



Biorobotik

Soft Robotics



151-0653-00L

Introduction to Bio-Inspired Robotics

Tuesdays, 08-11, HG D5.2

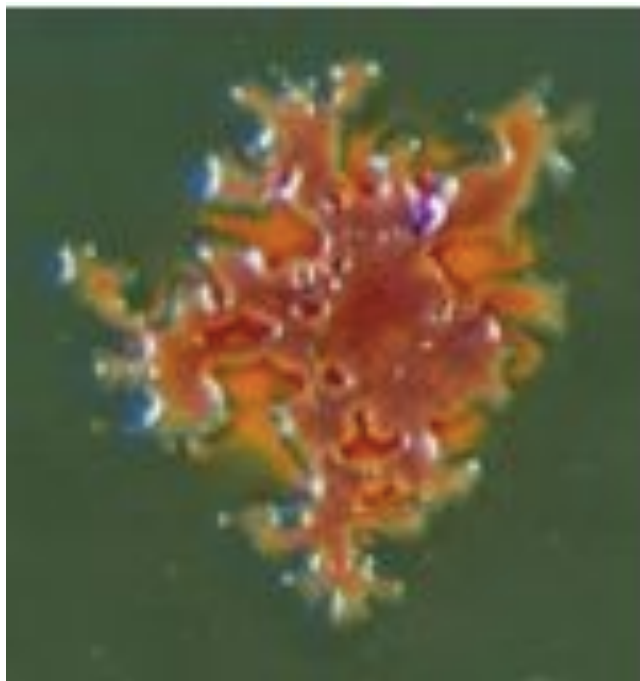
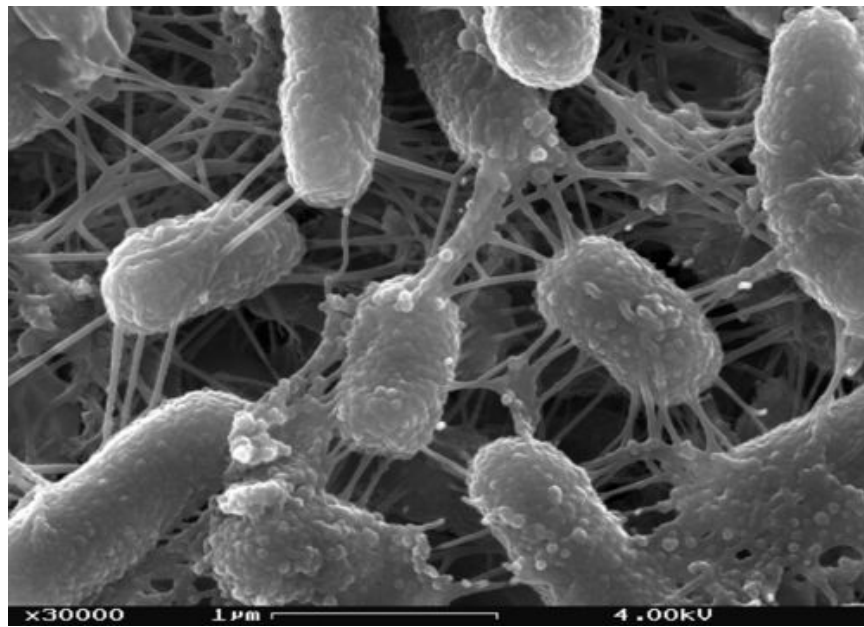
Fumiya Iida

Hugo Gravato Marques

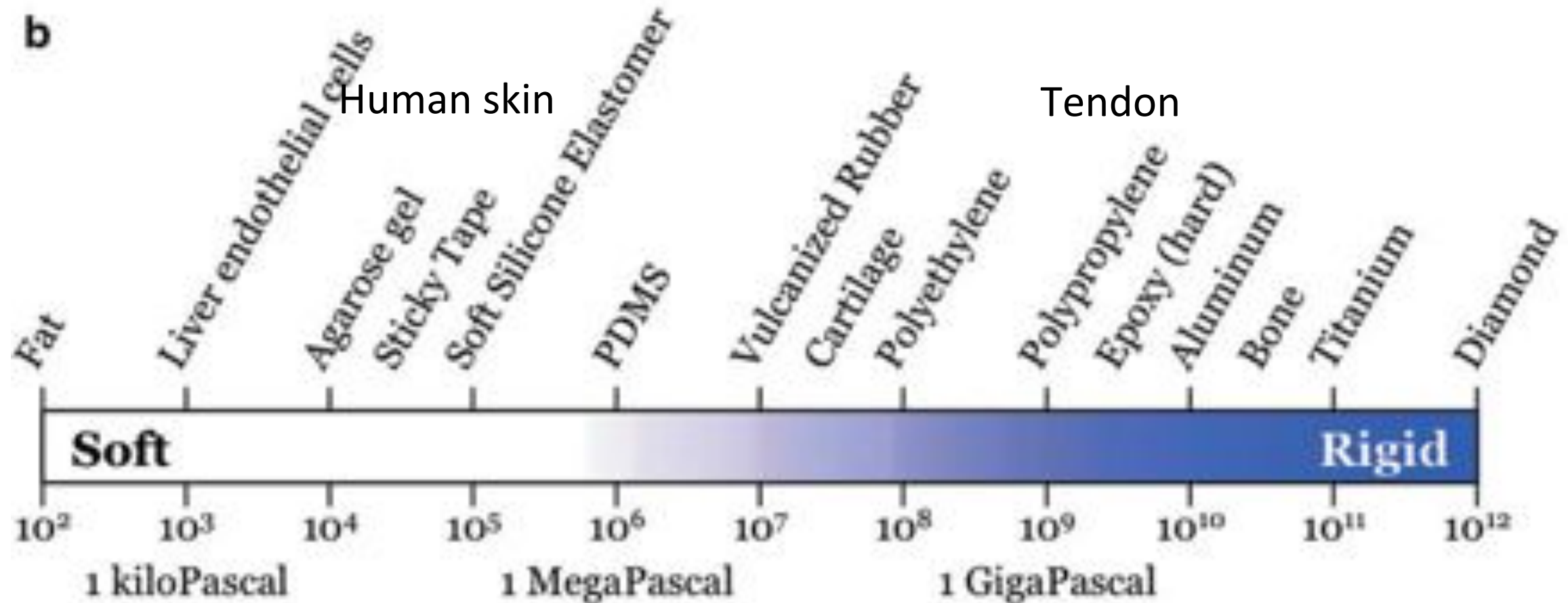
Utku Culha

Xiaoxiang Yu

Hung Quy Vu



Young's Modulus



Young's modulus

Passive muscle	10-100 kPa
Silicone rubber	3 MPa
Tendon	1-2 GPa
Soft wood (pine)	1-10 GPa
Hard wood (oak)	10-15 GPa
Cortical bone	10-20 GPa
Steel	100-200 GPa

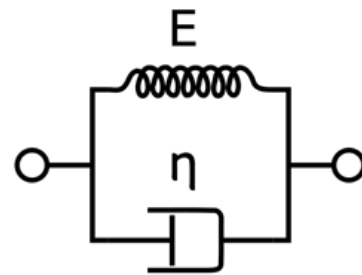
Constitutive laws

- Linearly elastic solids - Hooke's law

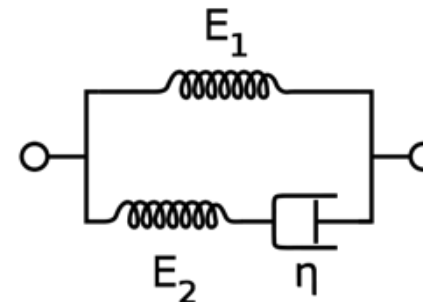
$$\sigma_T = \sigma_E = E \cdot \varepsilon_E$$

- Viscoelastic solid

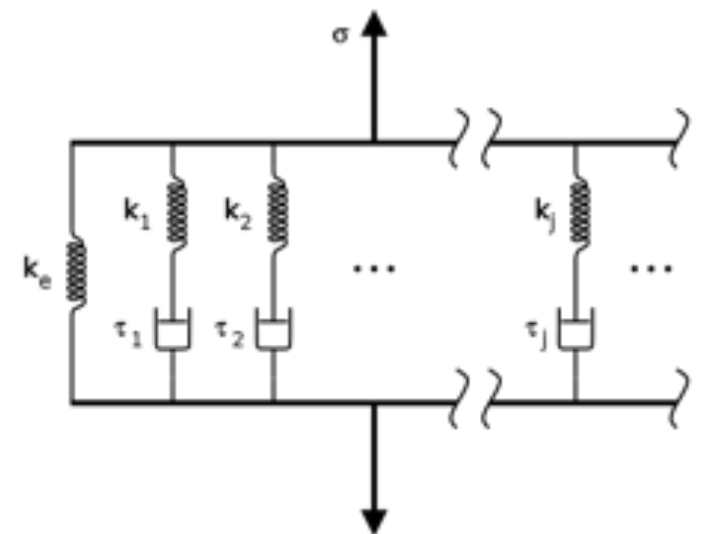
- Kelvin-Voigt model



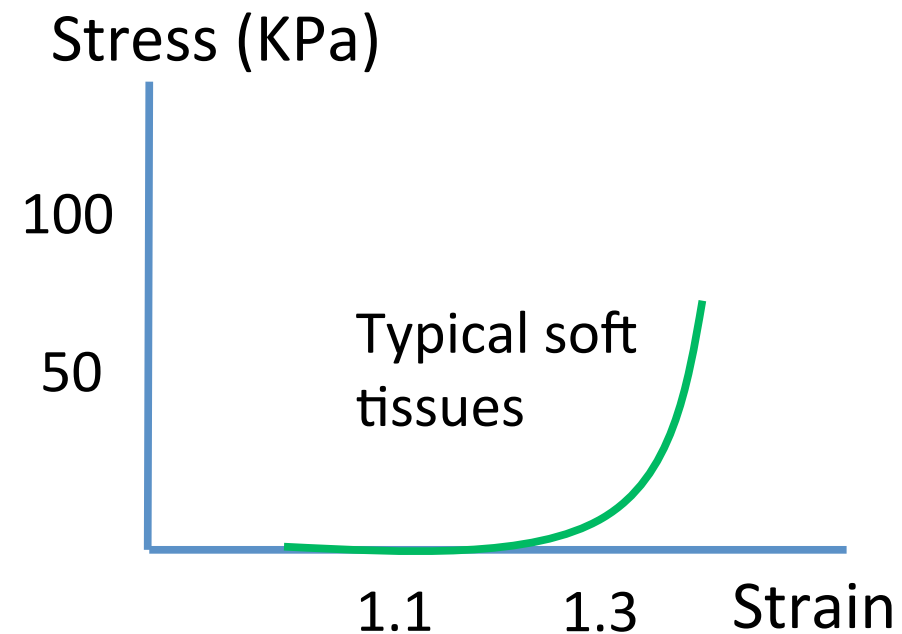
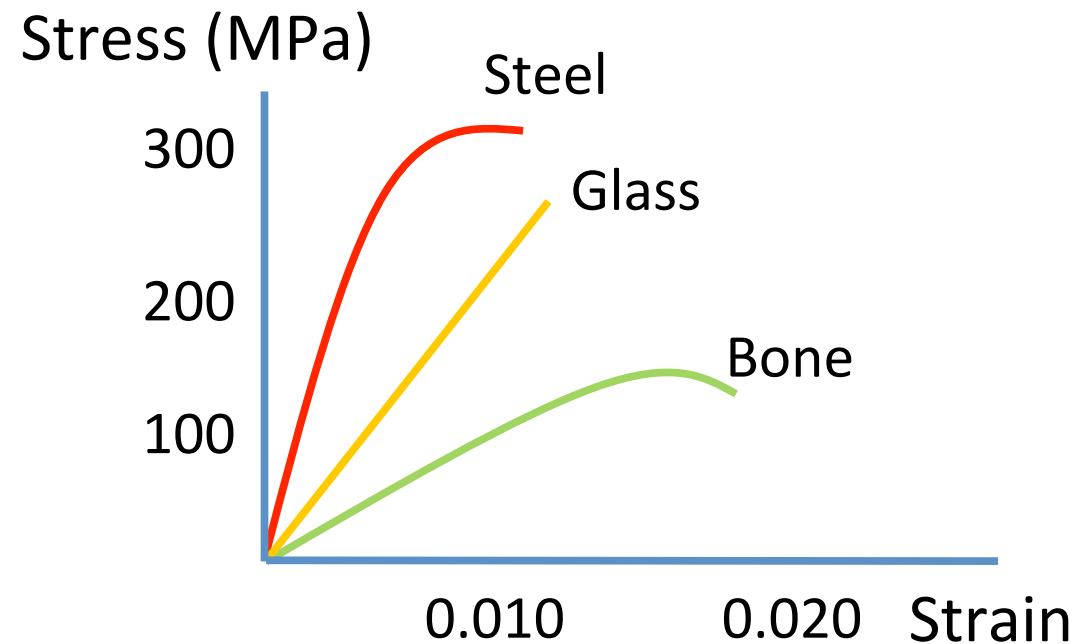
- Standard linear solid model



- Generalized Maxwell model



Variations of Elasticity



Humphrey (2003), *Proc. R. Soc. Lond. A* 459:3-46

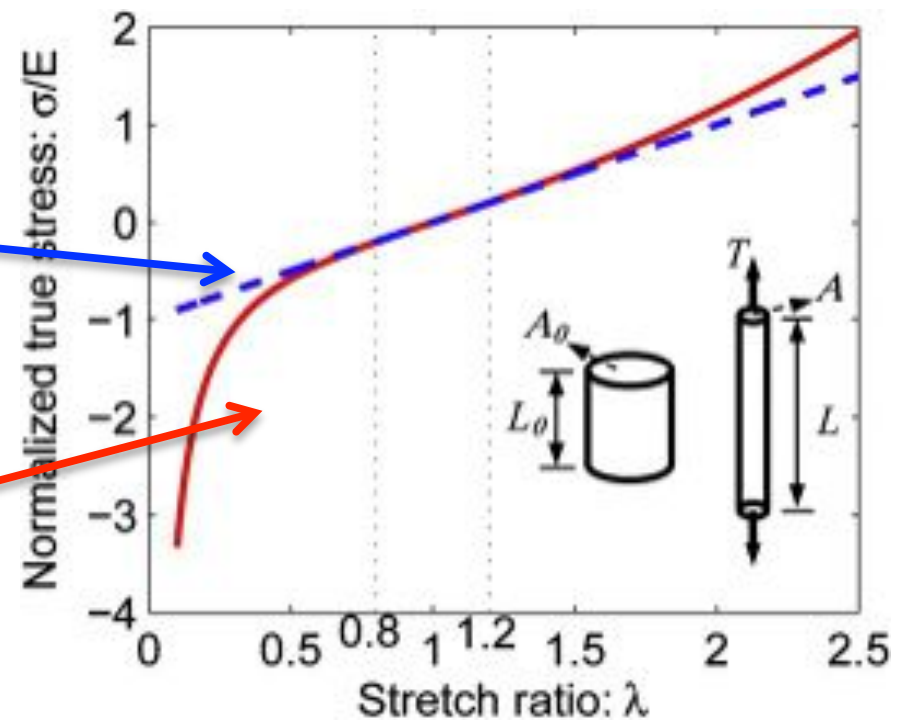
Hooke's law

$$\sigma_T = E \cdot \varepsilon_E = E(\lambda - 1)$$

Neo Hookean solids

$$\sigma_T = 2C_1\left(\lambda_2 - \frac{1}{\lambda}\right)$$

$$\therefore \left. \frac{d\sigma_T}{d\lambda} \right|_{(\lambda=1)} = E \quad \therefore C_1 = \frac{E}{6}$$



Long et al. (2011) *Biophys. J.*, 101(3):643-650

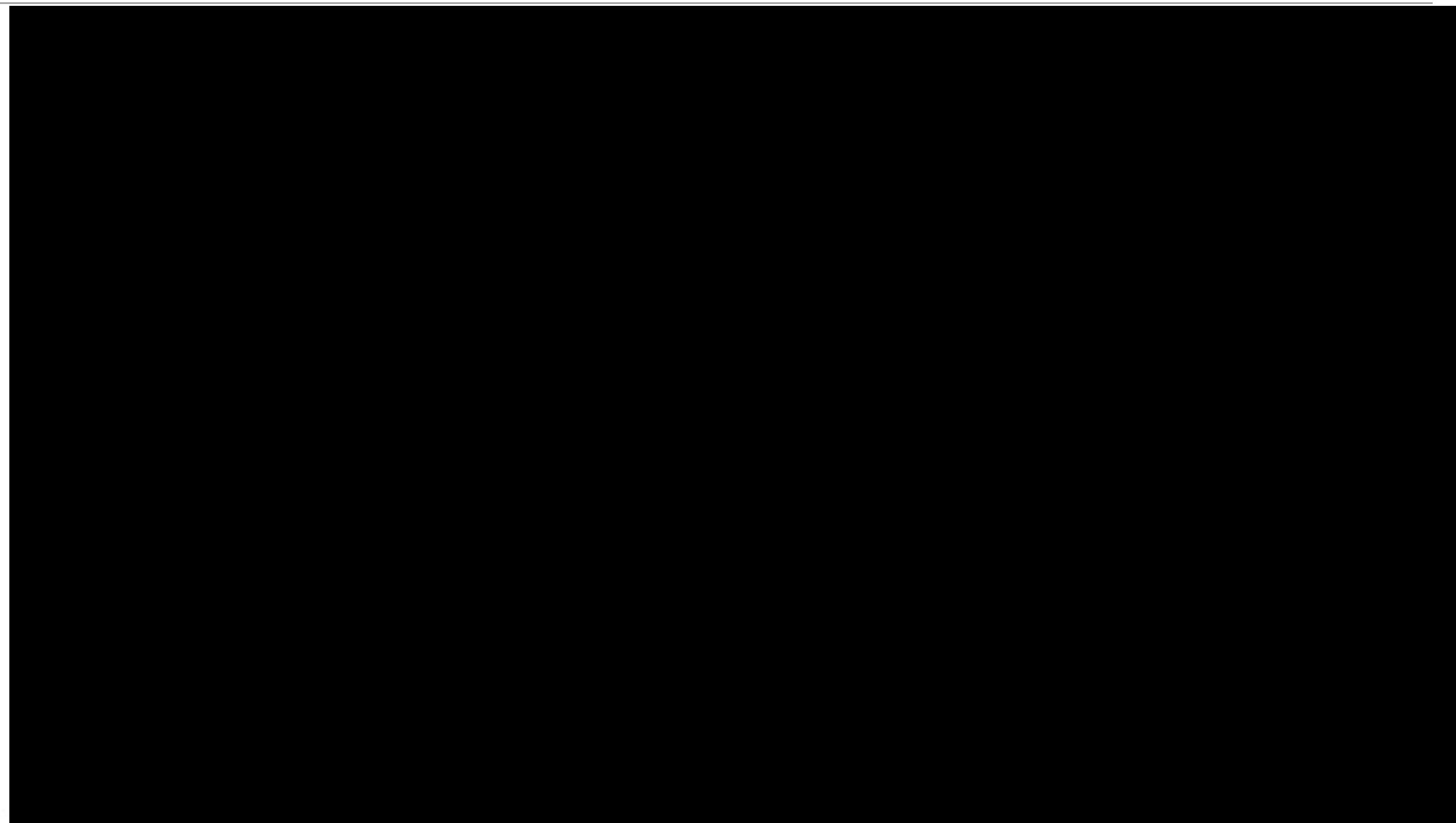
Nature: soft robots



<http://www.nature.com/news/meet-the-soft-cuddly-robots-of-the-future-1.19285>



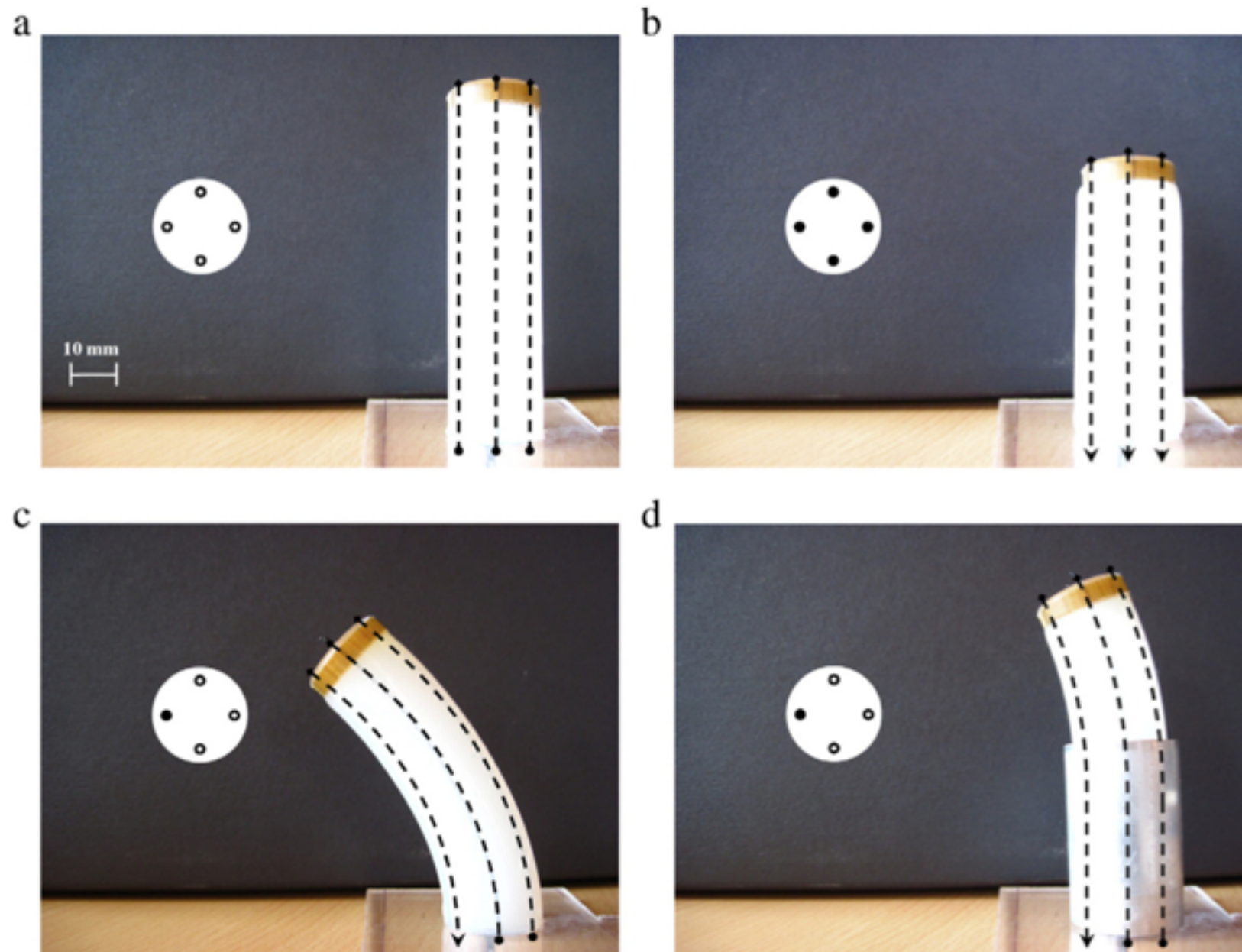
Barry Trimmer



Beispiel 1: Octopus Arm



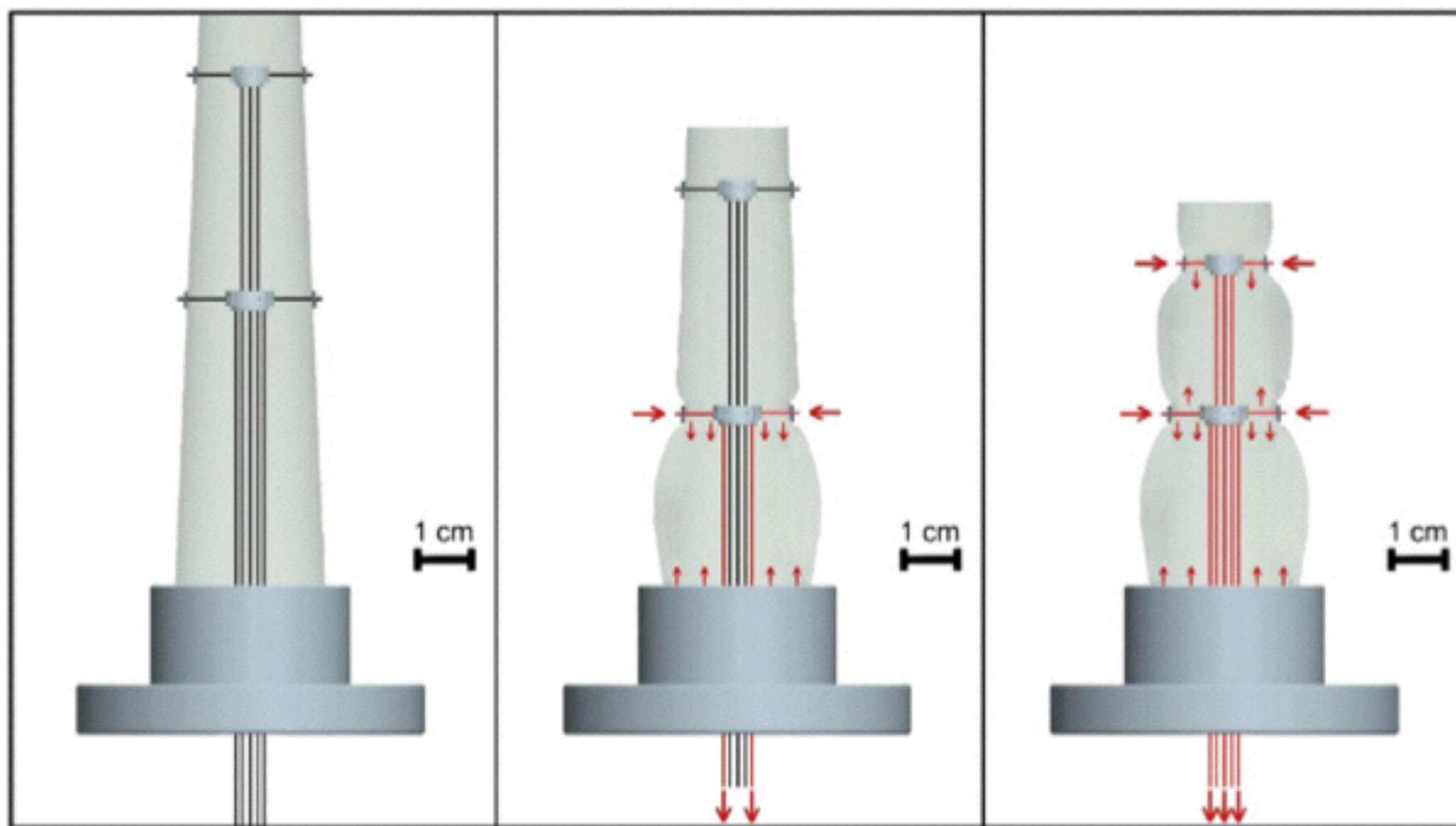
Beispiel 1: Octopus Arm



Cianchetti et al. / Materials Science and Engineering C 31 (2011)

Dr. Daniel Häufle¹¹

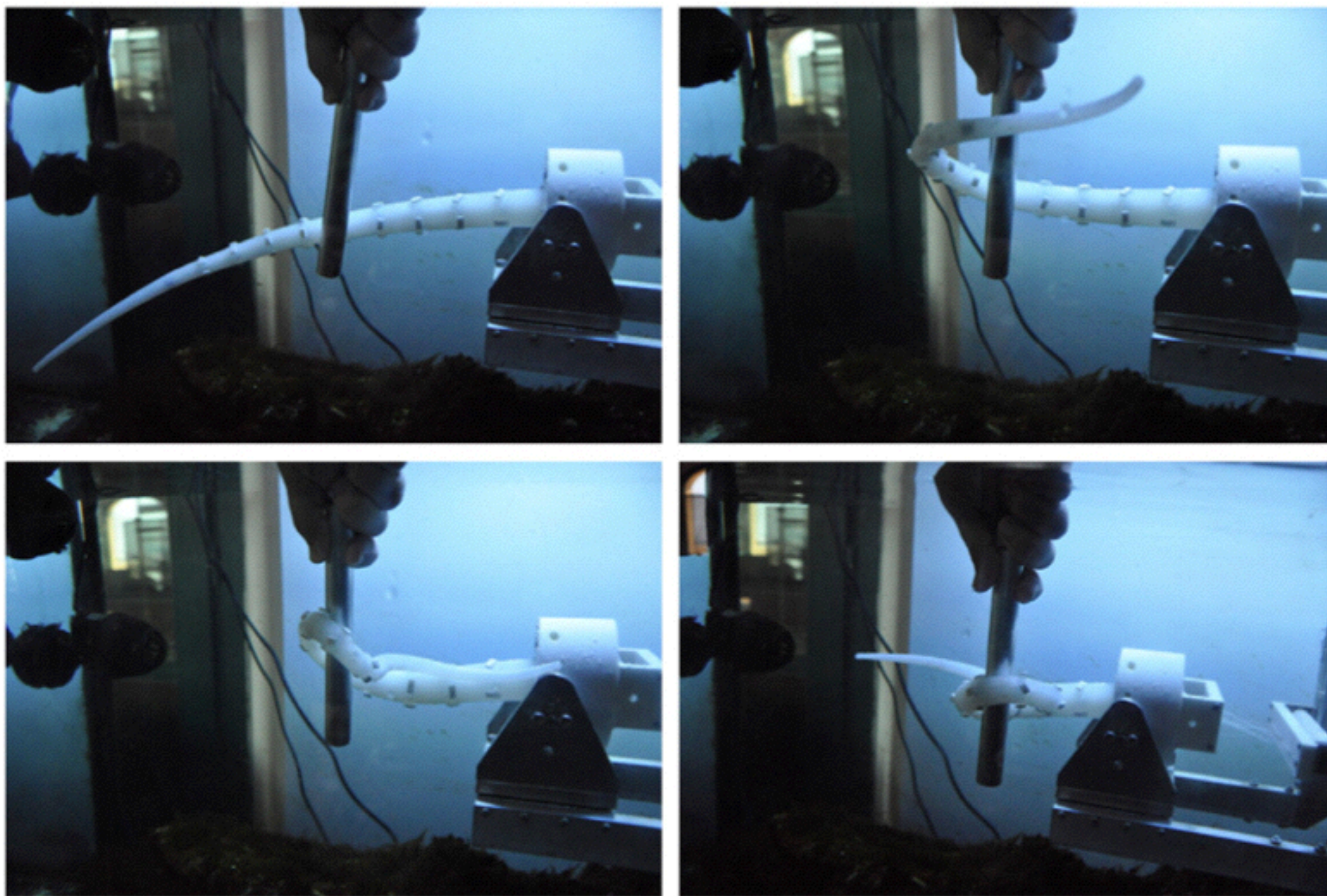
Beispiel 1: Octopus Arm



Cianchetti et al. / Materials Science and Engineering C 31 (2011)

Dr. Daniel Häufle¹²

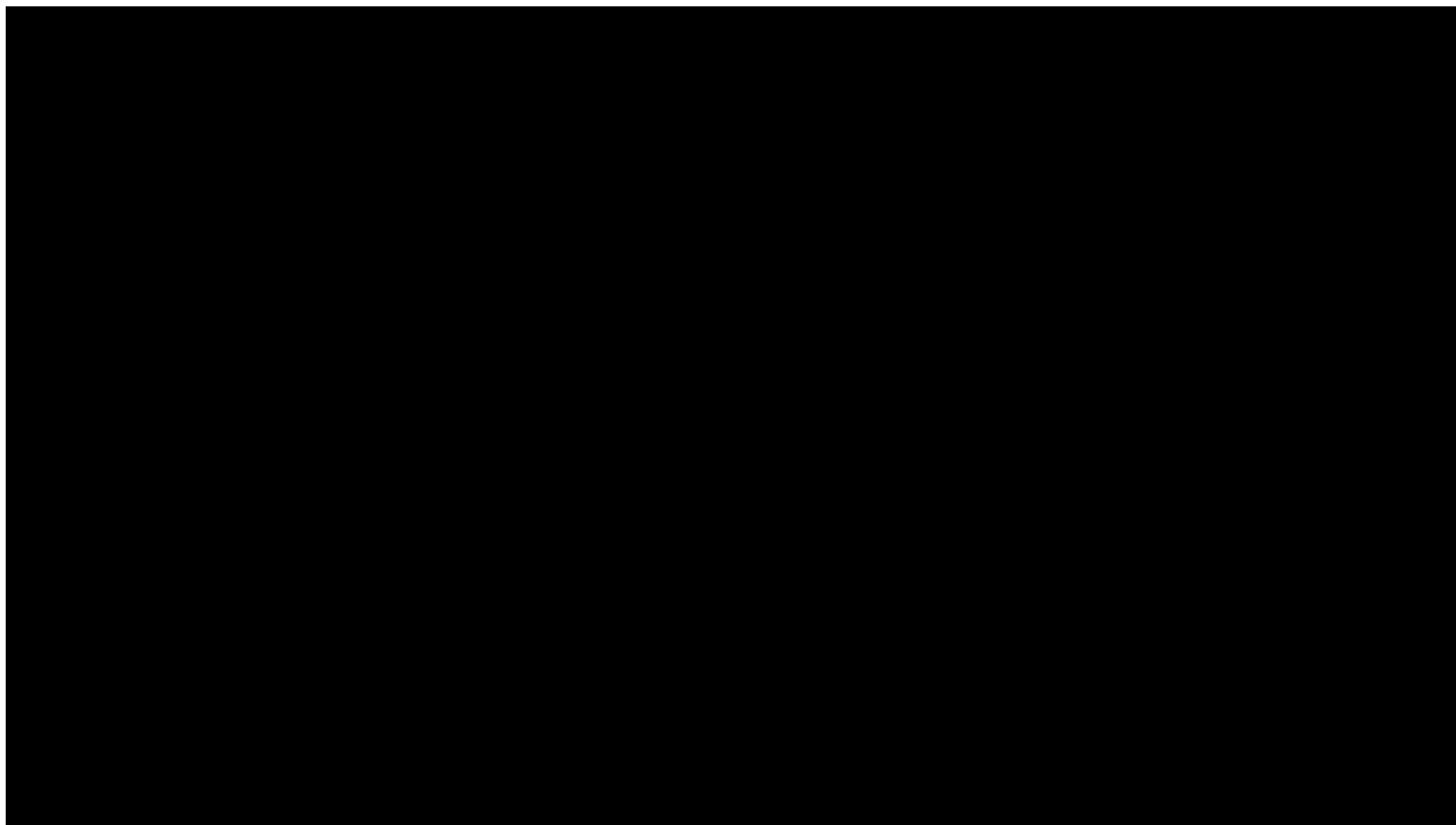
Beispiel 1: Octopus Arm



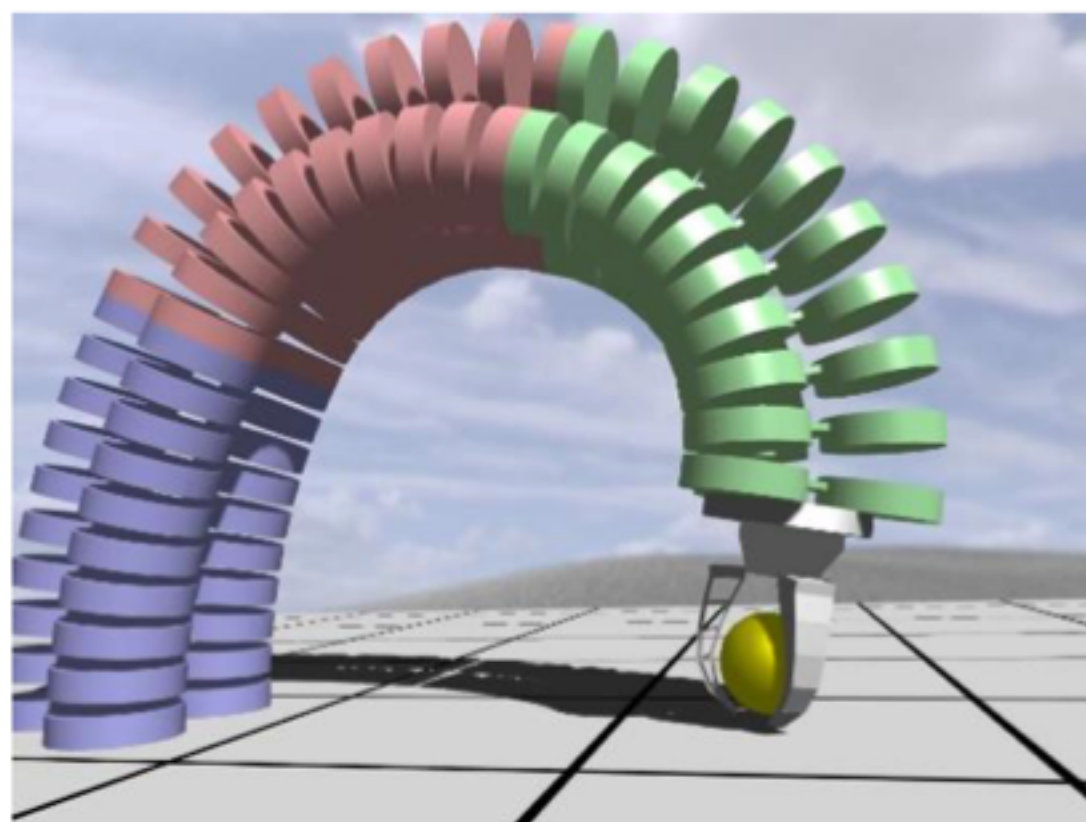
Cianchetti et al. / Materials Science and Engineering C 31 (2011)

Dr. Daniel Häufle¹³

Festo Bionic Handling Assistant



Festo Bionic Handling Assistant



Roßmann et al. 2015

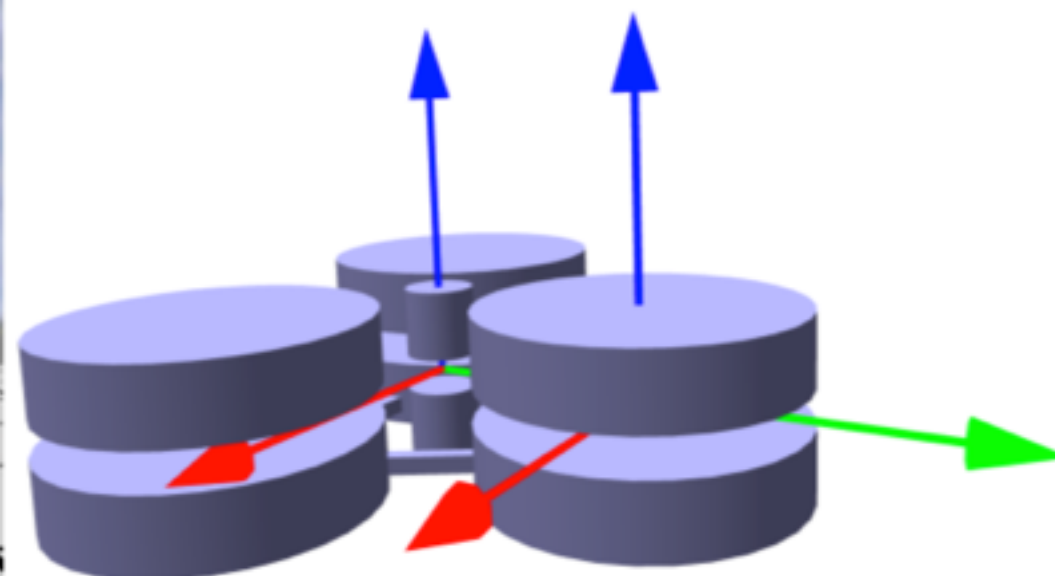


Fig. 10.7 Simulation of the FESTO Bionic Handling Assistant

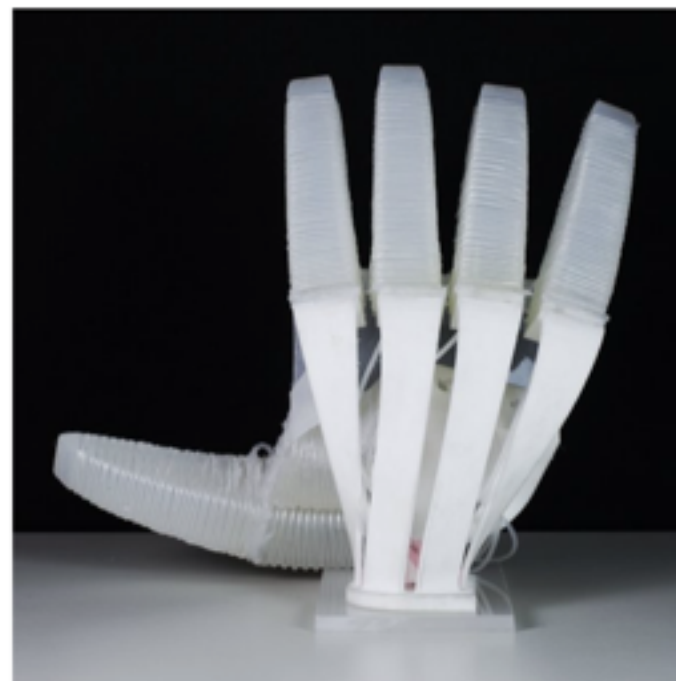
Ansatz: Starre Körper,
Feder-Dämpfer Elemente

$$\ddot{x} = F/m$$

$$F = -k\Delta x - d\Delta \dot{x}$$

Compliant and Underactuated Robotic Hand

Deimel & Brock 2015





Compliant and Underactuated Robotic Hand

Deimel & Brock 2015

A Novel Type of Compliant, Underactuated Robotic Hand for Dexterous Grasping

Raphael Deimel and Oliver Brock
Robotics and Biology Lab, Berlin UT

Feix Grasps

Multimedia Extension #4

International Journal of Robotics Research



Compliant and Underactuated Robotic Hand

Deimel & Brock 2015

A Novel Type of Compliant, Underactuated Hand for Dexterous Grasping

Raphael Deimel and Oliver Brock

"5 Example Grasps from a Table"

Multimedia Extension #5

International Journal of Robotics Research



Compliant and Underactuated Robotic Hand

Deimel & Brock 2015

A Novel Type of Compliant, Underactuated Hand for Dexterous Grasping

Raphael Deimel and Oliver Brock

"Heavy Objects"

Multimedia Extension #6

International Journal of Robotics Research

Compliant and Underactuated Robotic Hand

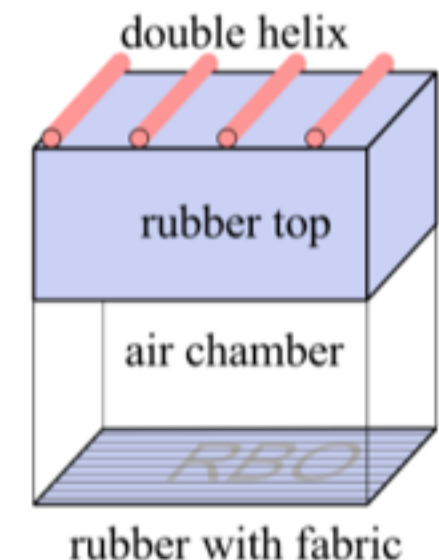
Deimel & Brock 2015



(a) An inflated PneuFlex actuator in front of deflated ones.



(b) Cut of a PneuFlex continuum actuator.

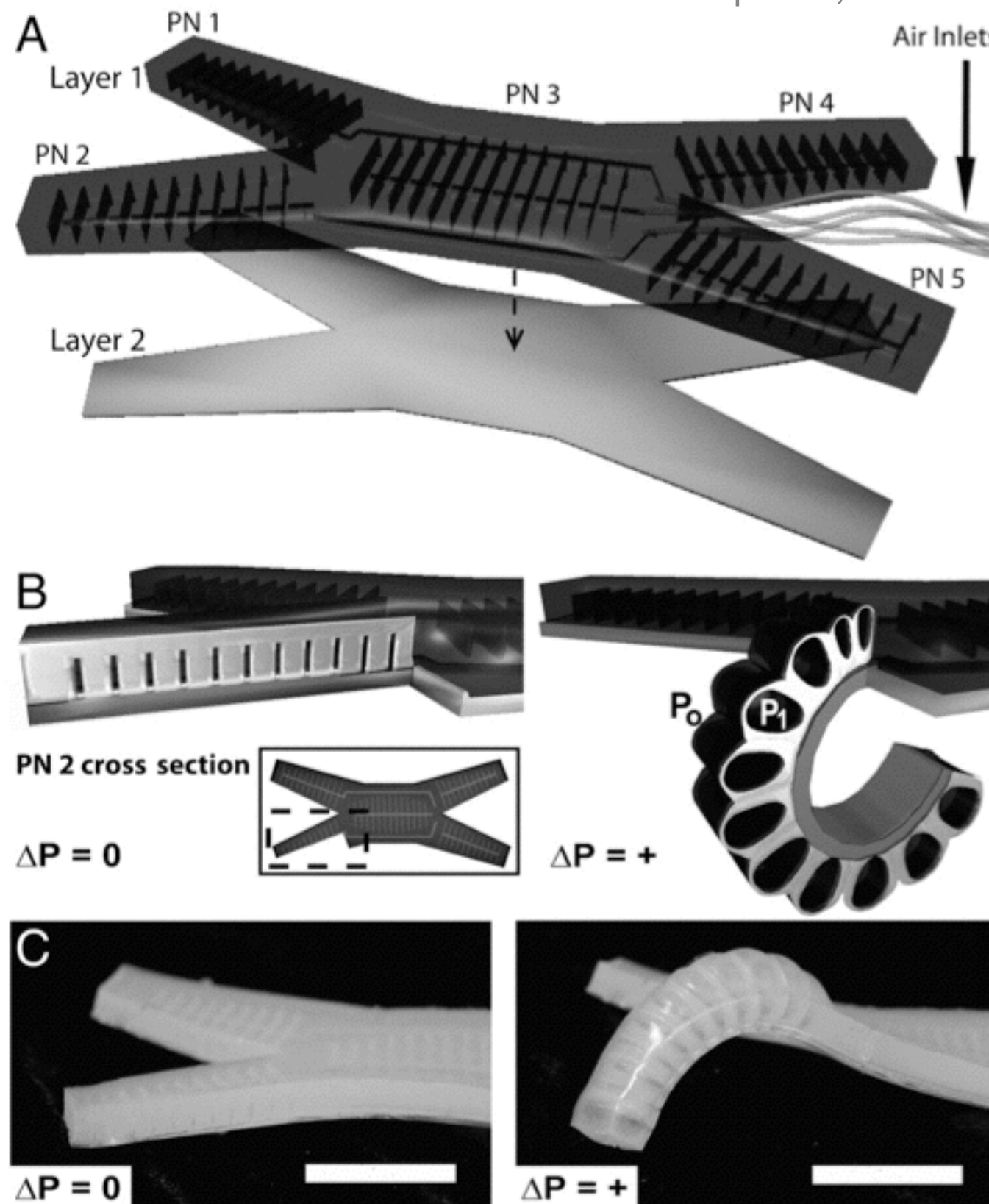


(c) Functional parts

discuss paper: A Novel Type of Compliant and Underactuated Robotic Hand for Dexterous Grasping
Raphael Deimel Oliver Brock, 2015 The International Journal of Robotics Research

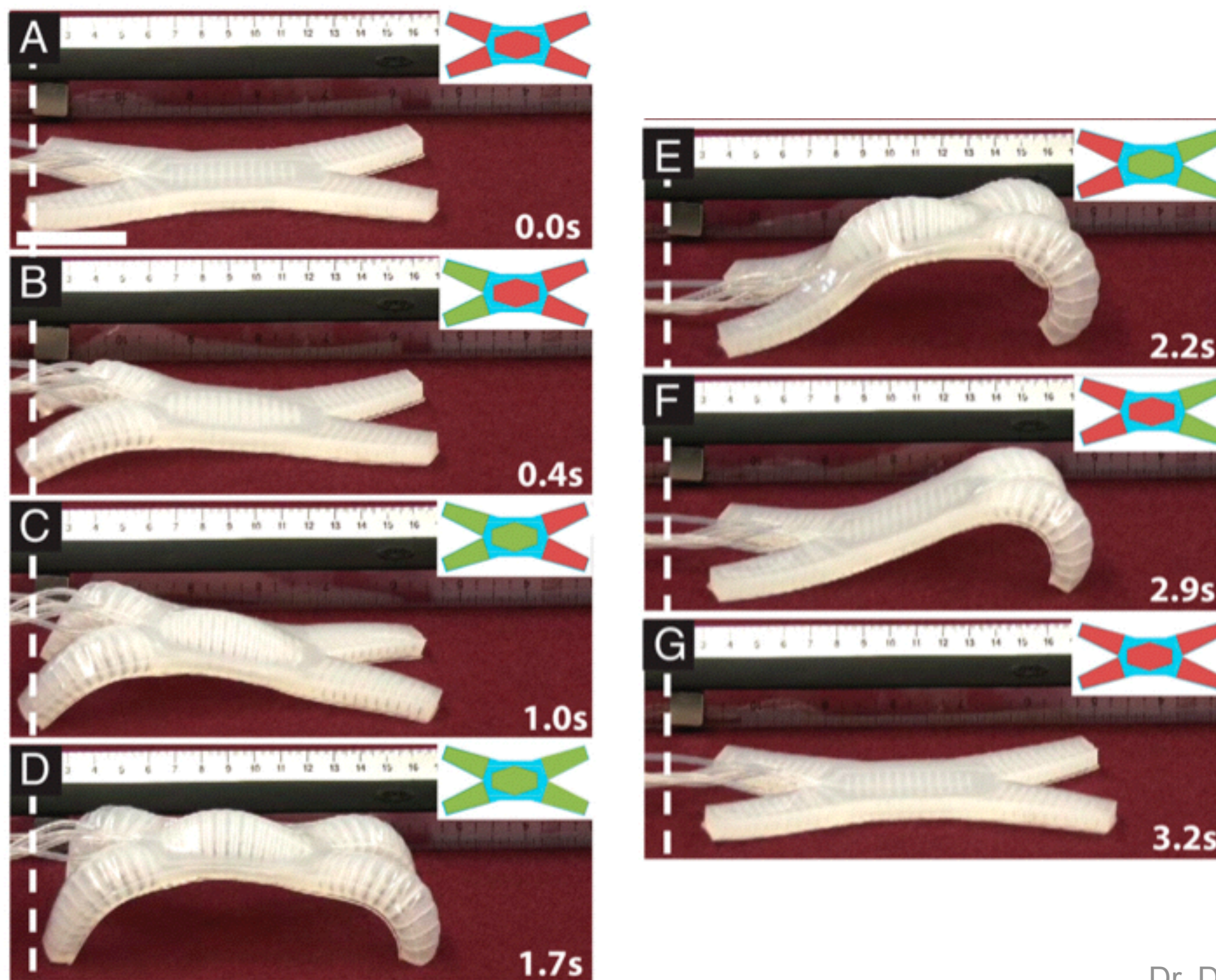
Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



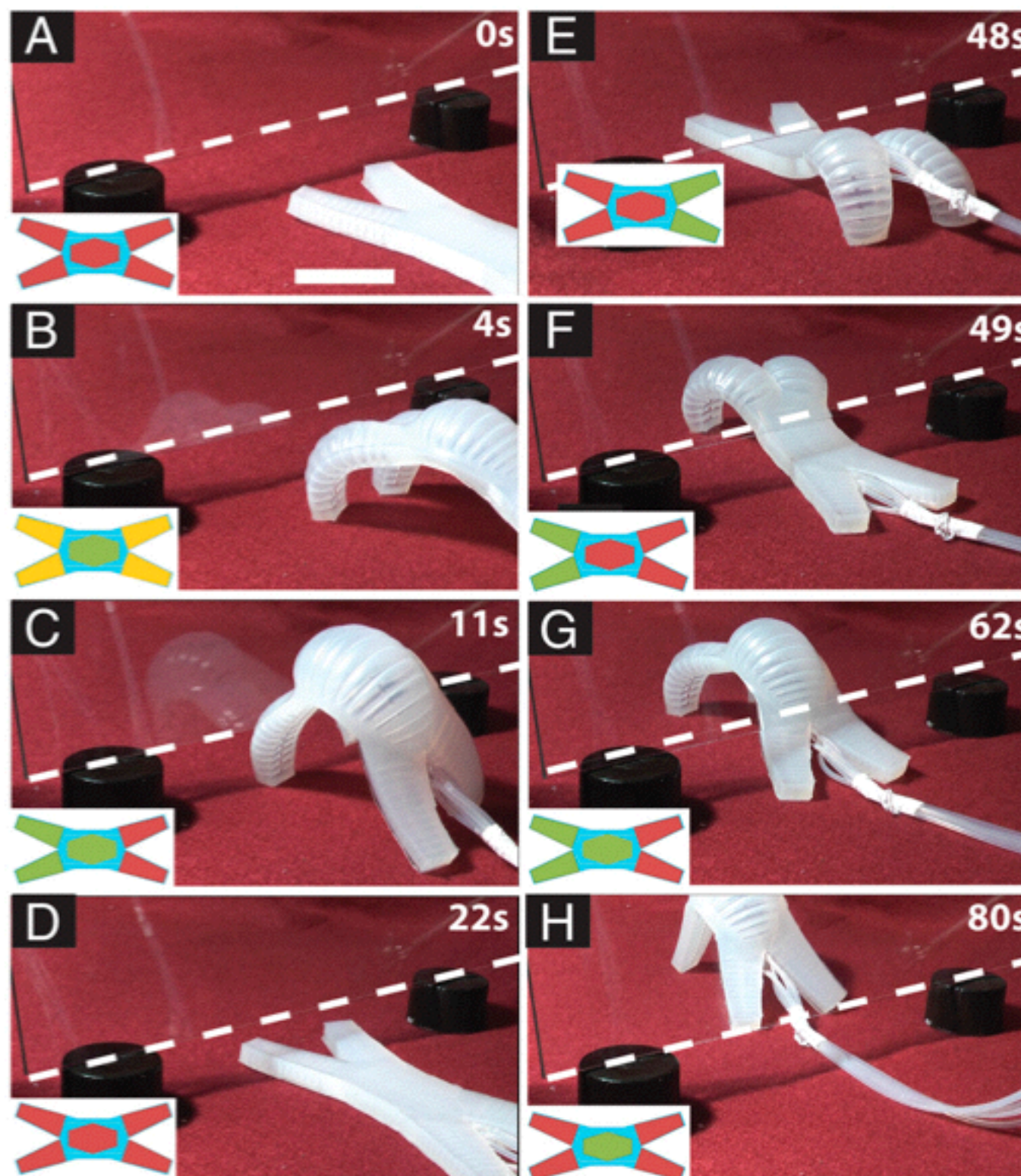
Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



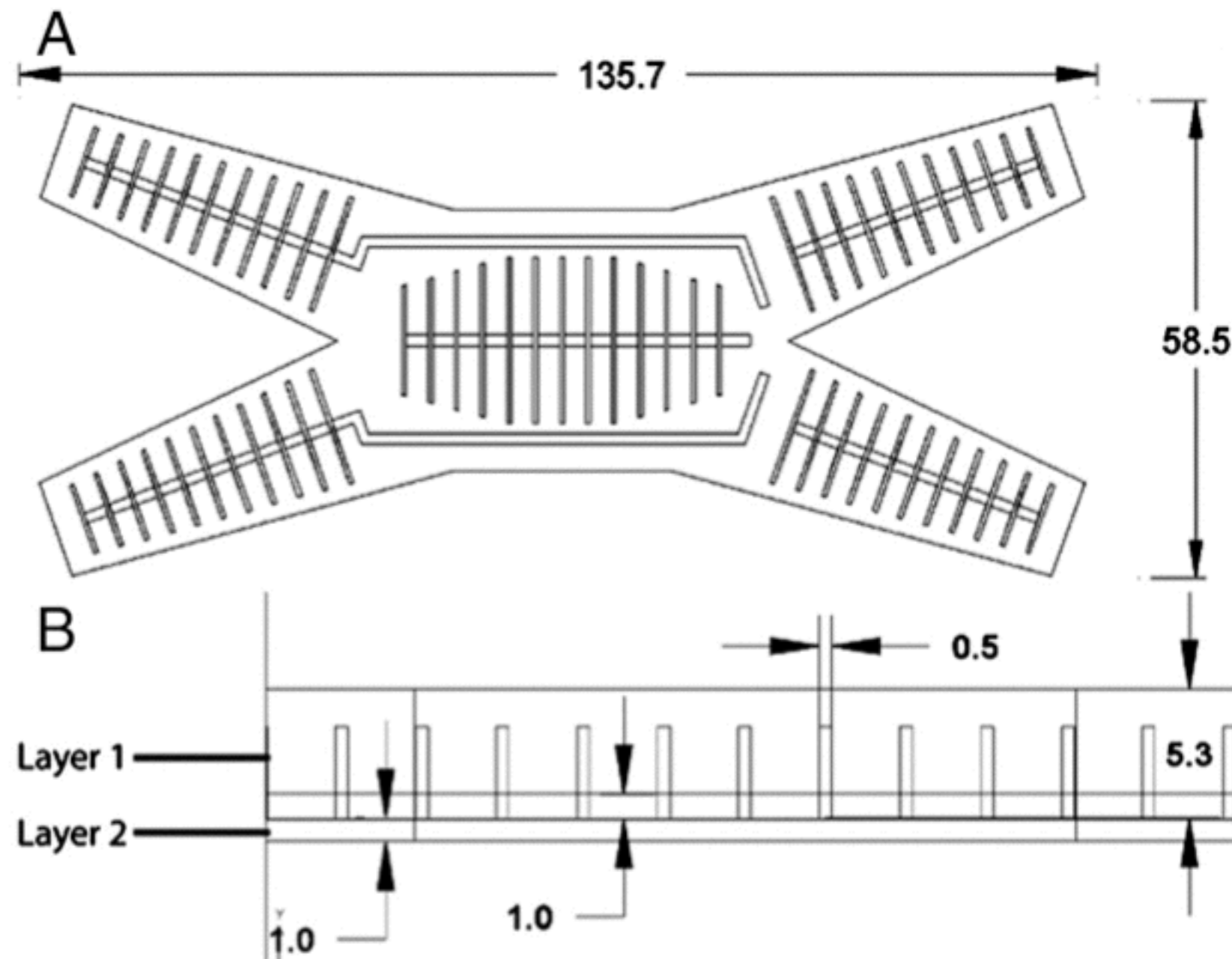
Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



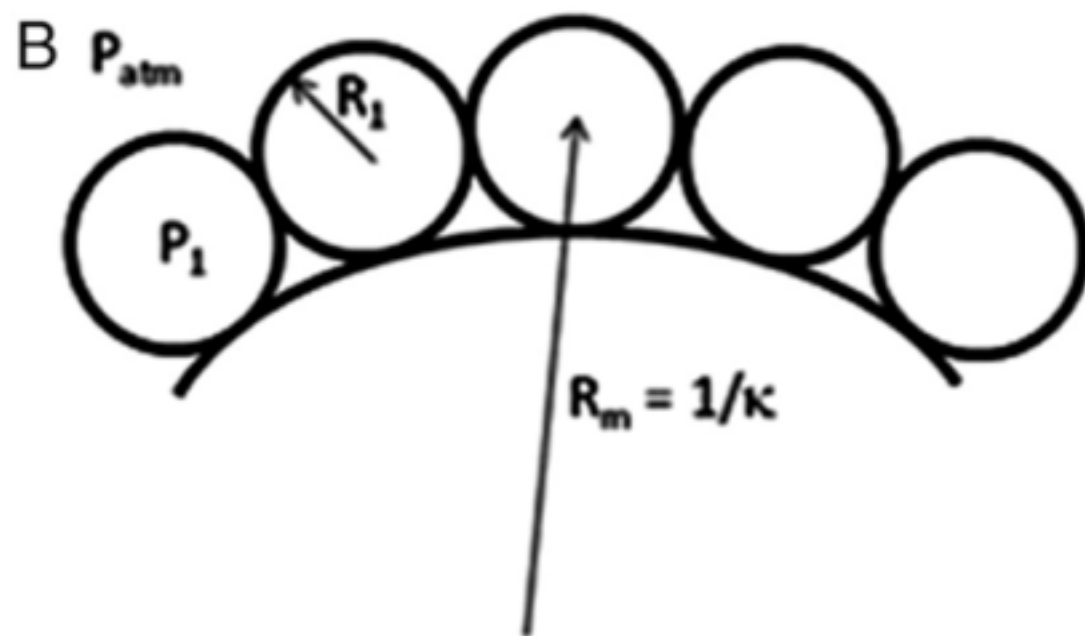
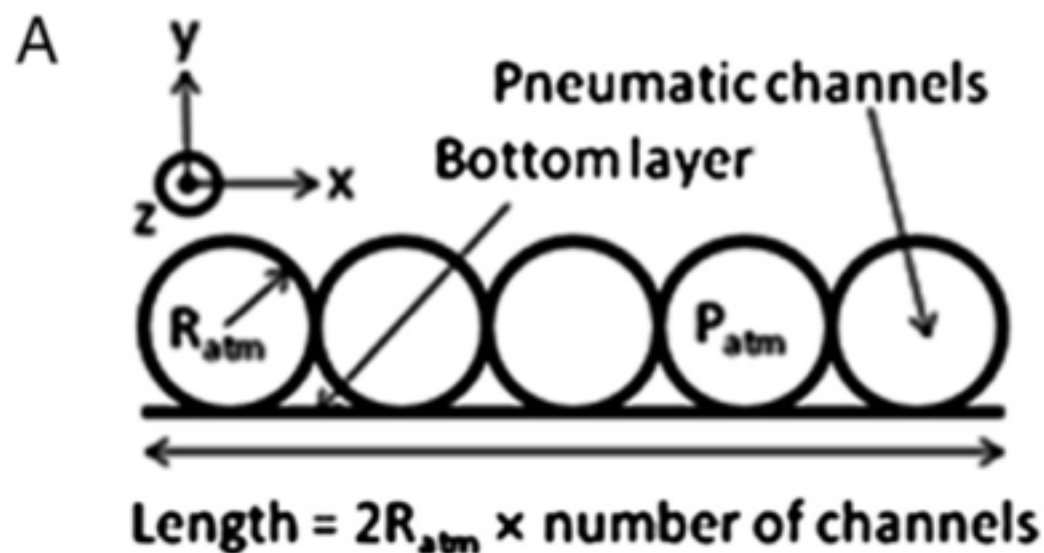
Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



$$\kappa = \frac{1}{R_{atm}} \cdot \frac{\chi - 1}{\chi^2}$$

$$\chi = \frac{R_1}{R_{atm}} = \frac{Et}{Et - R_{atm}(P_1 - P_{atm})}$$

R: Radien

E: Elastizitätsmodul

t: Dicke des Materials

P: Drücke

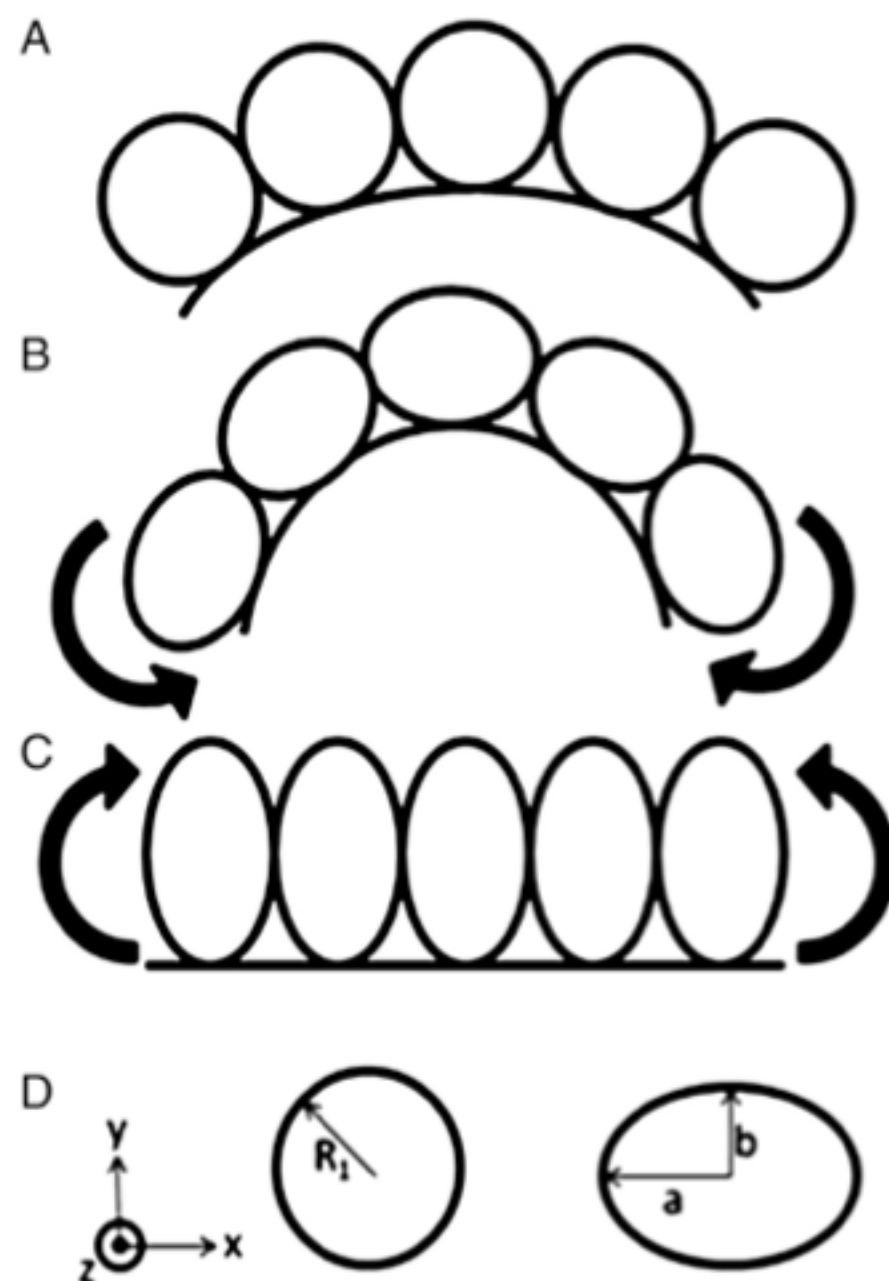
Indizes:

atm: ohne zusätzlichen Druck

1: im Zustand unter Druck P_1

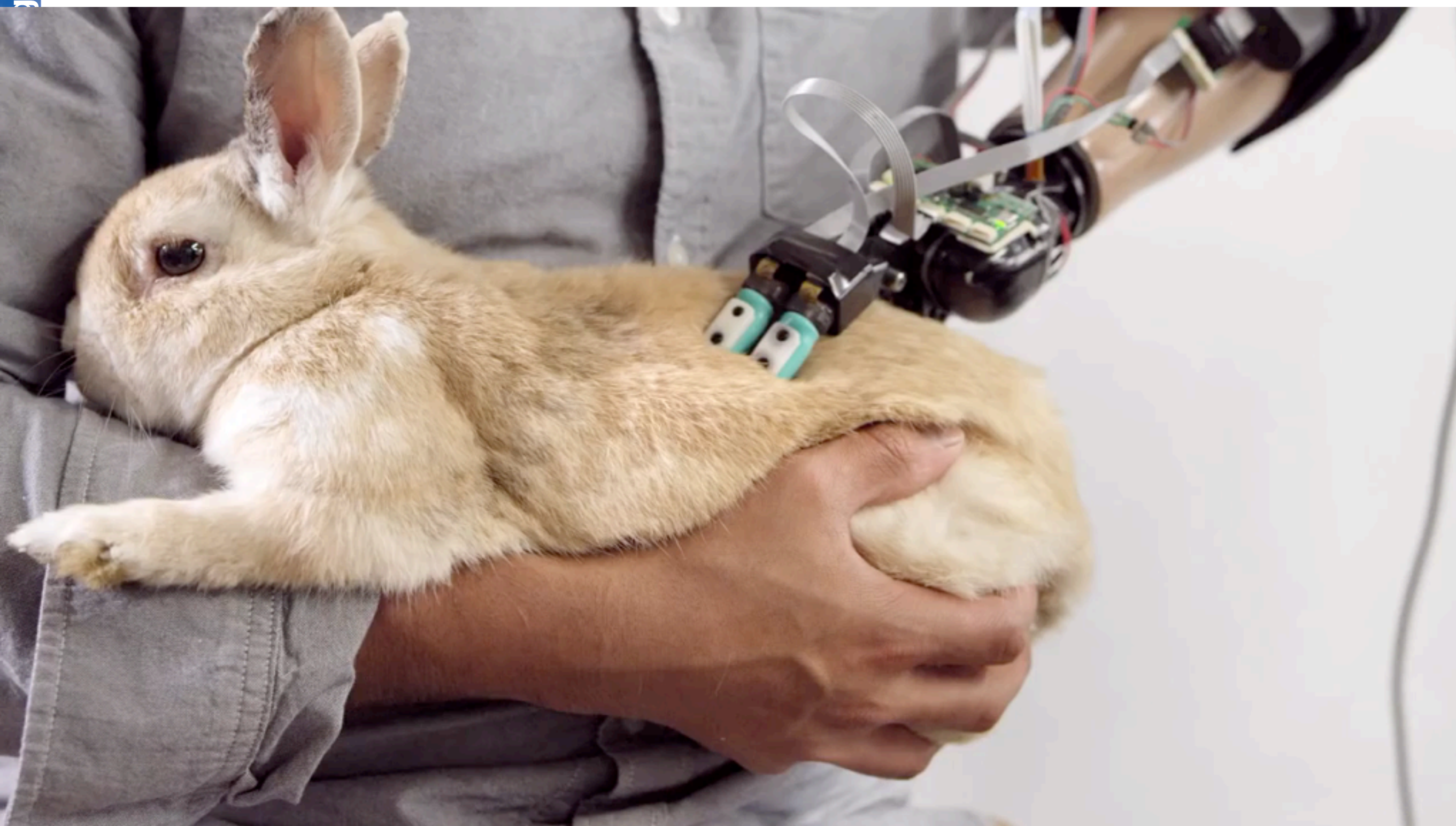
Beispiel 3: Multigait soft robot

Shepherd, et al. 2011. "Multigait Soft Robot."



Prosthetics

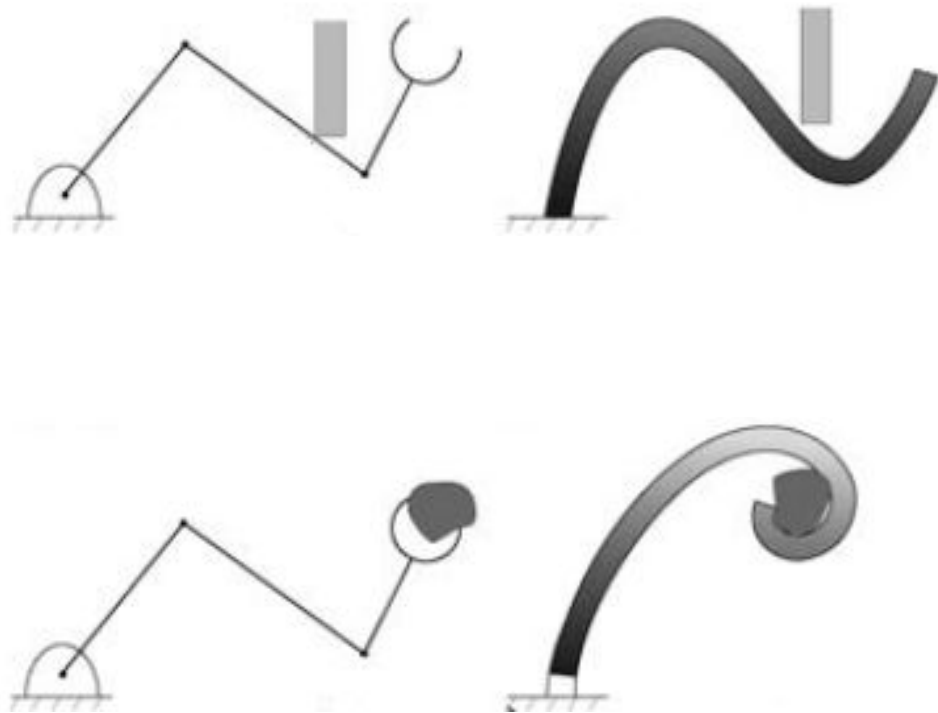
https://www.youtube.com/watch?v=GJ_Zki8e8Kw



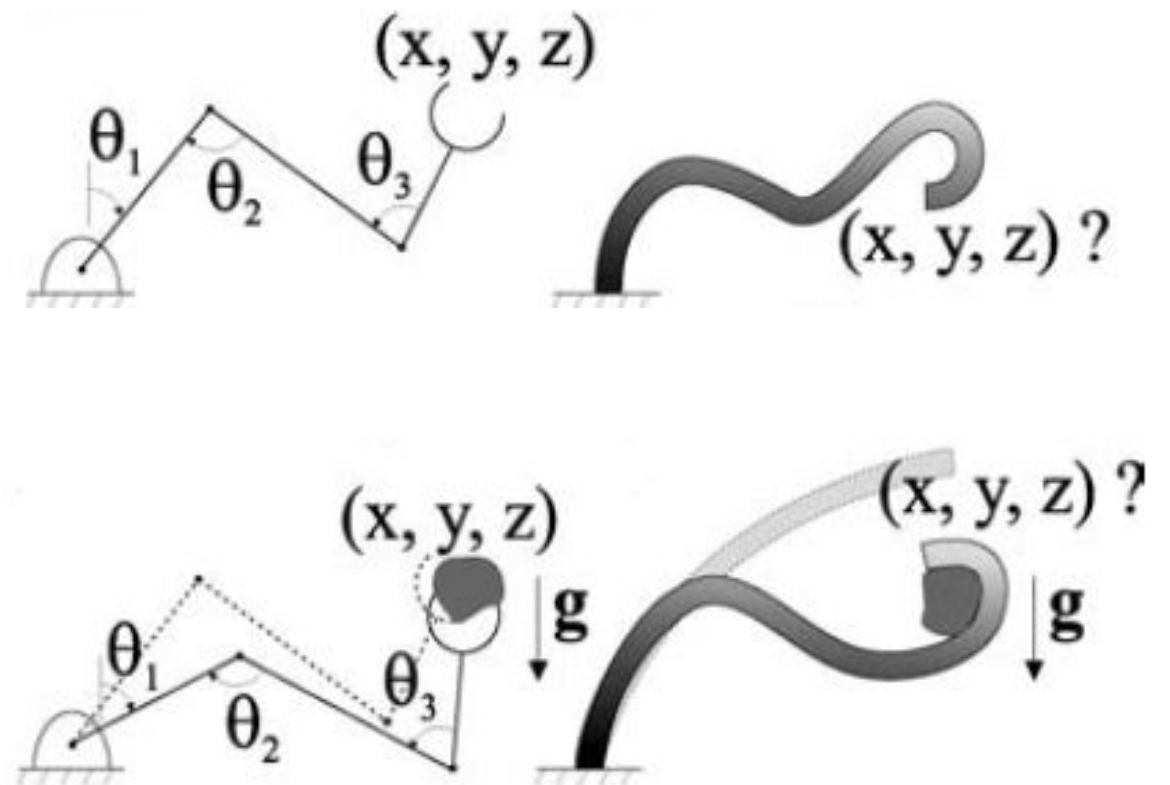
Soft-bodied robots: benefits and challenges



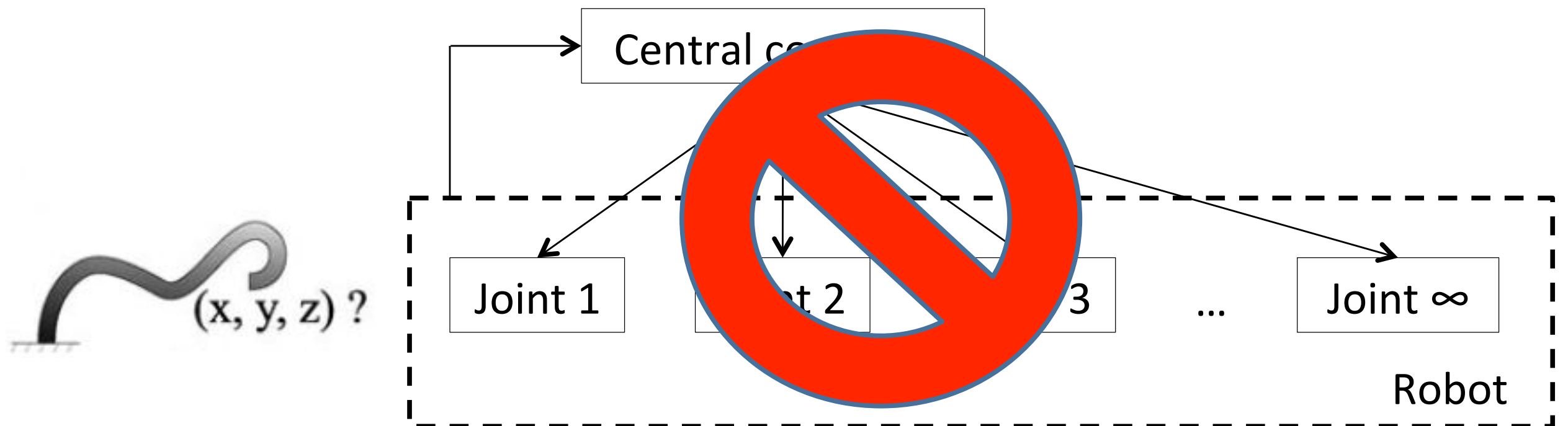
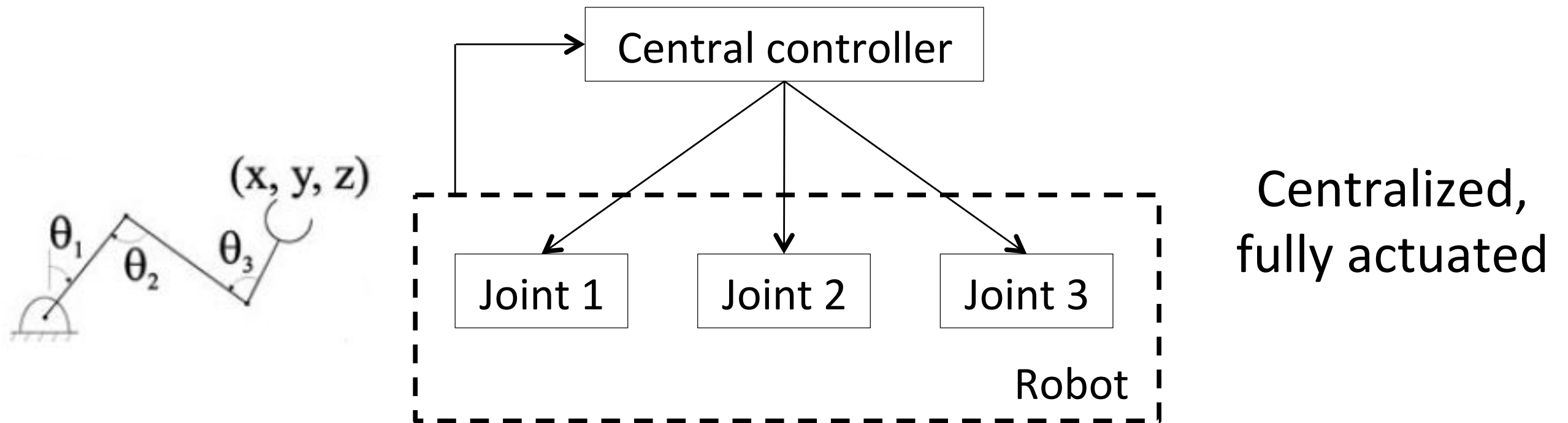
Benefits



Challenges



Classical control approach



Übersichtstabelle mit Eigenschaften

Table 1. Characteristics of different types of hard (first three columns) and soft robots.

	Rigid	Discrete hyperredundant	Hard continuum	Soft
Properties				
df	Few	Large	Infinite	Infinite
Actuators	Few, discrete	Many, discrete	Continuous	Continuous
Material strain	None	None	Small	Large
Materials	Metals, plastics	Metals, plastics	Shape memory alloy	Rubber, electroactive polymer
Capabilities				
Accuracy	Very high	High	High	Low
Load capacity	High	Lower	Lower	Lowest
Safety	Dangerous	Dangerous	Dangerous	Safe
Dexterity	Low	High	High	High
Working environment	Structured only	Structured and unstructured	Structured and unstructured	Structured and unstructured
Manipulable objects	Fixed sized	Variable size	Variable size	Variable size
Conformability to obstacles	None	Good	Fair	Highest
Design				
Controllability	Easy	Medium	Difficult	Difficult
Path planning	Easy	Harder	Difficult	Difficult
Position Sensing	Easy	Harder	Difficult	Difficult
Inspiration	Mammalian limbs	Snakes, fish		Muscular hydrostats

Trivedi et al. 2008

Dr. Daniel Häufle30