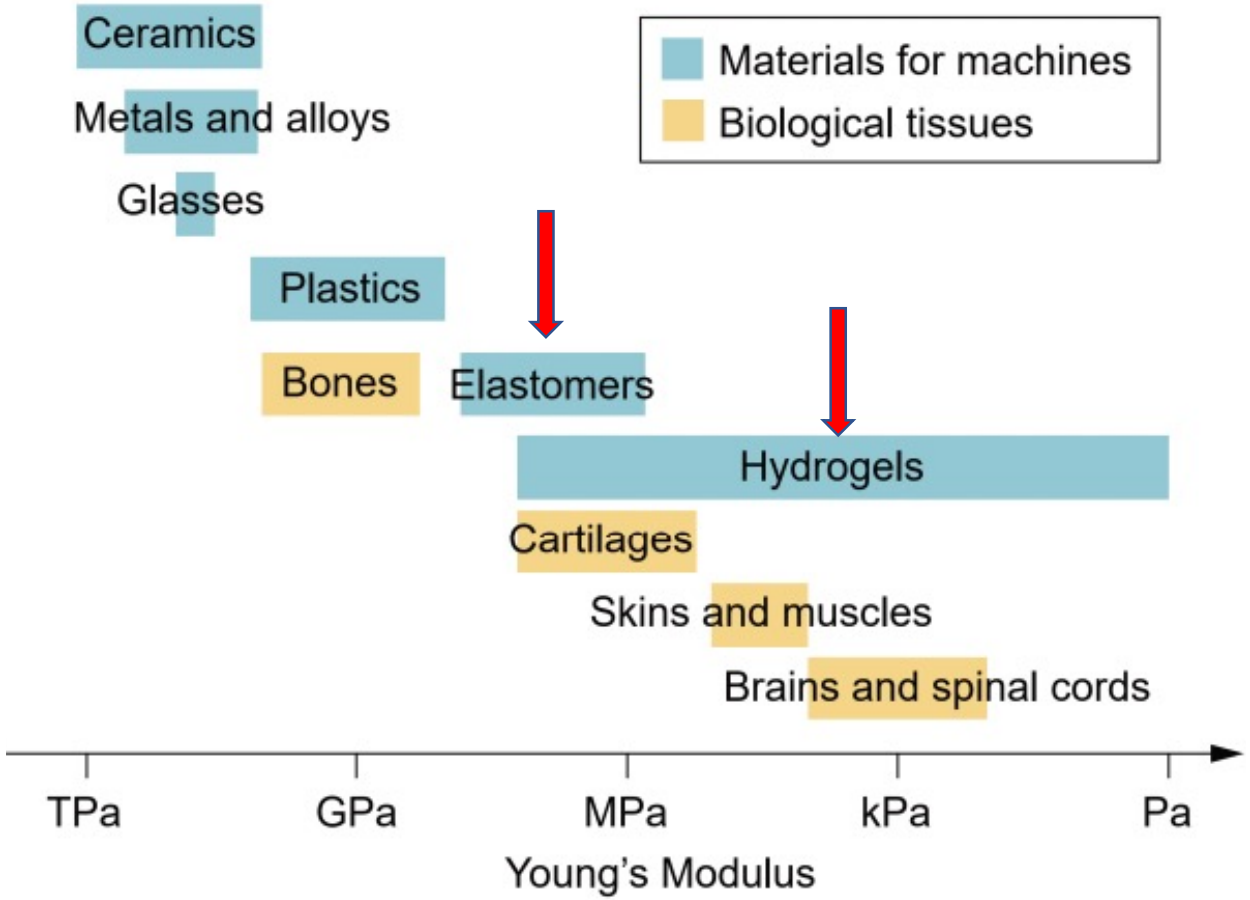
Week 06 | Lecture 05
Soft robotics II

Wan Fang

Southern University of Science and Technology

Introduction to Soft Robotics

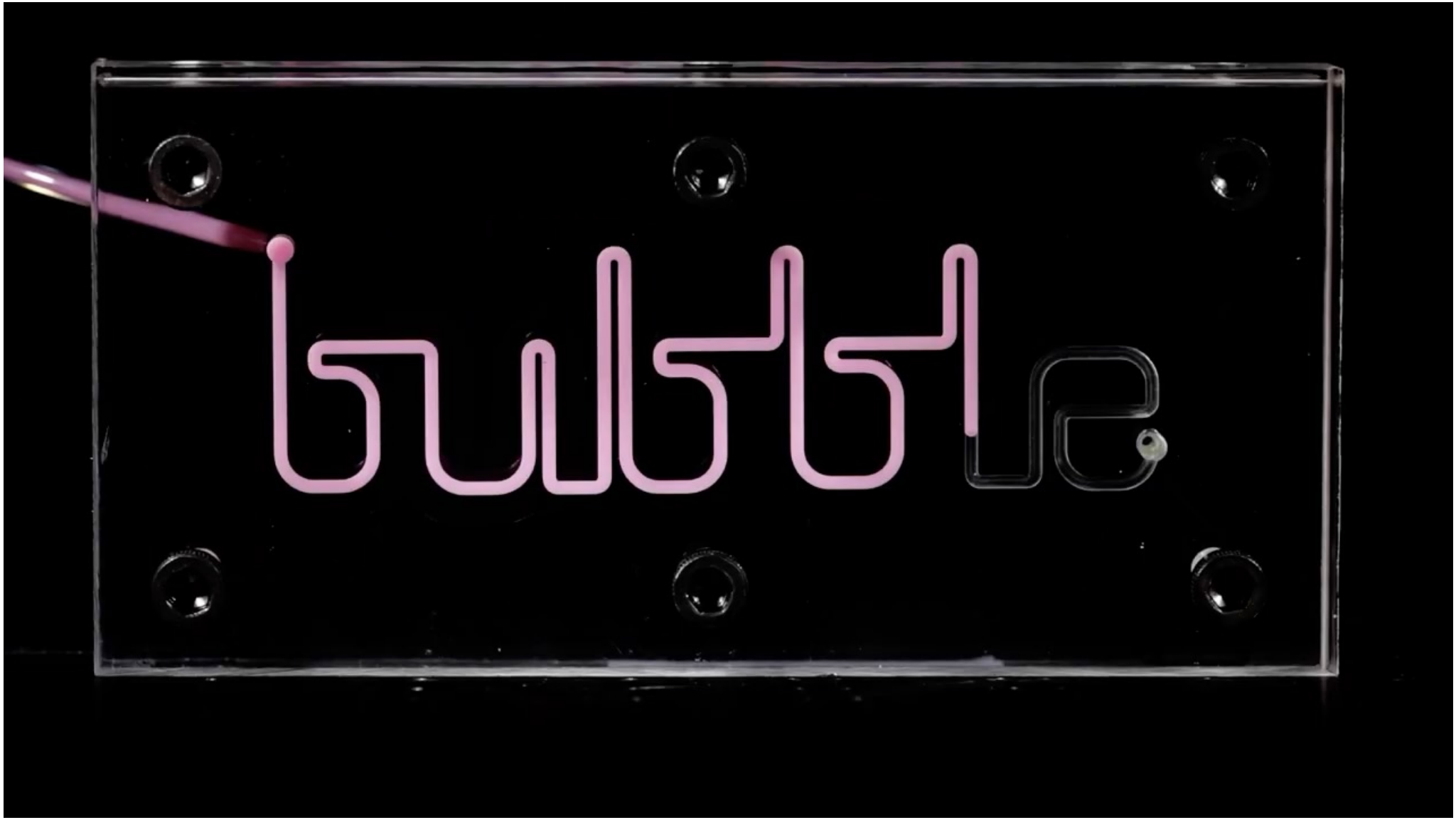
- Soft robotics
  - Material Selection
  - Actuation
  - Sensation



Soft Actuation

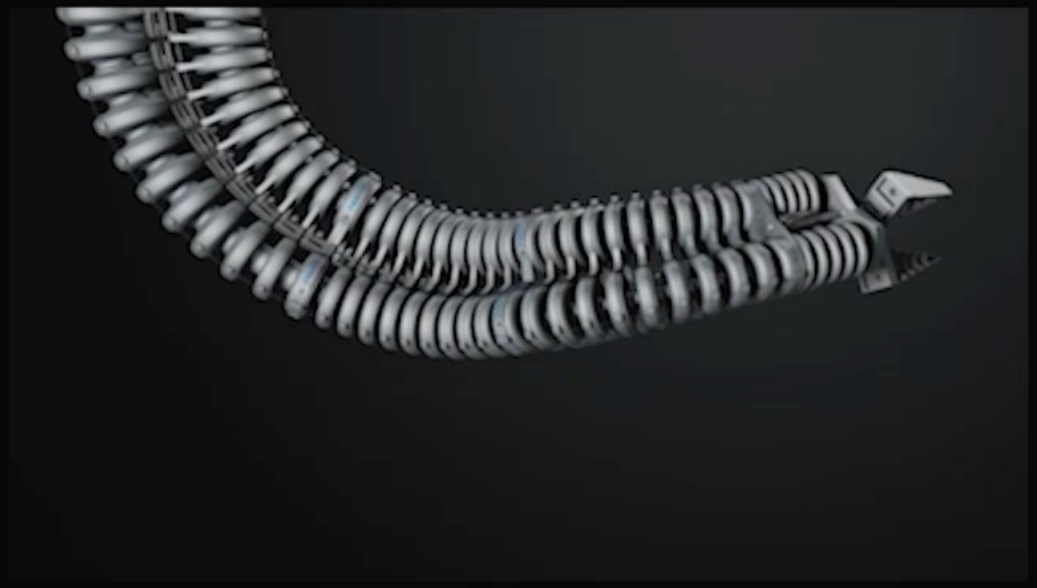
- Soft actuators
  - systems that are compliant and flexible
  - Can used for shape changes, joining and locomotion
- Stimuli for soft actuators
  - Fluidic
  - Electrical
  - Themal
  - Chemical
  - Magnetic

Fluidic

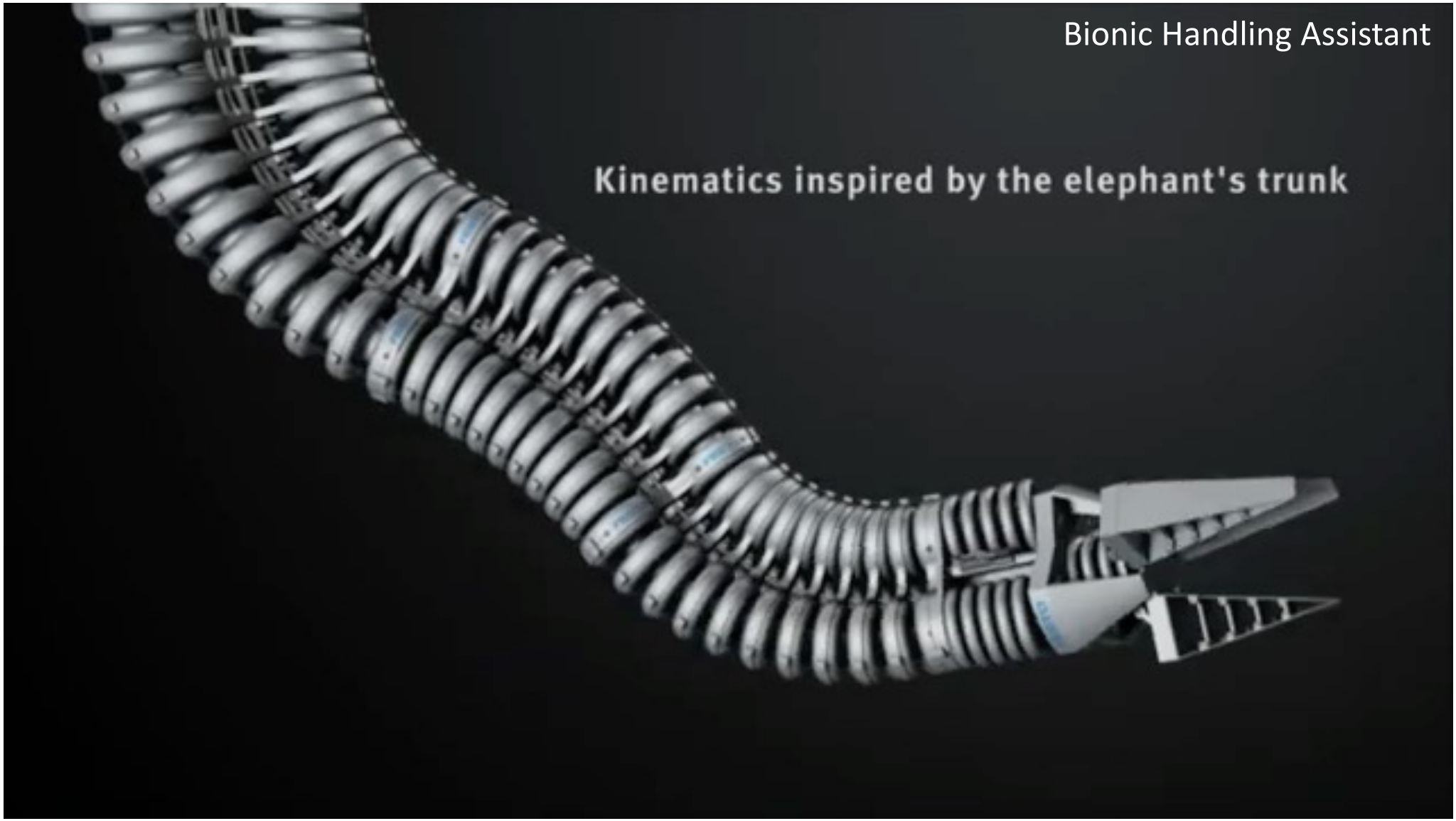


Fluidic – Festo

Bionic Handling Assistant

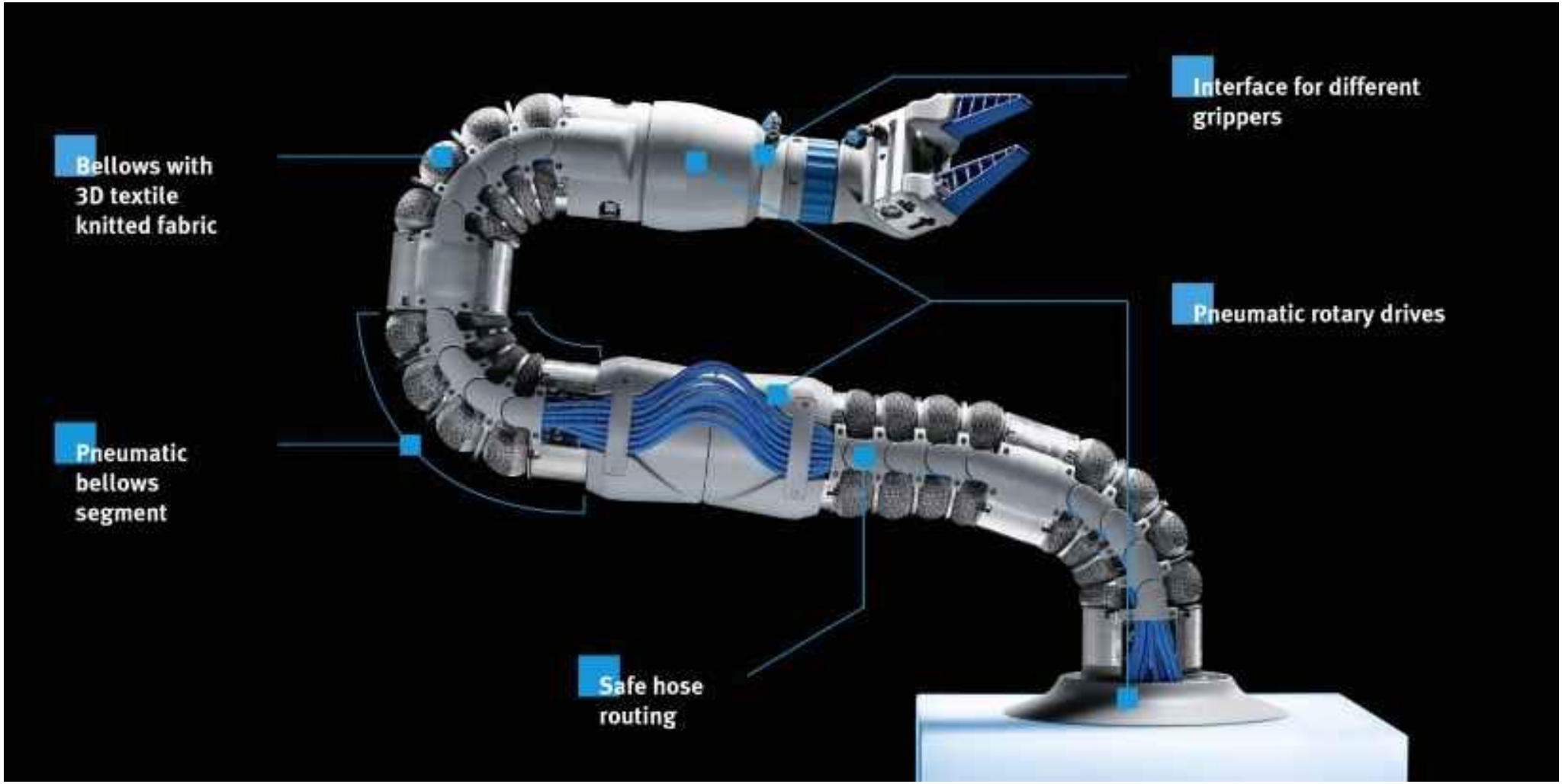


Fluidic – Festo

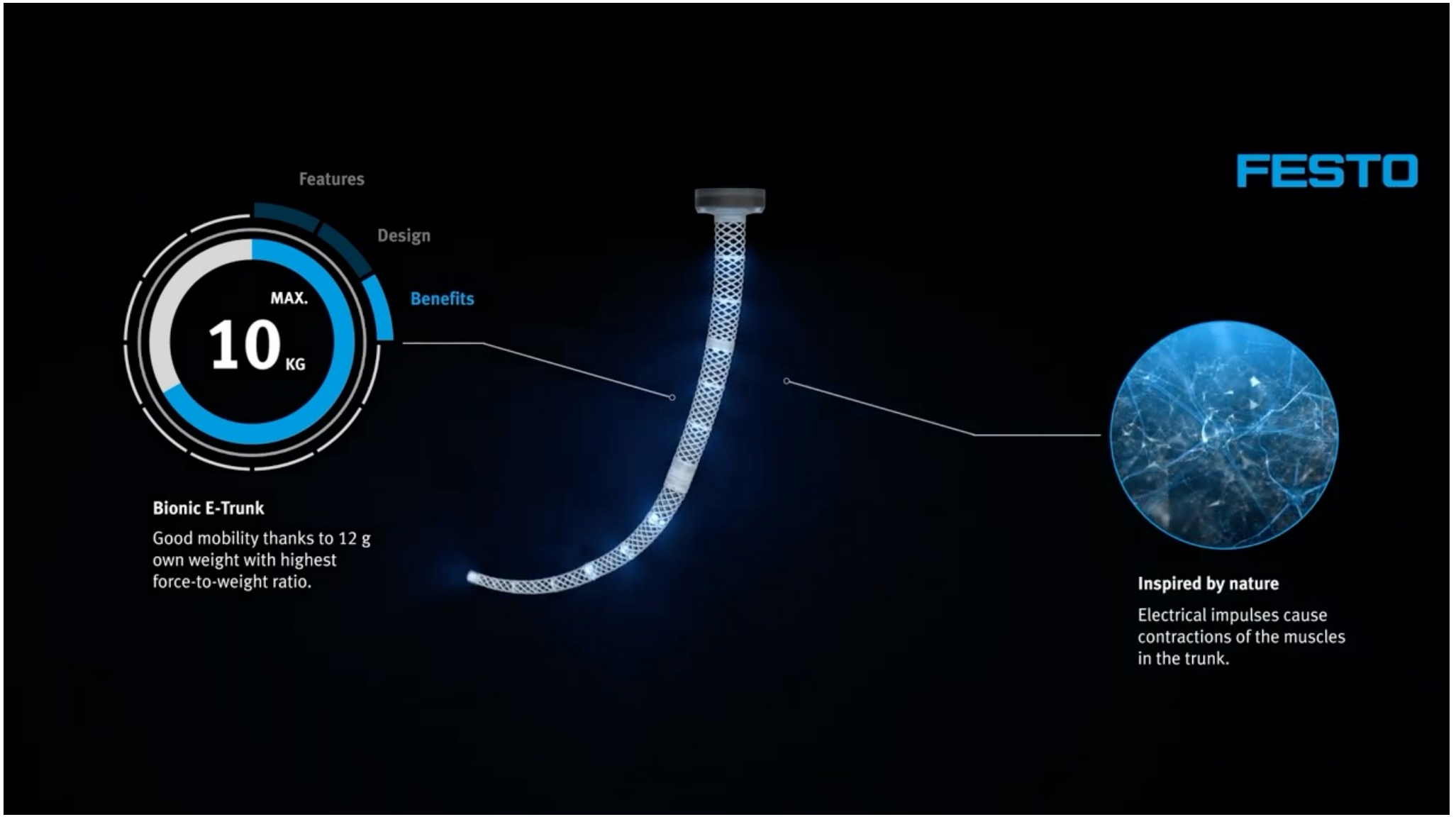


Fluidic – Festo

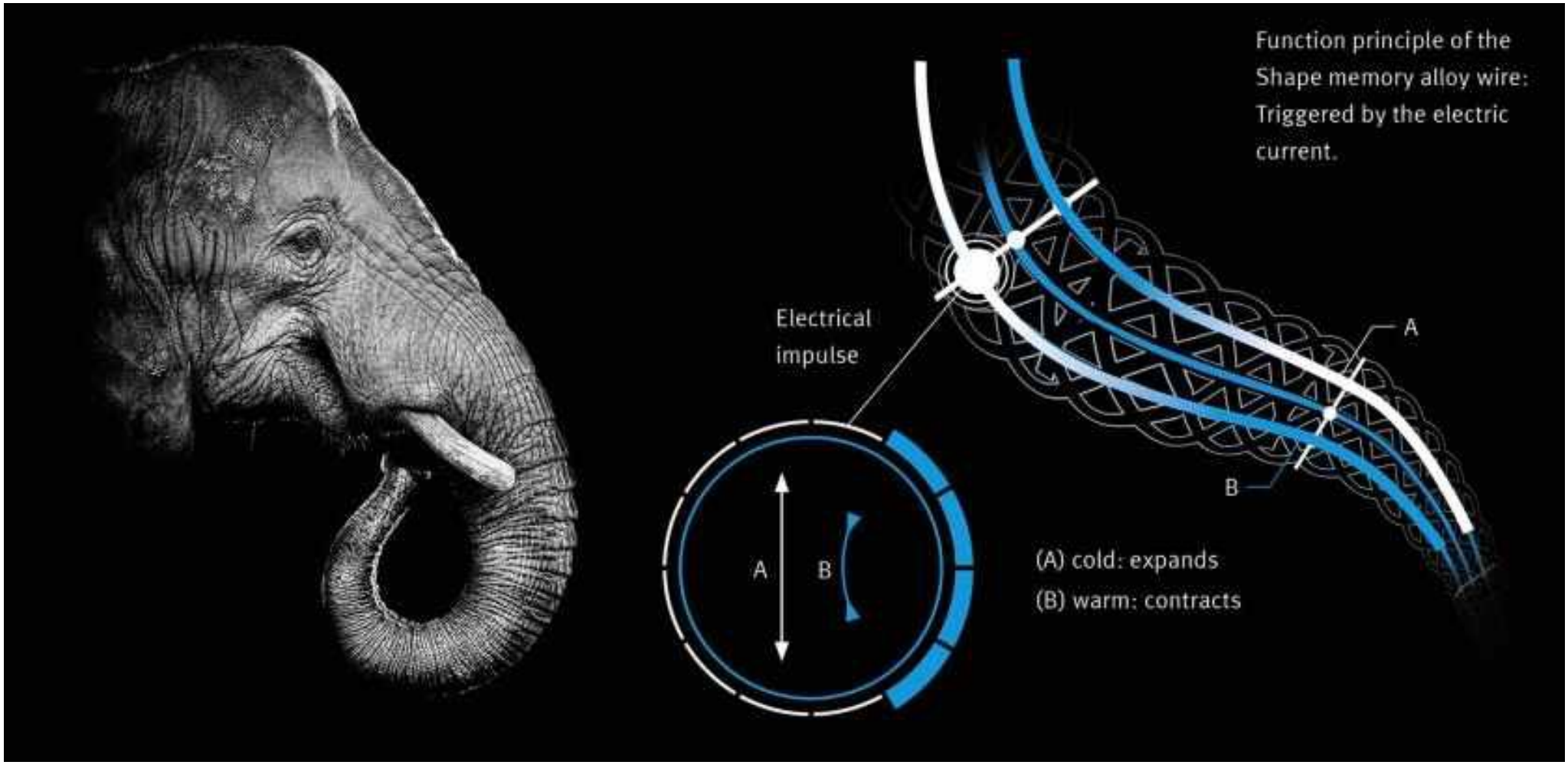
BionicSoftArm from Festo with seven pneumatic actuators



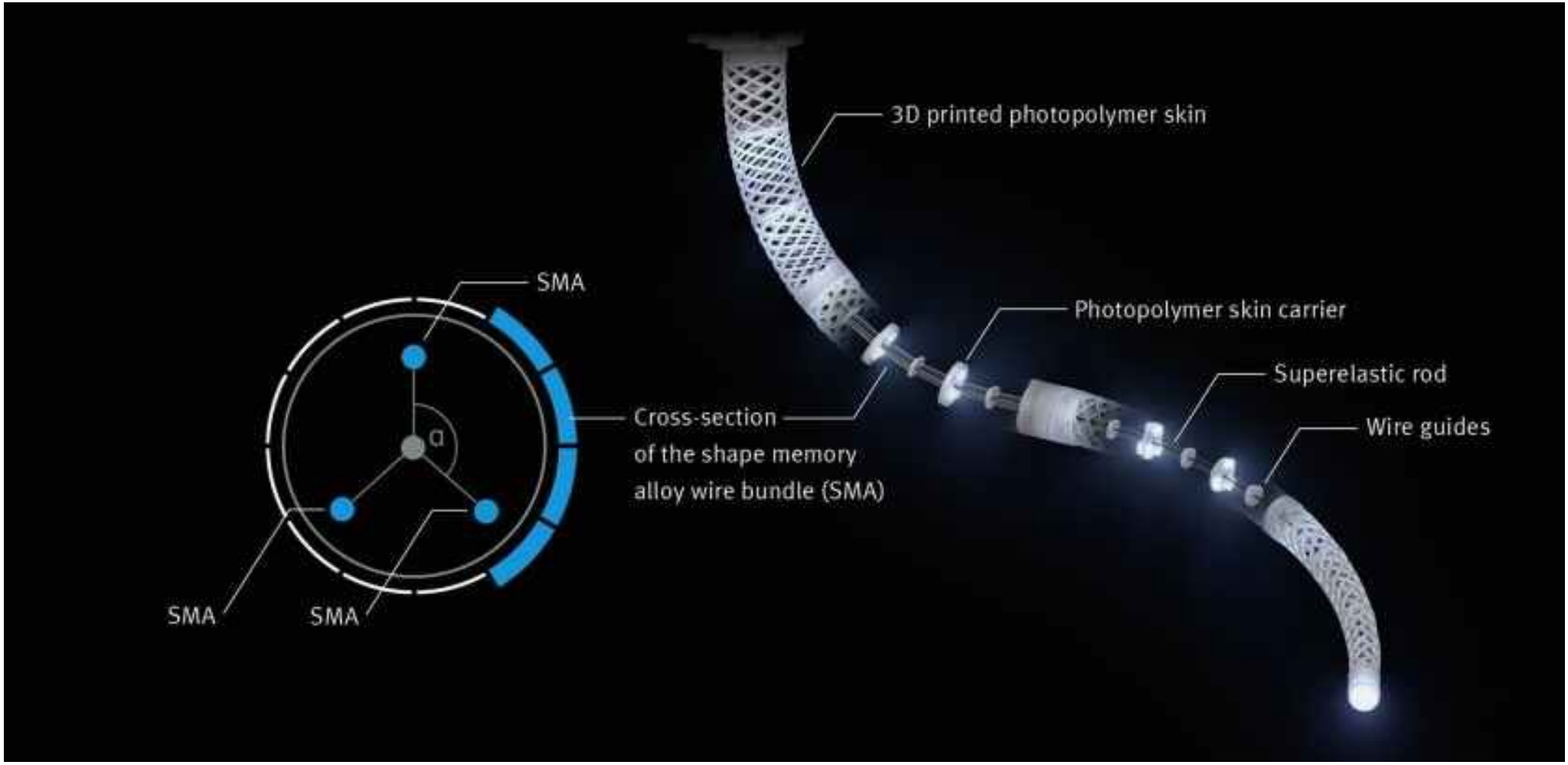
Electrical – Festo



Electrical

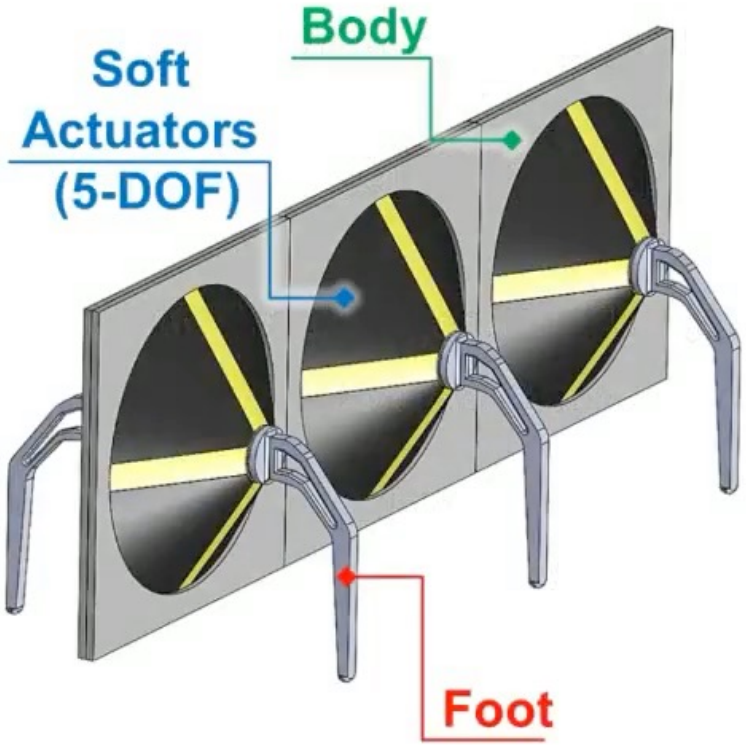

Function principle of the Shape memory alloy wire: Triggered by the electric current.
Electrical impulse
A
B
A
B
(A) cold: expands
(B) warm: contracts

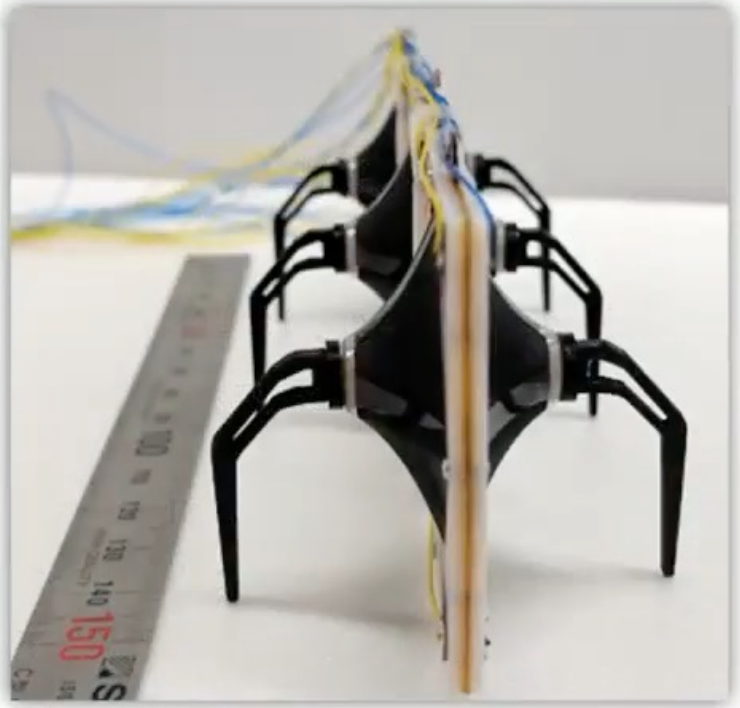
Electrical


3D printed photopolymer skin
SMA
Photopolymer skin carrier
Superelastic rod
Cross-section
of the shape memory
alloy wire bundle (SMA)
Wire guides
α
SMA
SMA

Electrical

2nd Sungkyunkwan hexapod robot (S-Hex II)





- Weight: 20 g
- 150 mm x 54 mm x 55 mm (L × W × H)

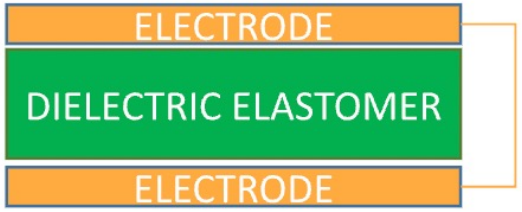
Overall design, mechanical components and prototype of the S-Hex II robot

Nguyen et al., 2017

Electrical

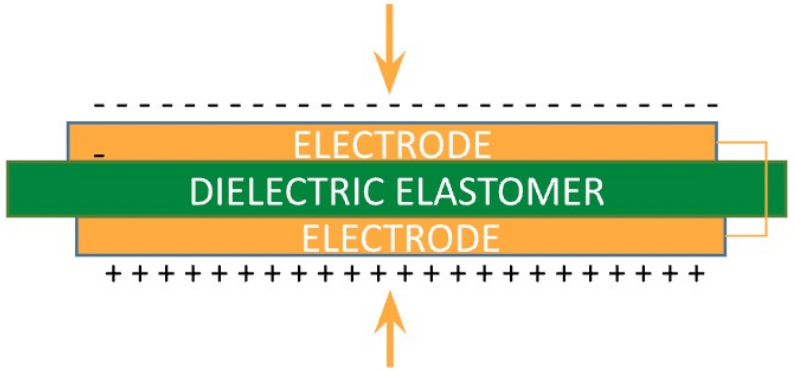
Dielectric elastomers actuators (DEA，介电弹性体执行器)

Voltage off



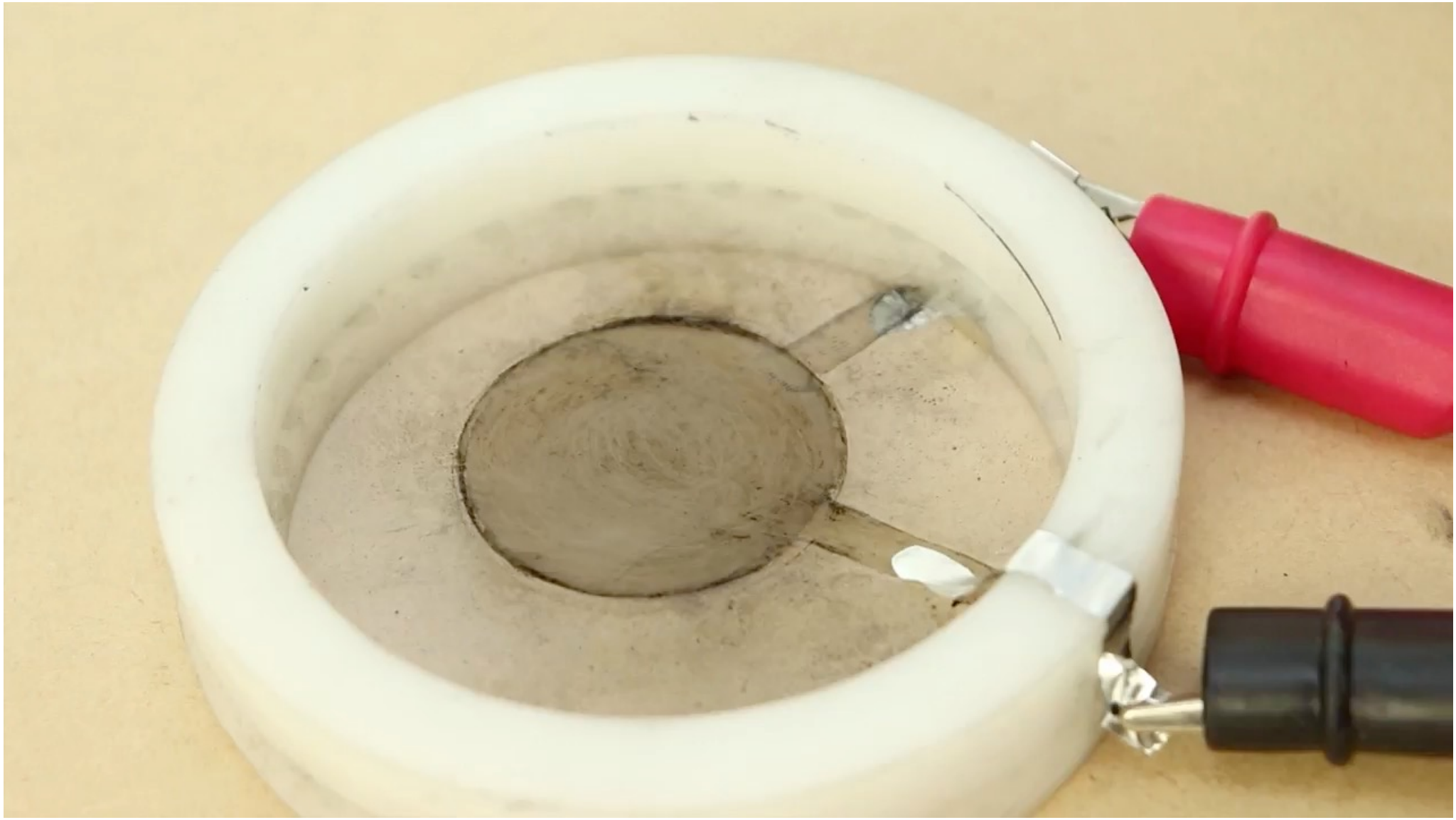
$$P = e_r e_o \left(\frac{V}{y}\right)^2$$

Voltage on

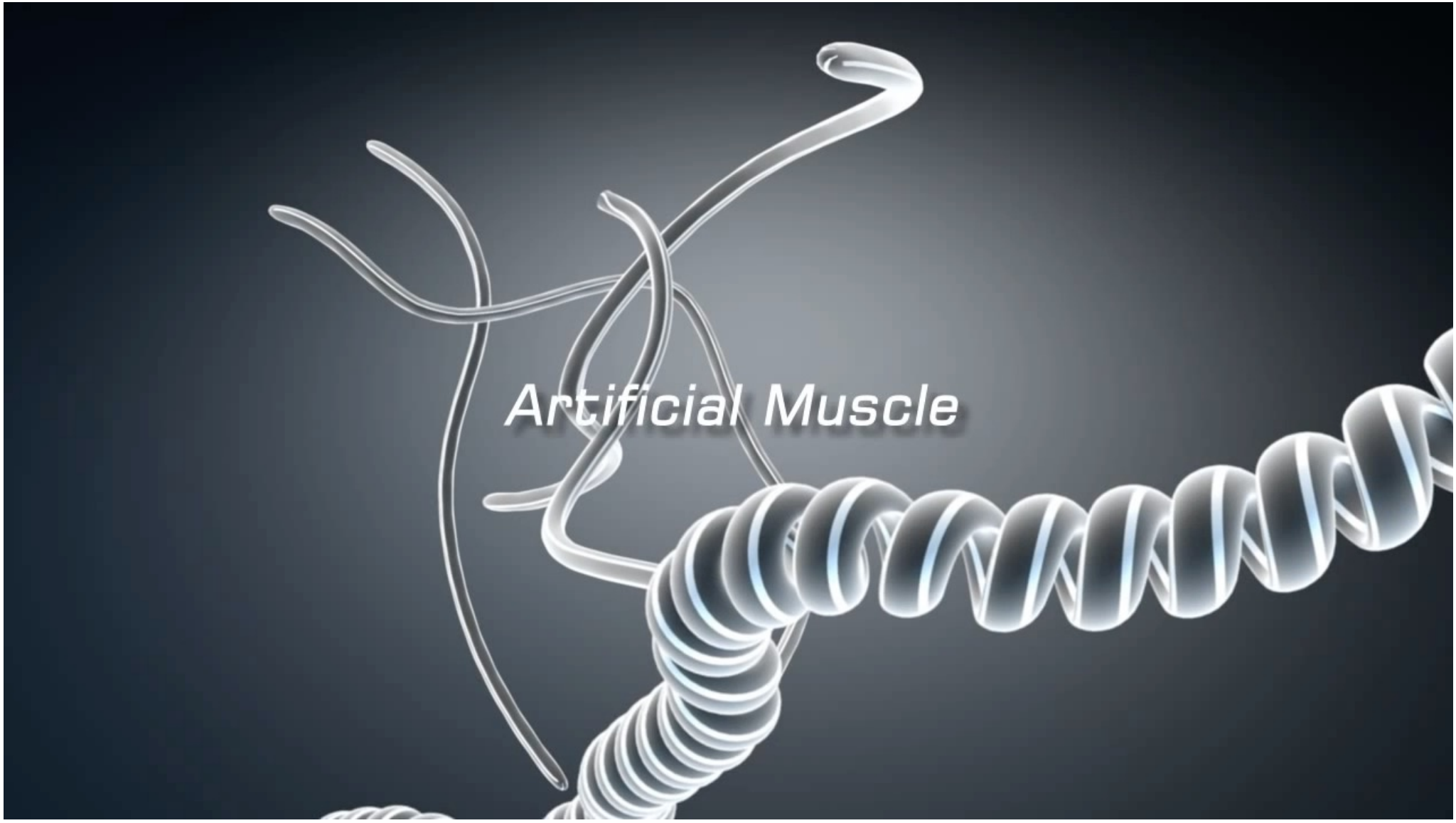


介电质（英语：dielectric，又称电介质）是一种可被电极化的绝缘体。 当向电极施加高电压时，电极之间的静电引力导致弹性体膜在厚度方向上收缩并在平面方向上膨胀。

Electrical



Thermal

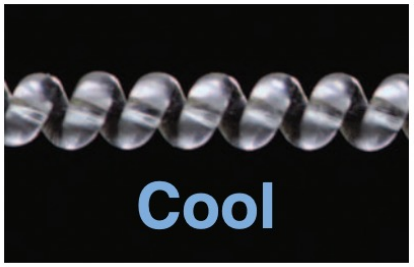


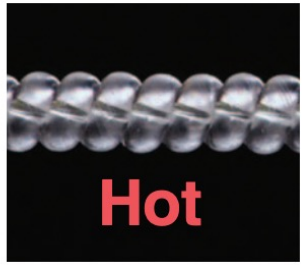
Haines et al., 2014

Thermal

Haines et al., 2014

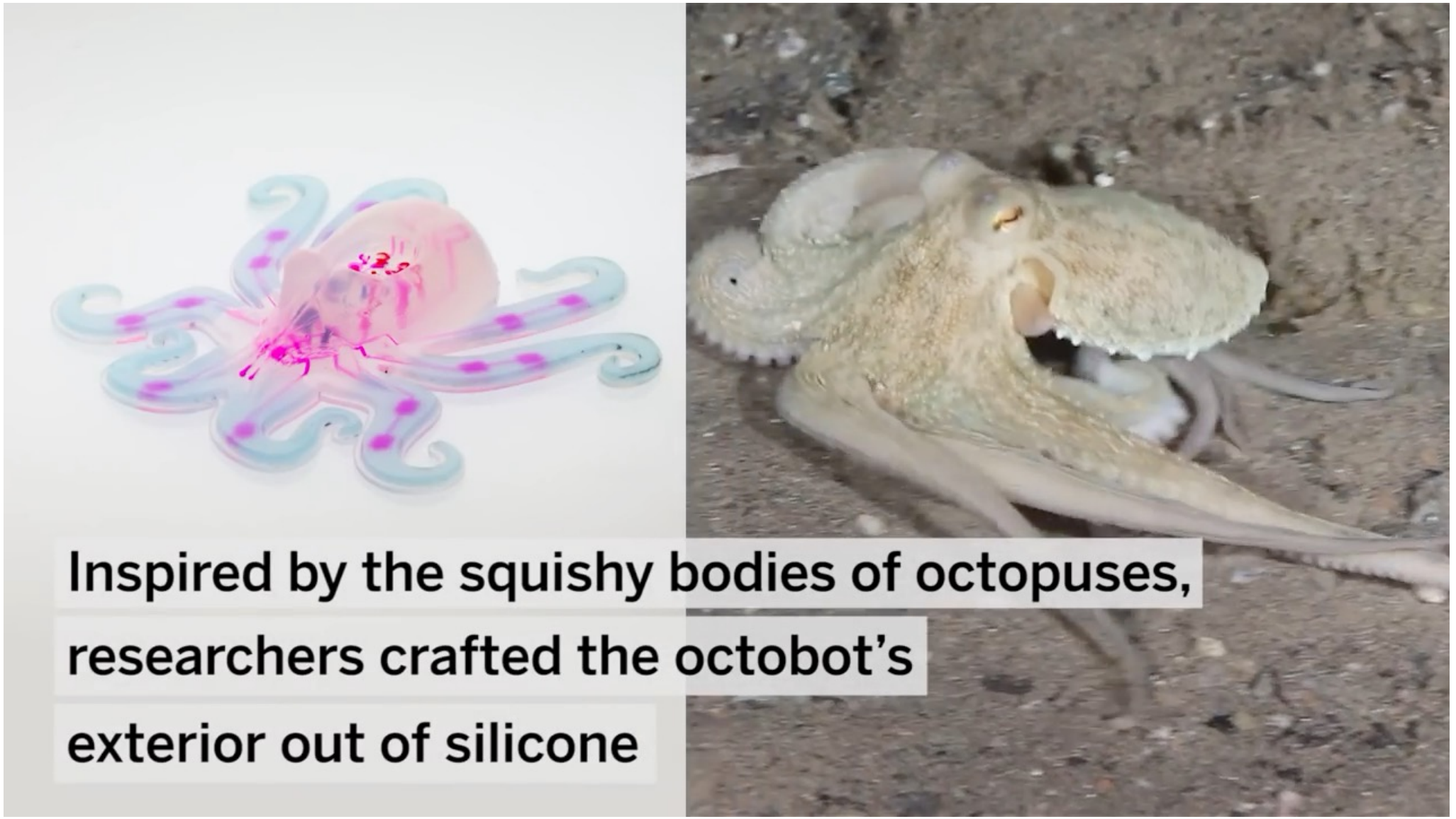
Thermal



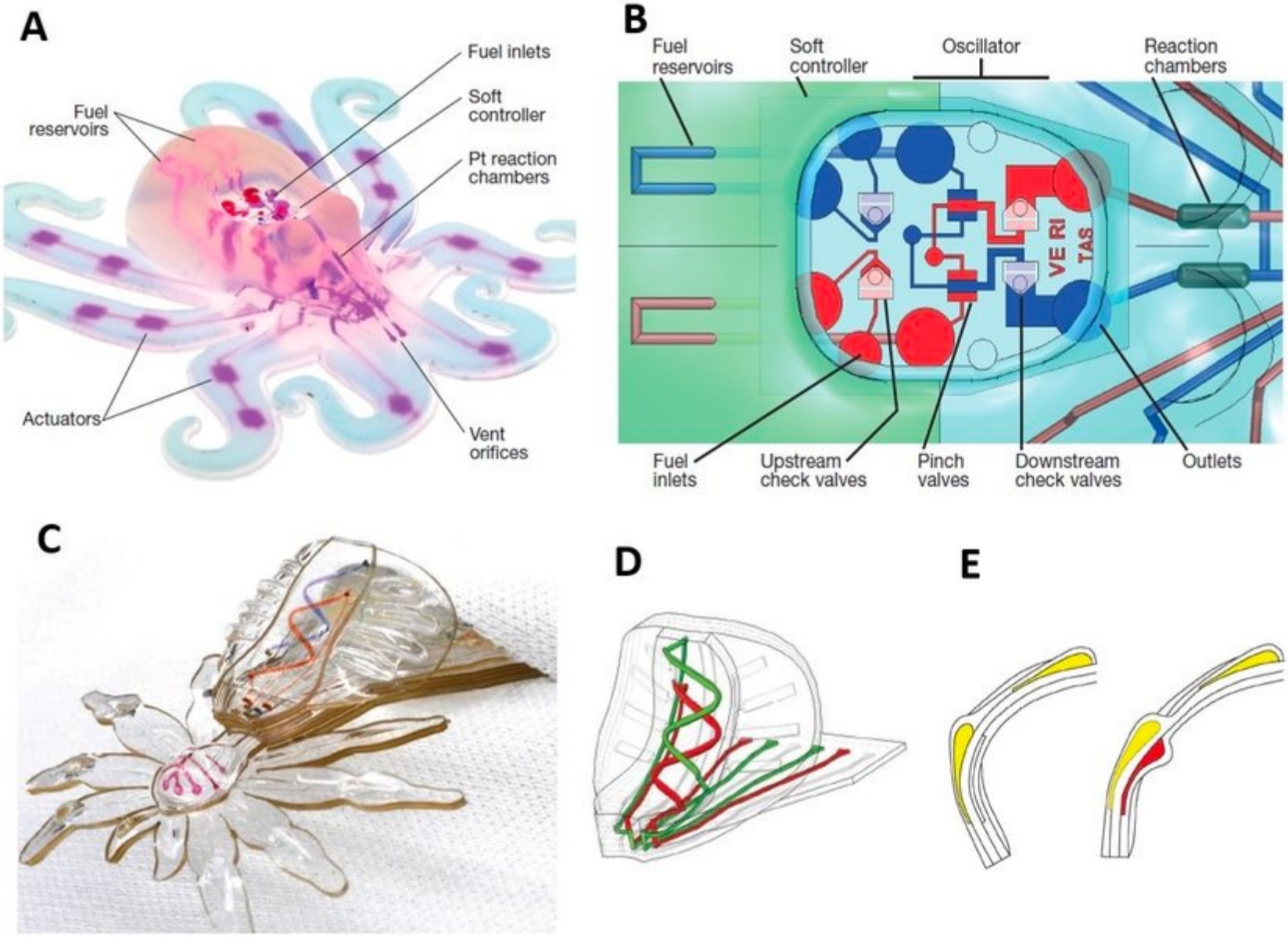


Haines et al., 2014

Chemical - Octobot

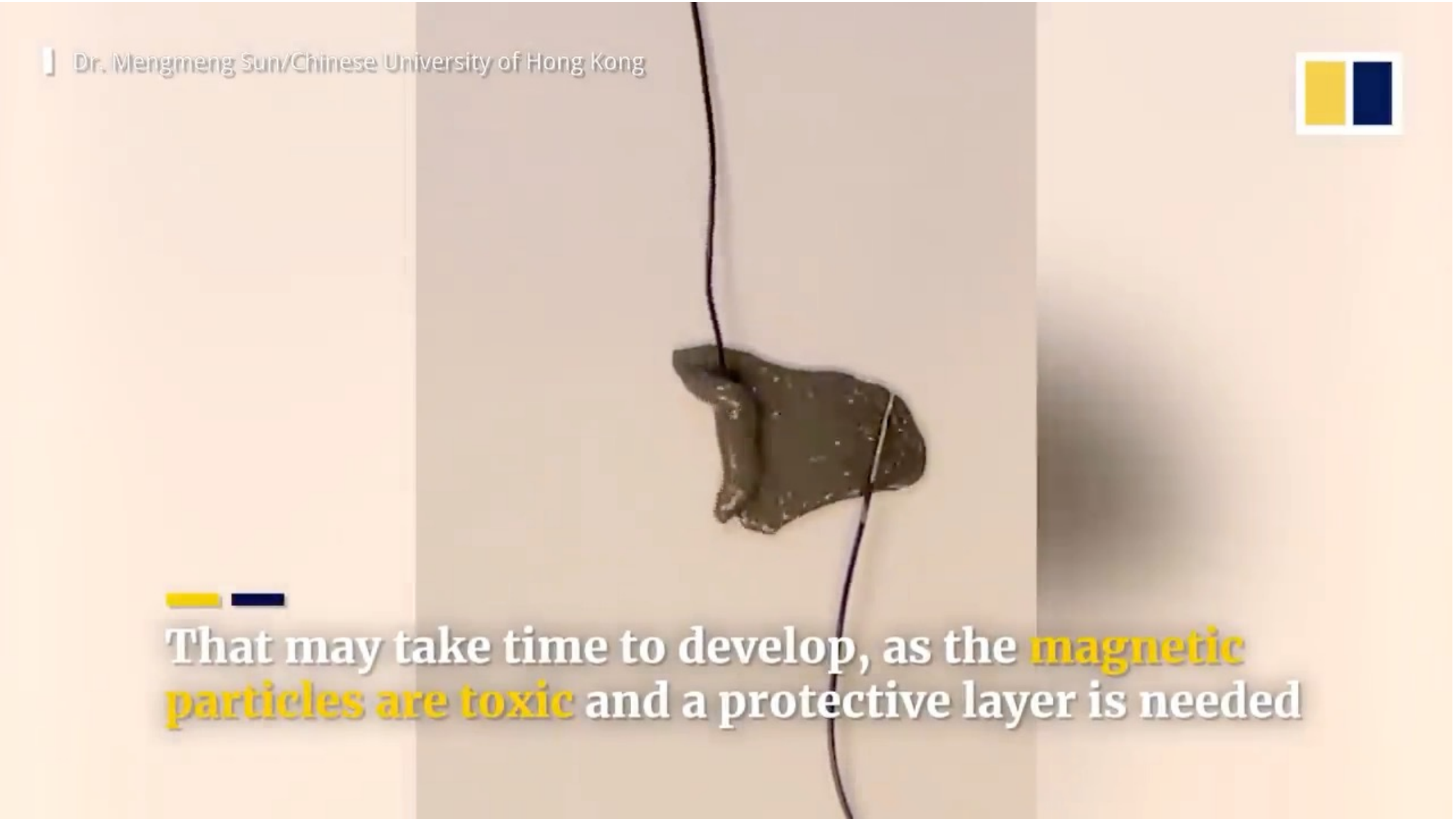


Chemical - Octobot



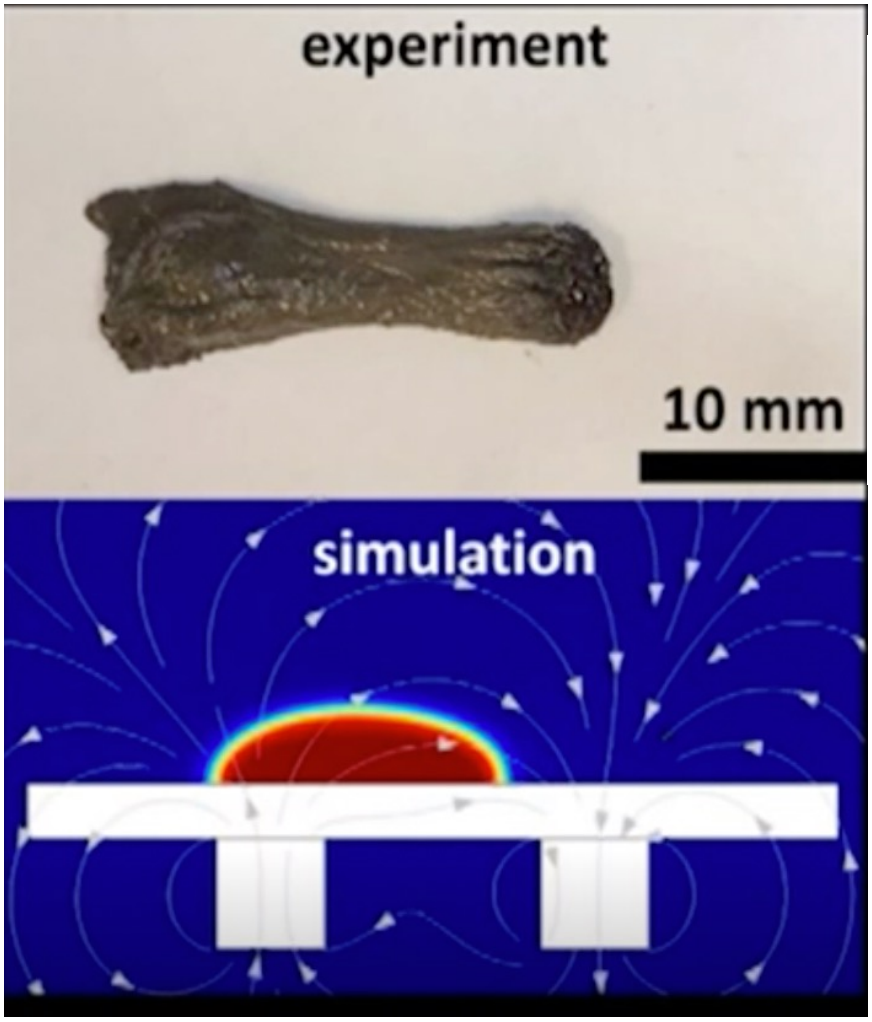
Magnetic

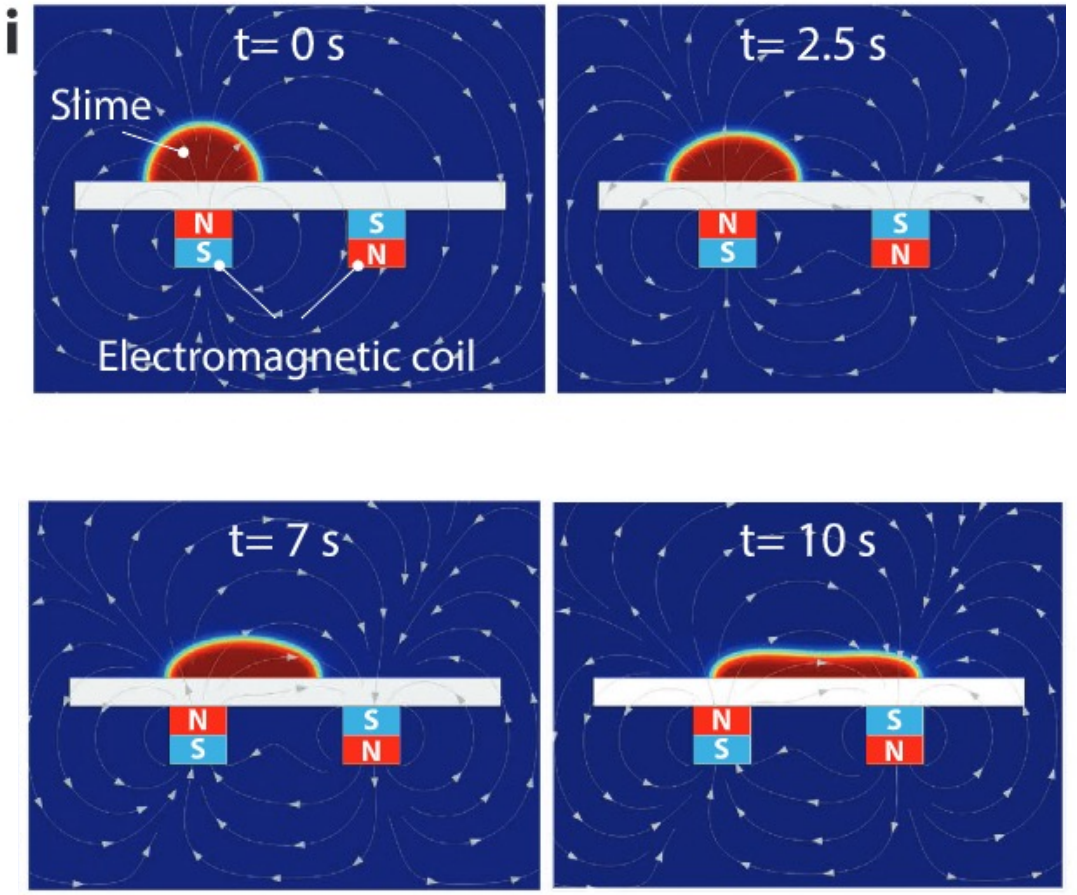
Magnetic



Sun et al., 2022

Magnetic

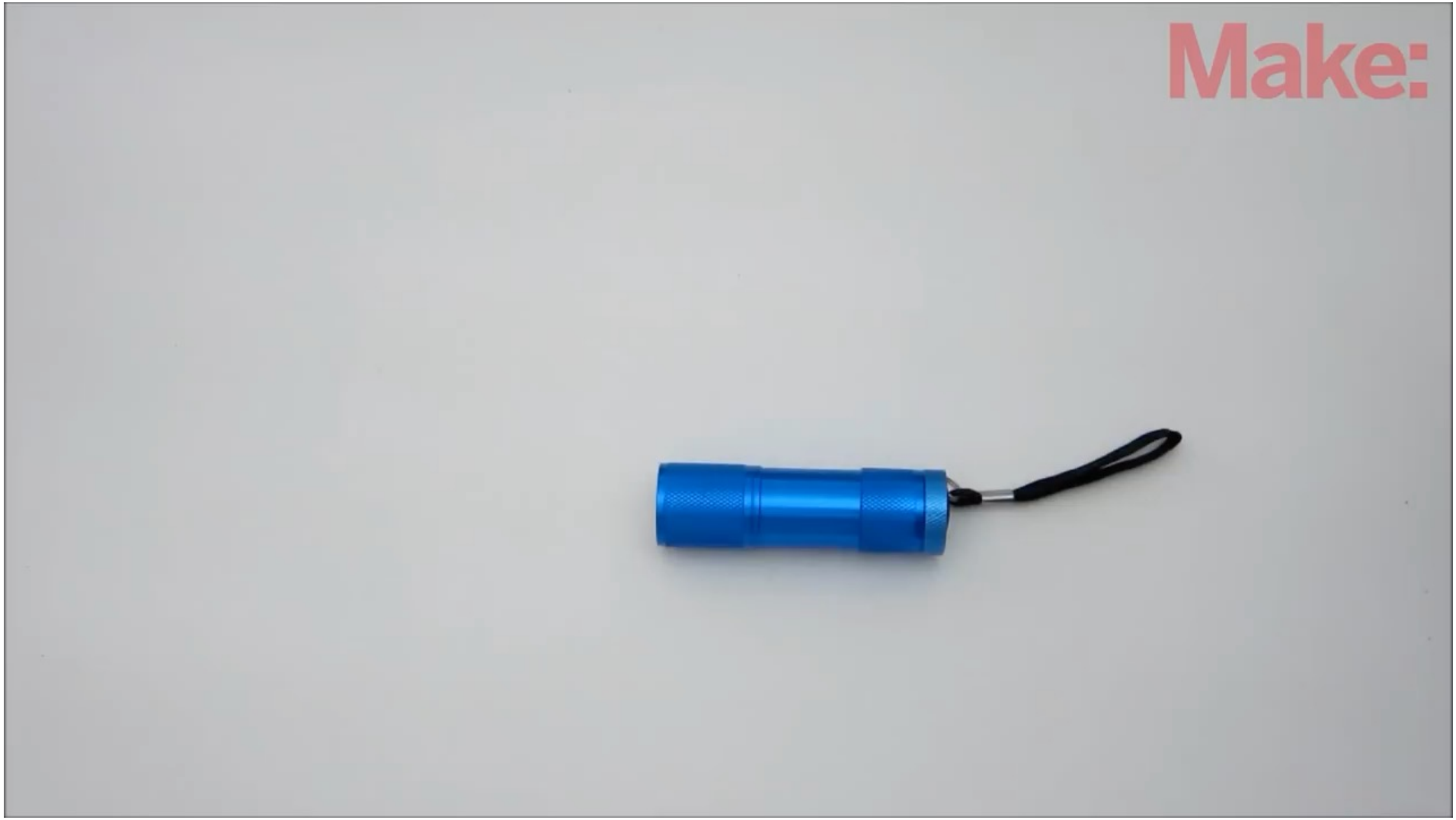




Sun et al., 2022

Mechamisms of Actuation

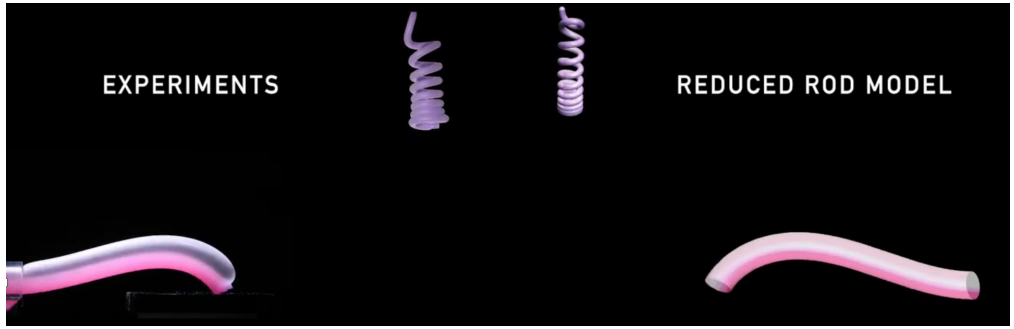
1. Variable Stiffness 变刚度

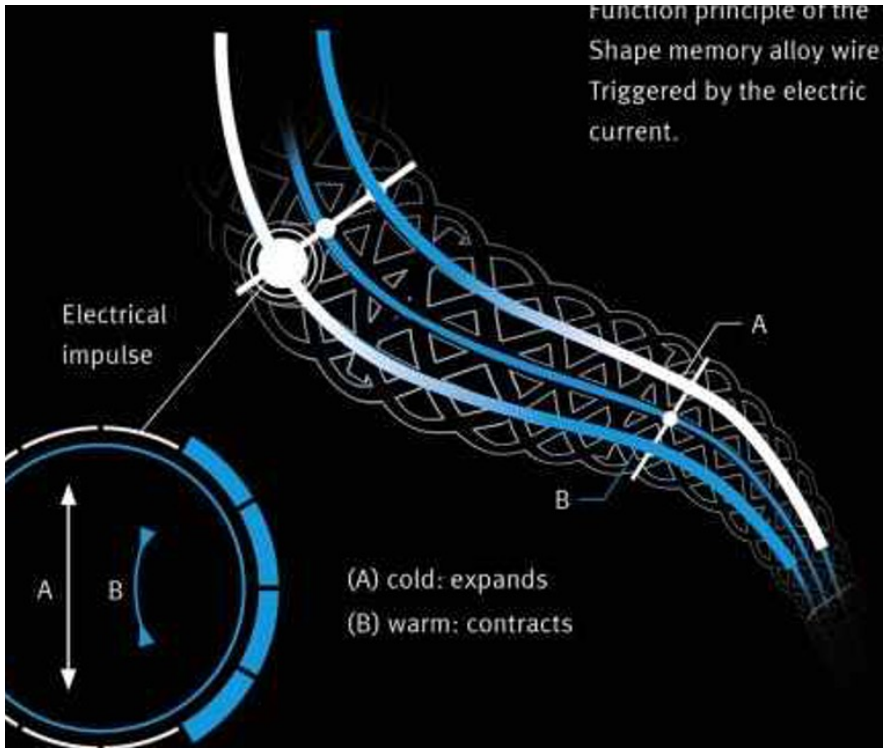


Mechamisms of Actuation

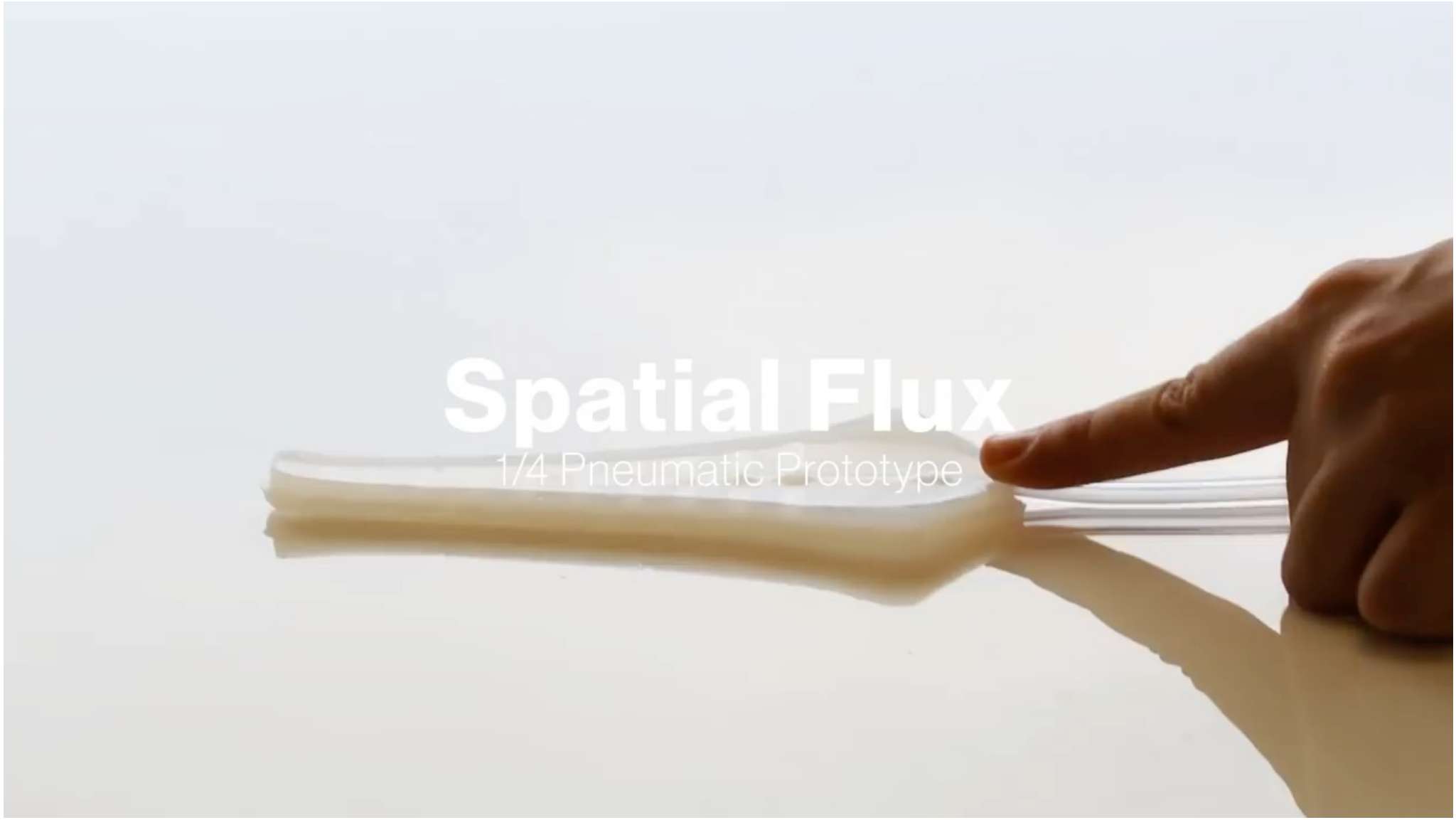
2. Mismatch Strain 差异化变形

- Central principal in the operation of unimorph acturators
- 3D change of shape in heterogeneous materials





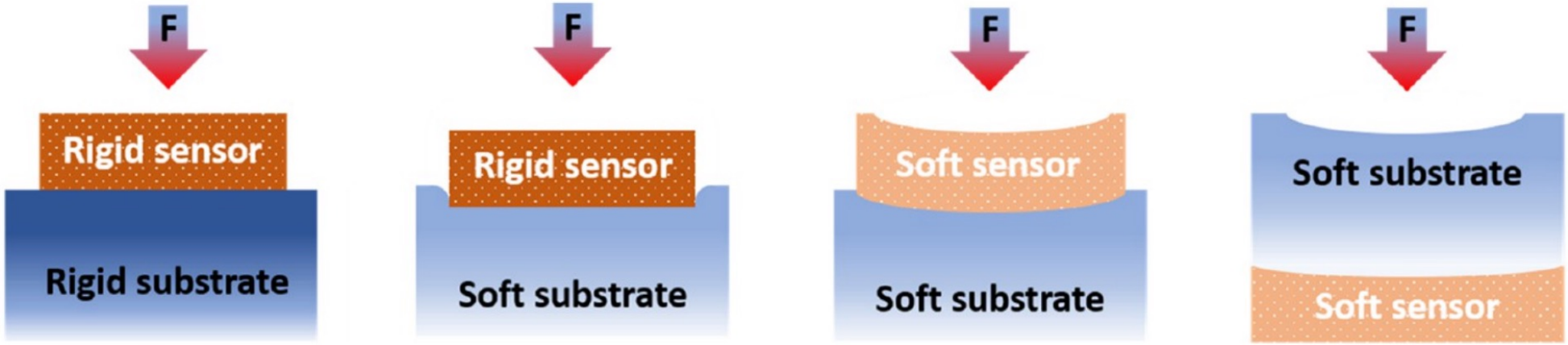
Human Robot Interaction



Human Robot Interaction

Sensing of Soft Robitcs

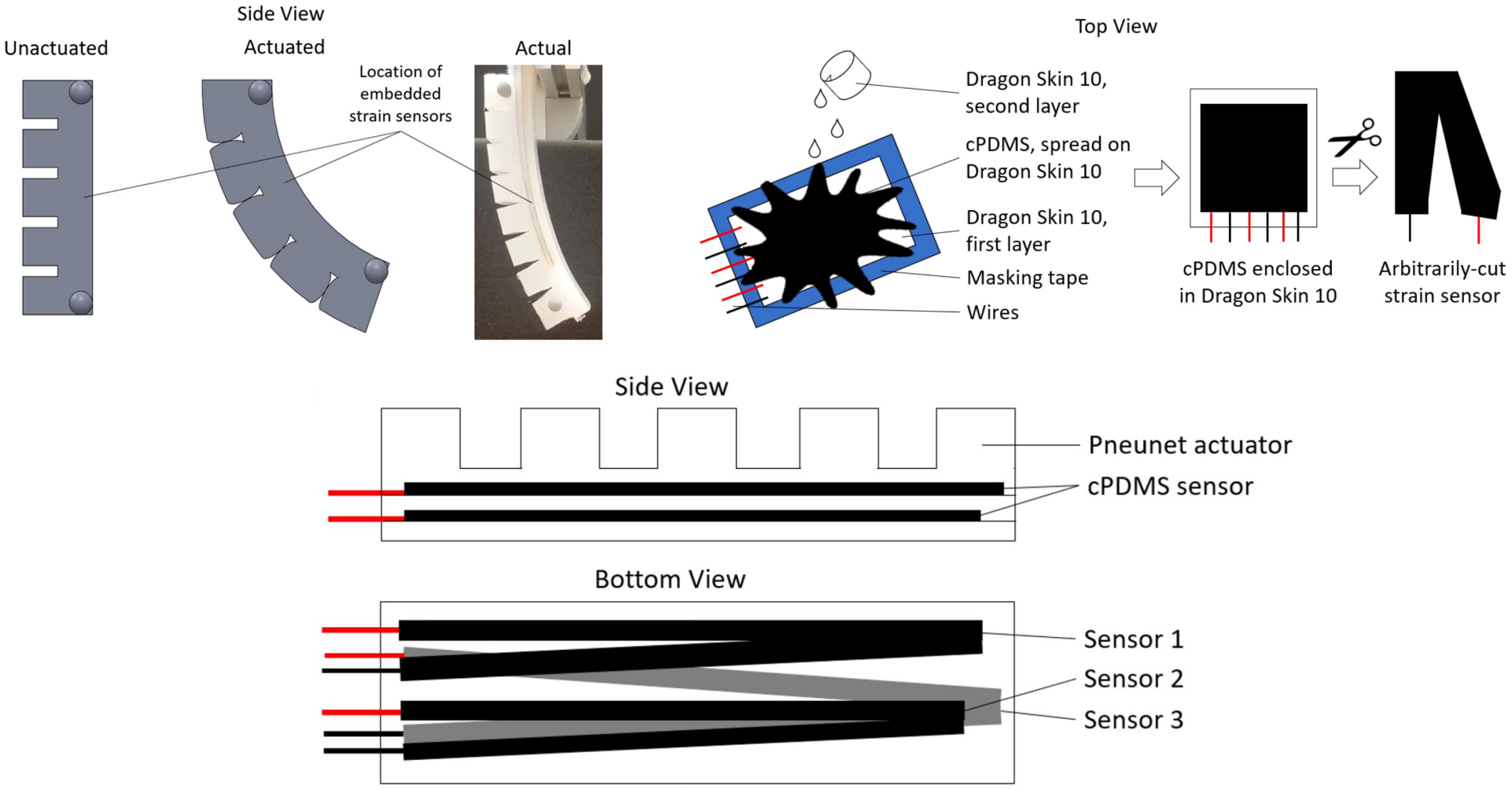
Ren, Luquan, et al. "Biology and bioinspiration of soft robotics: Actuation, sensing, and system integration." Iscience 24.9 (2021).



Different scenarios of the combination of sensor and substrate rigidities for integration of sensors in soft robots

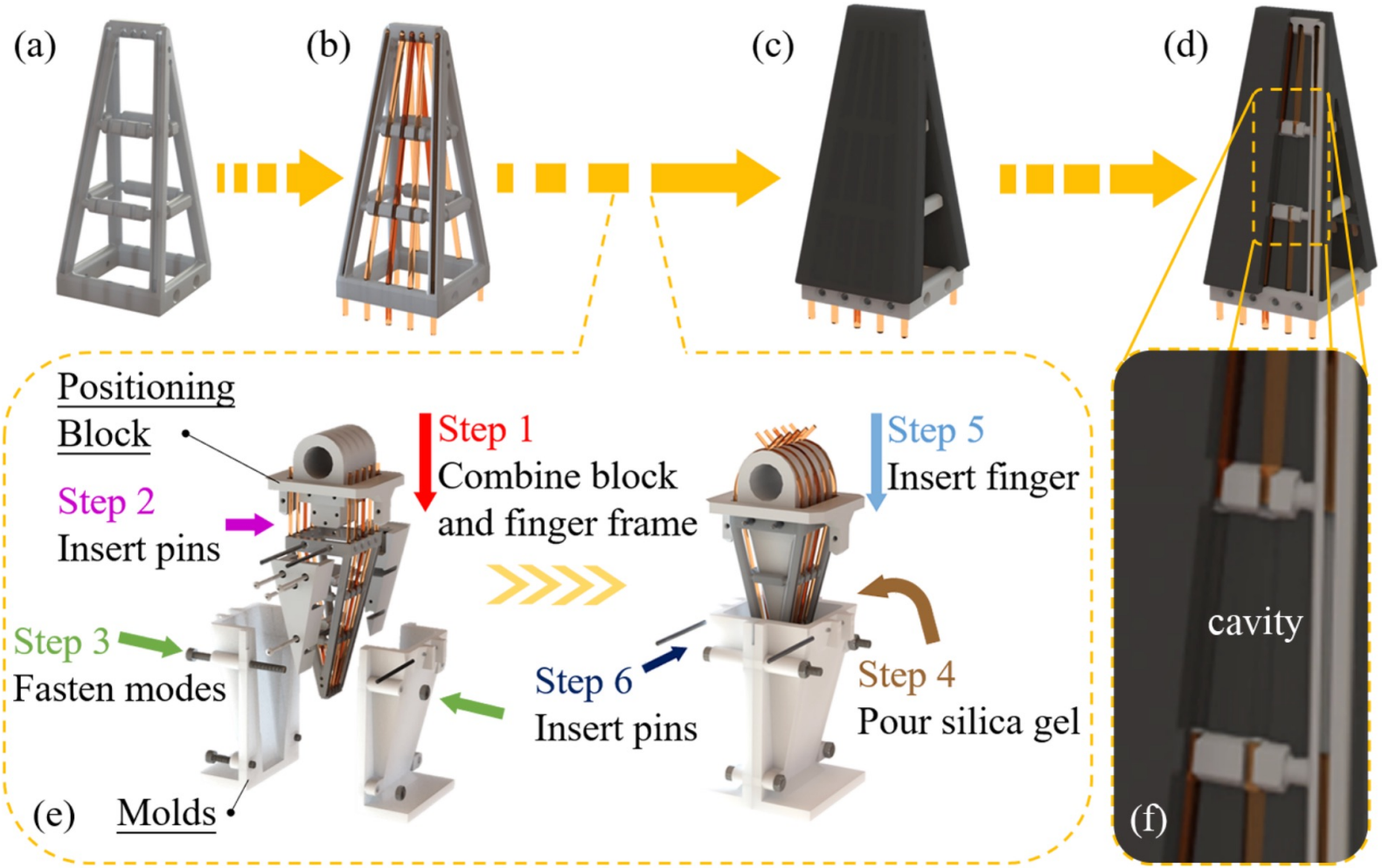
- Resistive Sensors and Piezoresistive Sensors
- Capacitive Sensors
- Optical Sensors
- …

Resistive Sensors and Piezoresistive Sensors



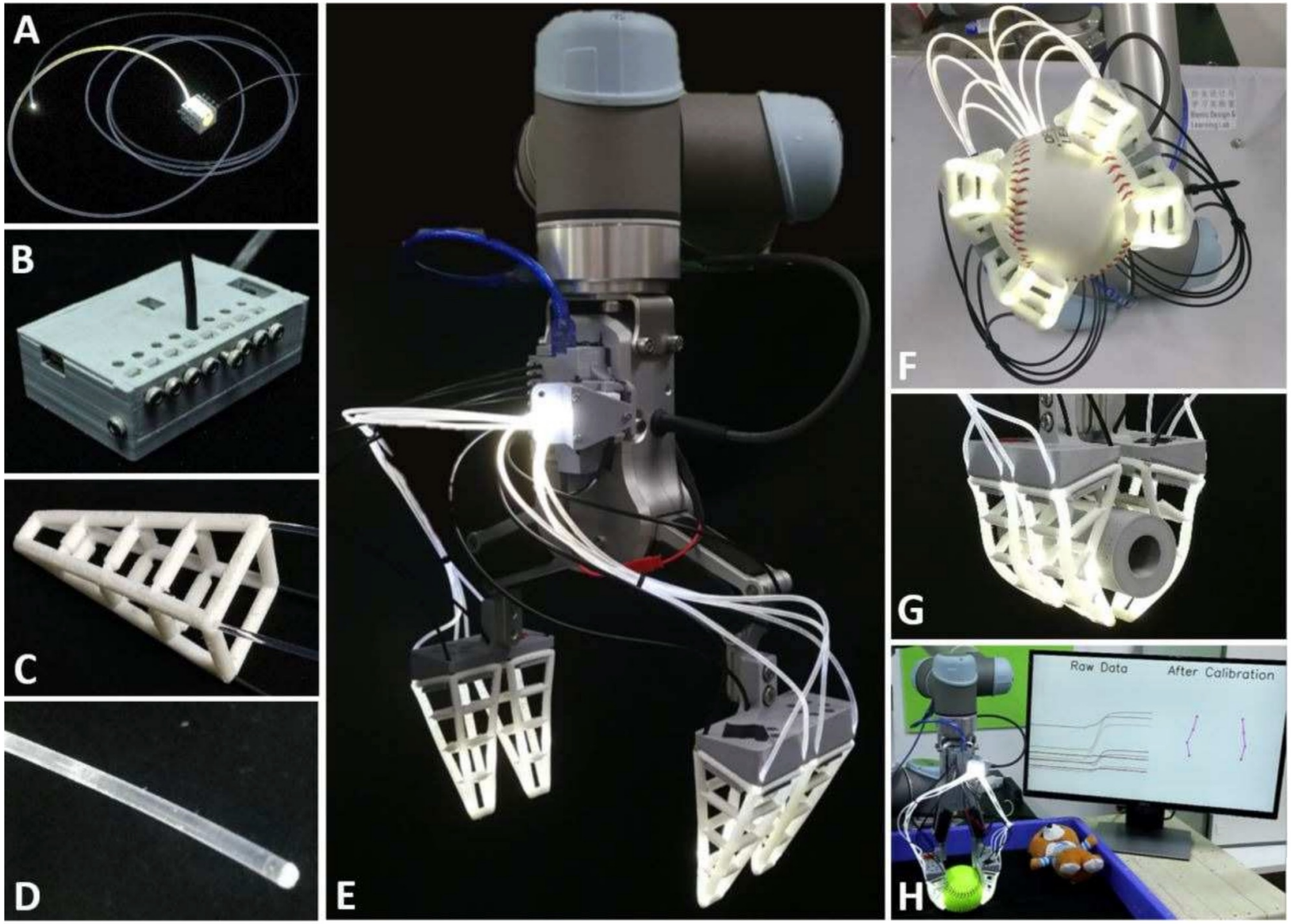
https://www.science.org/doi/10.1126/scirobotics.aav1488

Optical Sensors



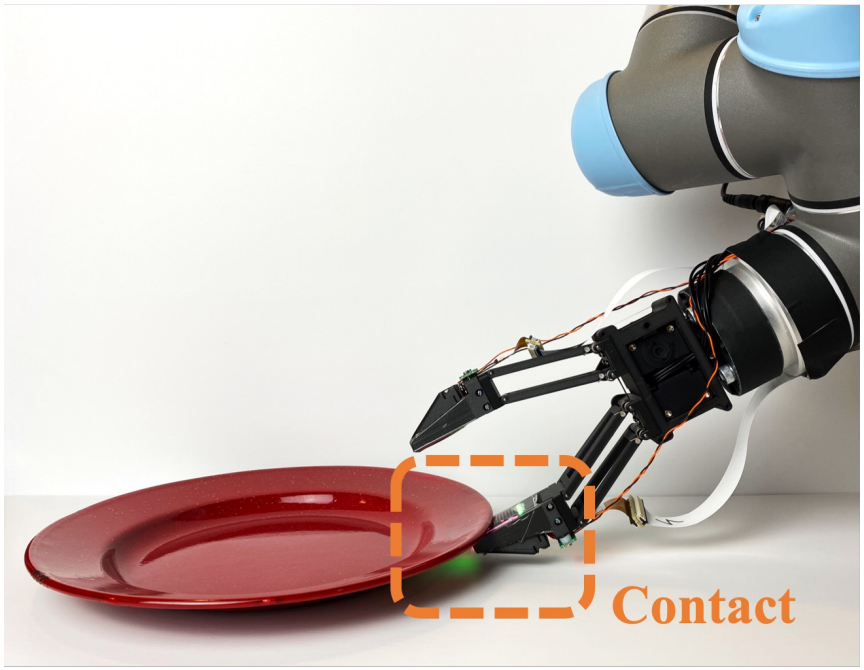
https://arxiv.org/pdf/2101.12379

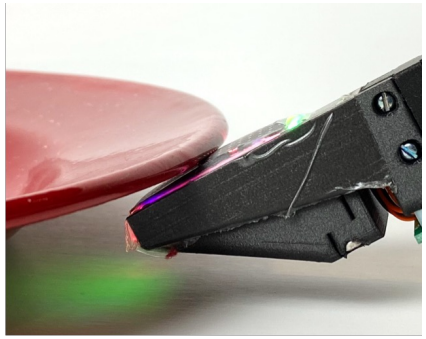
Optical Sensors

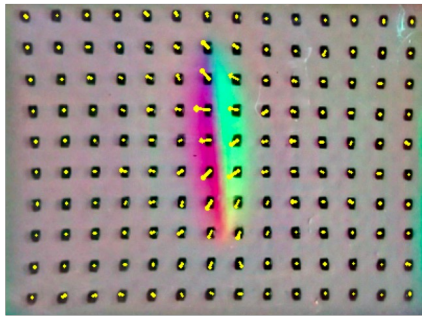


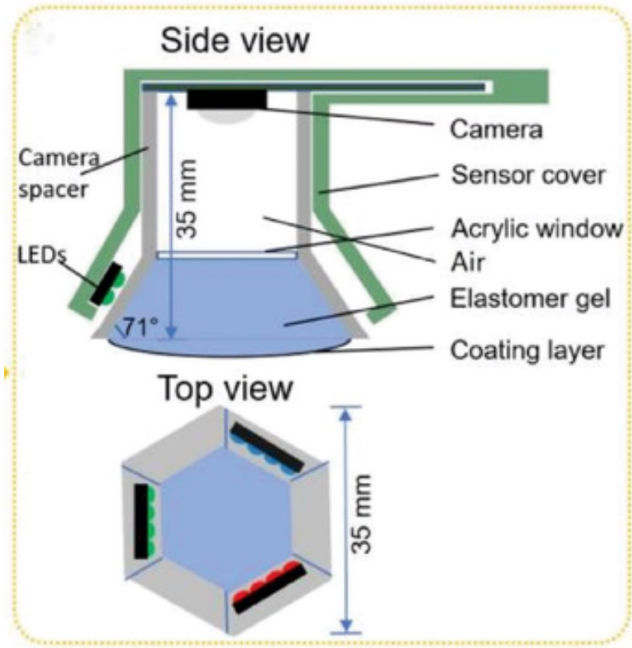
https://arxiv.org/pdf/2003.01583

Optical Sensors

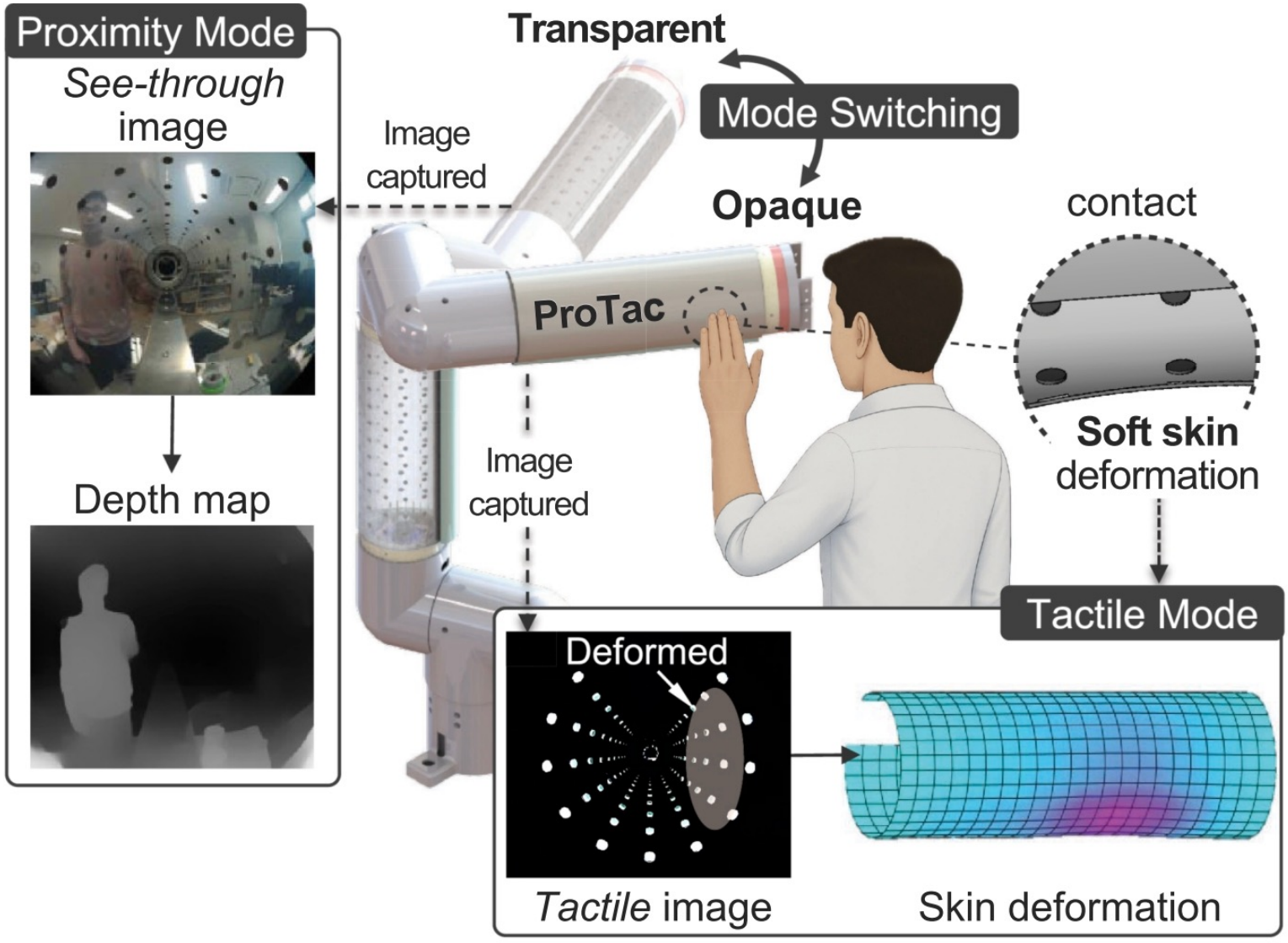




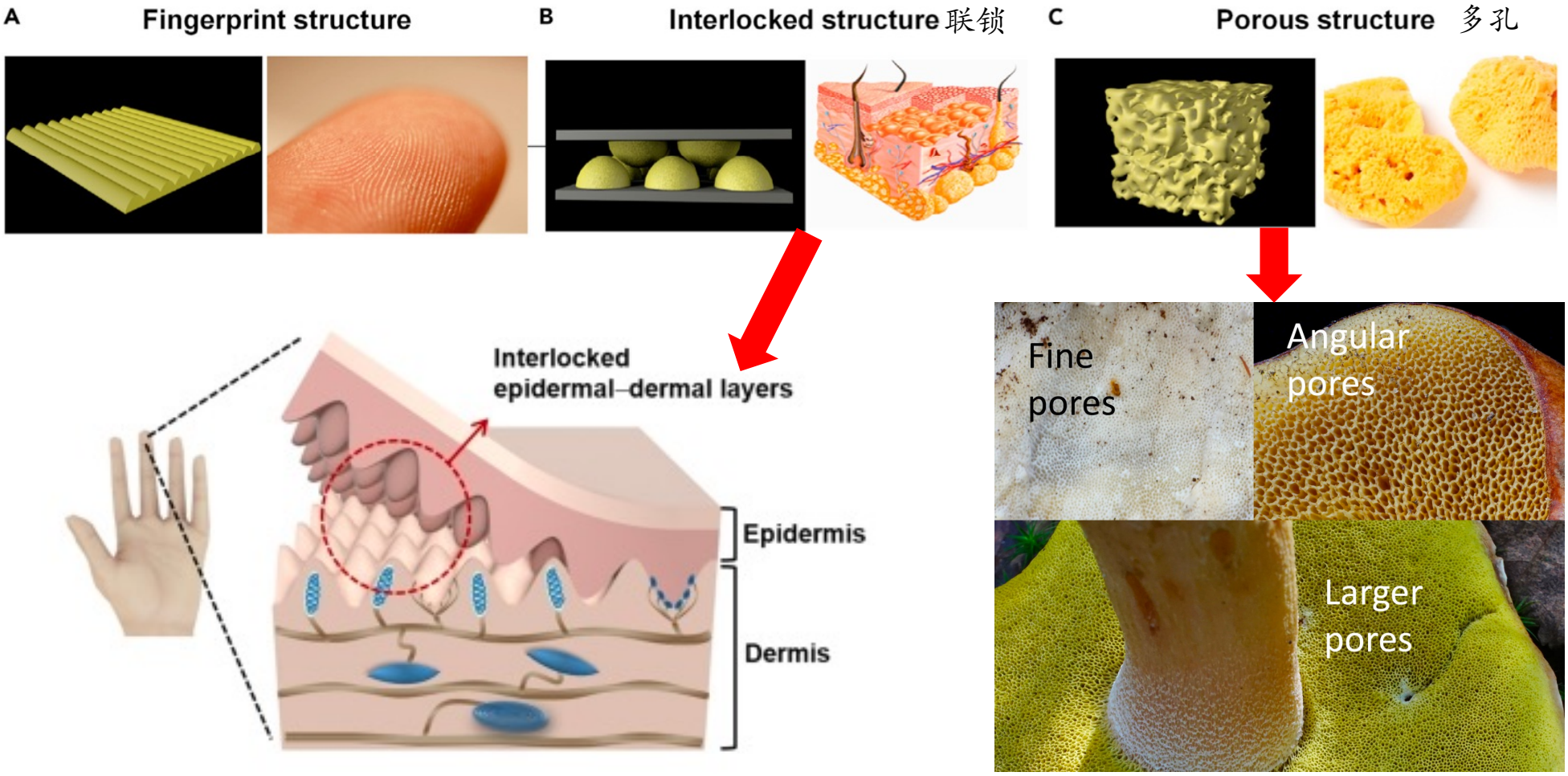




Optical Sensors



Mechanotransduction structural and functional (motif and prototypes) in the natural world
自然界的机械传导结构和功能（概念与原型）



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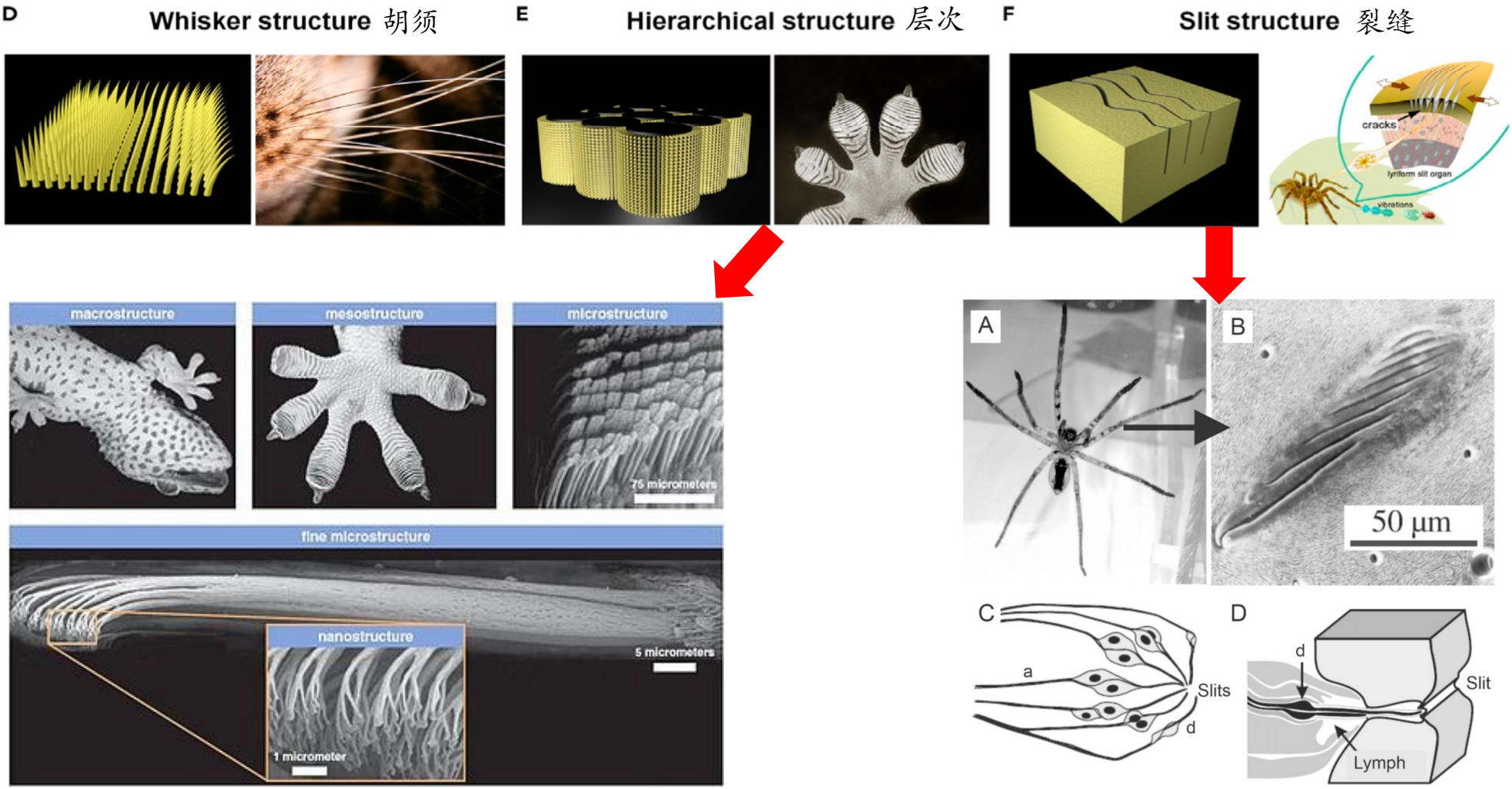
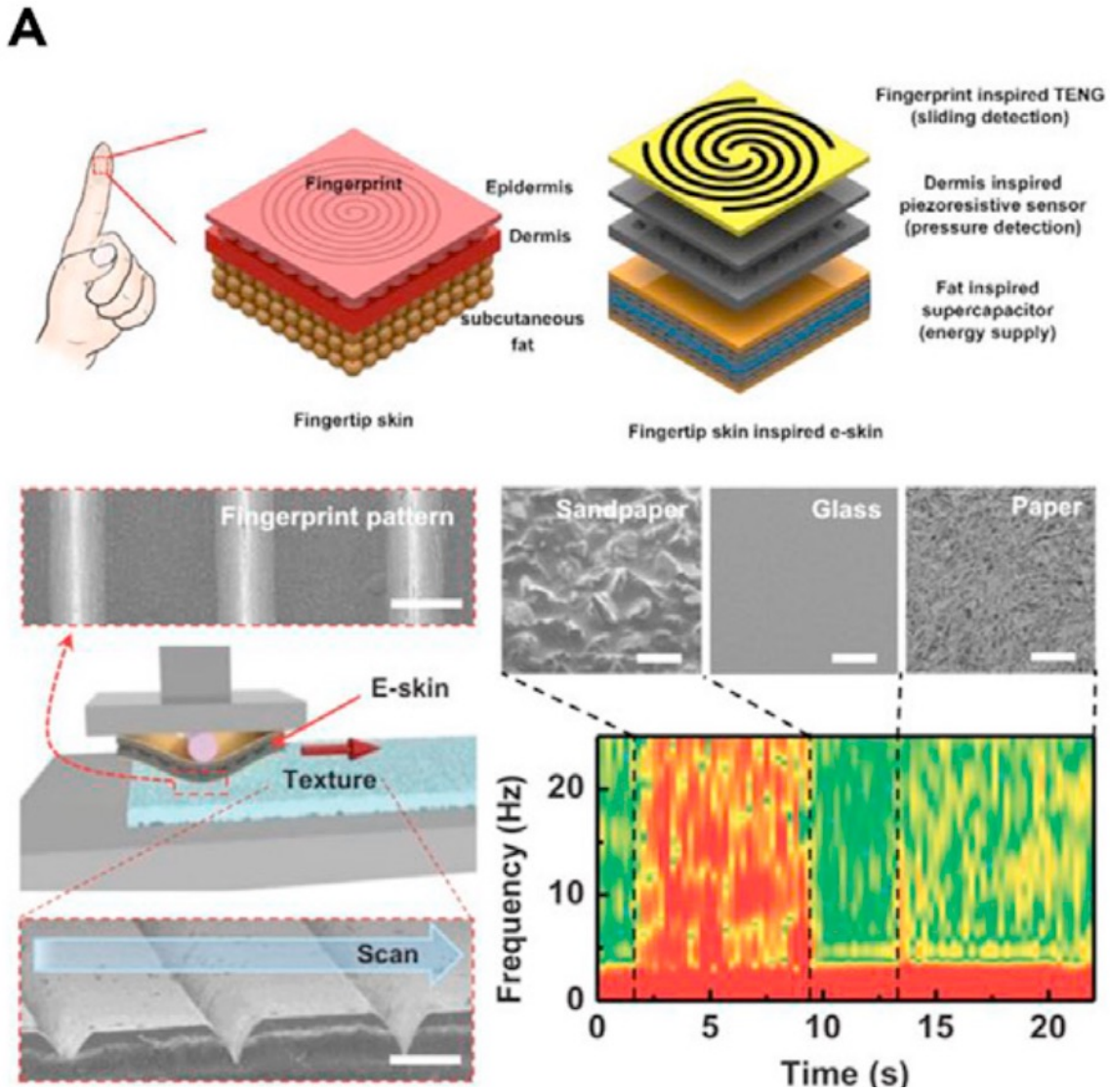
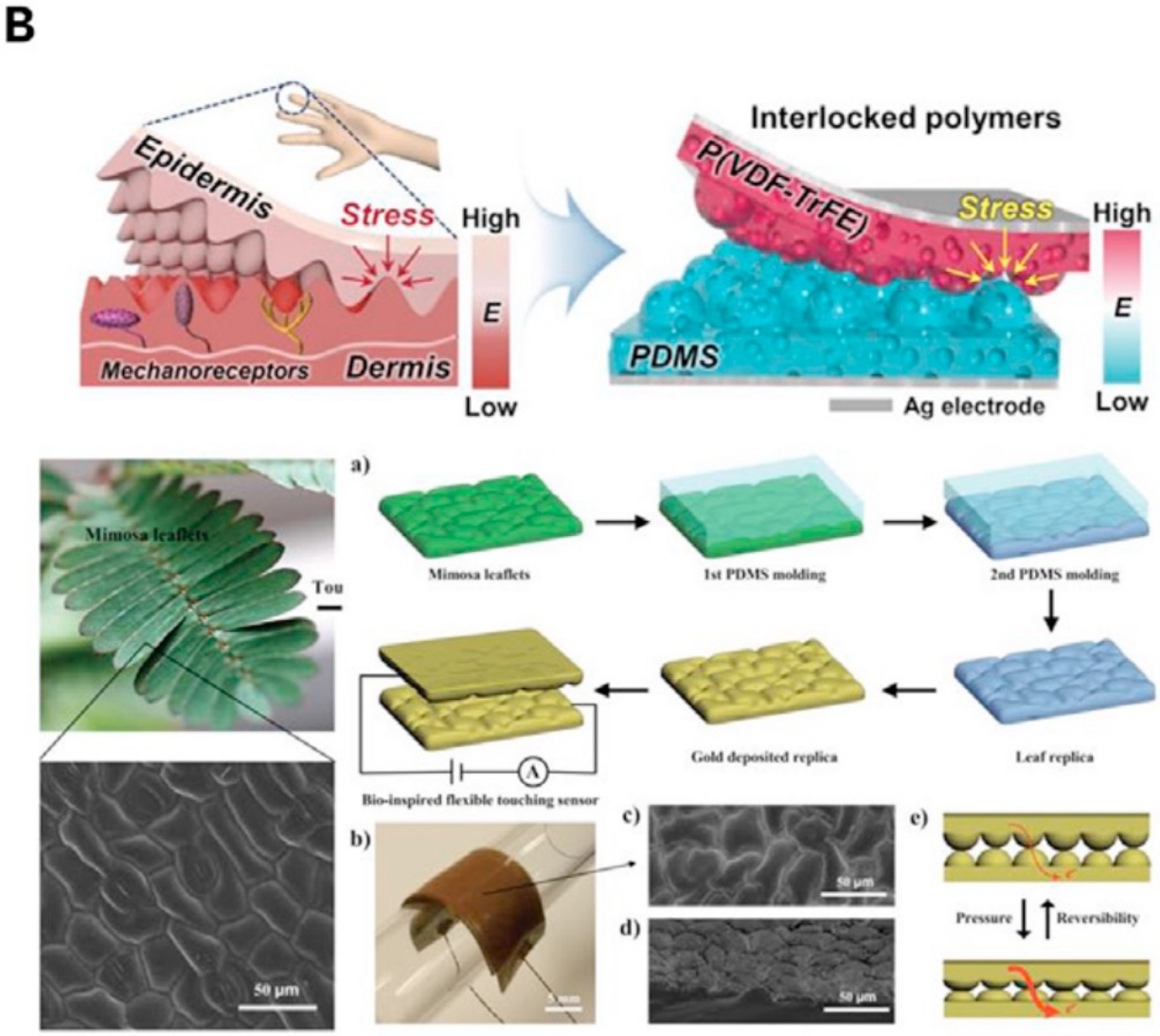


Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）



- Spiral-shaped fingerprint inspired sensor for the detection of both sliding direction and speed (top), as well as the perception of surface textures (bottom)

Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）

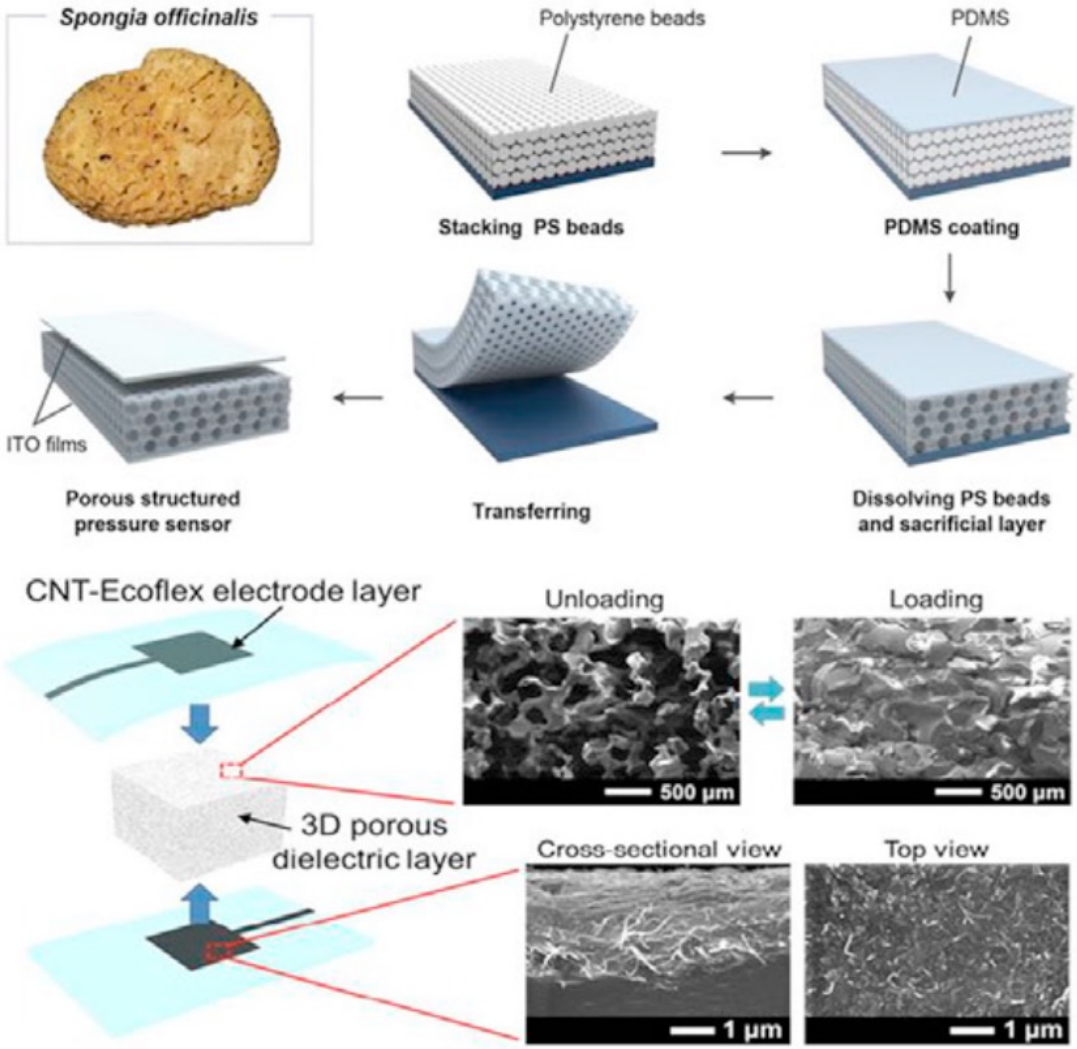


- Triboelectric e-skins based on the interlocked geometry with gradient stiffness differentiating multidirectional tactile stimuli

- Flexible pressure sensors with an irregular pattern of microdomains sensitive enough to mimic mimosa leaves

Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）

c



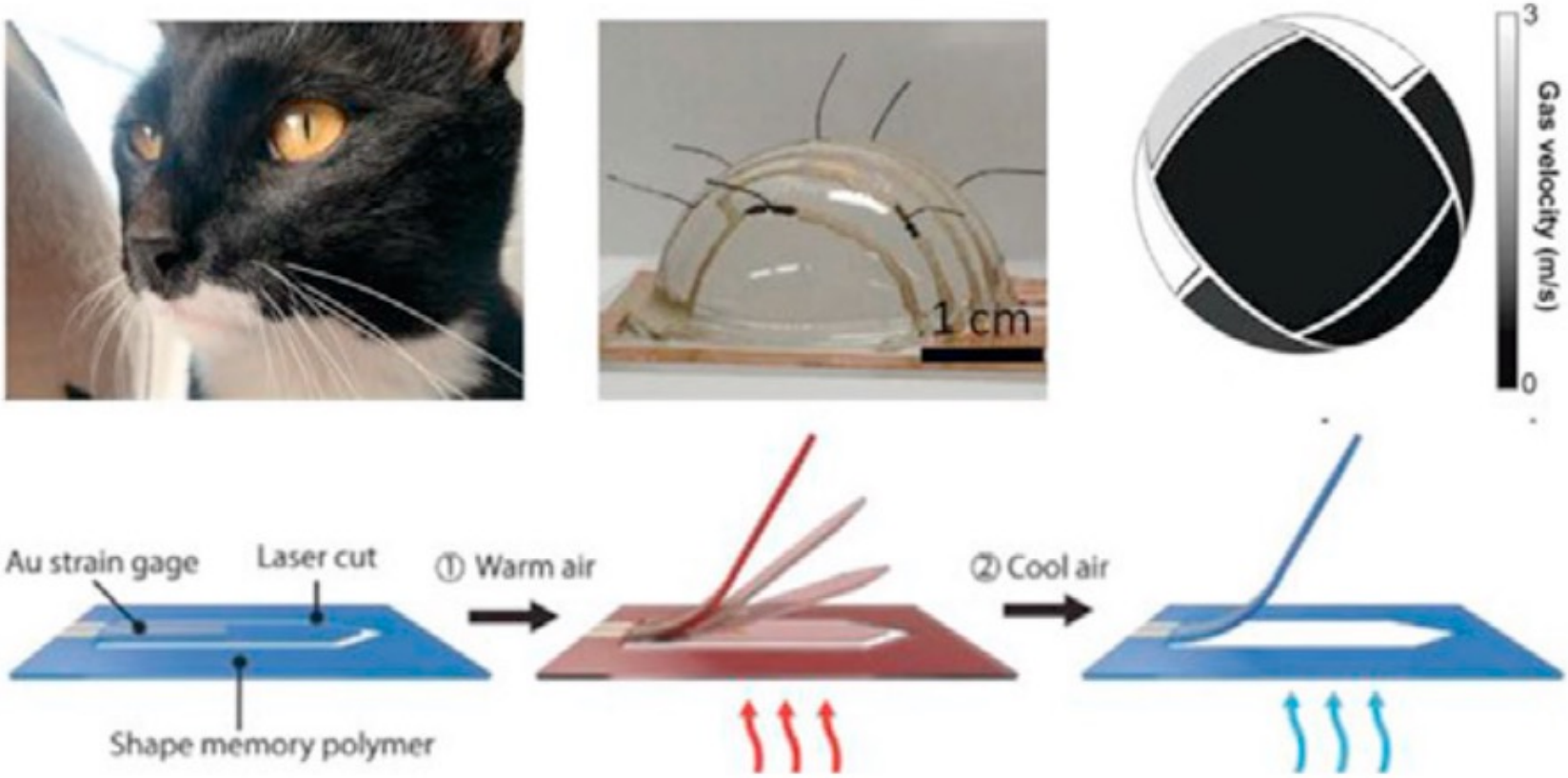
- Piezocapacitive（压容）tactile sensors based on a sponge-like structure of dielectric layer

- Flexible and wearable piezocapacitive pressure sensor based on a three-dimensional microporous Ecoflex dielectric elastomer

Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）

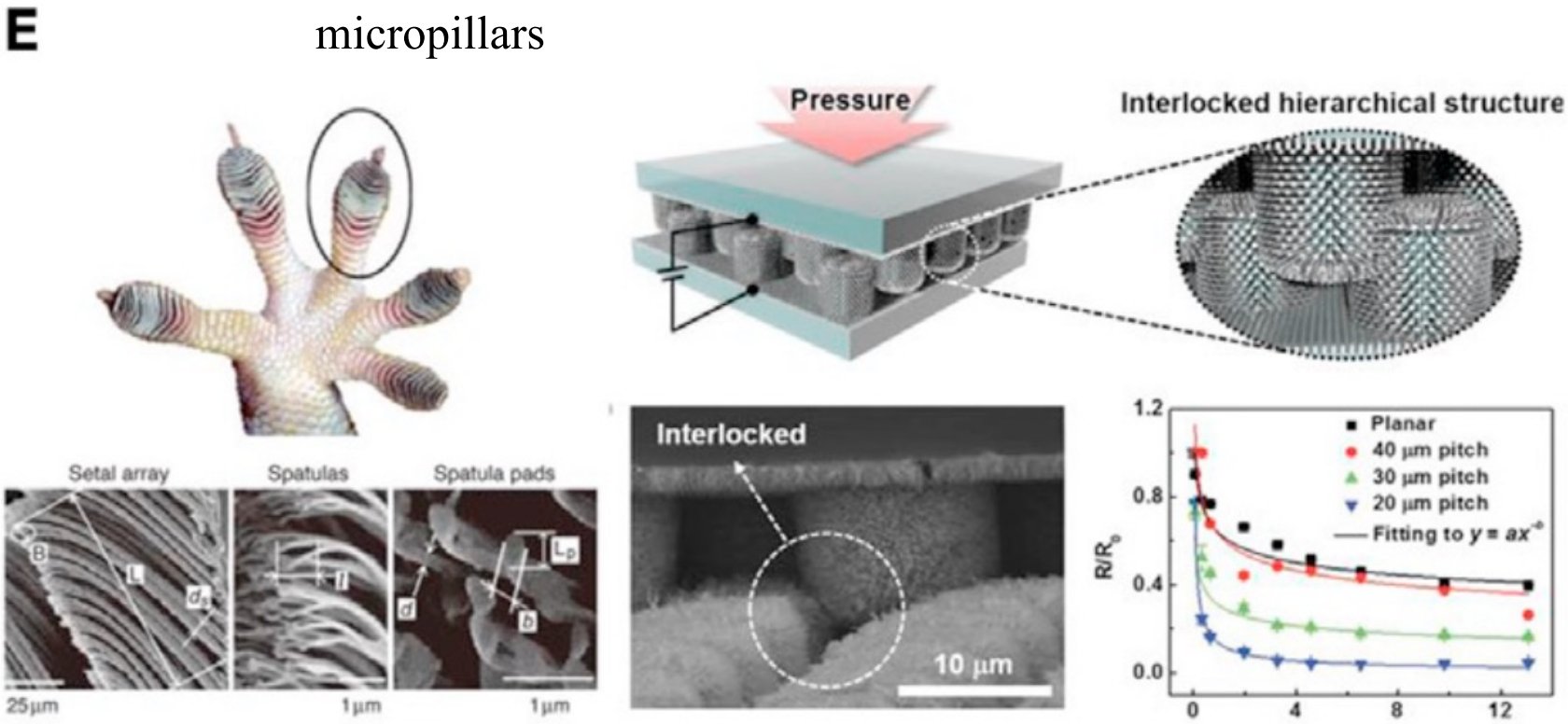
D

- Adaptive electronic whiskers based on shape memory polymers able to translate proximity, surface topology, friction, force, material stiffness, and temperature into precise electrical quantities



Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）

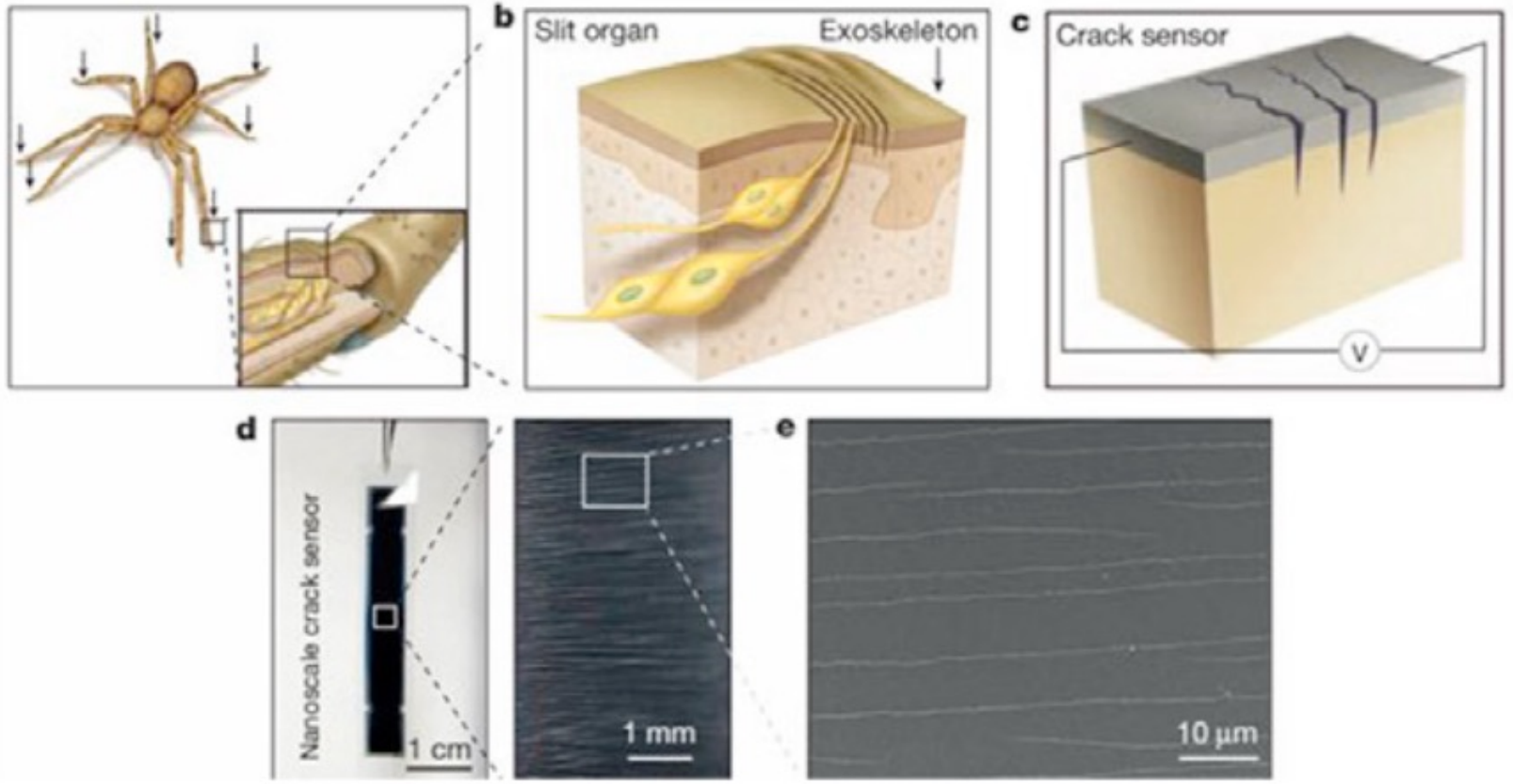
- Piezoresistive(压阻式) tactile sensors based on hierarchical microstructures and nanostructures of micropillars



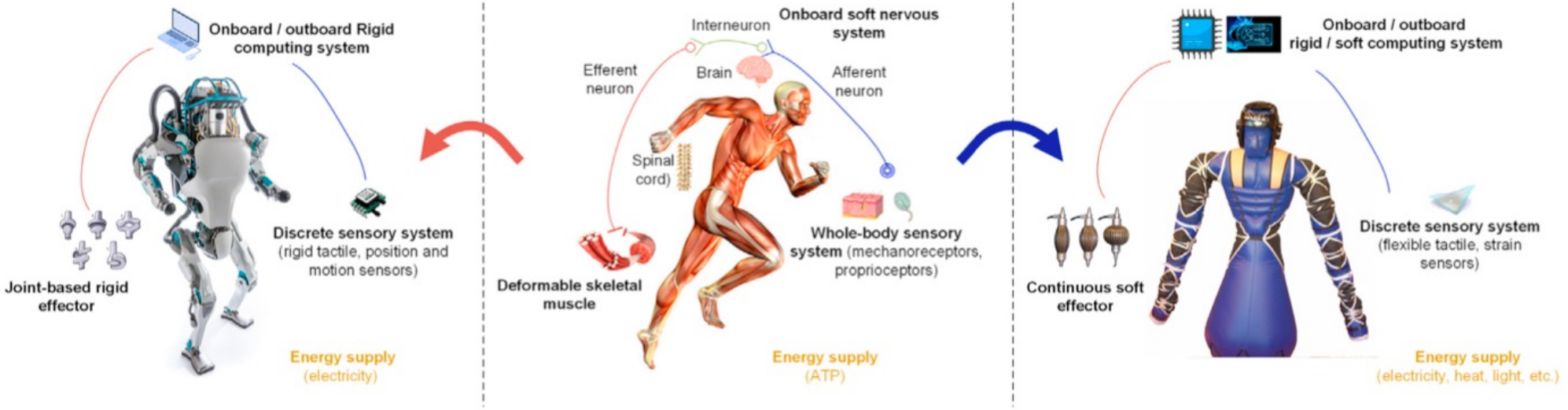
Flexible mechanosensors inspired by biological sensory motifs 柔性机械传感器（受生物启发的）

F

- Multifunctional ultrasensitive sensor mimicking nanoscale crack junction able of detecting subtle strains and vibrations



Comparison of natural lives, rigid robots, and soft robots



Rigid robots
(assembled sensory, computation and actuation system)

Natural lives
(coordinated sensory, nervous and actuation system)

Soft robots
(promising with coordinated sensory, computation and actuation system)

	Building unit	Energy efficency	Versatility	Agility	Adaptability	System robustness	Self-healing
Natural lives	cell	★★★	★★★	★★★	★★★	★★★	★★★
Rigid robots	Metal, polymer, silicon, etc.	★★	★	★★	★	★	★
Soft robots	Polymer, hydrogel, etc.	★	★★	★	★★	★	★★

★★★ Excellent
★★ Average
★ Promising

Thank you~

Wan Fang
Southern University of Science and Technology