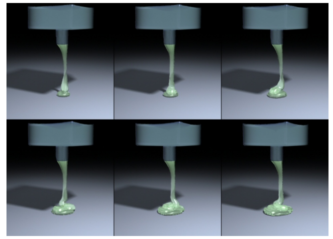
stiffness flexible ↔ stiff	Young-modulus, E (Pa)
elasticity rigid ↔ elastic	elastic strain recovery, ε_r resilience, w_r (J/m^3)
ductility not ductile↔ ductile	$\varepsilon_y - \varepsilon_s$
strength weak ↔ strong	σ_s (Pa)
toughness not tough (brittle) ↔ tough	toughness, w_s (J/m^3)
Hardness soft ↔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

1



Physical bases of dental materials science
9.
Viscoelasticity

Keynotes:
- *Viscoelastic behavior*
- Viscoelastic models
- Viscoelastic phenomena

E-book chapter: 18

2

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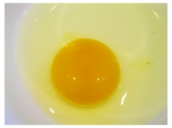
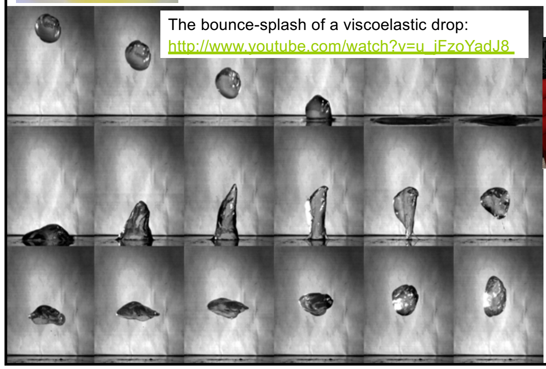
Viscoelasticity





The bounce-splash of a viscoelastic drop:
http://www.youtube.com/watch?v=u_iFzoYadJ8

3

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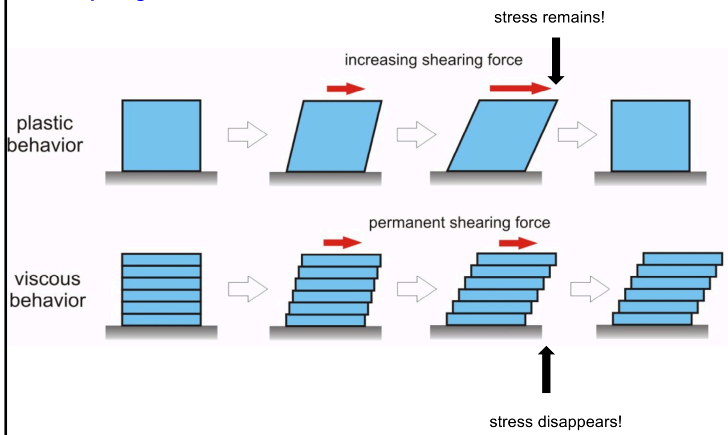
Comparing elastic and viscous behavior:



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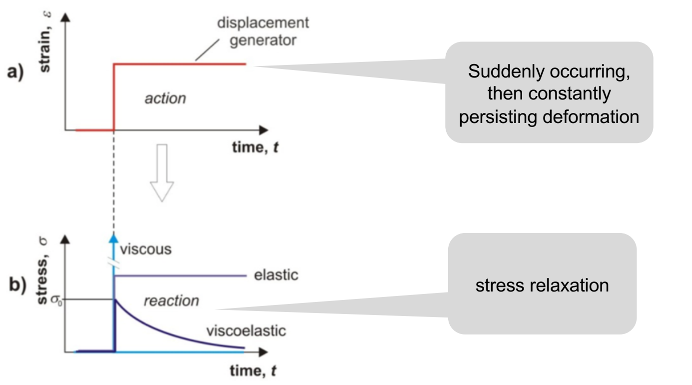
Viscoelasticity



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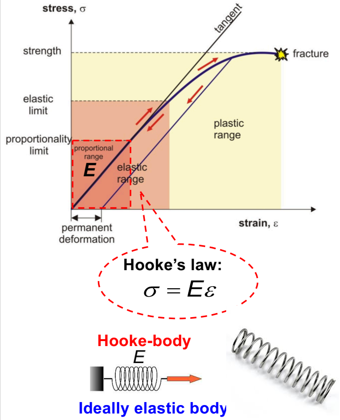
Reminder:

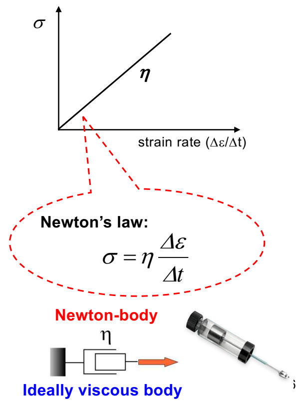
Elastic behavior:

- sudden
- force is required to maintain strain



Viscous behavior

- time dependent
- force is required to maintain stress rate



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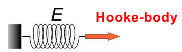
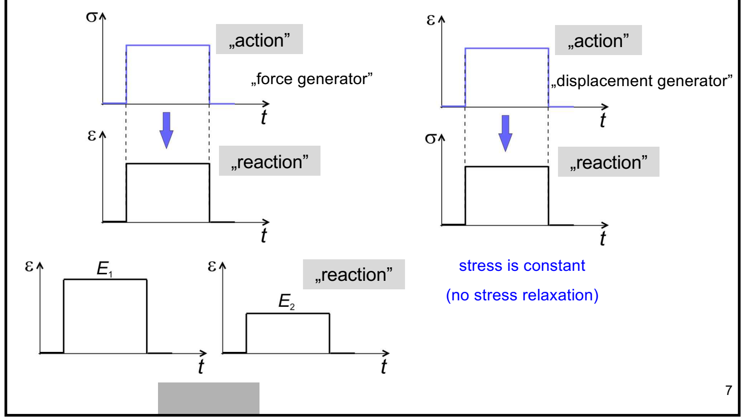
Ideal elastic behavior



How would strain change in case of constant stress?

How would stress change in case of constant strain?



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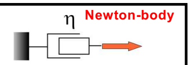
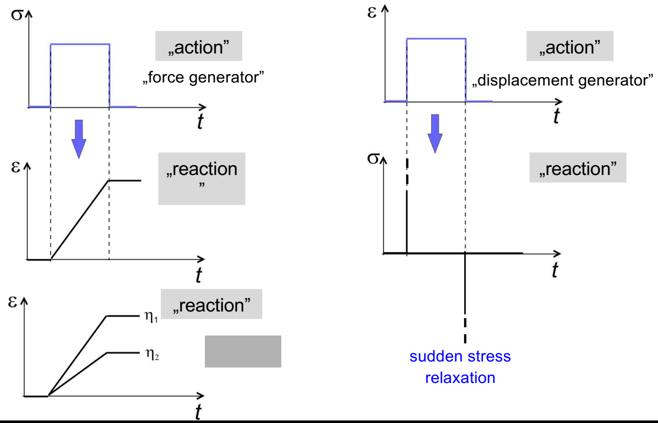
Behavior of an ideally viscous body



How would strain change in case of constant stress?

How would stress change in case of constant strain?



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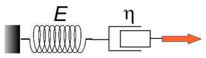
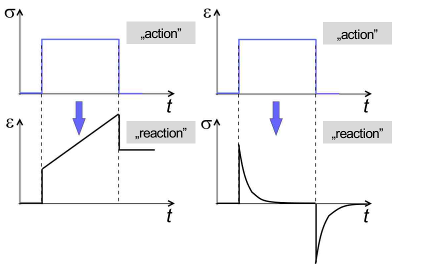
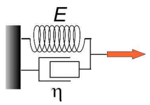
Viscoelastic models

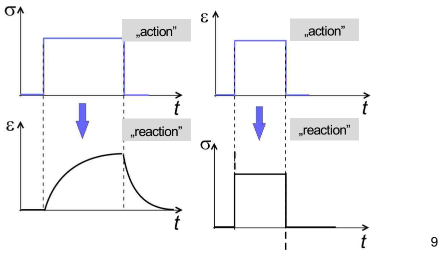
Maxwell-model





Kelvin-Voigt-model





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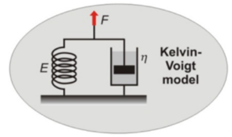
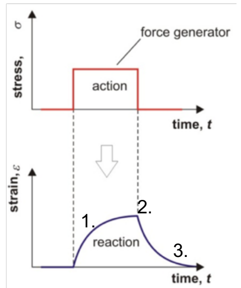
Viscoelasticity

(mechanical model)





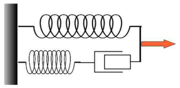
Viscoelasticity means the co-appearance of viscous and elastic behavior.

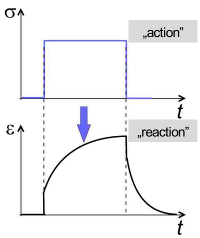
model: parallel connection of spring and dashpot (Kelvin-Voigt model)

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

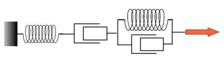
1. Upon stretch, the extension of the spring is slowed down by the dashpot.
2. Extension stops when the elastic spring force equals the external force.
3. When the external force is quenched, the contraction of the spring is slowed down by the dashpot.

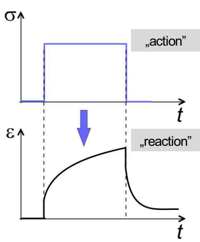
Standard linear modell





Burgers-modell





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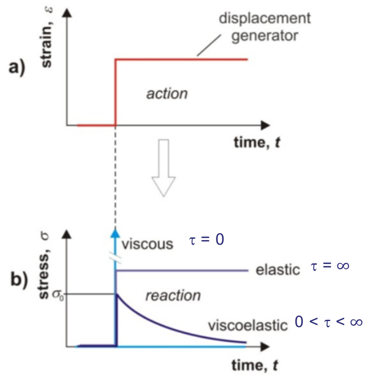
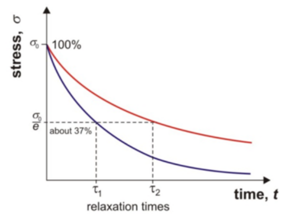
1./a Stress-relaxation in viscoelastic system

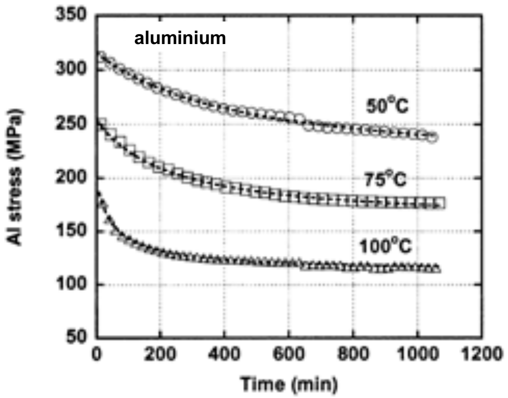
Decrease in stress while strain remains constant





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

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



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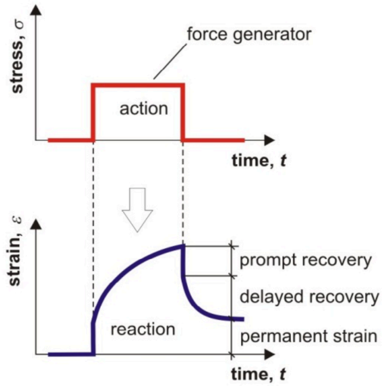
1./b Shape relaxation (recovery)

Recovery of shape after the stress is quenched.



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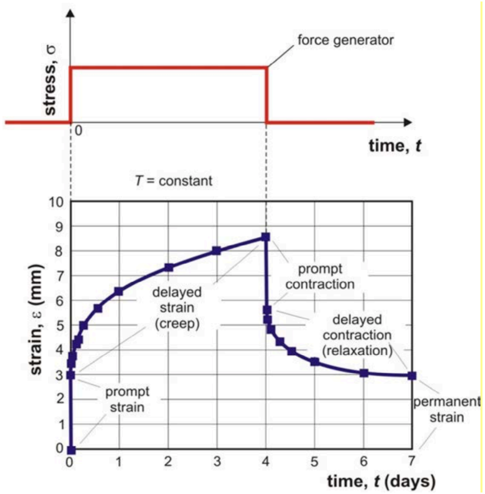
bone cement



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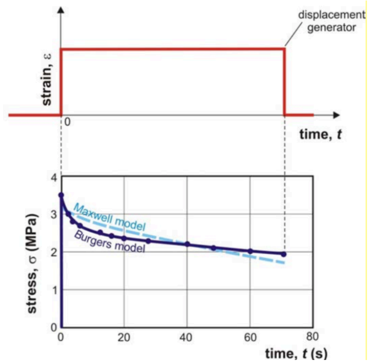
film made of miofibrillar proteins:



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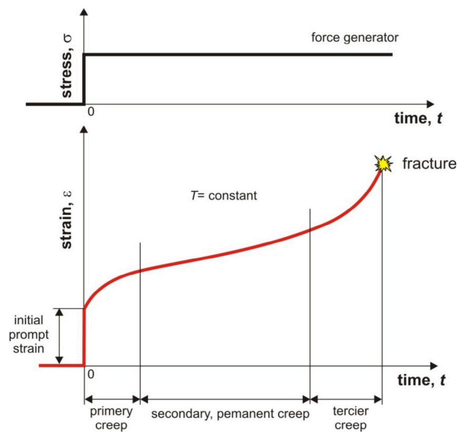
2. Creep

Continuously increasing strain upon constant long-time stress.



Modell: ? — Maxwell

— Burgers

1–10^7 s **!!**

17

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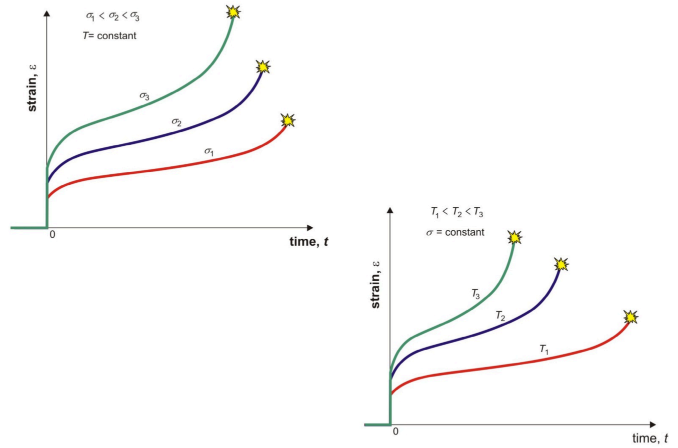

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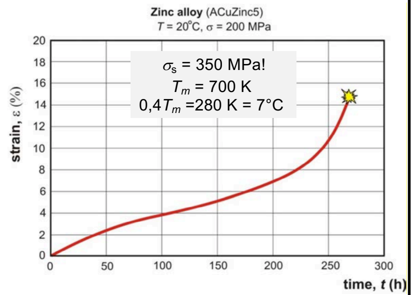
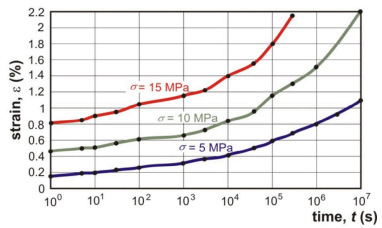
Effect of temperature on creep!. in case of metals it is signifficant if:

$0{,}4T_m < T$



Polypropilene:



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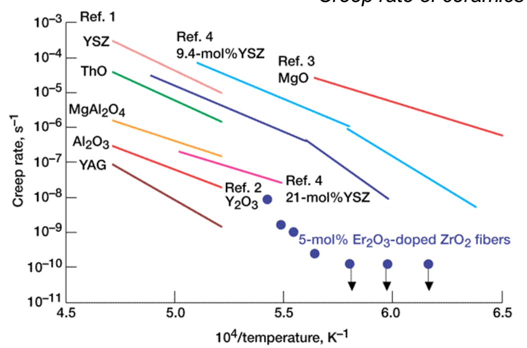
Creep rate of ceramics



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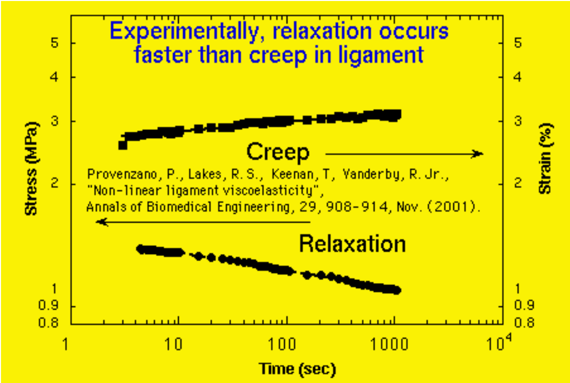

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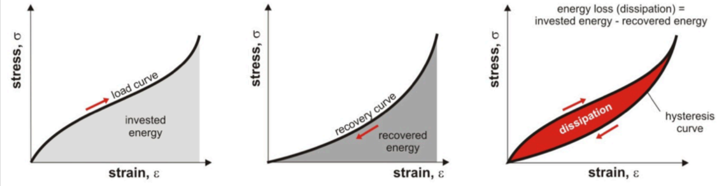
Hysteresis

Energy dissipation in viscoelastic system



shock absorption

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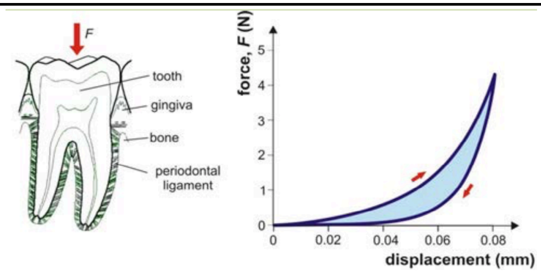

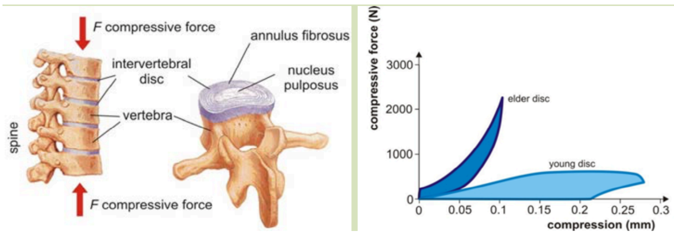

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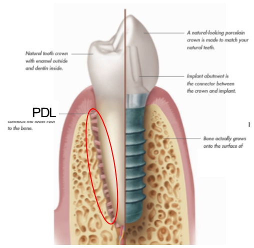
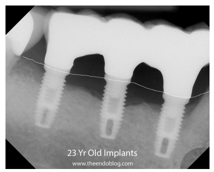
Example II: Implant vs. Natural tooth?

The difference is the periodontal ligament (PDL)!





Absence of PDL results in:
loss of masticatory force perception
loss of viscoelastic dampening
loss of force sensory mechanism
no implant movement

Implant is in direct contact with bone tissue

Increased compressive stress during mastication

Bone loss (0.2 mm /year)
Loss of gingival height

Implants ⇔ Root canal treatment

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Example I: Consequence of mechanical stress on intervertebral discs
(*discus hernia*)