



DES 5002: Designing Robots for Social Good

Week 06 | Lecture 04

Soft robotics I

Wan Fang

Southern University of Science and Technology

Introduction to Soft Robotics

- Motivation for soft robots
- Soft robotics
 - Material Selection
 - Actuation
 - Sensation

Why soft robots

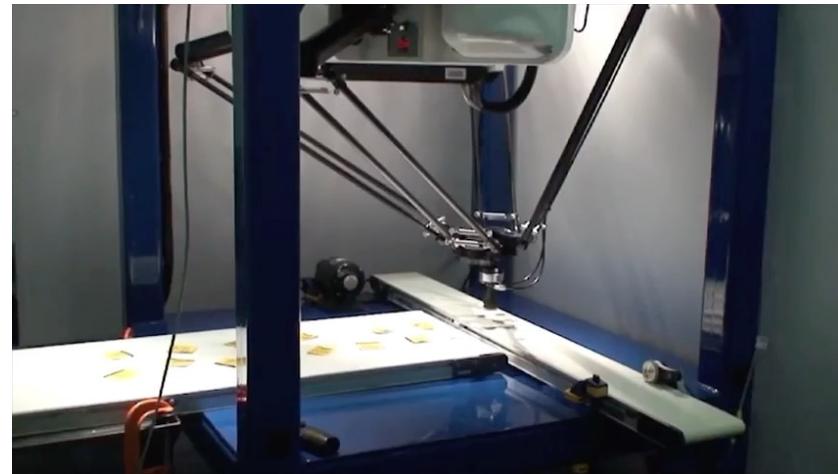
- The development of robotics as a field has been heavily influenced by industry, especially automation, manufacturing, transportation, and aerospace.
- The robotic platforms that developed aspired to ideals such as strength, high precision and speed.

Titan from Kuka

Payload
1000 kg



Quattro from Omron

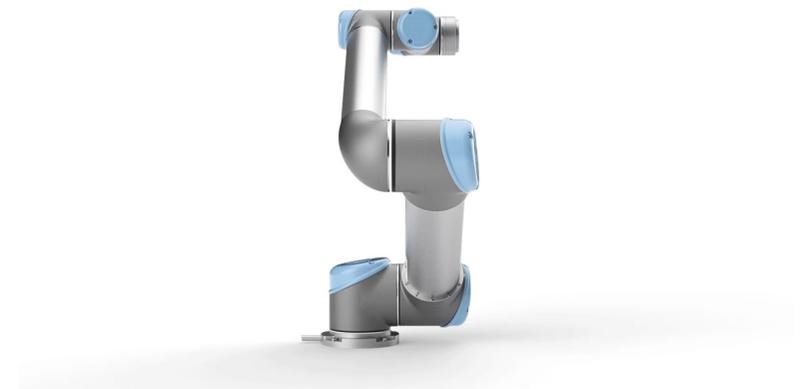
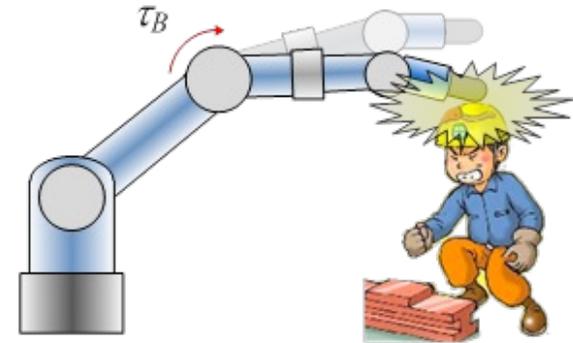


Robots falling down



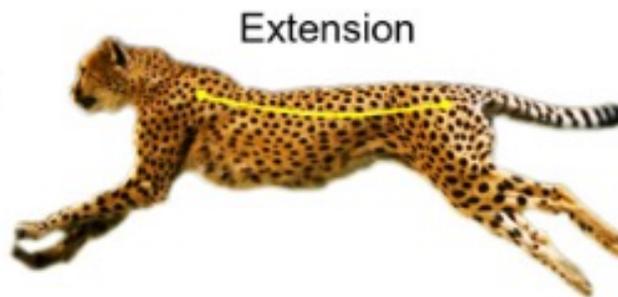
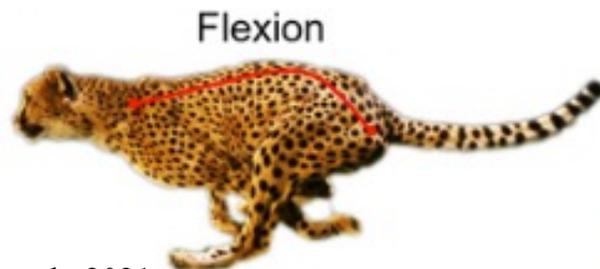
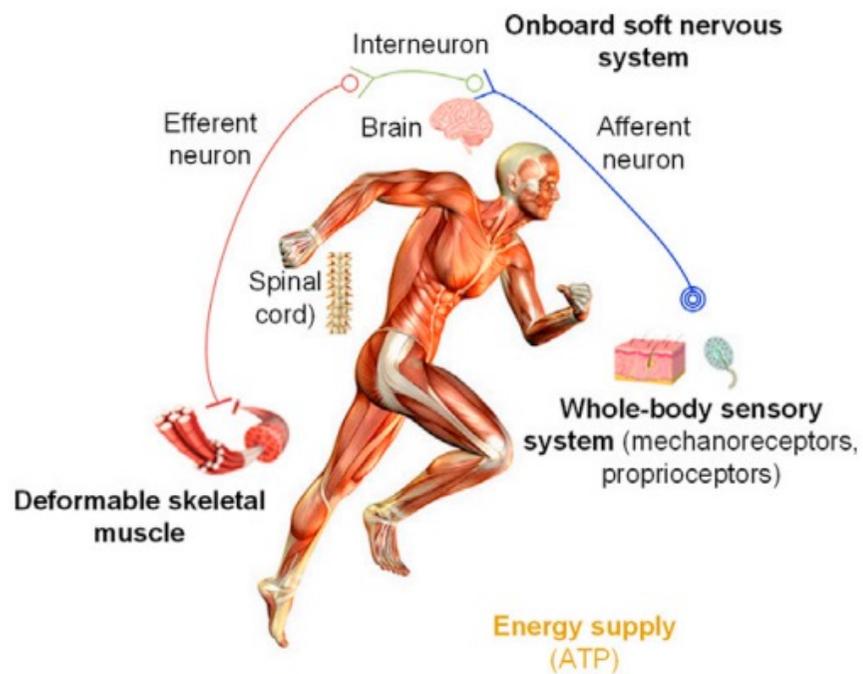
Disadvantages of rigid robots

- Rigid links -> dangerous
- Can be mechanically complex
- Lack of compliance -> limited adaptability -> difficult to interact with uncertain environments
- Can be inappropriate for handling delicate or soft materials



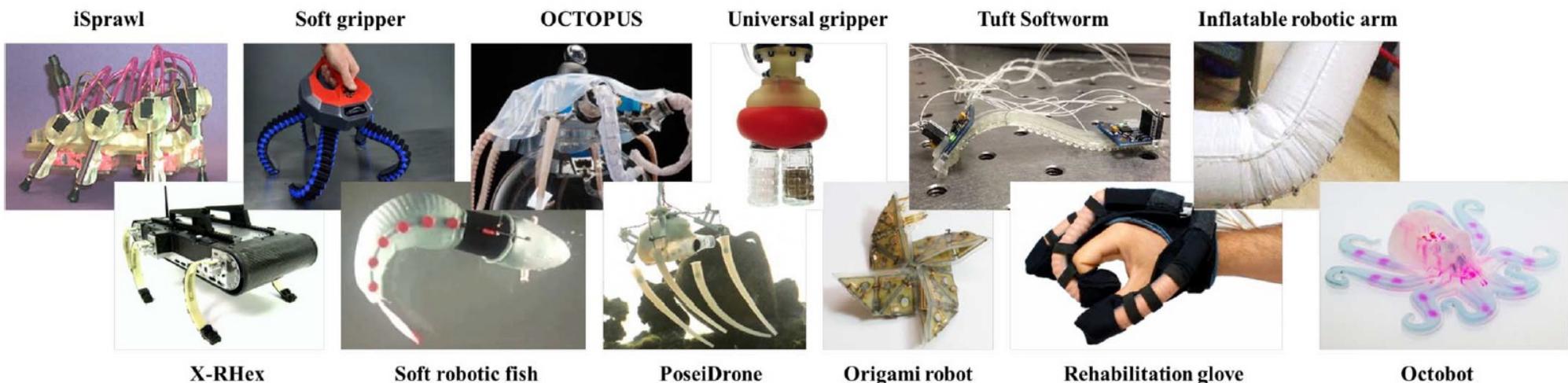
Nature

- Soft, sustainable, robust and flexible



Soft robotics

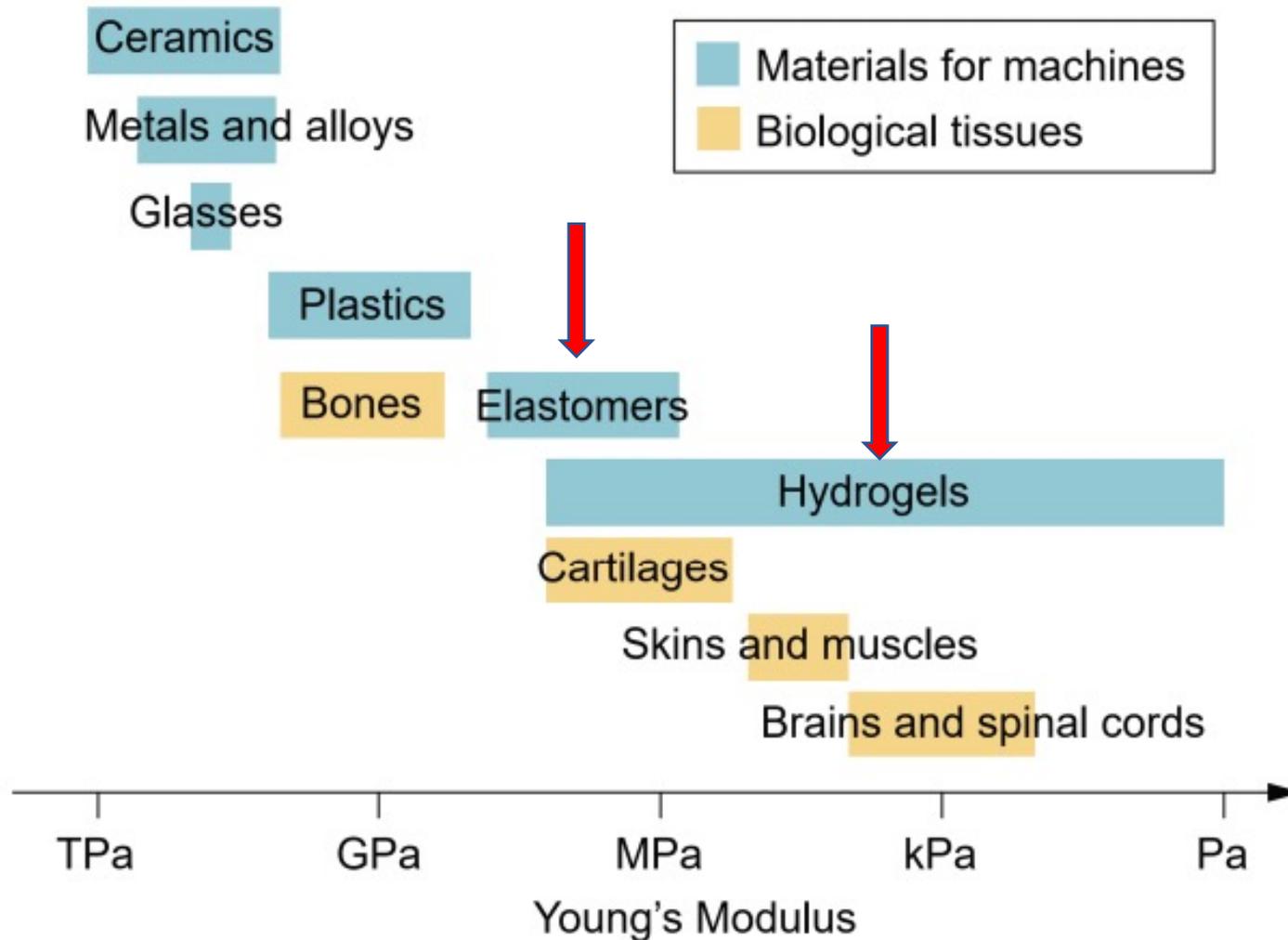
- Goal: Endow robots with new, **bioinspired features** that permit **morphologically adaptive interactions** with **unpredictable environments**.
- Soft robots:
 - systems that are compliant and flexible
 - Have a feedback sensory and control system



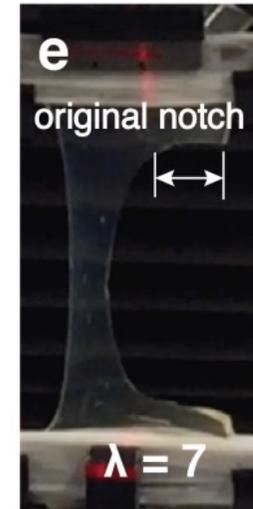
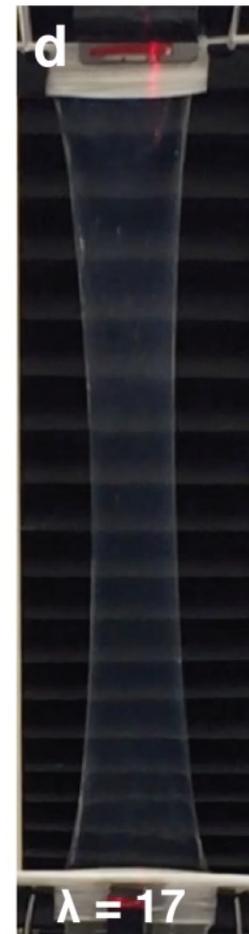
Mostly stiff
Few selectively compliant elements

Entirely soft

Young's moduli of biological tissues and common materials for machines

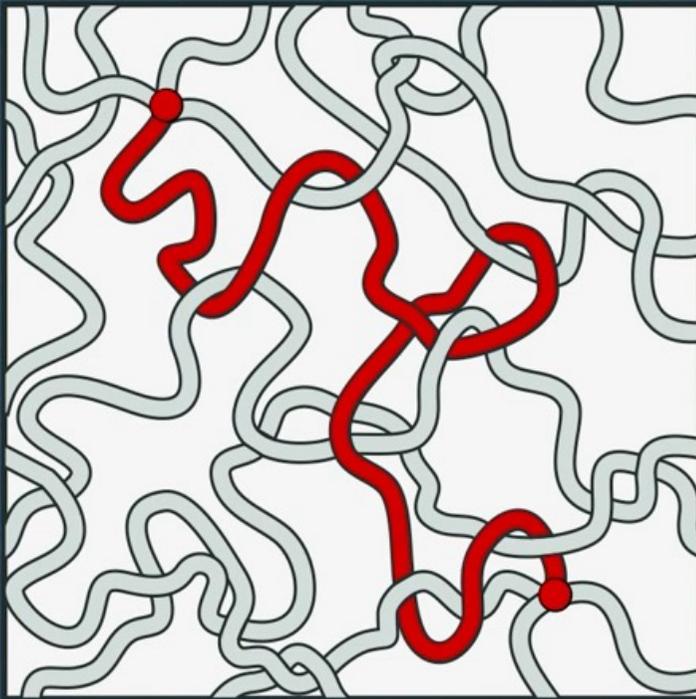


1. Hydrogels 水凝胶，一类极为亲水的三维网络结构凝胶

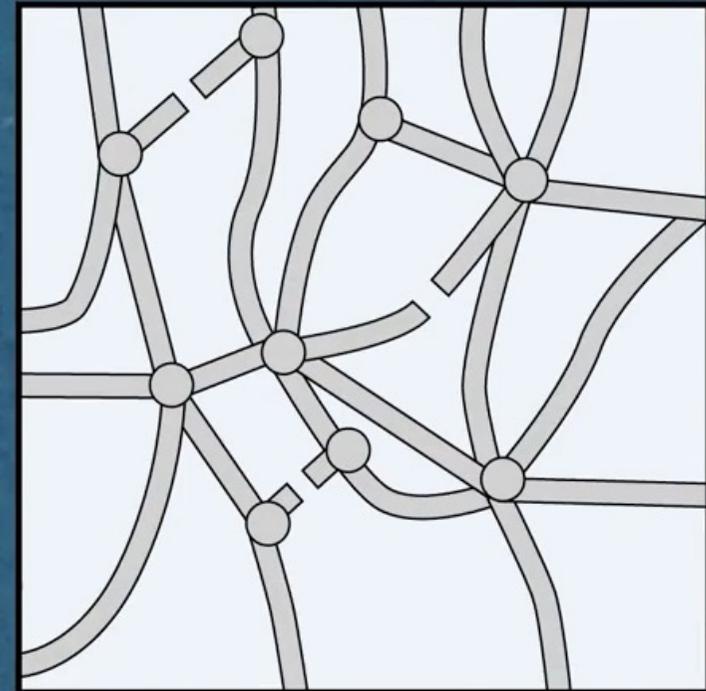


1. Hydrogels 水凝胶，一类极为亲水的三维网络结构凝胶

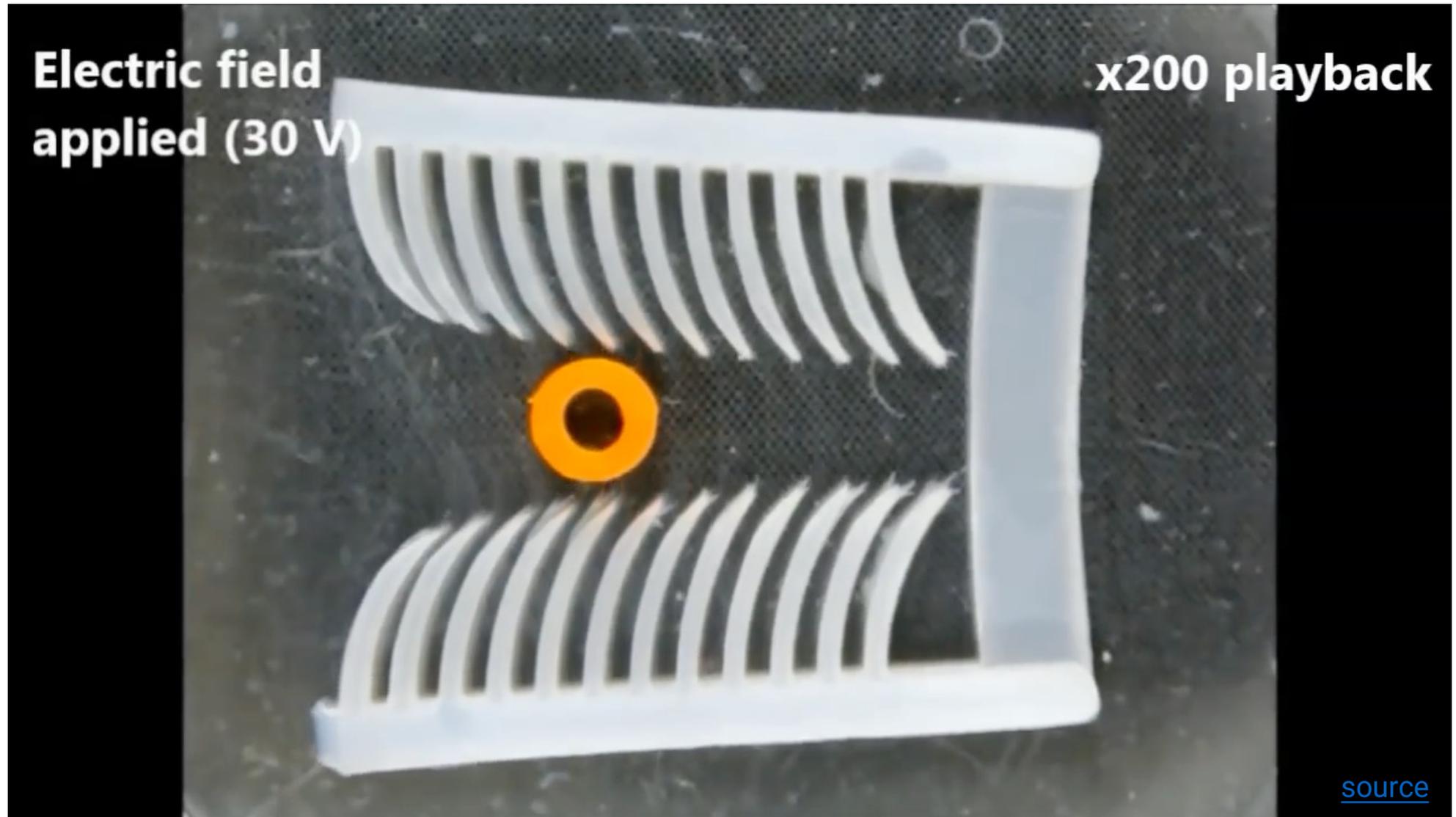
Entanglement-rich polymer



Crosslink-rich polymer

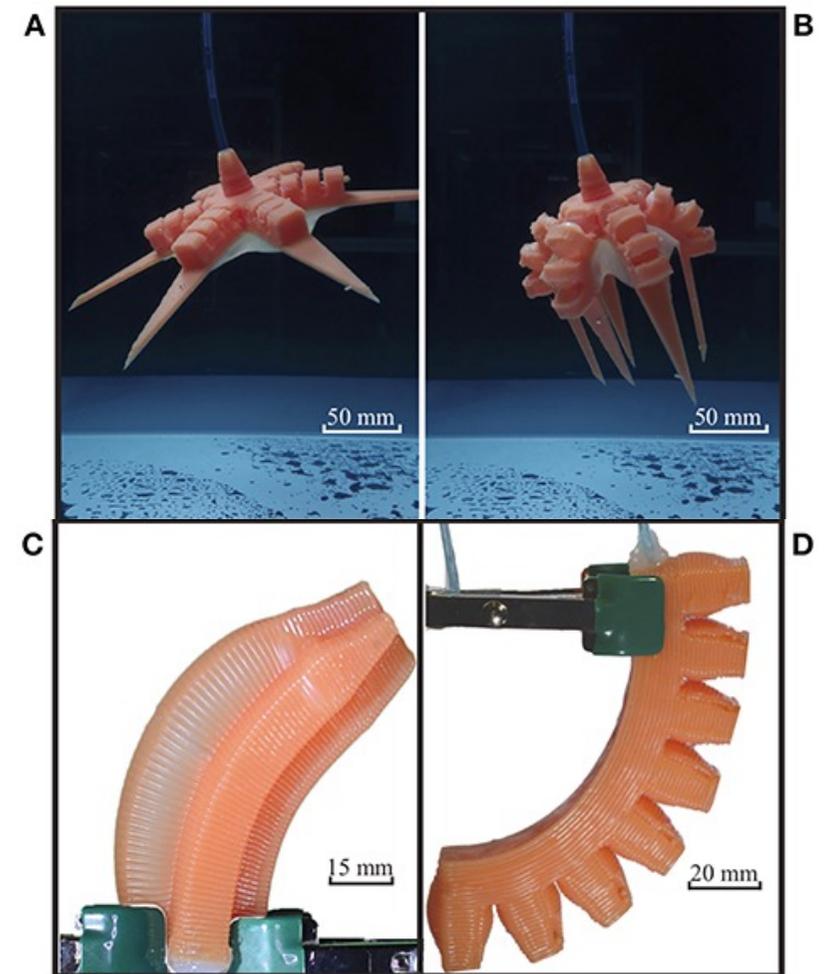


1. Hydrogels 水凝胶，一类极为亲水的三维网络结构凝胶



2. Silicone-based elastomers 硅基的弹性聚合物

- Silicone rubber 硅橡胶 (e.g. Ecoflex, patented material), high strain
- Polydimethylsiloxane (PDMS silicone) 聚二甲基硅氧烷, low strain



2. Silicone-based elastomers 硅基的弹性聚合物

- Silicone rubber 硅橡胶 (Ecoflex), high strain
- PDMS silicone 聚二甲基硅氧烷, low strain

a) ECOFLEX (+PAPER SHEET)

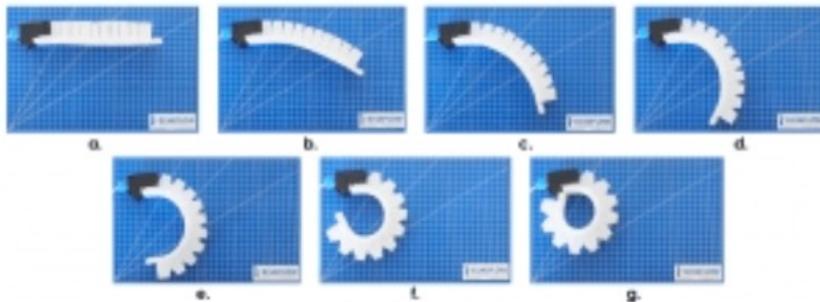


Figure 3: Deformation of the « finger » made of Ecoflex under different pressure: a. $p=0\text{mbar}$, b. $p=20\text{mbar}$, c. $p=40\text{mbar}$, d. $p=60\text{mbar}$, e. $p=80\text{mbar}$, f. $p=100\text{mbar}$, g. $p=120\text{mbar}$

b) PDMS + ECOFLEX (+PAPER SHEET)

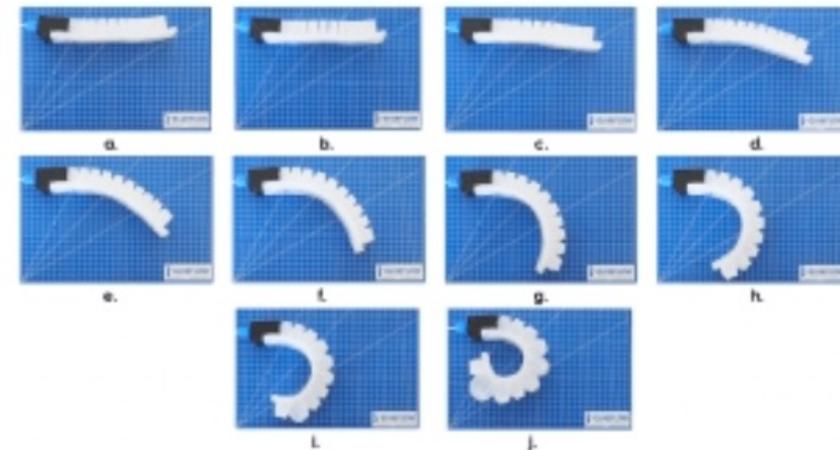


Figure 4: Deformation of the « finger » made of Ecoflex and PDMS under different pressure: a. $p=0\text{mbar}$, b. $p=20\text{mbar}$, c. $p=40\text{mbar}$, d. $p=60\text{mbar}$, e. $p=80\text{mbar}$, f. $p=100\text{mbar}$, g. $p=120\text{mbar}$, h. $p=140\text{mbar}$, i. $p=160\text{mbar}$, j. $p=180\text{mbar}$

3. Polyurethanes elastomers 聚氨酯弹性体 (PU)

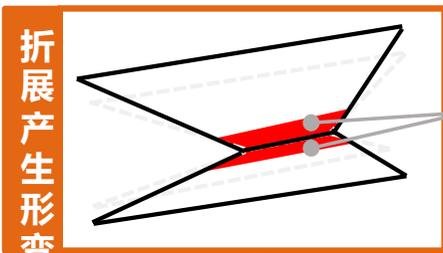
- TPU stands for Thermoplastic Polyurethane (热塑性聚氨酯) and is often referred to as the bridge between rubbers and plastics. The material appears **rubber-like**, which means it is very elastic, flexible, and smooth to the touch, but at the same time, it is extremely **durable and strong**.



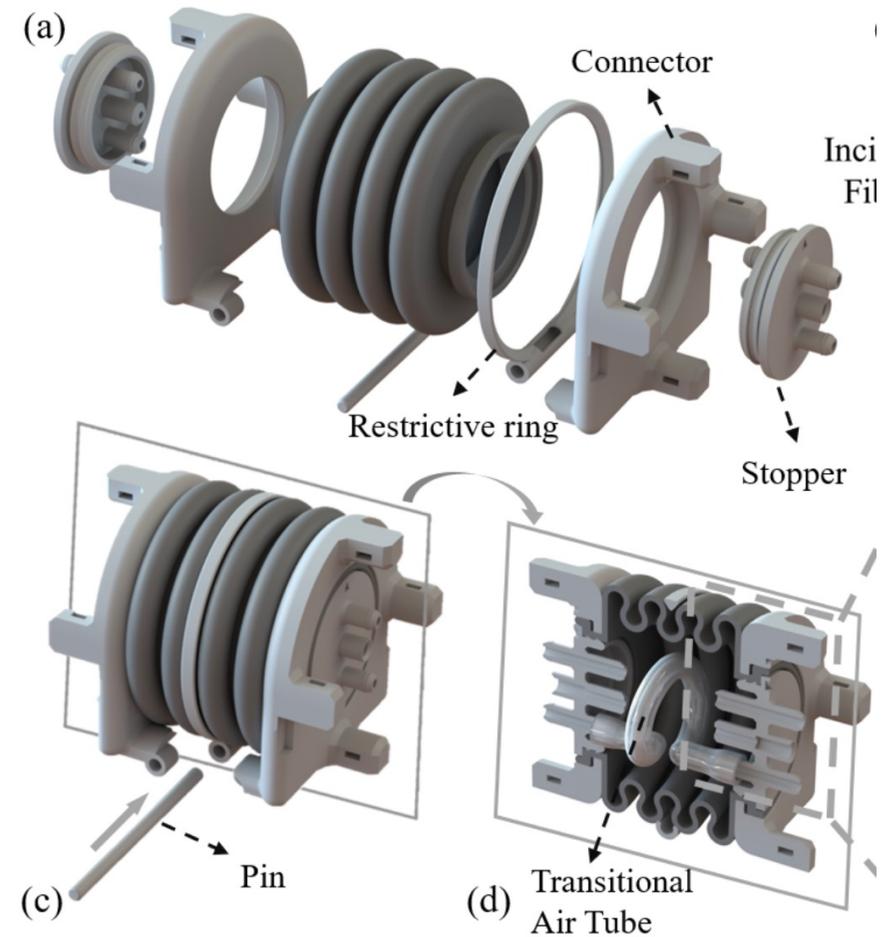
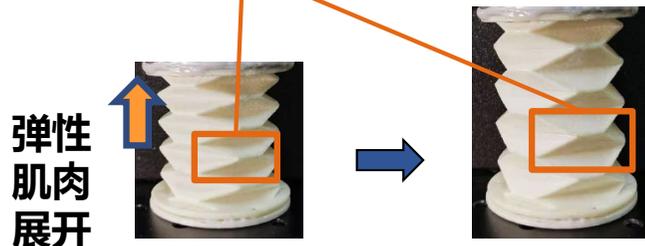
Meta material – soft structures

- Compliant 3D structures made from TPU (common for 3D printing).

Origami 折纸构型

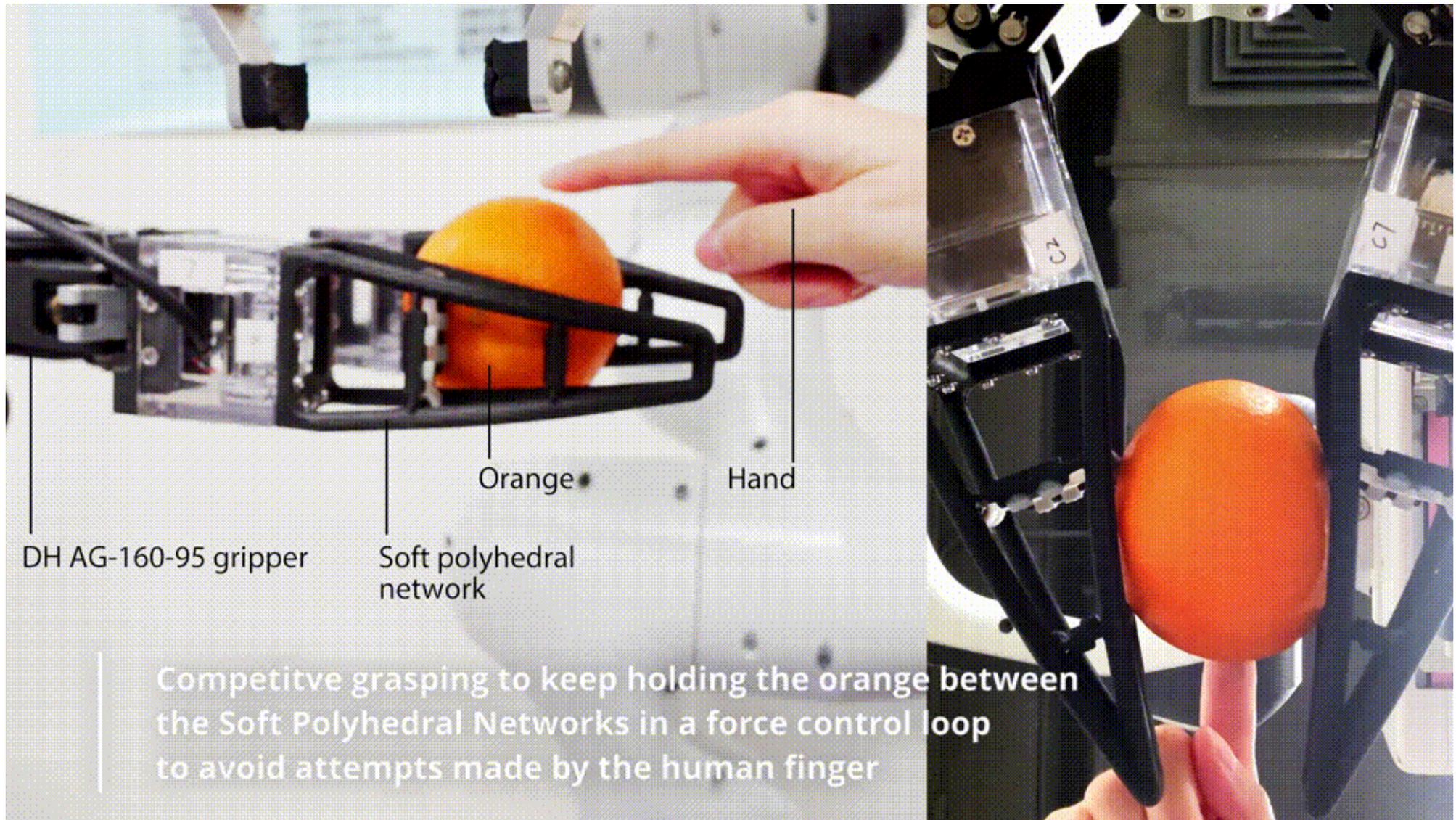


小应变弹性
折展变形



Meta material – soft structures

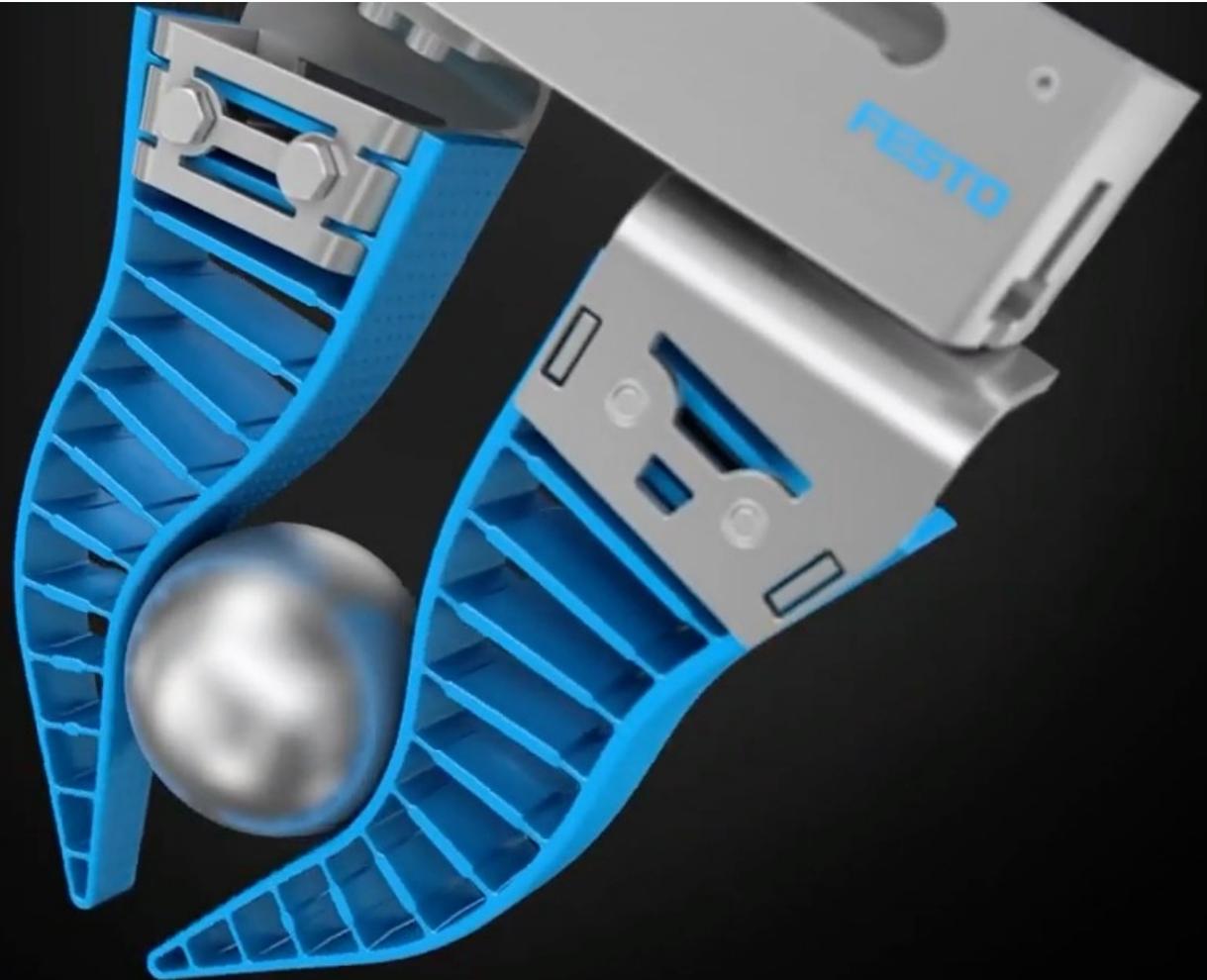
- Compliant 3D structures made from Hei-cast 8400 (三液型聚氨脂橡胶)



Meta material – soft structures

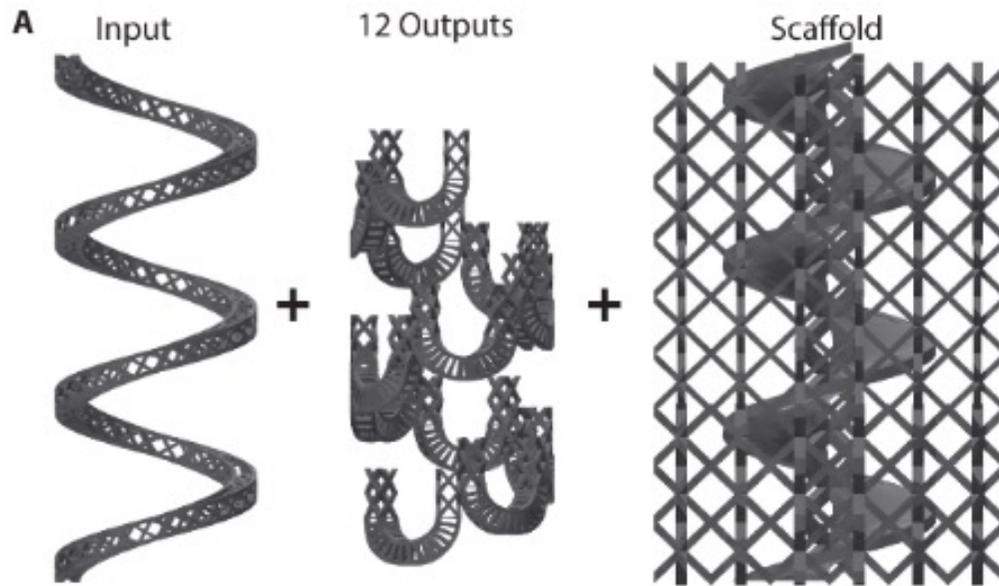
- Compliant 3D structures made from PU

Form-fitting and reliable
gripping of different shapes

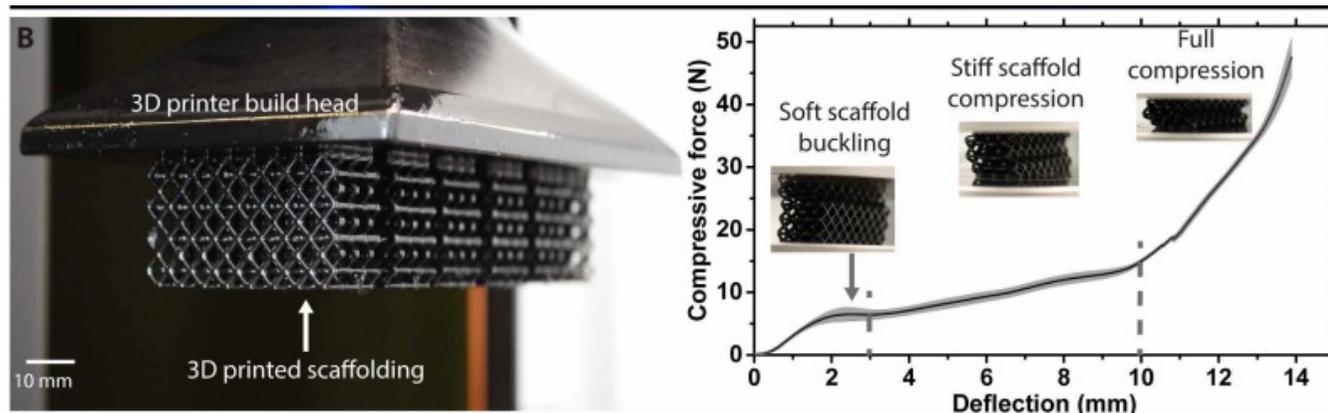


Meta material – soft structures

- Compliant 3D structures made from Elastic Polyurethane (EPU)



A urethane-based material that has been developed to compensate for the shortcomings of TPU, such as transmittance, smoothness, impact resistance, and lack of resilience.



Meta material – soft structures

- braided fabrics 纺织物:



Graduate School of Biomedical Engineering
UNSW Medical Robotics Lab

Smart Textiles

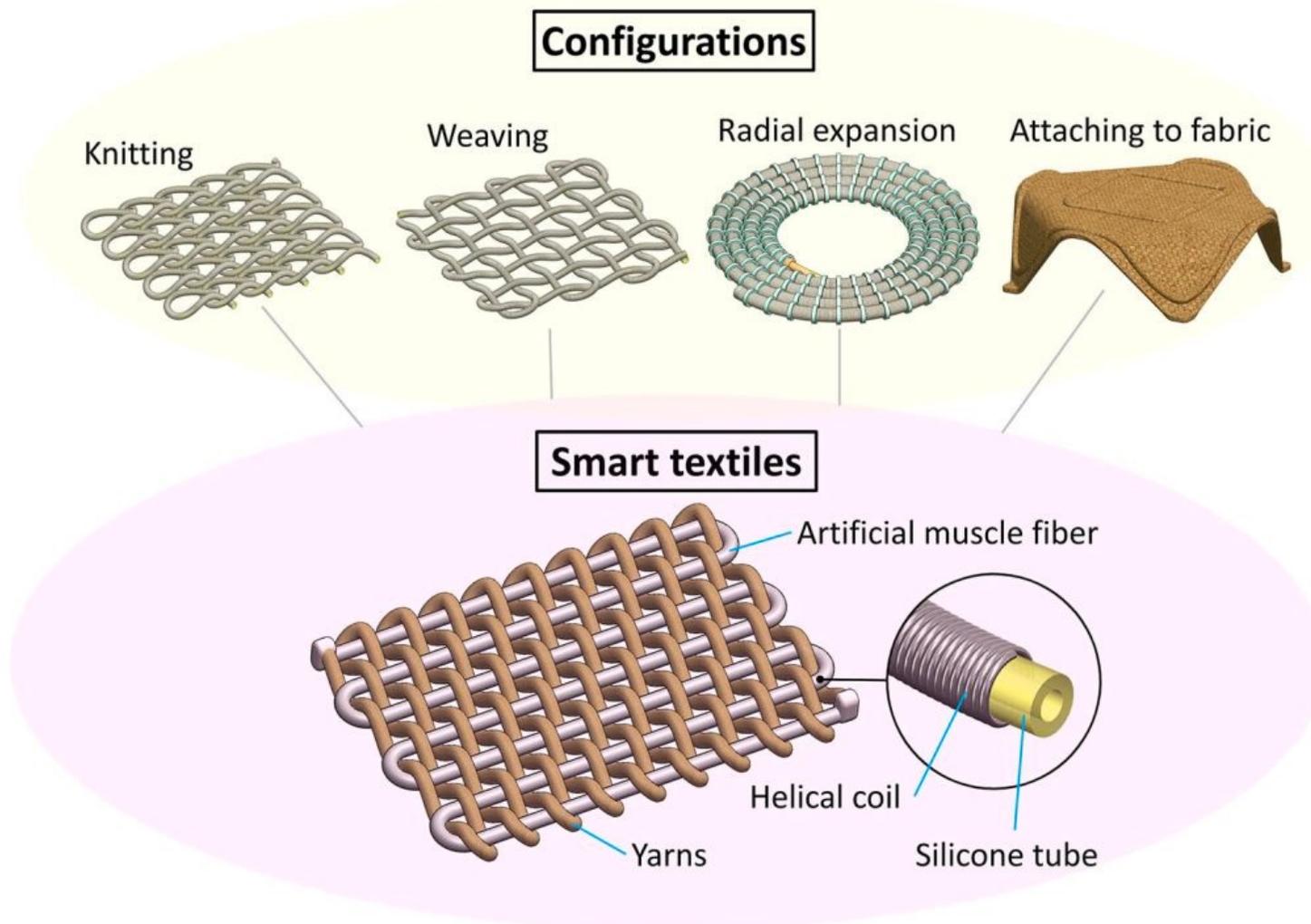
Using Fluid-Driven Artificial Muscle Fibers

<https://www.medicalrobotics-lab.com/>

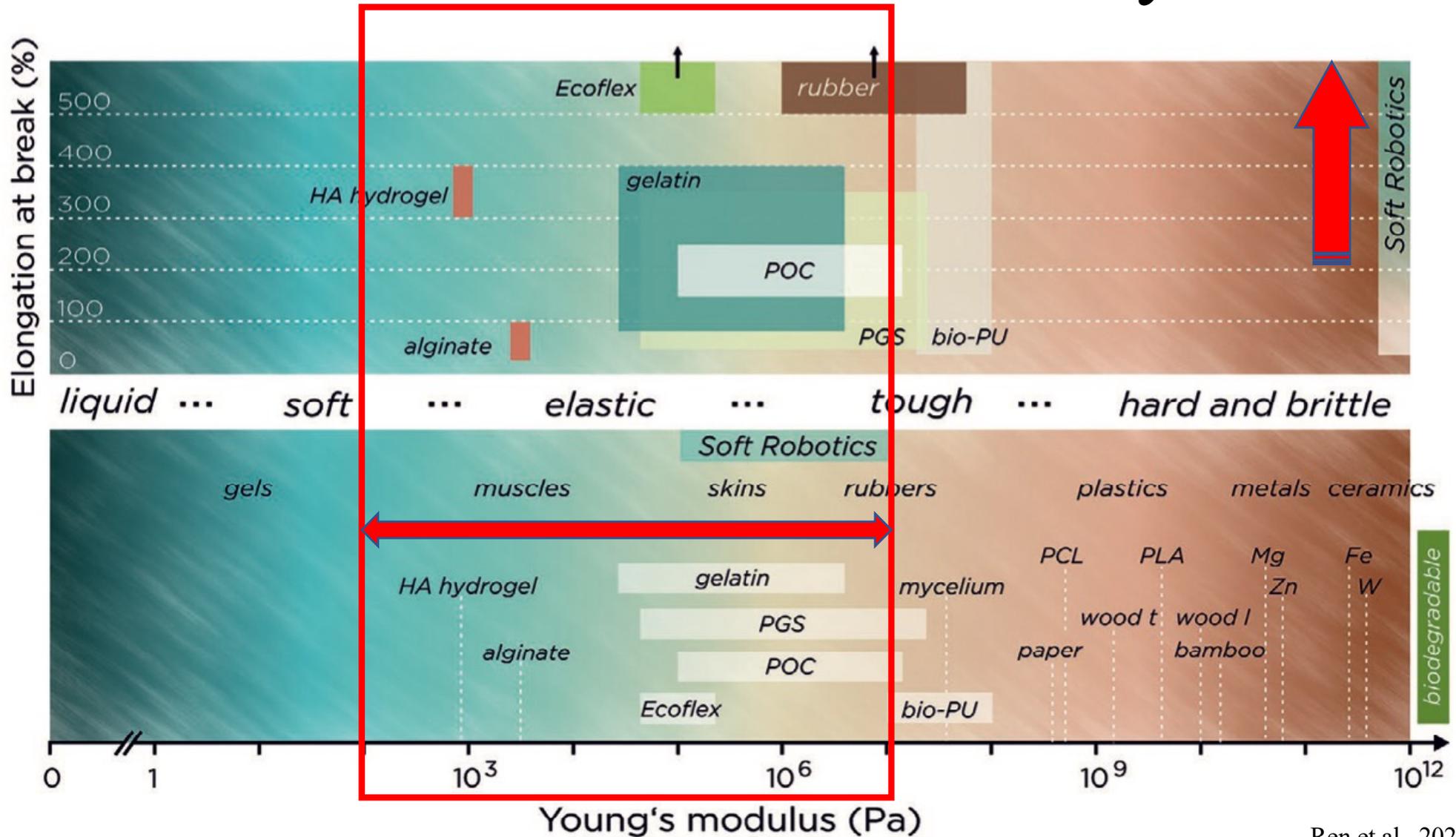


Meta material – soft structures

- braided fabrics: smart textiles combining textiles with artificial muscles



Material Selection Criteria 1: Softness and Stretchability



Material Selection Criteria 2: Reversibility

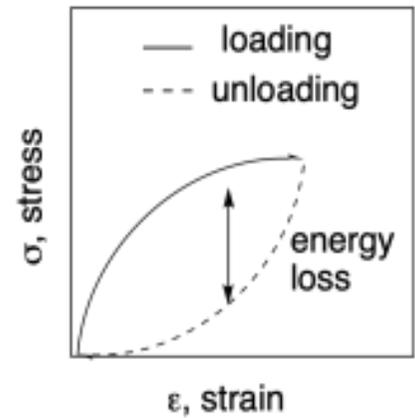
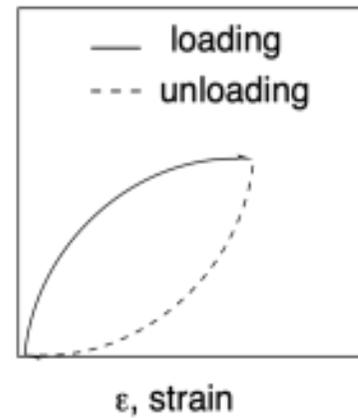
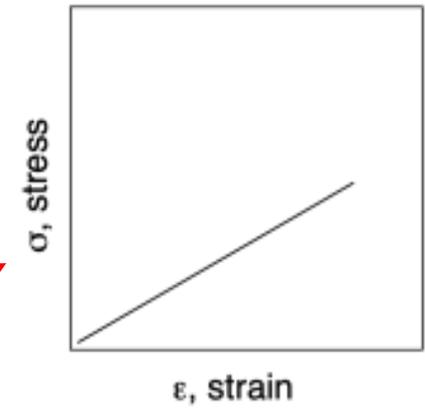
Viscoelasticity

Rheology

Science of deformation & flow of liquids & soft matter

Greater Viscosity

Greater Elasticity



Material Selection Criteria 2: Reversibility

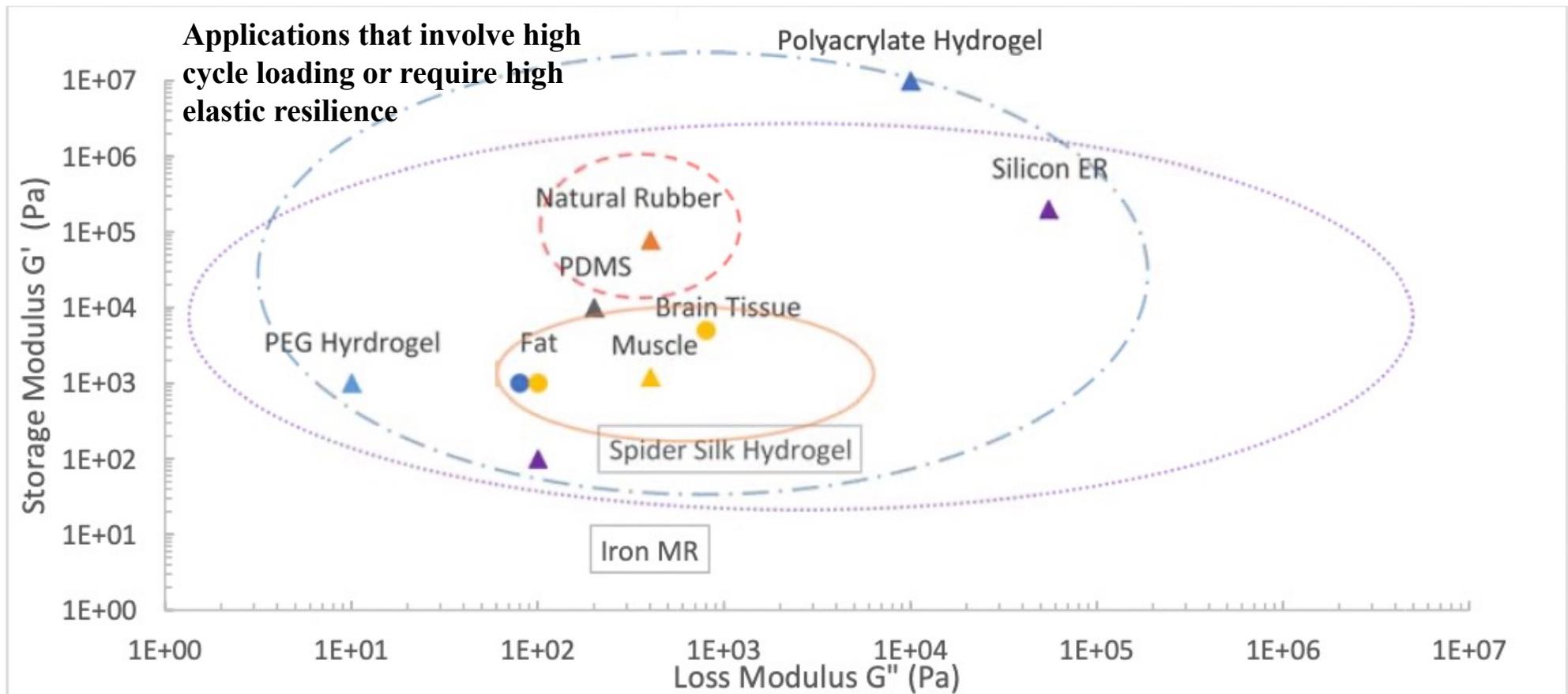
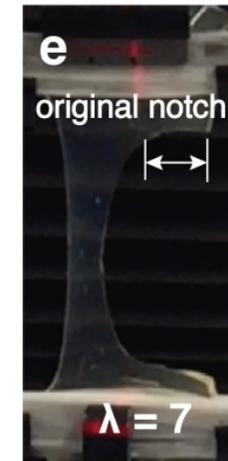
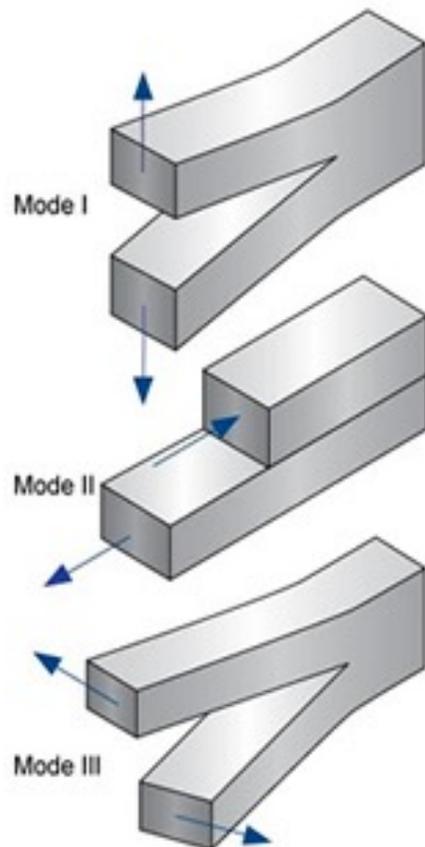


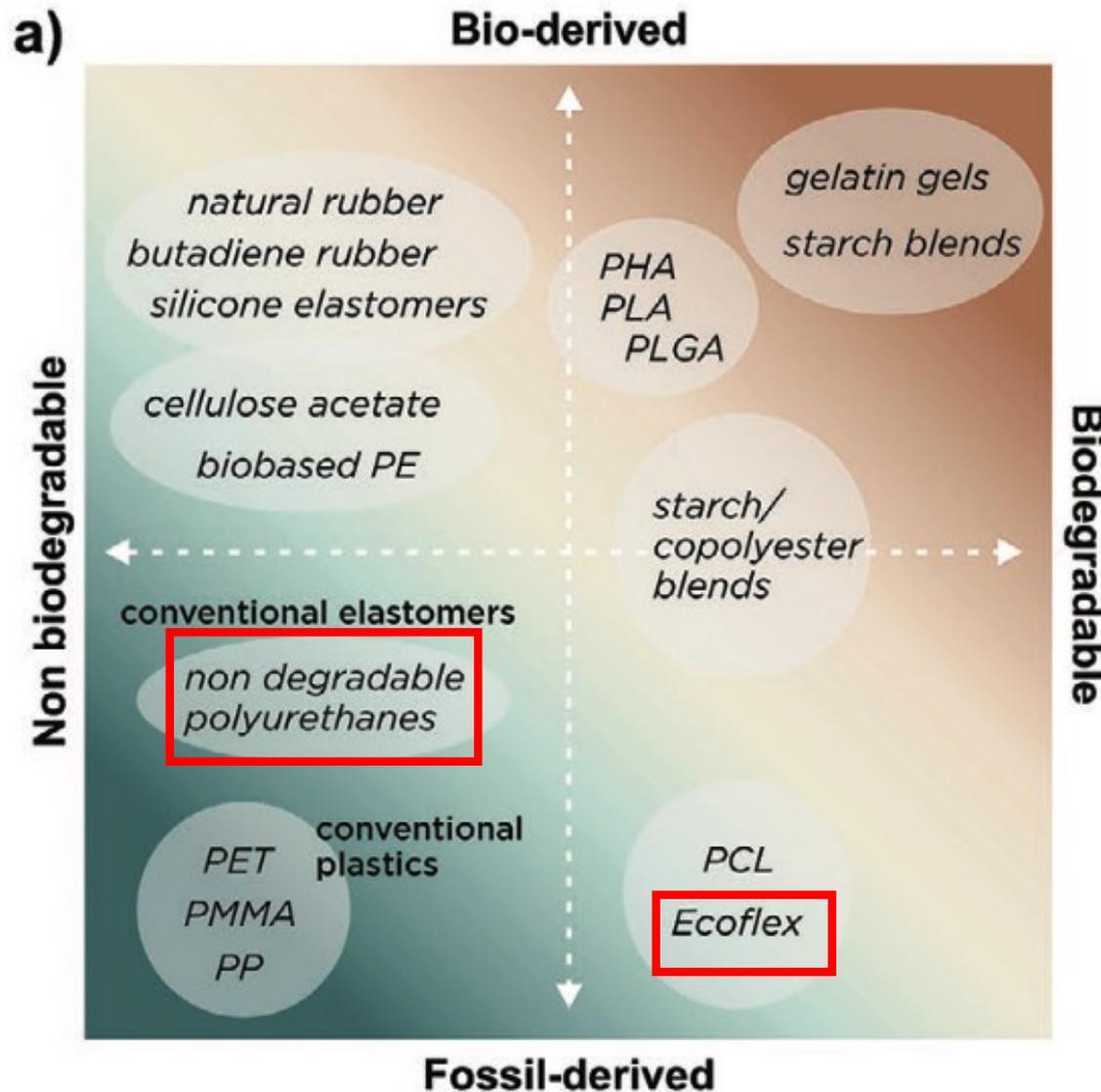
Fig.1. Approximation of Storage Modulus vs Loss Modulus of various organic and inorganic materials. Hydrogels: $-\cdot-\cdot-$; Biological Tissue: $---$; Natural Rubber: $-\cdot-\cdot-$; Electrorheological (ER) and Magnetorheological (MR) Fluid Based Polymers: \cdots ; Materials that have been used in soft robots: Triangle; Hard Materials: Diamond

Material Selection Criteria 3: Fracture toughness

- The critical stress intensity factor of a sharp crack where propagation of the crack suddenly becomes rapid and unlimited.



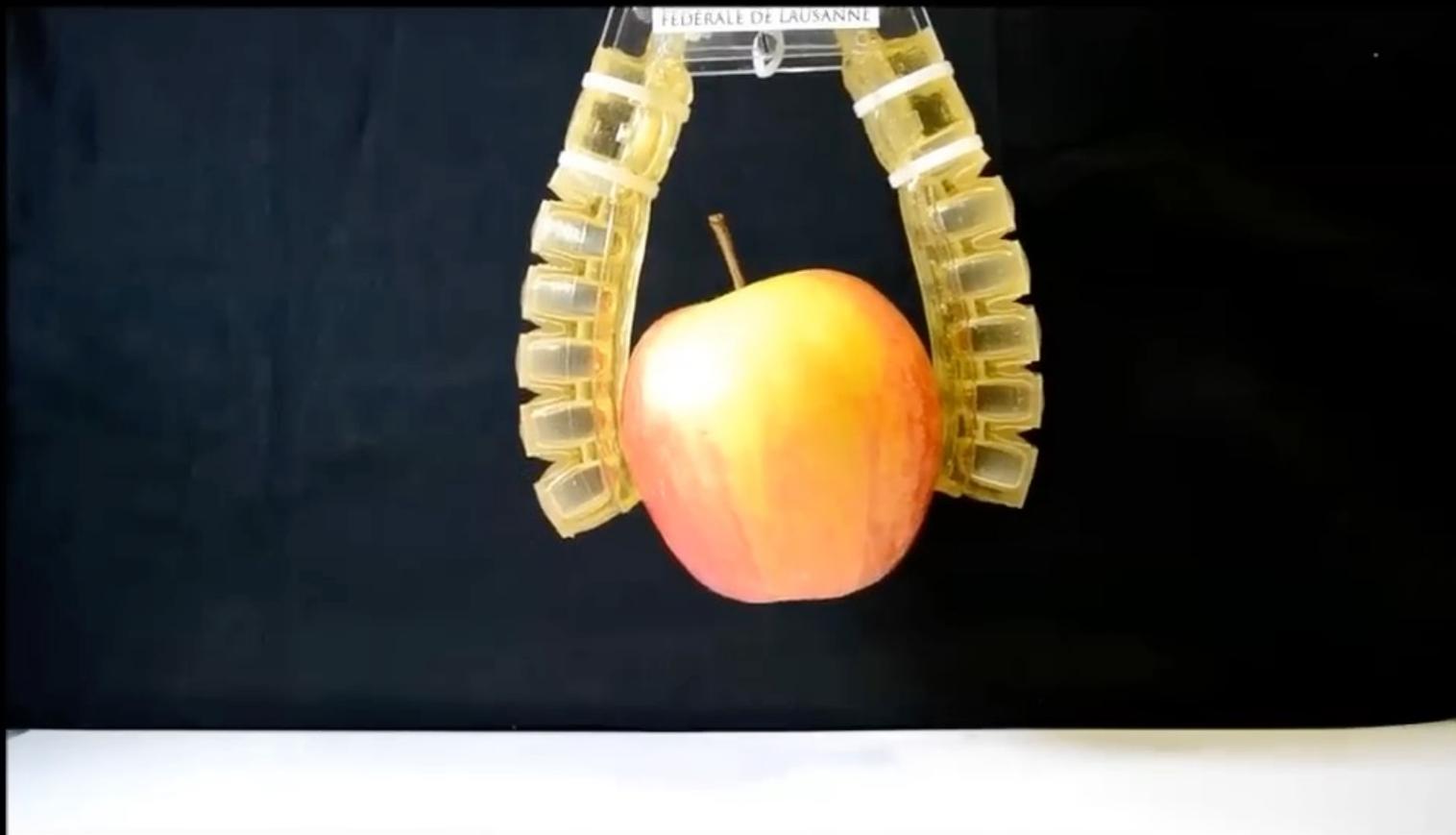
Becoming Sustainable



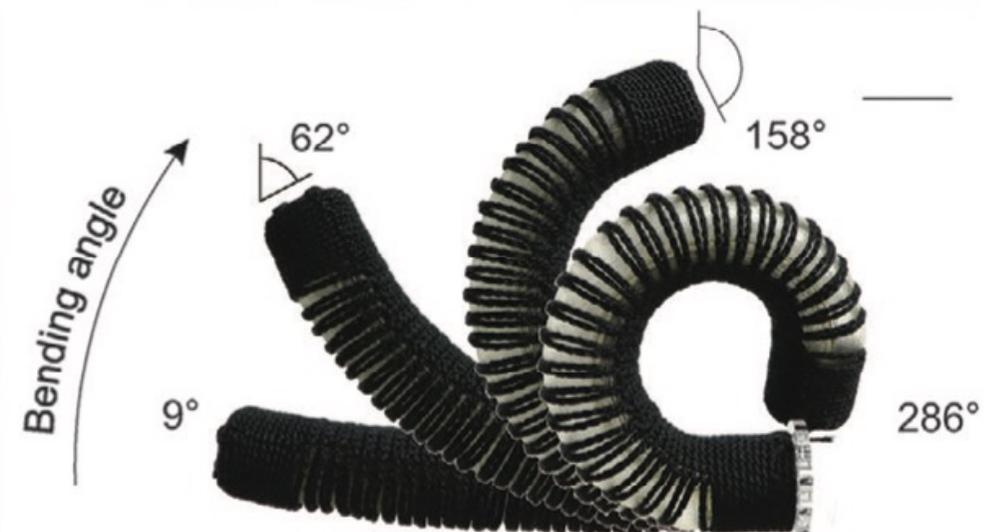
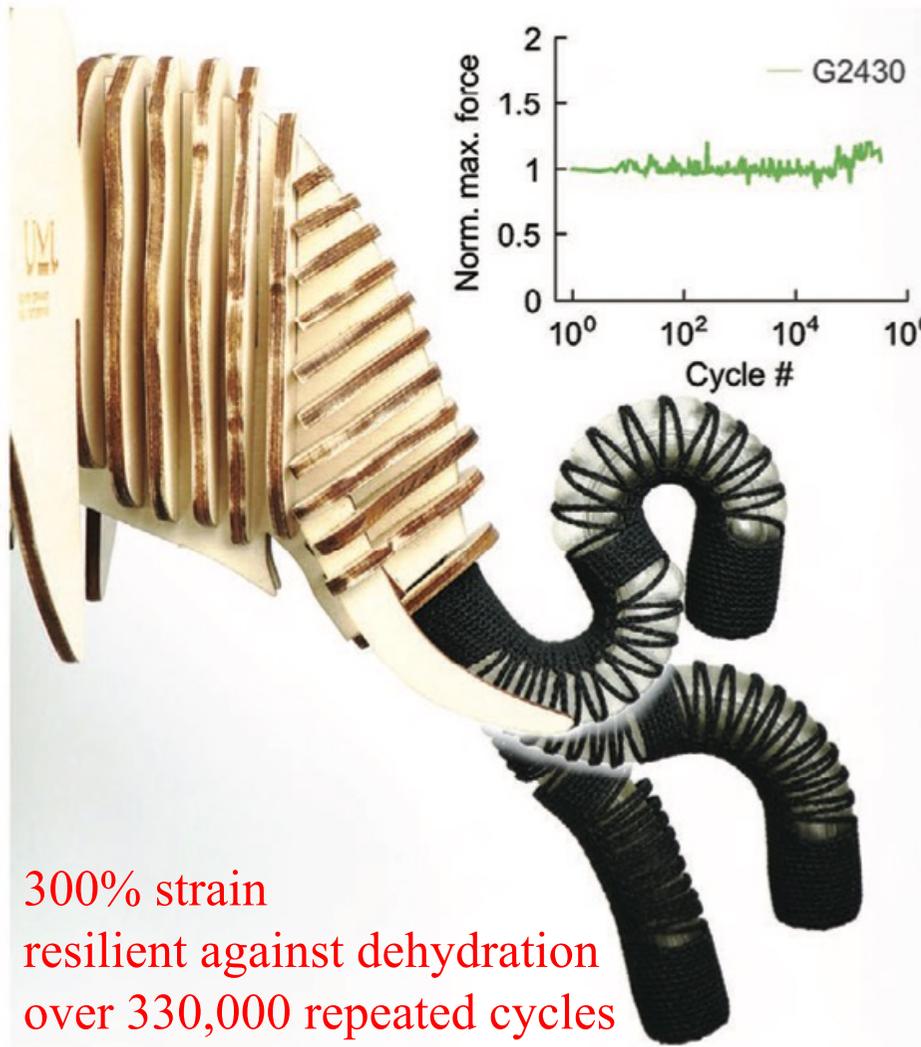
Ecoflex:

- Fossil-derived 化石基
- Biodegradable through industrial compost 可工业降解

Edible Robotics from Gelatin



Edible Robotics from Gelatin





DES 5002: Designing Robots for Social Good

Thank you~

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