

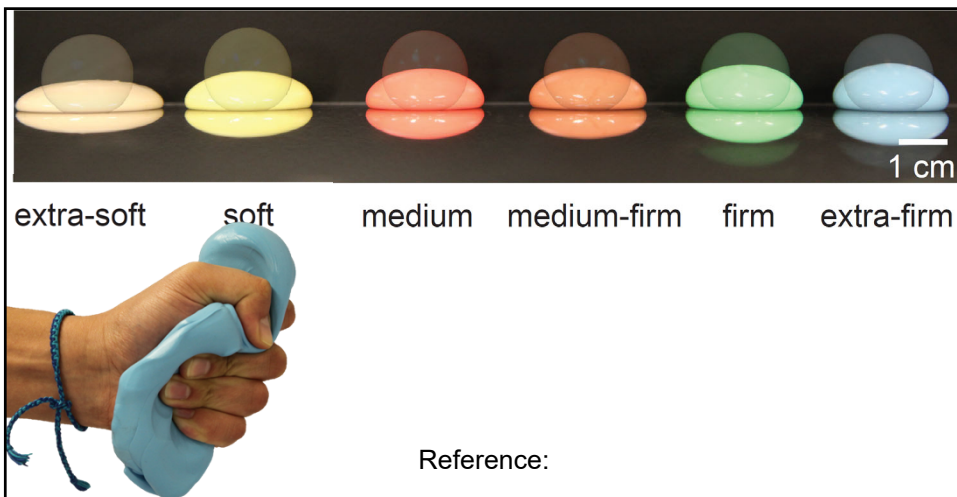
03 Linear Viscoelasticity: Hands-On Data Interpretation



Randy H. Ewoldt

Department of Mechanical Science and Engineering
University of Illinois Urbana-Champaign
Urbana, Illinois 61874

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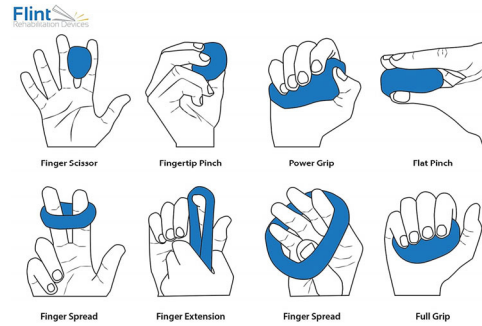


Reference:

Corman, R. E., and R. H. Ewoldt,
“Mapping linear viscoelasticity for design and tactile intuition,”
Applied Rheology, 29 (1):141–161 (2019).
<https://doi.org/10.1515/arh-2019-0013>
(Open Access)

Therapy Putty

(compare two putties: "Soft" versus "Firm")



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What is different (rheologically) between putties?

Push, pull, bounce,...is difference Viscous? Elastic? Relaxation timescale?

Source (images & data):
Thera-Flex therapy putty

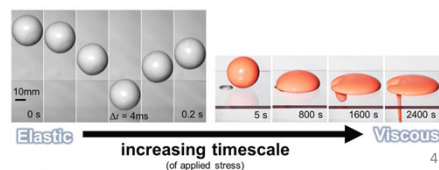
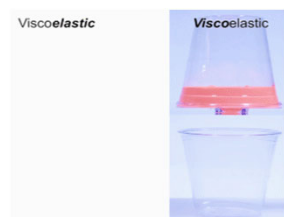
Source (2021 putty samples):
Therapy Putty from Flint
Rehabilitation Devices, LLC

What rheological test would measure this?

What deformation? (shear, extension, ...)

What is controlled input? (strain, strain-rate, stress, ...)

Scheduling of input (step, oscillation, ...)



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Actual material functions

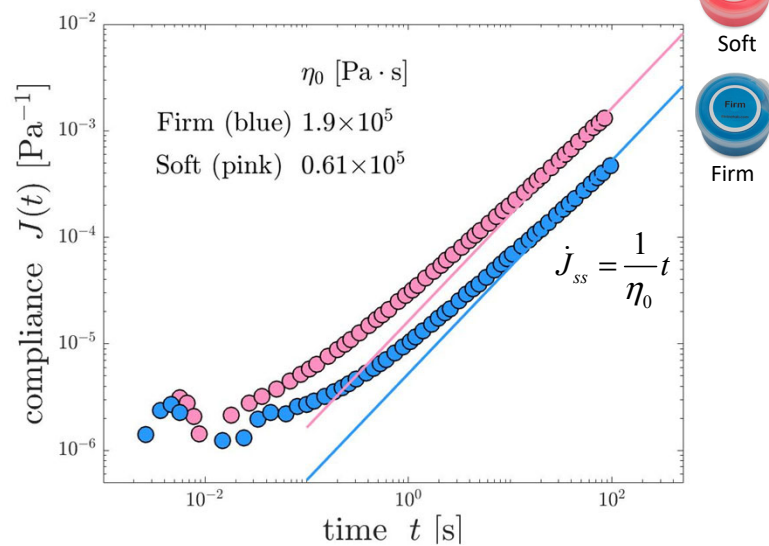
RESULTS

Results to be shown *after* your hands-on
'do it yourself rheometry' session

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Data from Yilin Wang (Illinois)
August 2020

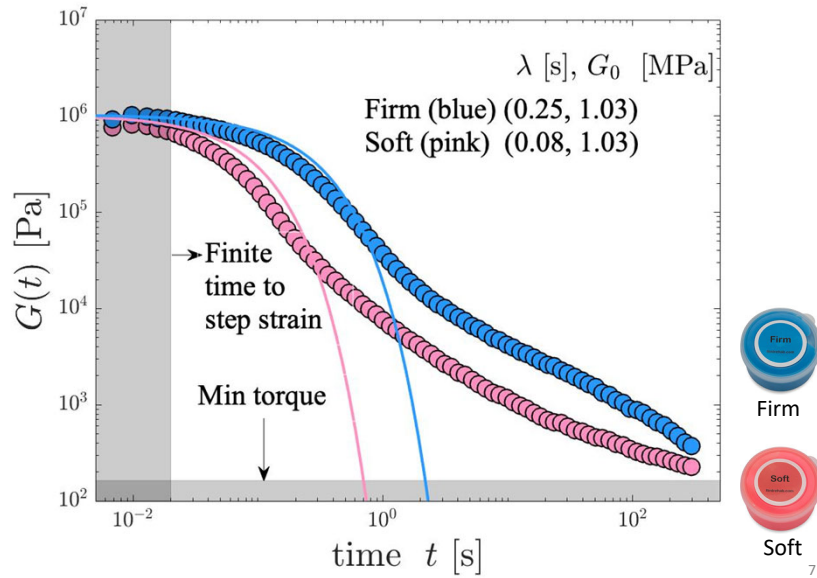
Creep $J(t)$



Data from Yilin Wang (Illinois)
August 2020

Stress relaxation $G(t)$

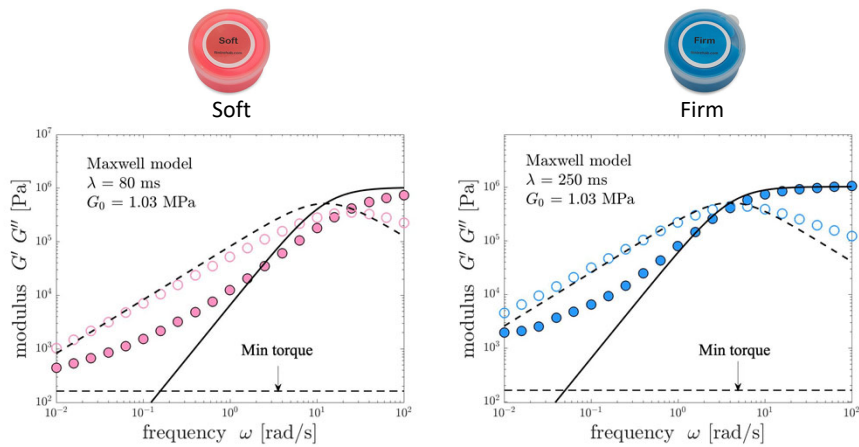
(with Maxwell model fit: not perfect!)



Data from Yilin Wang (Illinois)
August 2020

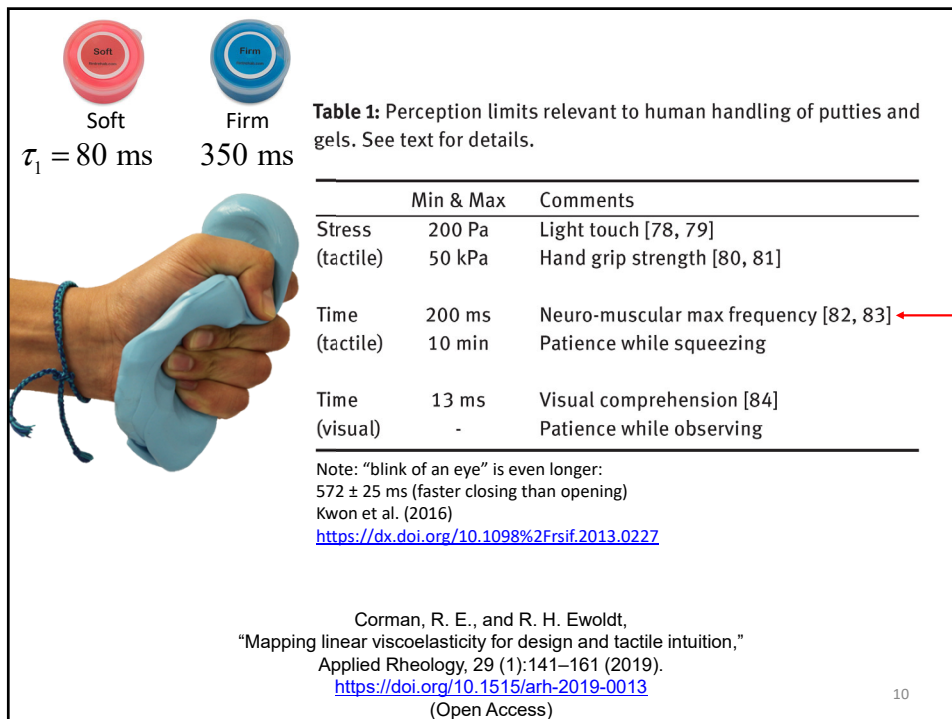
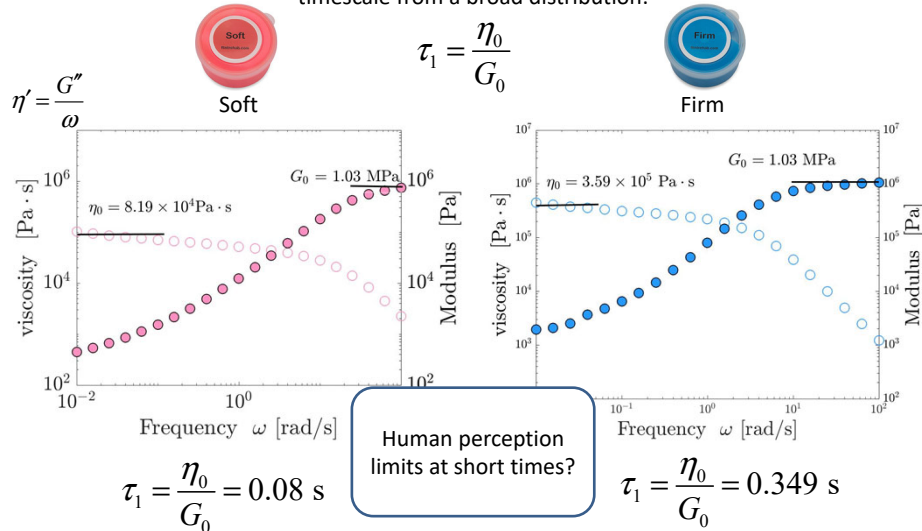
Oscillation: Dynamic Moduli

(with Maxwell model fit: not perfect!)



Plateaus from Dynamic Viscosity & Modulus

Can be used to evaluate an 'average' timescale from a broad distribution:



Given: Two different “putties”

**Find: Feel difference, describe in terms of material functions
(Elastic? Viscous? Timescale?)**

Solution: Viscous resistance (& maybe timescale, but < 0.35s)

Putty	G_0 (Pa)	η_0 (Pa.s)	τ_1 (s)
Soft	1.03×10^6	0.82×10^5	0.080
Firm	1.03×10^6	3.59×10^5	0.349



Recall:

200 ms is neuro-muscular maximum frequency.

Thus, cannot feel elastic modulus G_0 of soft putty.

But can feel a difference in *viscosity* η_0 at $t > \tau_1$ for each.

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Intuition Unlocked!



Modulus & Viscosity



Soft



Firm

$G_0 \sim 1$ MPa

1 MPa

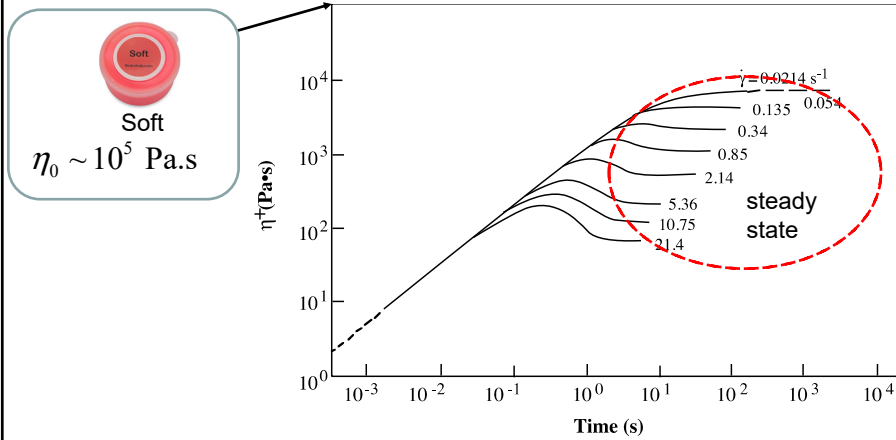
$\eta_0 \sim 10^5$ Pa.s

(few) $\cdot 10^5$ Pa.s

Examples of how to use this intuition?

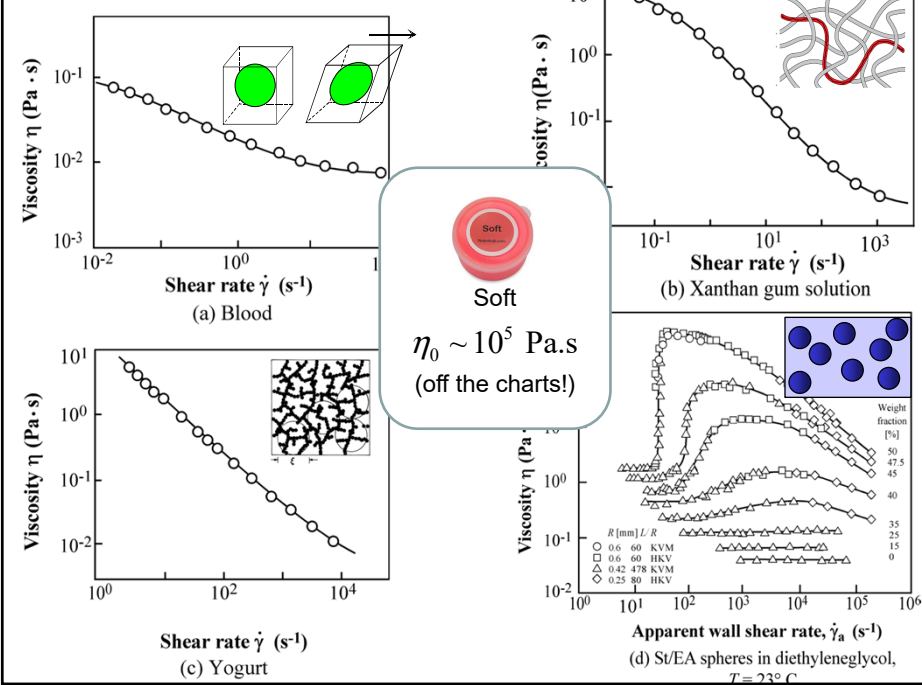
From Introduction (viscosity example)

Viscosity also depends on time of shearing (strain)



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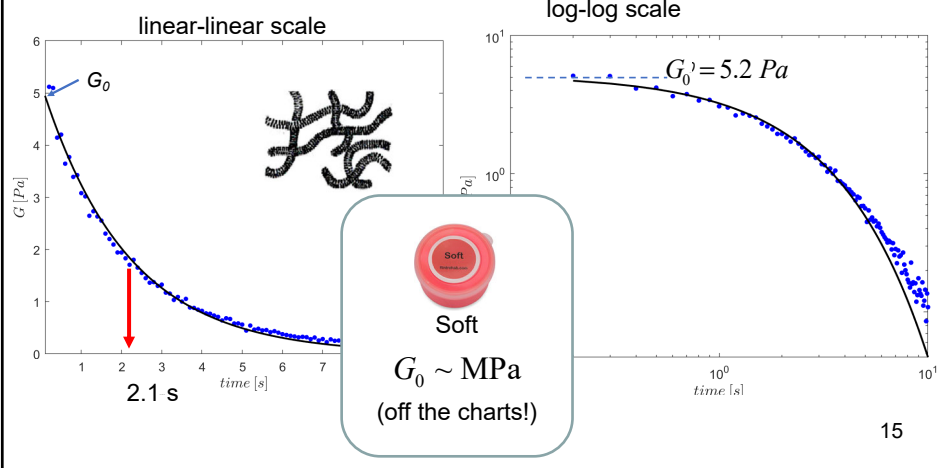
From Introduction (viscosity example)



From Introduction (modulus example)

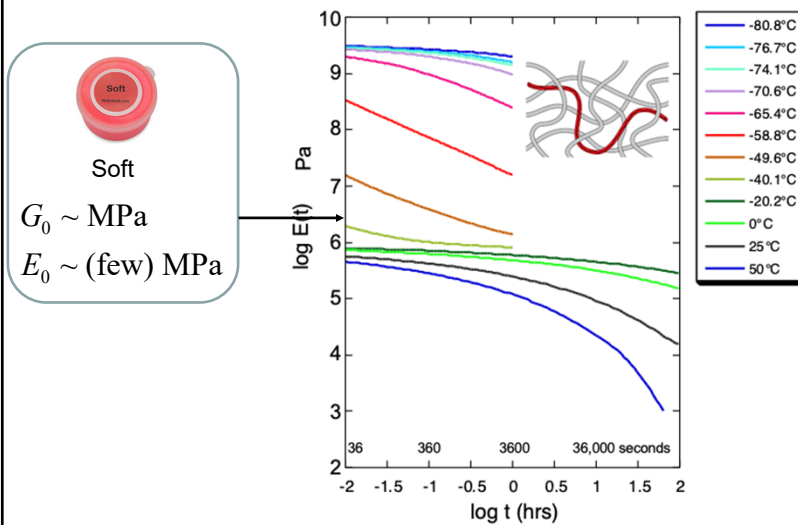
$$G(t) = G_0 e^{-t/\tau}$$

fits relaxation of surfactant with worm-like micelles



From Introduction (modulus example)

Stress relaxation modulus for PIB (polyisobutylene)



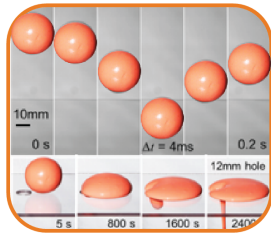
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Ferry *Viscoelastic Properties of Polymers* 1980

Summary

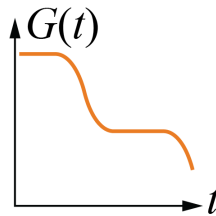
Typical workflow of a rheologist:
observe evidence, choose rheometric test(s), think about it

evidence



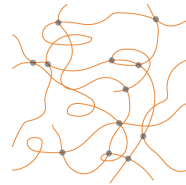
visco-
elasticity

material function



stress relaxation
modulus

microstructure



transient
polymer network