ME 23N: Soft Robots for Humanity
Autumn 2019

Week 6: Silicone elastomers and molding

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ME 23N Lunches with Allison

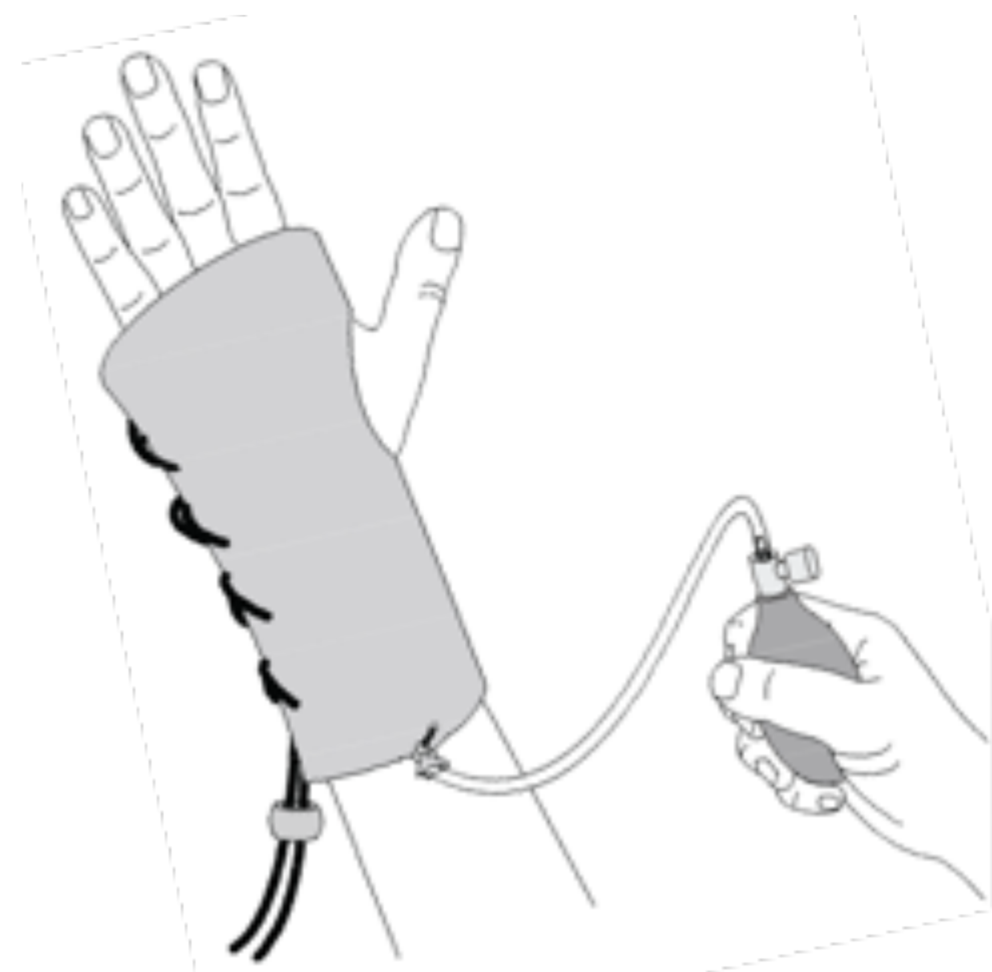
sign up here:
https://docs.google.com/spreadsheets/d/1iREg6tKNUenRAteRrD1XalKPoxzfJuQIrEp-cpVakvg/edit?usp=sharing

12-1 pm on:
Monday, Nov. 11
Wednesday, Nov. 13
Tuesday, Nov. 19
Friday, Nov. 22

Lab 4 recap: Fabrics and Wearable Soft Robots

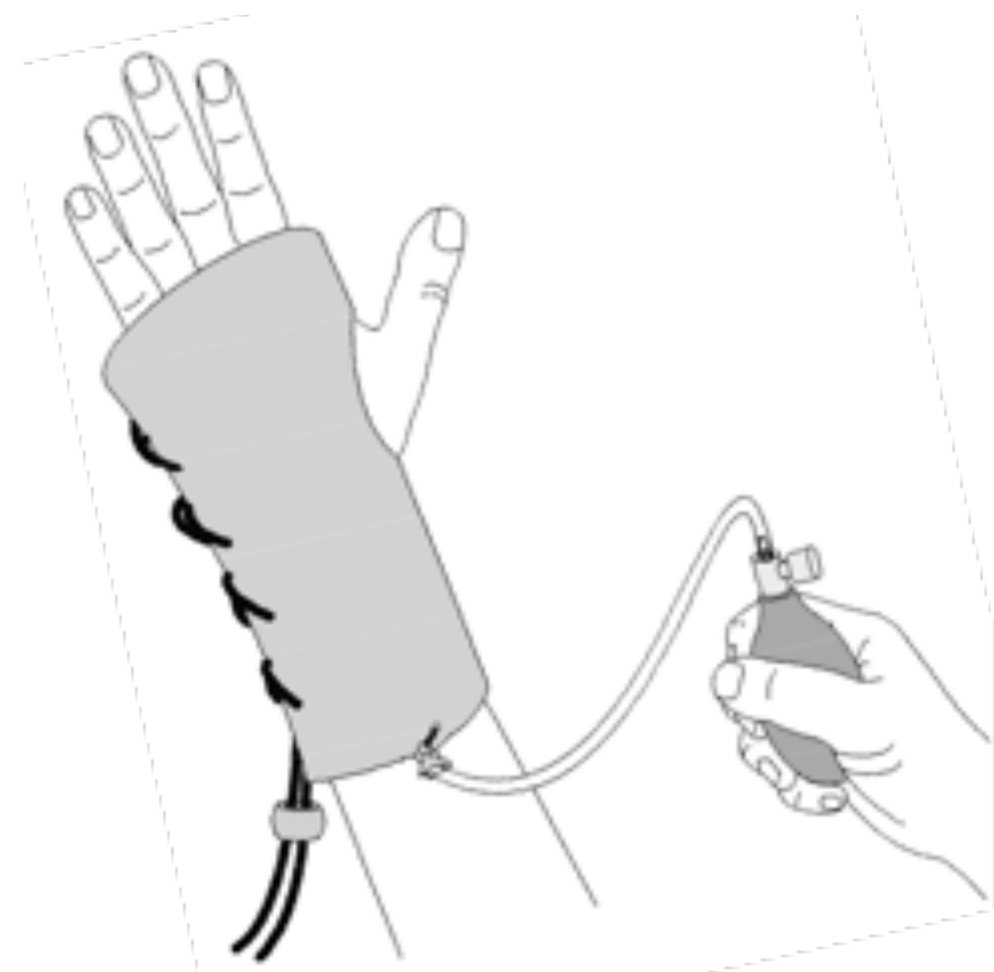
1. **Compare the behavior of the pneumatic wrist brace on and off the wrist.**

- When you inflate it with approximately the same amount of air (i.e. same number of pumps) does it have the same "stiffness" in both cases?
- What is the role of the hand and wrist in the function of the device as a brace (does it work as a brace without the hand inside)?



2. Describe the important features of the wrist brace as a wearable device.

- What allows it to fit well?
- To be comfortable?
- And to perform its function?
- How does this compare to traditional wrist braces?



3. What ways could you **improve the fit, comfort, or function** of the current device?

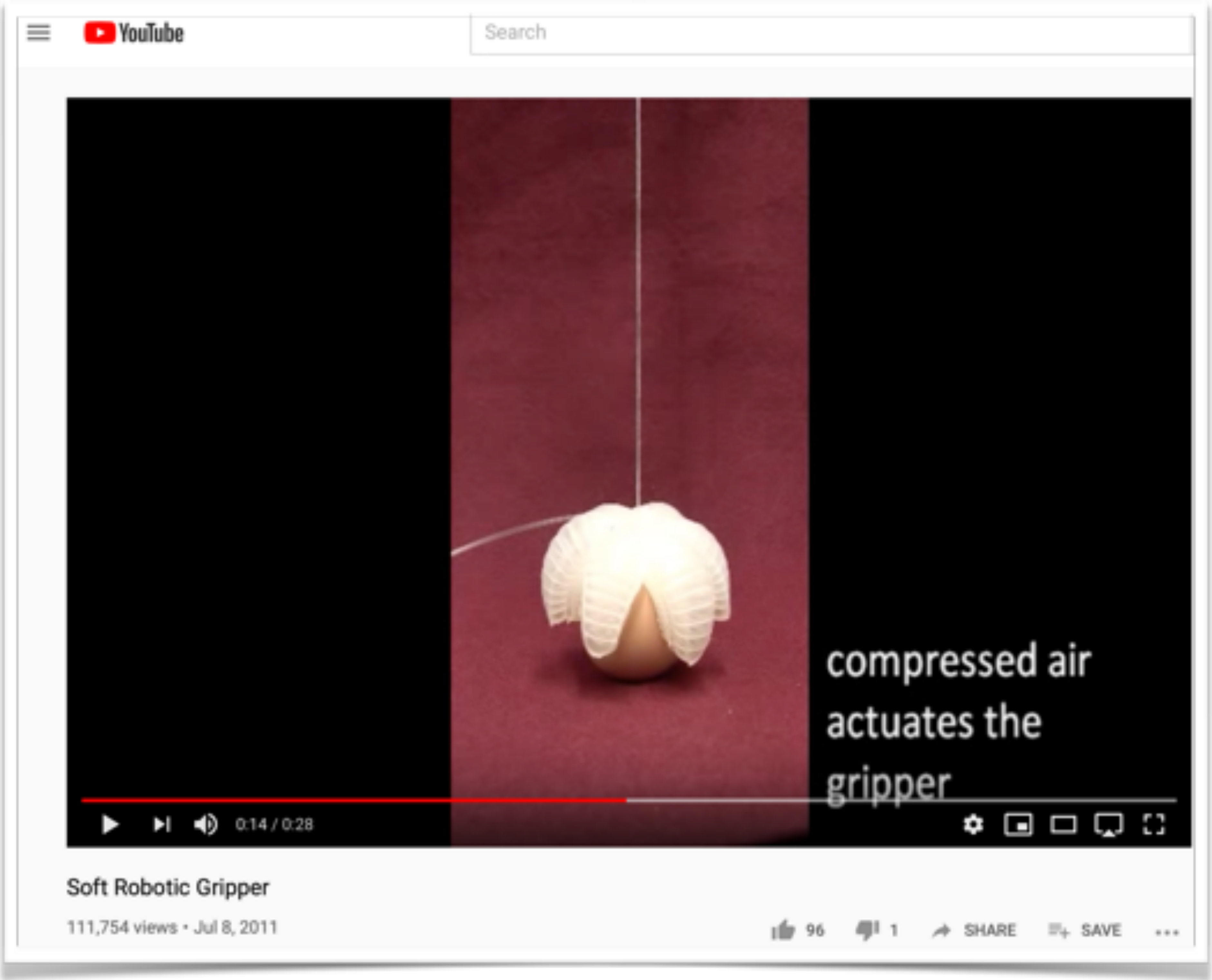
   How could we incorporate techniques and materials seen in previous labs to create an **“active” wearable soft robot**?

4. In what **other ways** and for what **other applications** could you use shaped pneumatic bladders like those created using heat-weldable fabrics in this lab?

5. Any other thoughts?

Lab 5: Elastomeric Soft Gripper

Soft Robotic Gripper



https://youtu.be/csFR52Z3T0I

To Do

- If you have not already turned in your lab notebook for Lab 4, do so now so I can give it back to you by end of class.
- Take over a lab bench with your partner (next slide).
- Read the lab handout (Day 1 part)
- Work on the lab for about 30 minutes today, then we will go back to lecture-style class. You'll finish the lab on Thursday.
- Answer the questions in your lab notebook (clearly label it with the date and "Lab 5"). Turn in the lab notebook by the end of class on Thursday, or let us know if you need more time/help.

Groups of two for Lab 5

1	Leena	Huy
2	Caroline	Emma
3	Brian	Josue
4	Tomas	Ellie
5	Sochima	Nadin
6	Cherié	Youngju
7	Nick	Angelo
8	Senkai	Alana

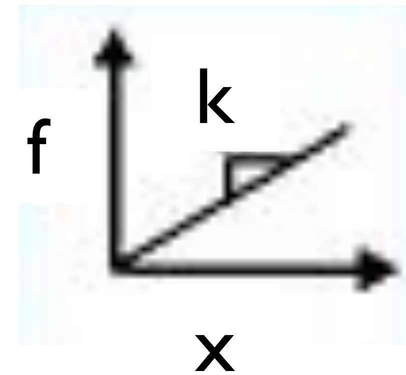
Elastomeric Soft Robots

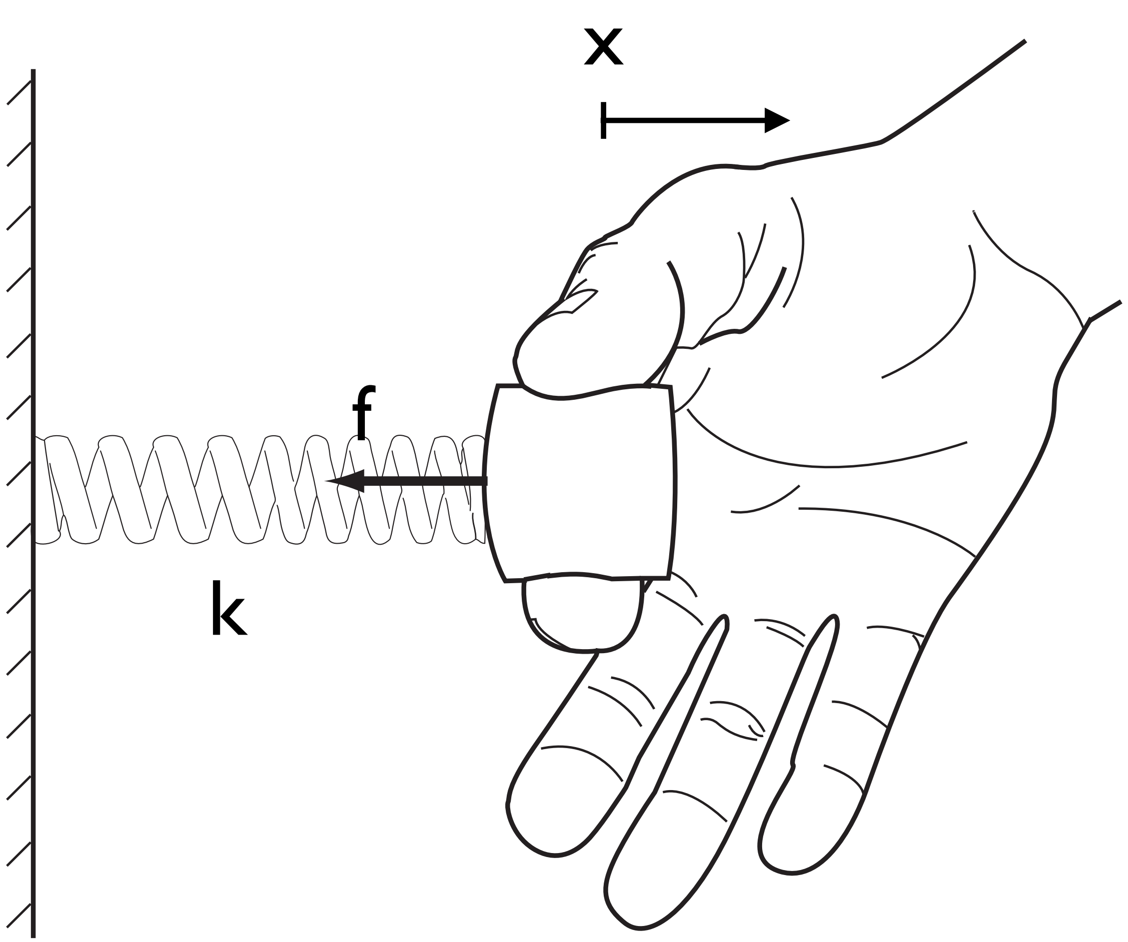
Elastomers

- Elastomers is short for **elastic polymers**, which are materials that typically have a low **Young's modulus** and **high failure strain**.
- They are available with a wide range of material properties, such as **tear strength**, **elongation at break** (stretchiness), **cure time**, and **durometer**.

Linear Stiffness/Compliance

$$f = kx$$





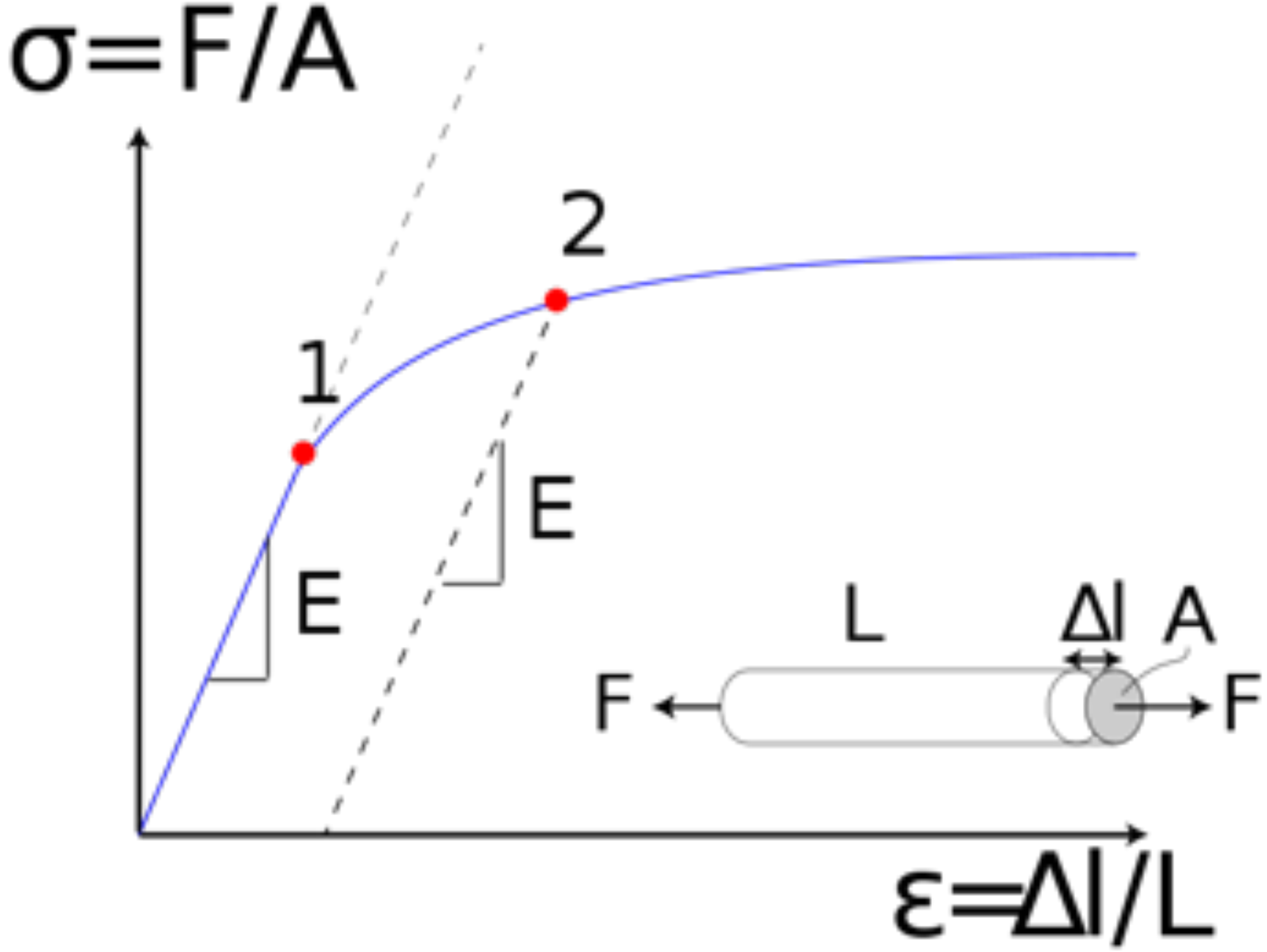
f is the force

k is the stiffness
(inverse of k is compliance)

x is the deflection of the spring, also referred to as ΔL.
(x = 0 at the equilibrium point of the spring)

Stress and Strain

While stiffness is the property of a *body*,
a stress-strain relationship describes a *material*



Stress–strain curve showing typical yield behavior

stress

$$\sigma = \frac{F}{A_0}$$

strain

$$\epsilon = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$$

E is **Young's modulus**

Stress and Strain

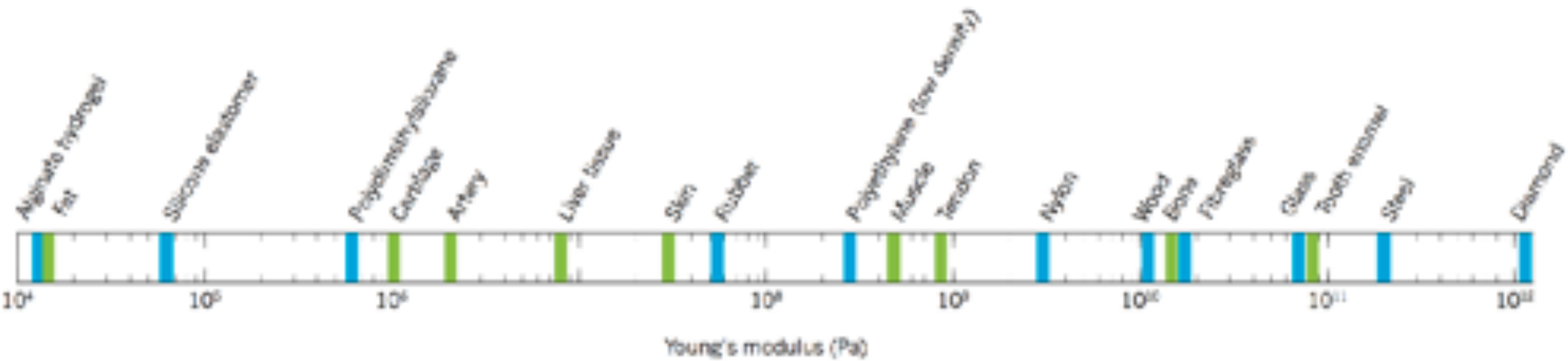


Figure 2 | Approximate tensile modulus (Young's modulus) of selected engineering and biological materials. Soft robots are composed primarily of materials with moduli comparable with those of soft biological materials (muscles, skin, cartilage, and so on), or of less than around 1 gigapascal. These materials exhibit considerable compliance under normal loading conditions.

SHORE HARDNESS SCALES

How to you make an elastomer?

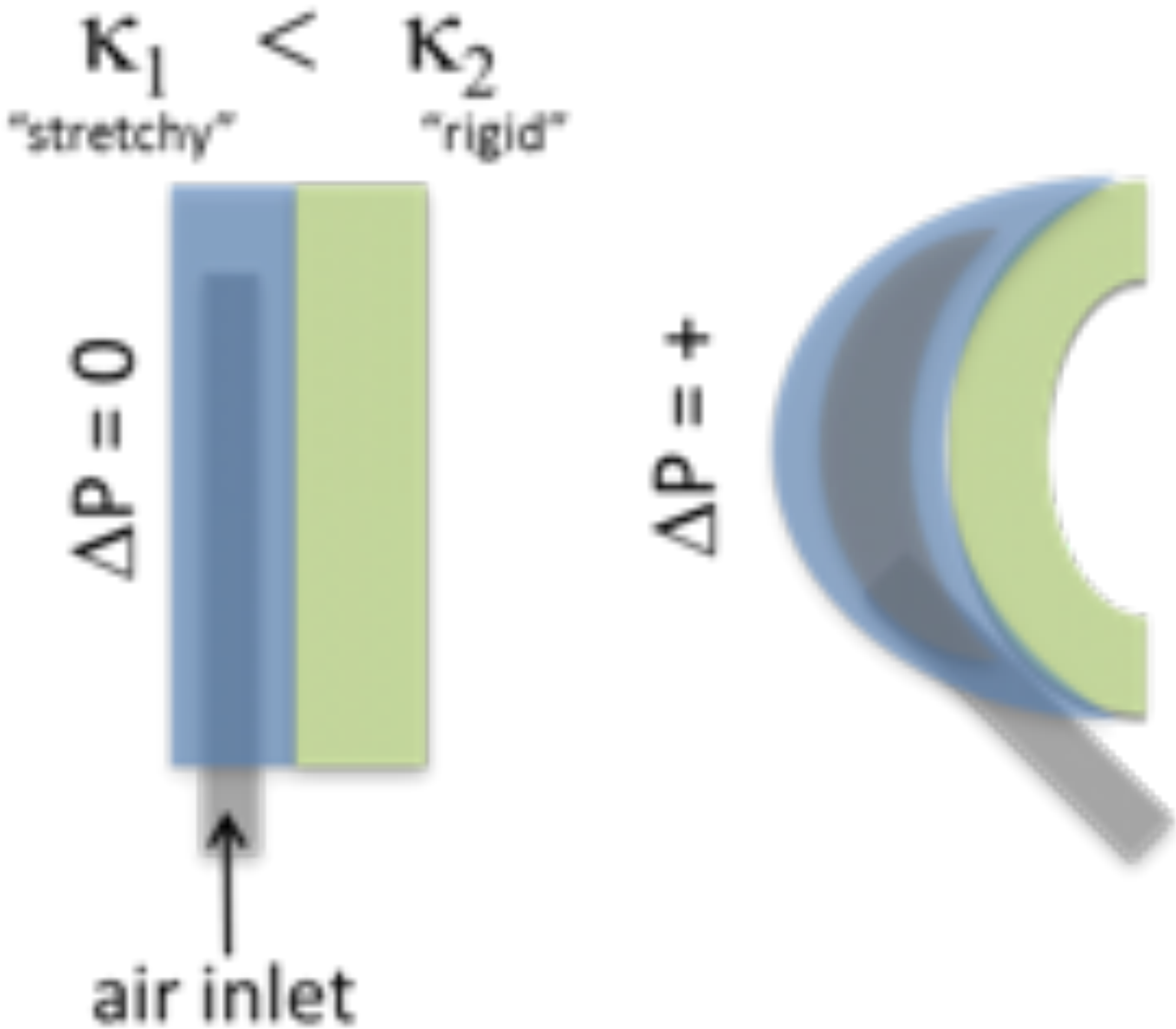
- Elastomers (and many other polymers) typically come in two parts: a **base material** containing free, non-crosslinked polymer chains, and a **curing agent**. To initiate curing, these two parts need to be mixed together thoroughly in the appropriate ratio. When this happens, the curing agent will cross-link polymer chains, hardening the material.
- Since this is a chemical reaction, **heat can accelerate curing**, but sometimes this can result in incomplete curing or unintended effects on material properties. [This is an undergraduate research project in my lab right now!]

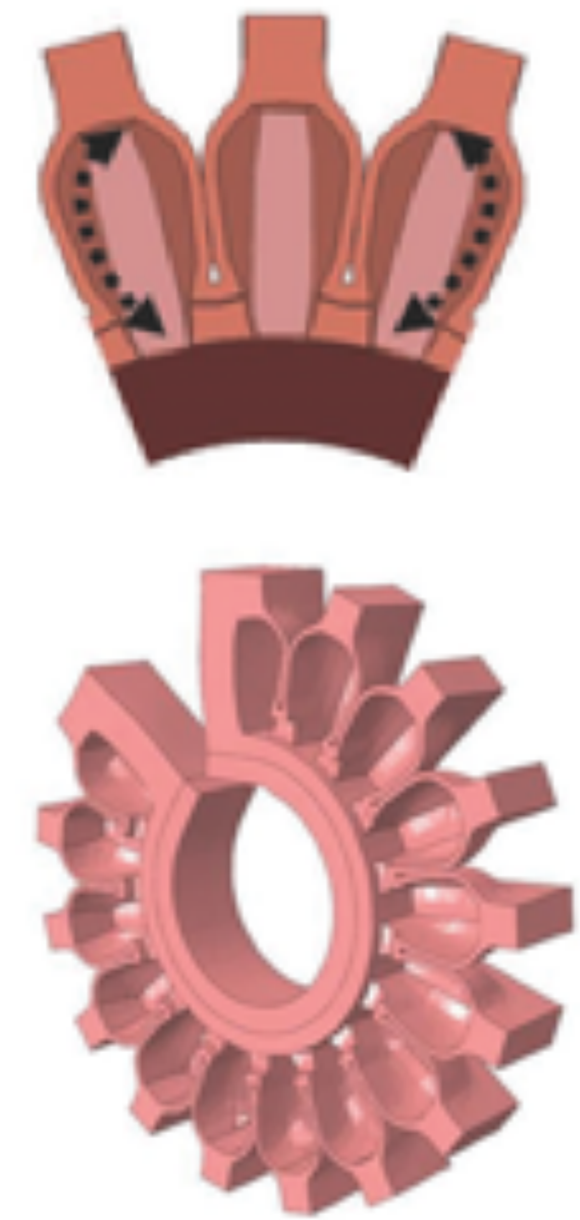
Material provided by the soft robotics Toolkit: https://softroboticstoolkit.com

PneuNets (pneumatic networks)

- Made up of a series of channels and chambers inside an elastomer.
- When pressurized, these channels inflate and create motion.
- The nature of this motion is controlled by modifying the geometry of the embedded chambers and the material properties of their walls. When a PneuNets actuator is pressurized, expansion occurs in the most compliant (least stiff) regions.

PneuNets (pneumatic networks)





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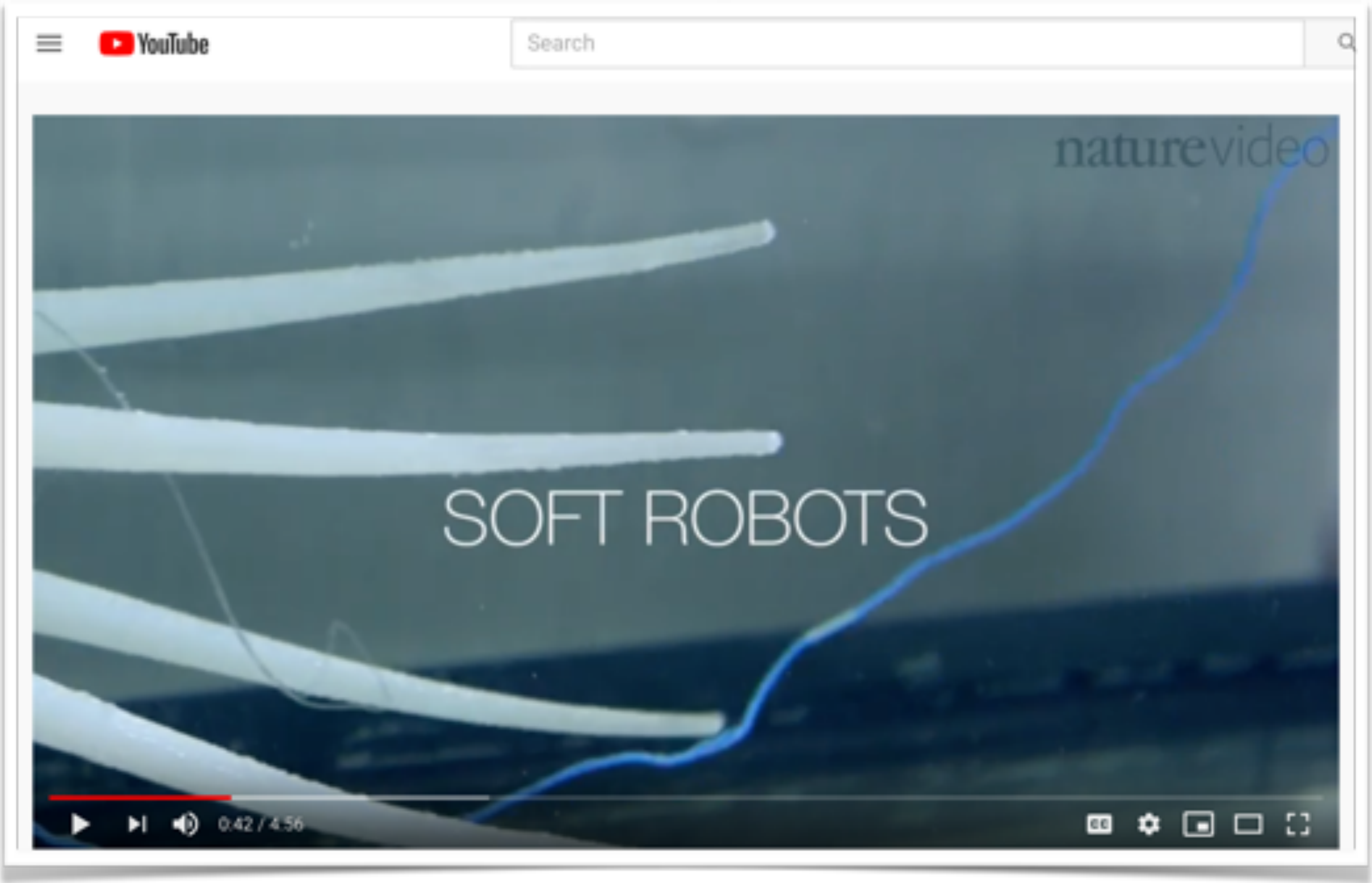
Early soft robot from Harvard

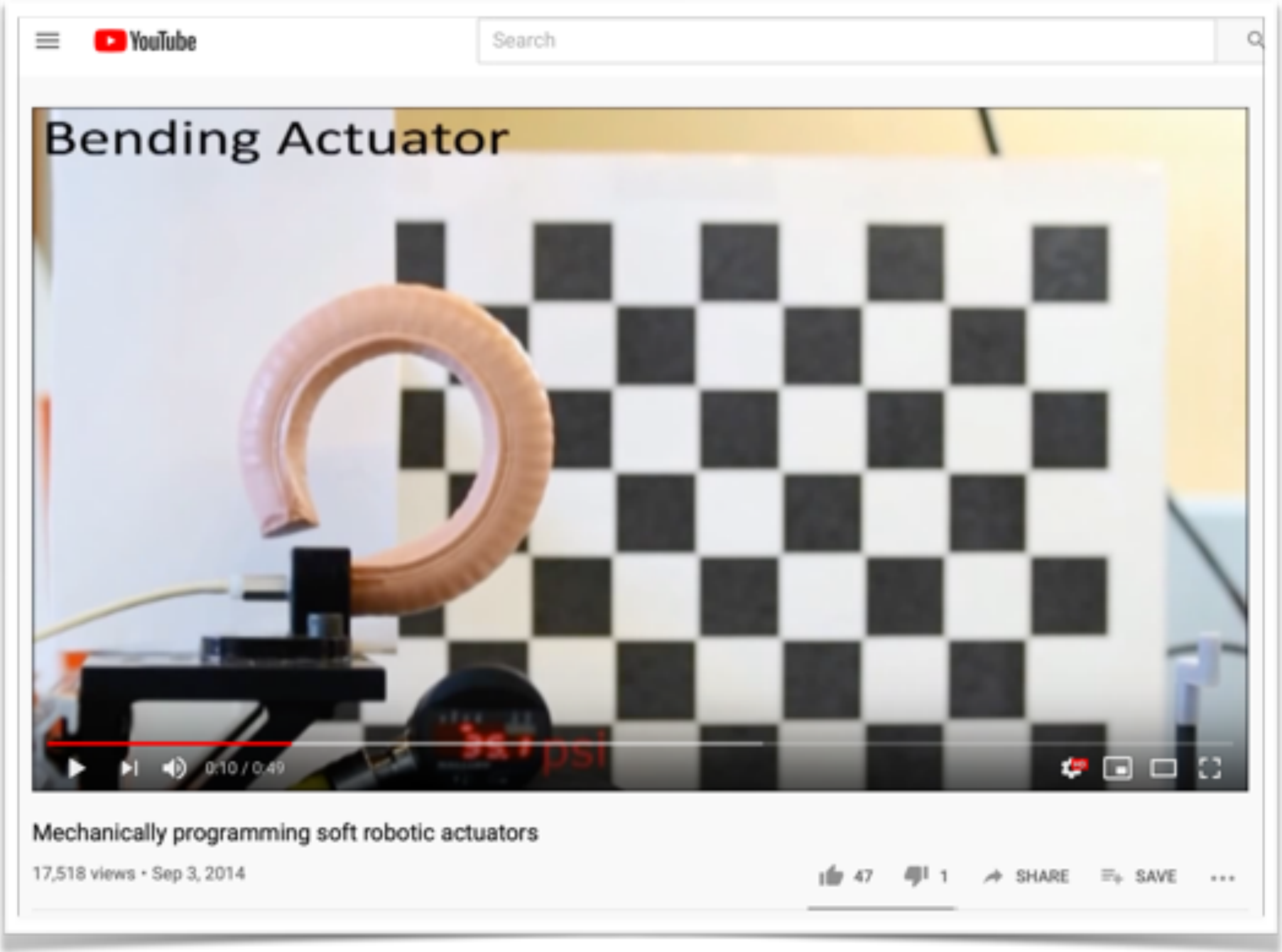
https://youtu.be/2DsbS9cMOAE

Bio-inspired robots from Scuola Superiore Sant'Anna, Pisa, Italy



https://youtu.be/A7AFsk40NGE

Fiber Reinforced Elastomeric Enclosures (FREEs)



https://youtu.be/8PV258_rZkQ

Vetricular Assist Device

https://youtu.be/0Qbvc3WusEU

Class Picture!