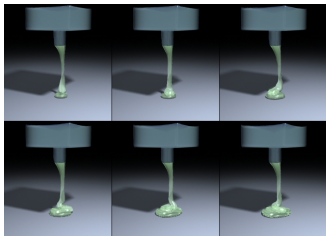


stiffness flexible ↔ stiff	Young-modulus, E (Pa)
elasticity rigid ↔ elastic	elastic strain recovery, ϵ_r resilience, w_r (J/m ³)
ductility not ductile ↔ ductile	$\epsilon_y - \epsilon_s$
strength weak ↔ strong	σ_s (Pa)
toughness not tough (brittle) ↔ tough	toughness, w_s (J/m ³)
Hardness soft ↔ hard	hardness scales, HB, HV, HK („Pa“)

1



Physical Foundations of dental materials science

9.

Viscoelasticity


Keynotes:

- ❖ Viscoelastic behavior
- ❖ Viscoelastic models
- ❖ Viscoelastic phenomena

E-book chapter: 18

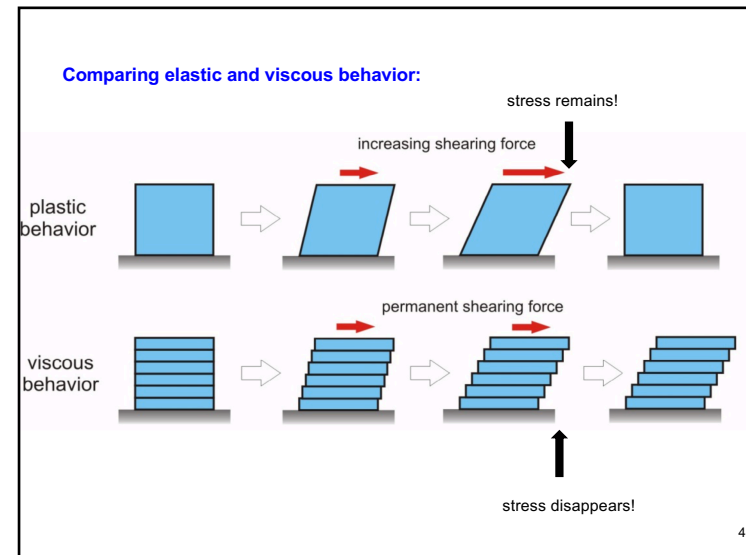
2

Viscoelasticity



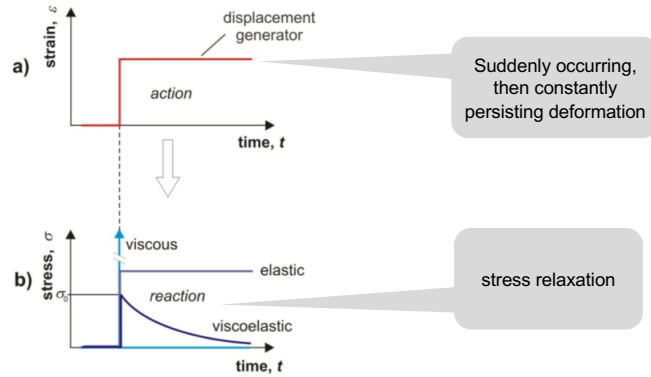
The bounce-splash of a viscoelastic drop:
http://www.youtube.com/watch?v=u_jEzoYadJ8

3



4

Viscoelasticity

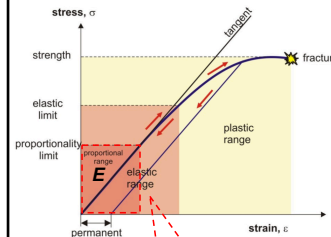


5

Reminder:

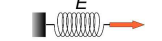
Elastic behavior:

- sudden
- force is required to maintain strain



Hooke's law:
 $\sigma = E\epsilon$

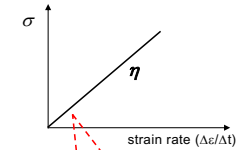
Hooke-body



Ideally elastic body

Viscous behavior

- time dependent
- force is required to maintain stress rate



Newton's law:
 $\sigma = \eta \frac{\Delta\epsilon}{\Delta t}$

Newton-body

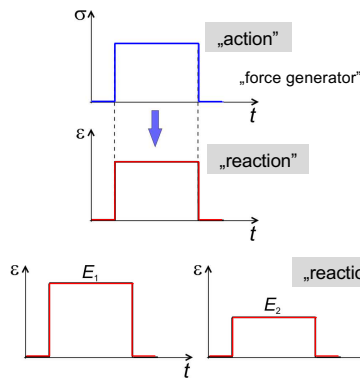


Ideally viscous body

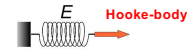
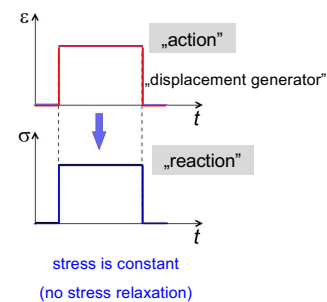
6

Ideal elastic behavior

How would strain change in case of constant stress?



How would stress change in case of constant strain?

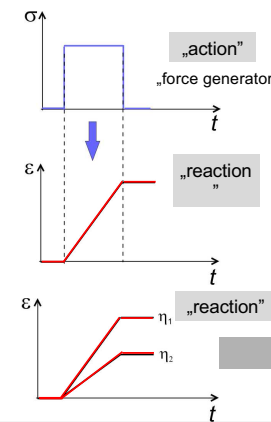


Hooke-body

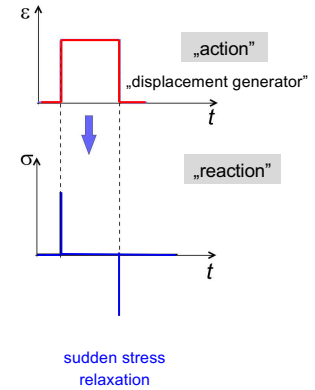
7

Behavior of an ideally viscous body

How would strain change in case of constant stress?



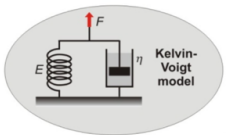
How would stress change in case of constant strain?



Newton-body

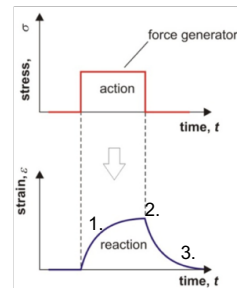
8

Viscoelasticity (mechanical model)



Viscoelasticity means the co-appearance of viscous and elastic behavior.
model: parallel connection of spring and dashpot (Kelvin-Voigt model)

Spring: ideal elastic (Hooke) body
Dashpot: ideal viscous (Newton) body

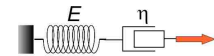
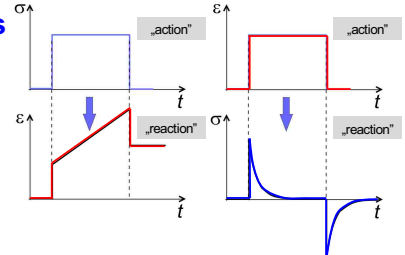


1. Upon stretch, the extension of the spring is slowed down by the dashpot.
2. Extension stops when the elastic spring force equals the external force.
3. When the external force is quenched, the contraction of the spring is slowed down by the dashpot.

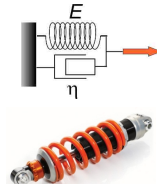
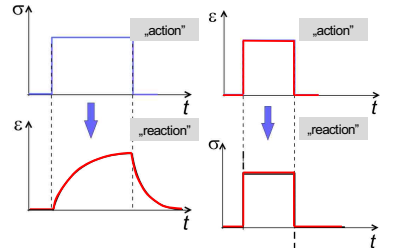
9

Viscoelastic models

Maxwell-model

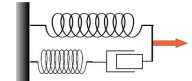
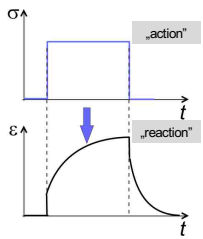



Kelvin-Voigt-model

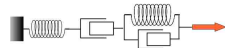
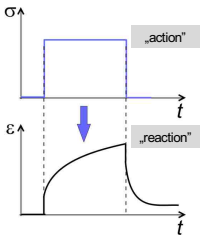



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Standard linear modell

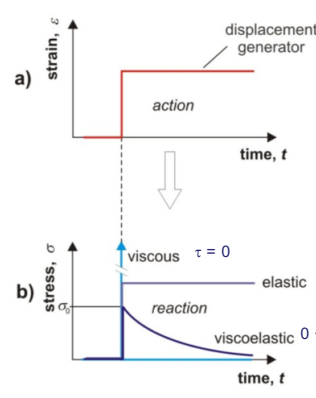
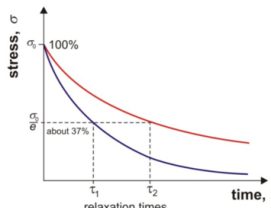
Burgers-modell

11

1/a Stress-relaxation in viscoelastic system

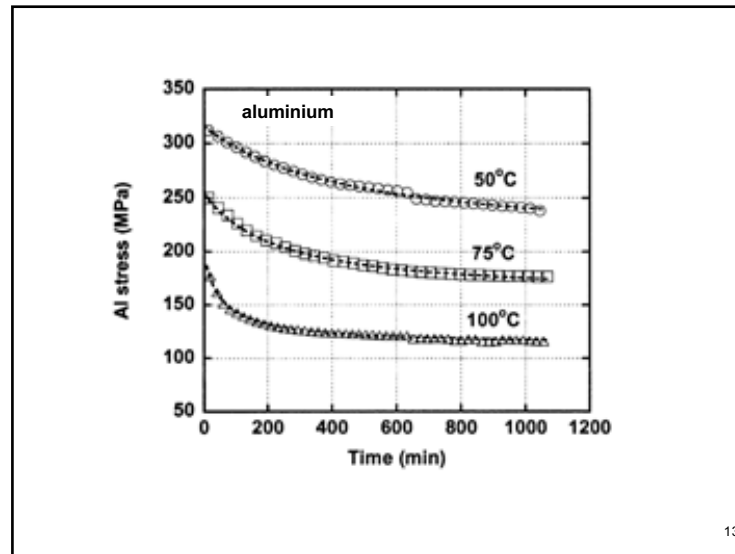
Decrease in stress while strain remains constant

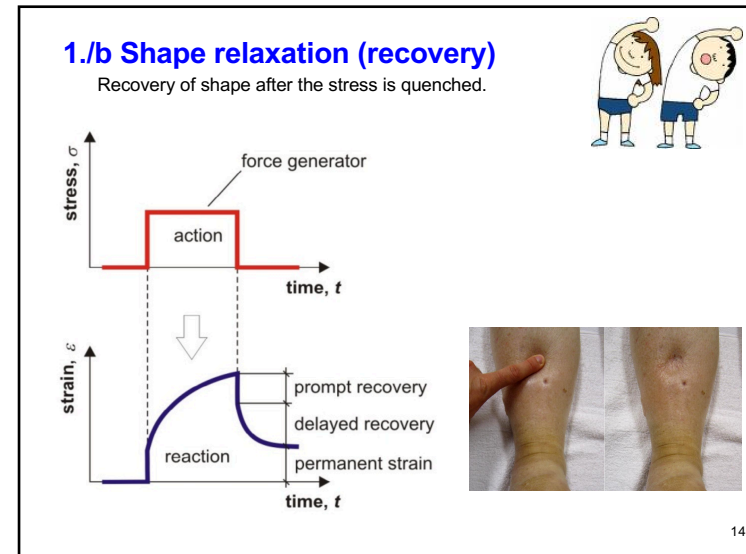
$$\sigma = \sigma_0 \cdot e^{-\frac{t}{\tau}}$$

$$\tau = \frac{\eta}{G} \quad G = \frac{E}{2(1 + \mu)}$$

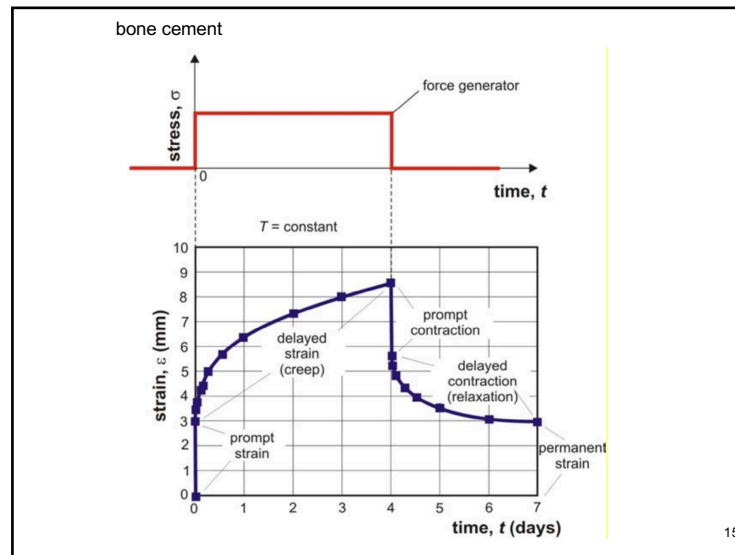
12



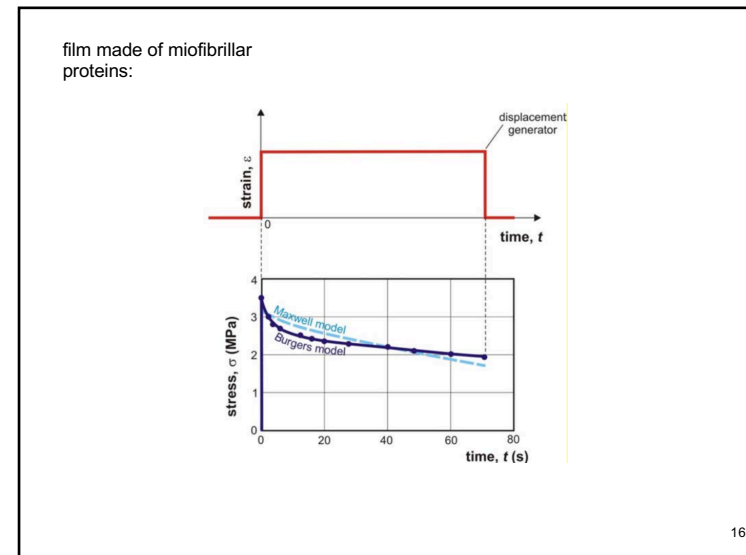
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14



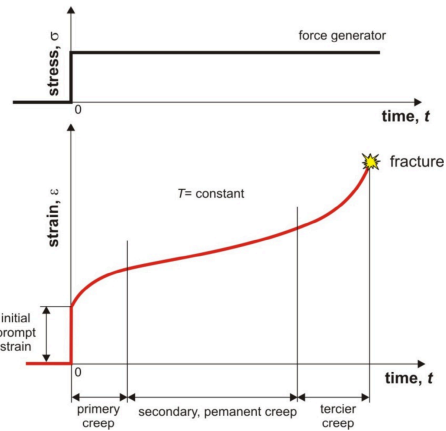
15



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2. Creep

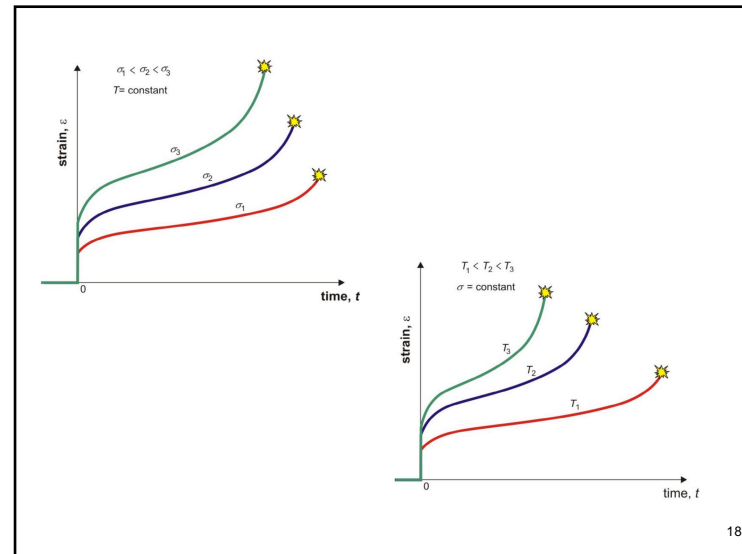
Continuously increasing strain upon constant long-time stress.



Model: ? — Maxwell
— Burgers

$1-10^7$ s !!

17

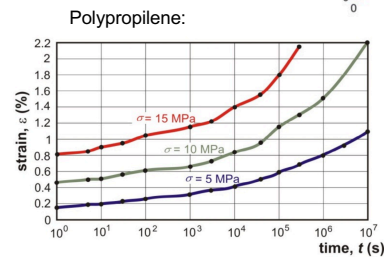
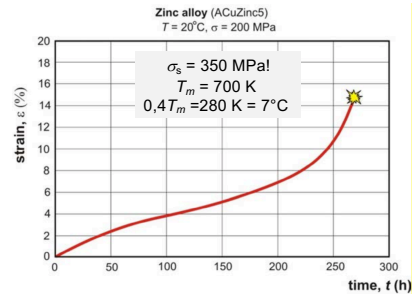


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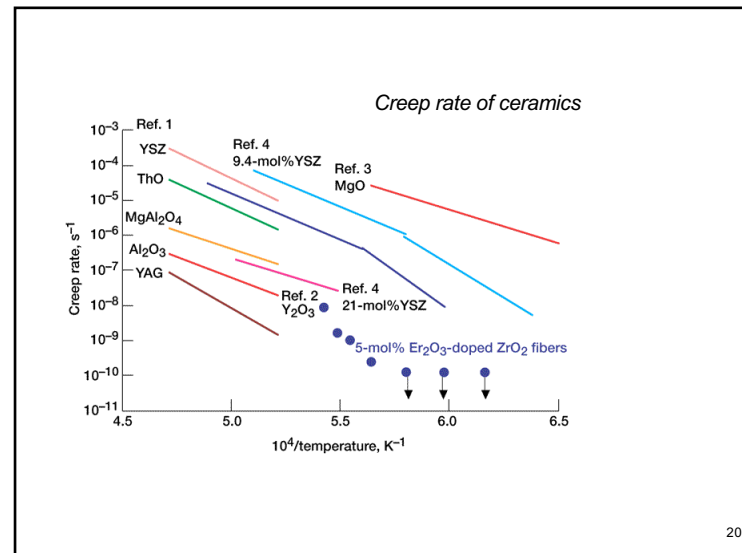
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Effect of temperature on creep! in case of metals it is significant if:
 $0,4T_m < T$



19

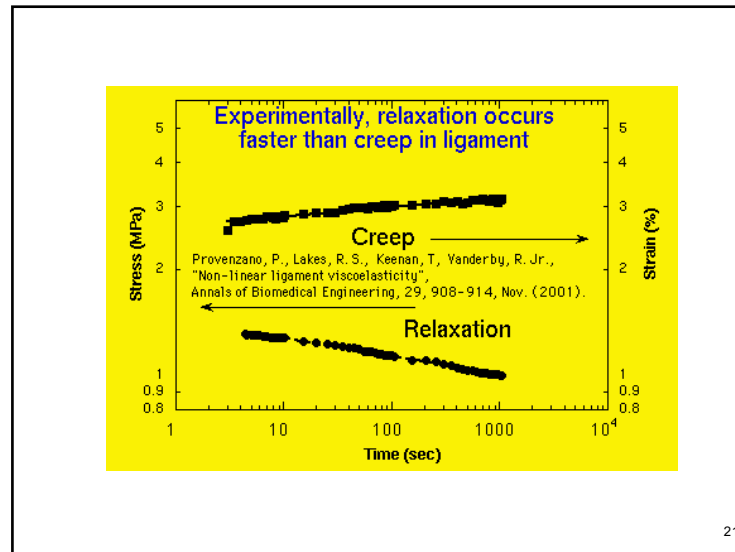
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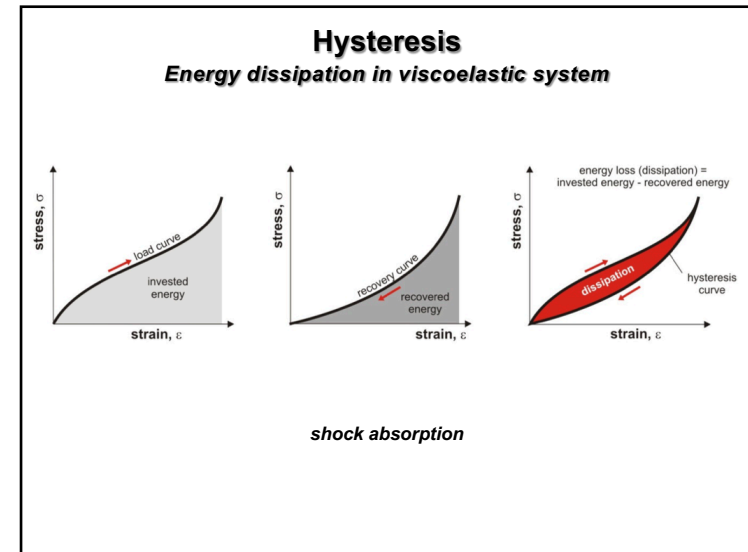
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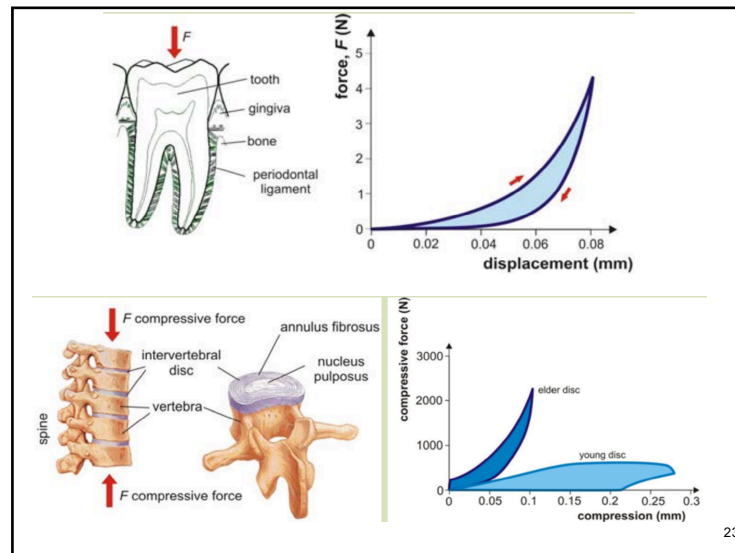


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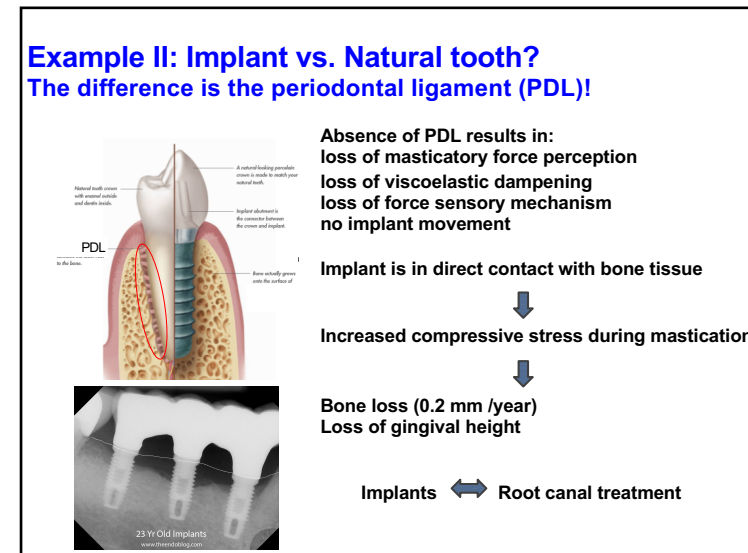


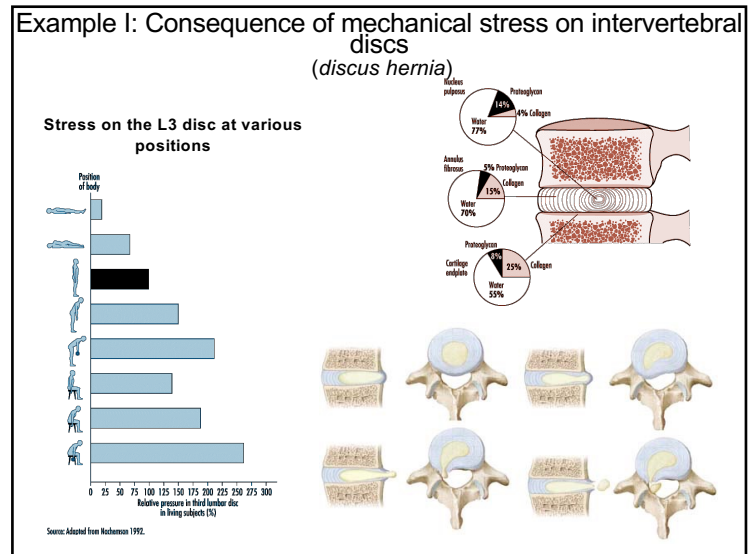
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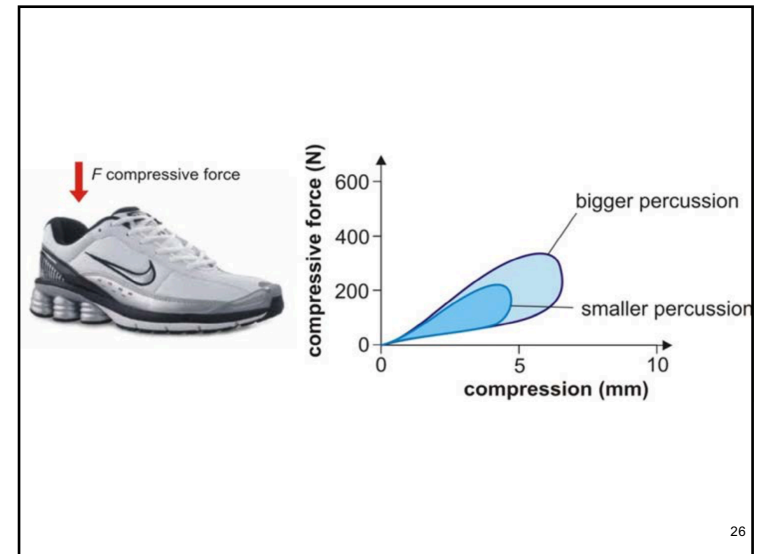
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