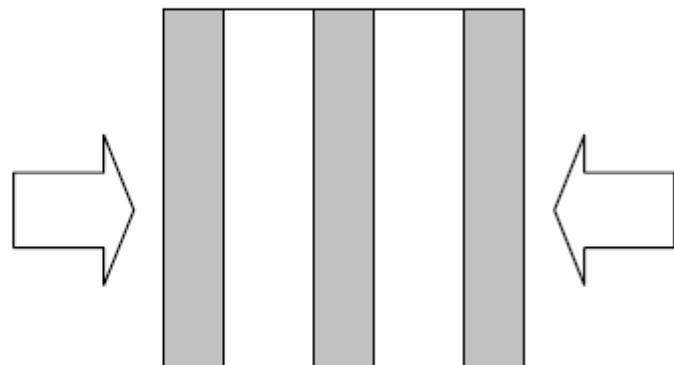
$$E = E_1 V_1 + E_2 V_2$$

( $V_i$  is volume fraction  
of  $i$ th component)

(Derived from  $F_i = A_i E_i \epsilon_i$ )

Load along transverse axis:

*Reuss model: equal stresses  
(series strain model)*



$$\frac{1}{E} = \frac{V_1}{E_1} + \frac{V_2}{E_2}$$

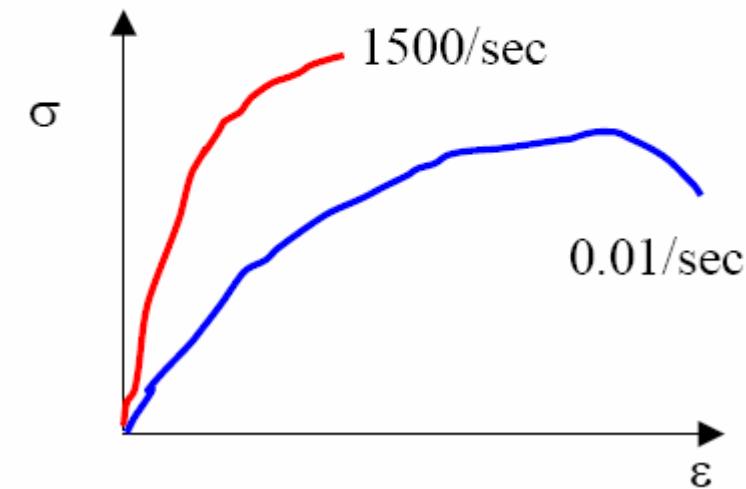
*(Note: text gives governing eqns for other composite structures, such as randomly oriented fiber/matrix composites)*

## Natural Bone has *Viscoelastic Response*

On short time scales: solid-like

On long time scales: liquid-like

Compression at different strain rates:



## Directions in Orthopedic Implants

- Polymer/fiber composites
- Polymer/ceramic composites
- Osteogenic materials