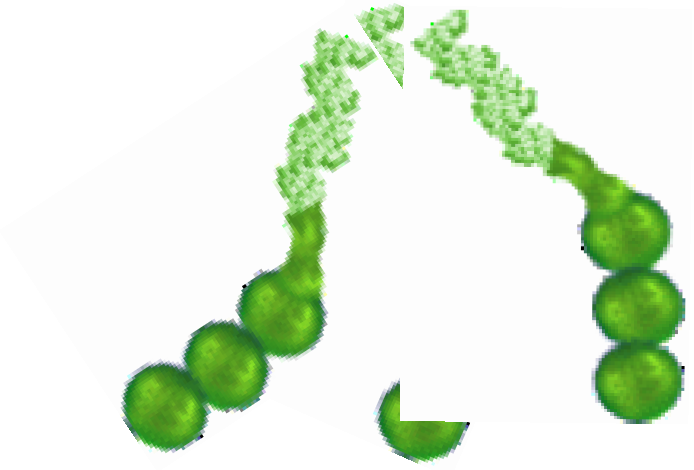
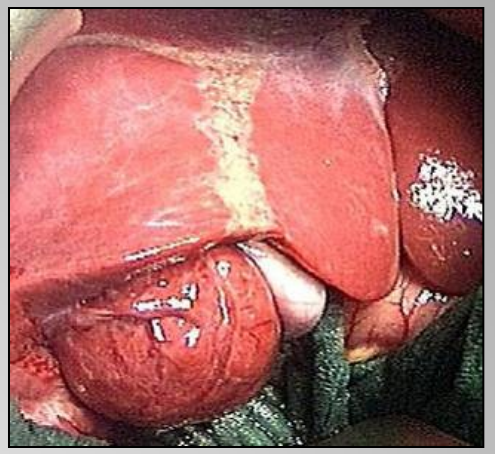
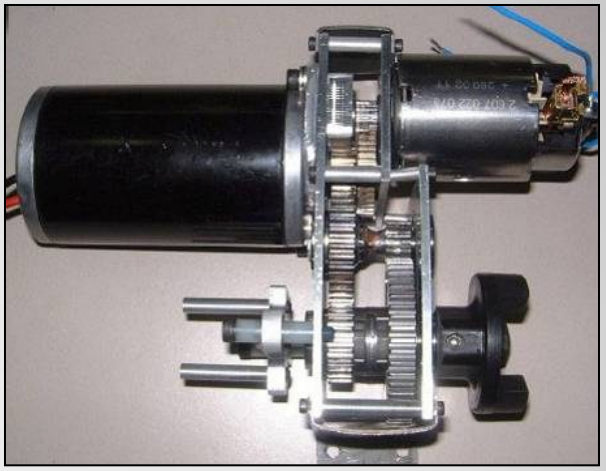
Living Machines:

Soft Animals, Soft Robots and Biohybrids



Robot materials vs animal tissues



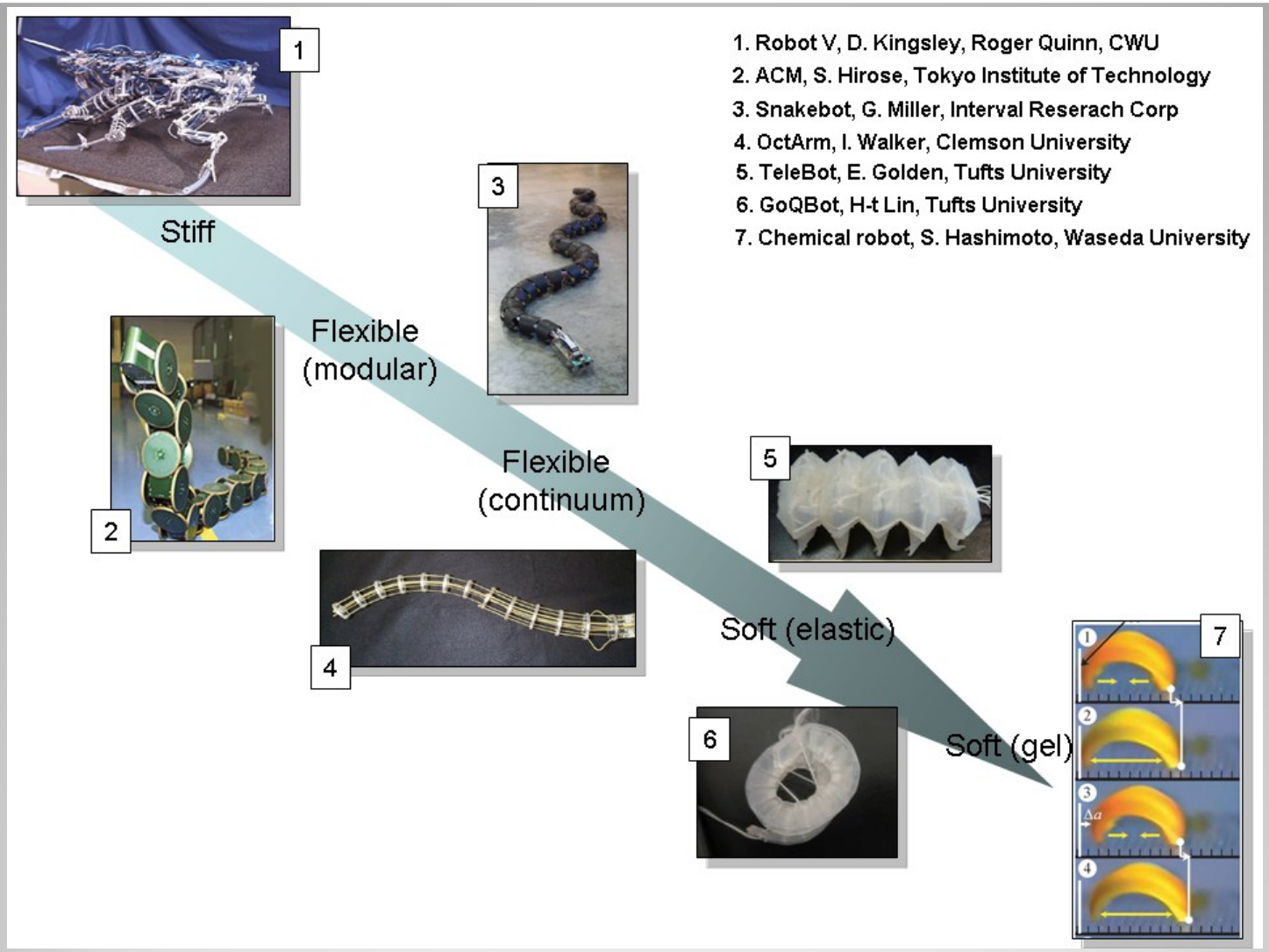


What is the meaning of soft?

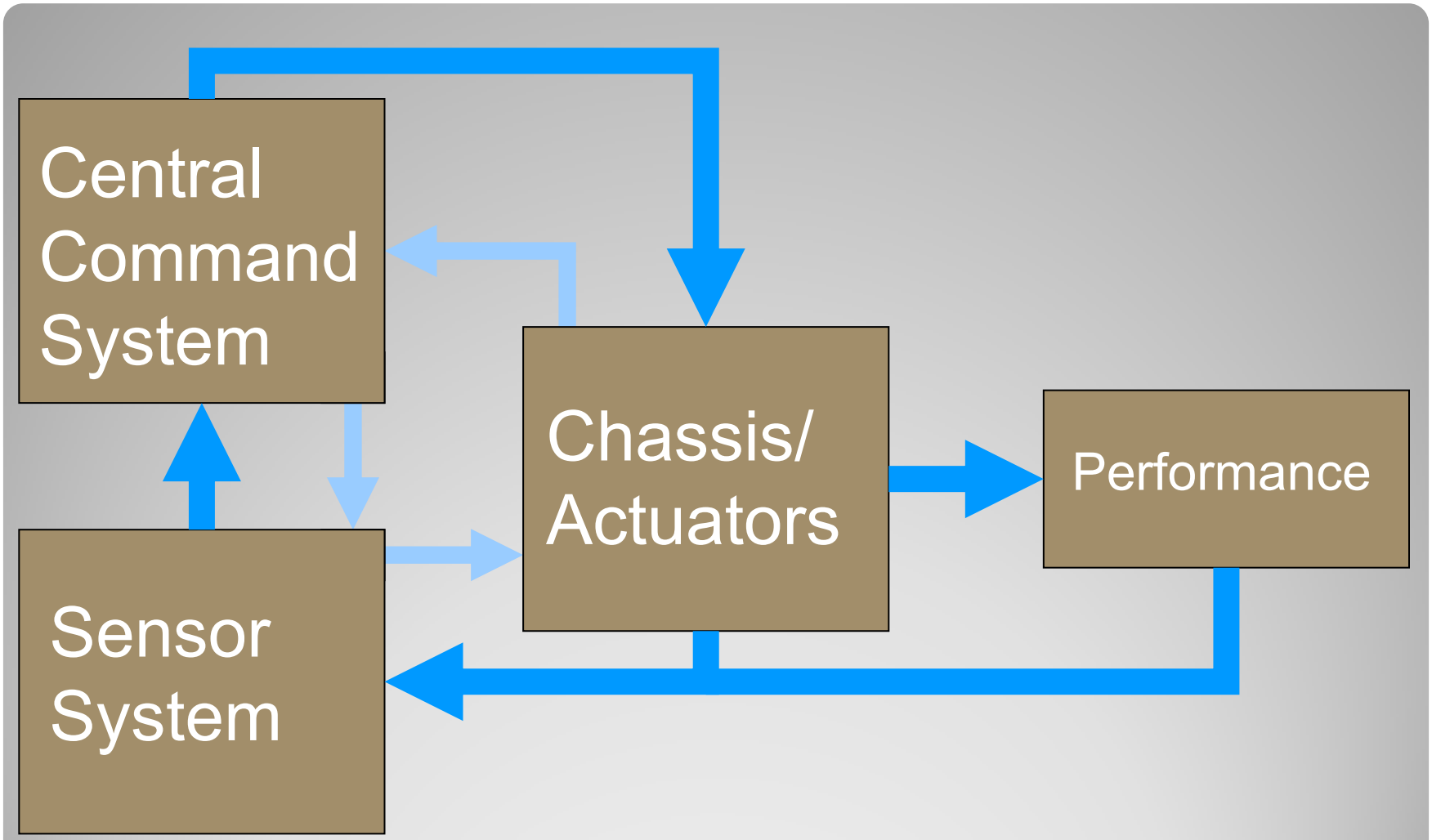
- Soft materials are easily deformed by the forces they normally encounter, this implies that for robots, soft is a relative term depending on size, mass and speed.
- Soft is not necessarily the opposite of hard or stiff however the bulk properties of soft materials are typically not hard or stiff
- Flexible materials are not necessarily very soft, flexible materials bend or twist but ultimately do not change their perimeter

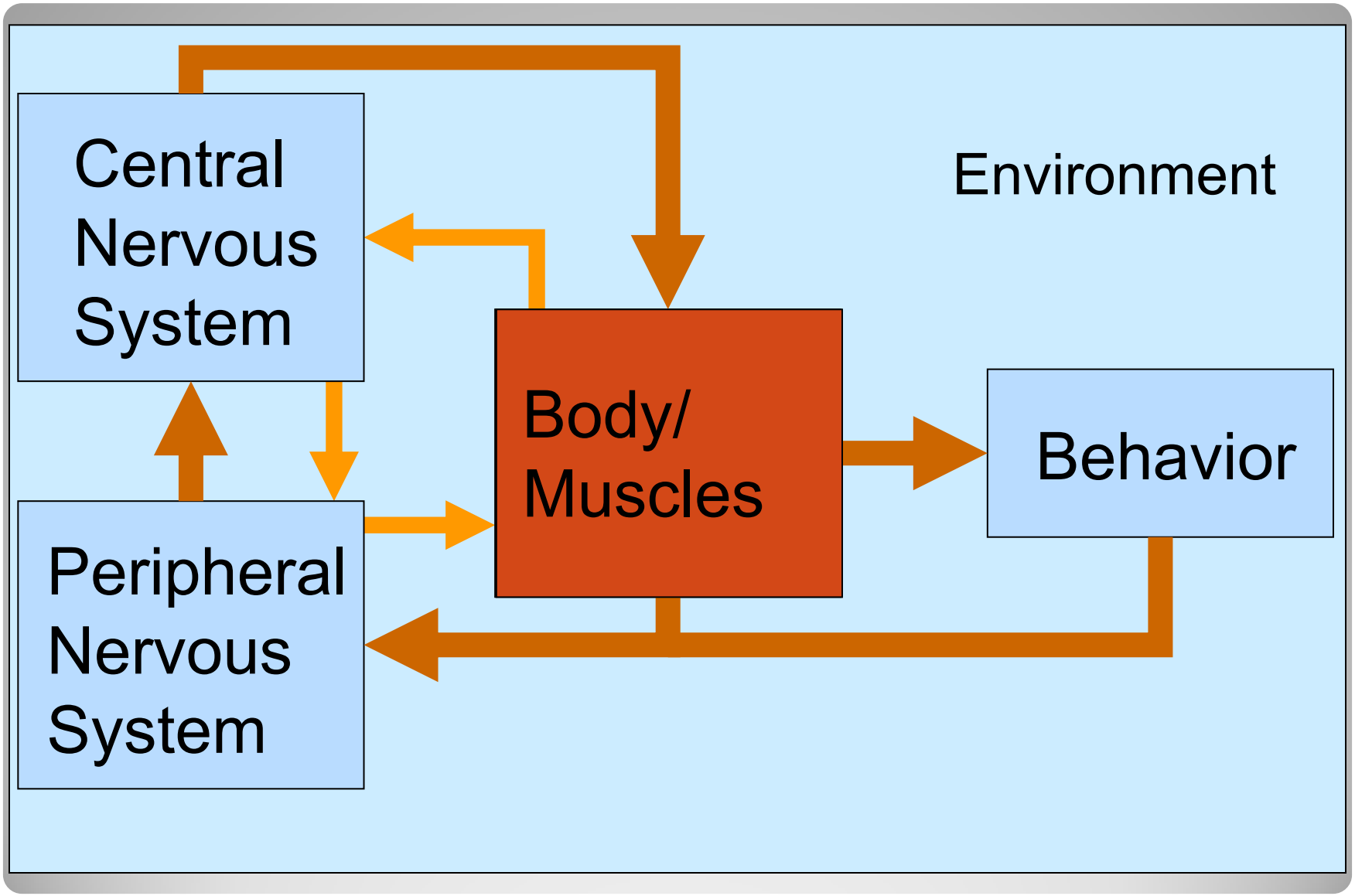
- Soft Robots are robust to sudden impact and large forces
- They can change shape and size to access denied spaces
- They can be made safe for use in human and natural environments
- They have better potential for interfacing with tissues
- They could be extremely cheap to produce
- They could be extremely light and low density
- They can be biodegradable and biocompatible

Soft robots
– the path to organic machines

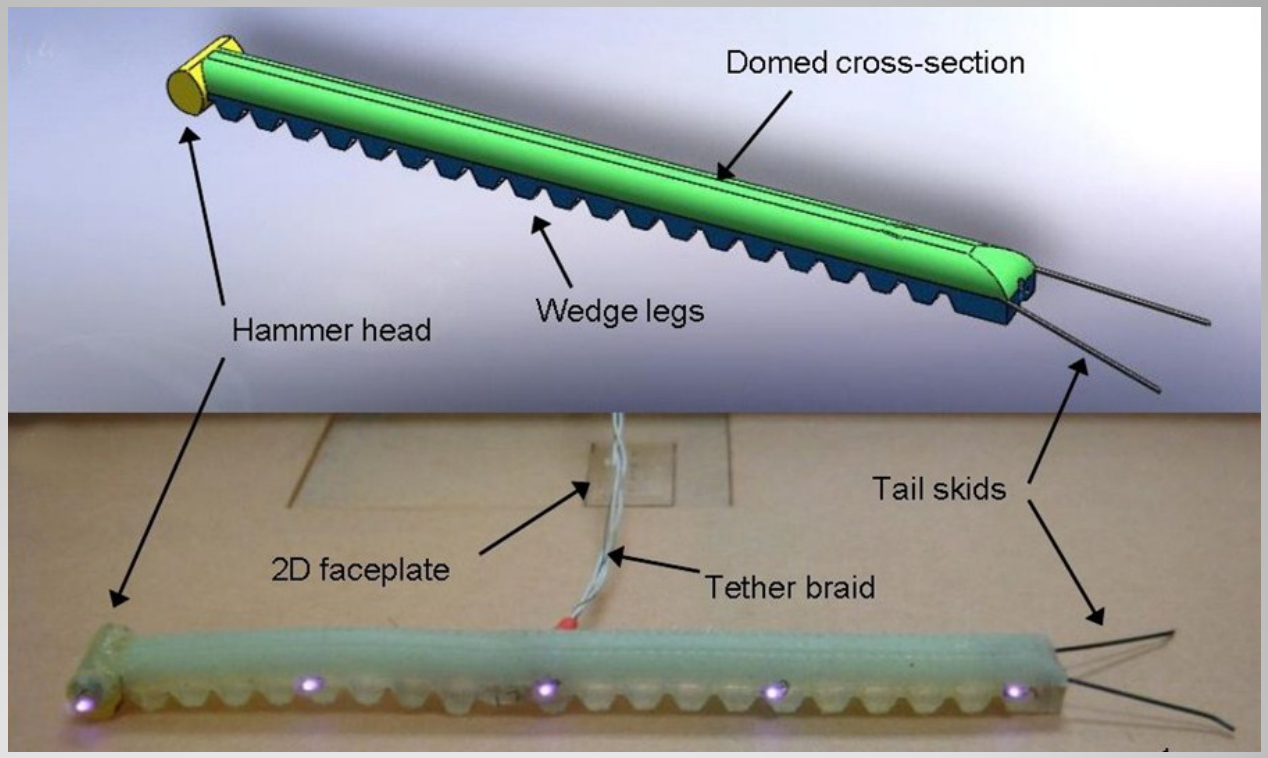


Compliance in biomimetic robots


Central Command System
Chassis/ Actuators
Performance
Sensor System

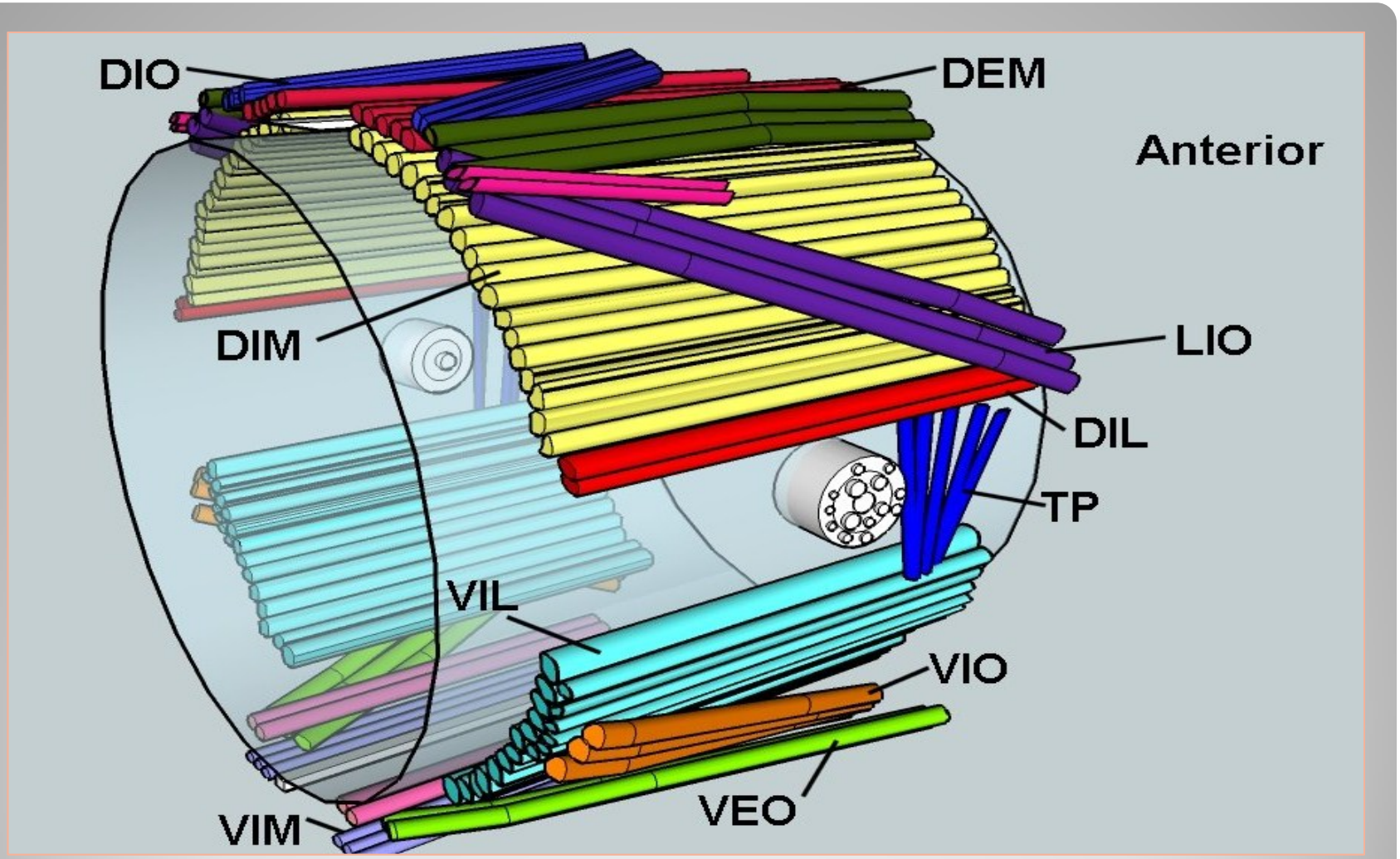

Central Nervous System
Environment
Body/ Muscles
Behavior
Peripheral Nervous System

- Biological
- Synthetic



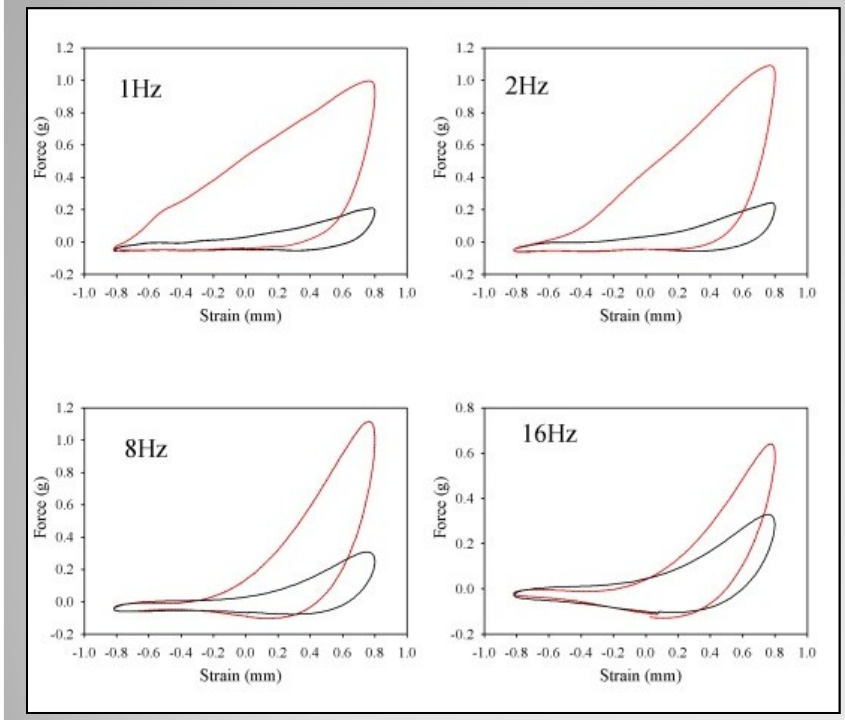
Movie 1. Manduca crawl

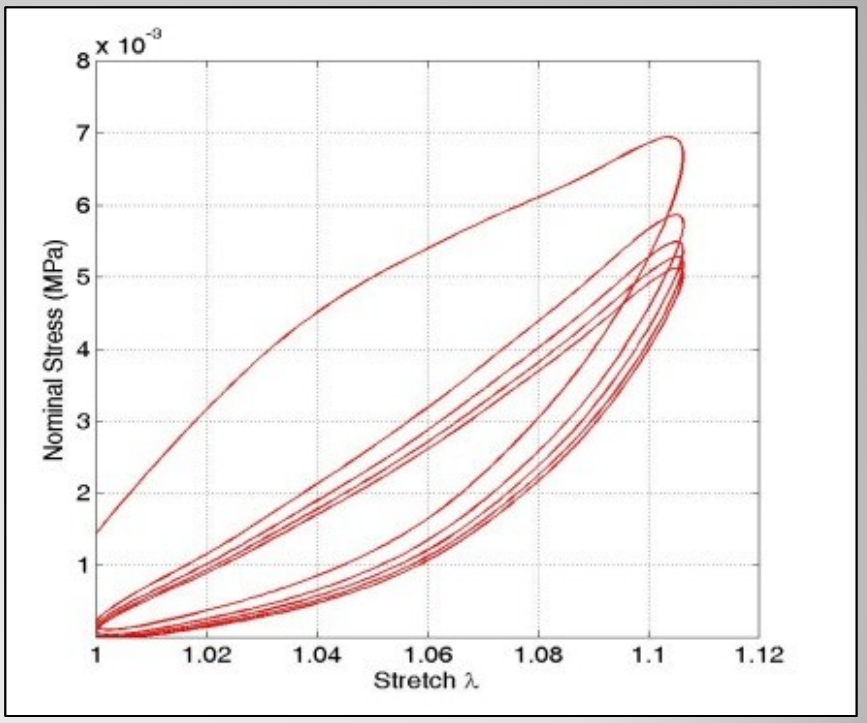
Actuators and Body



Biological Actuators – Muscle

- Force-length relationship is rate dependent
- - and history dependent (*e.g.*, Mullins effect)



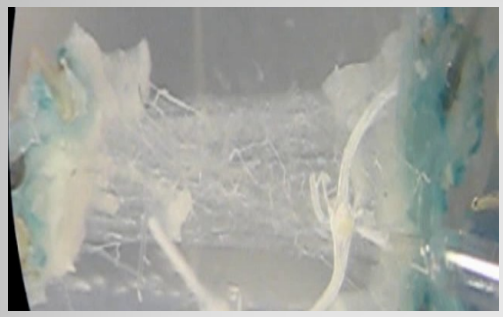


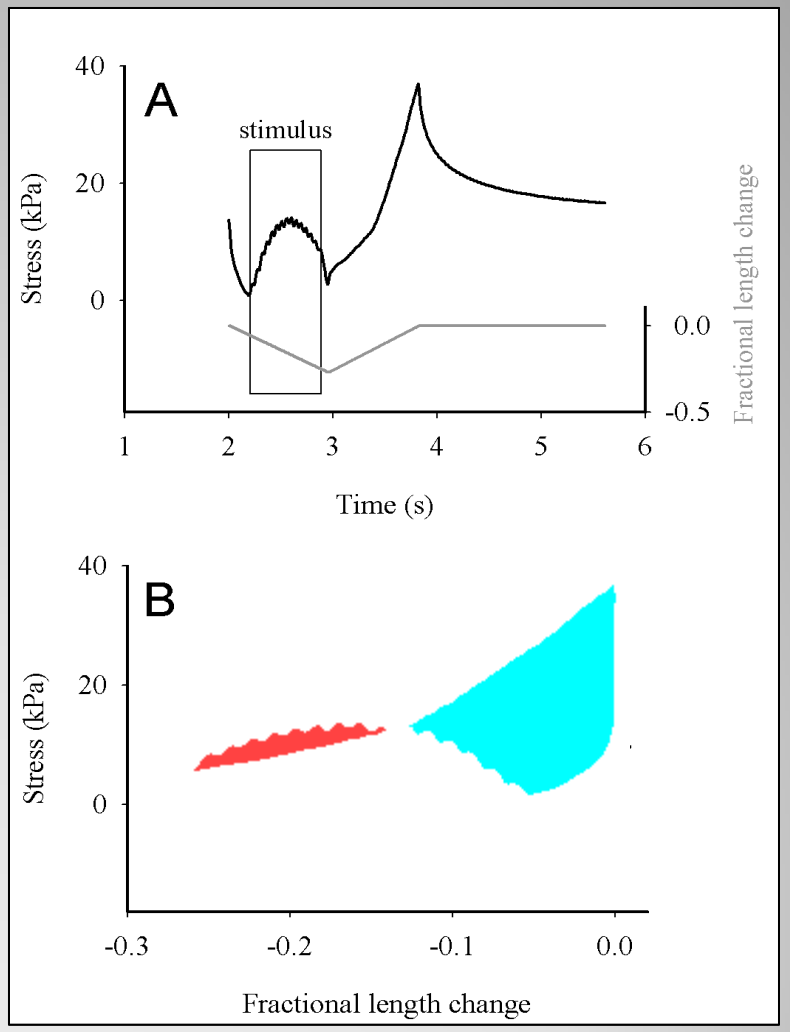
Muscle is a multistate material

- Work Loops

Natural strain cycles

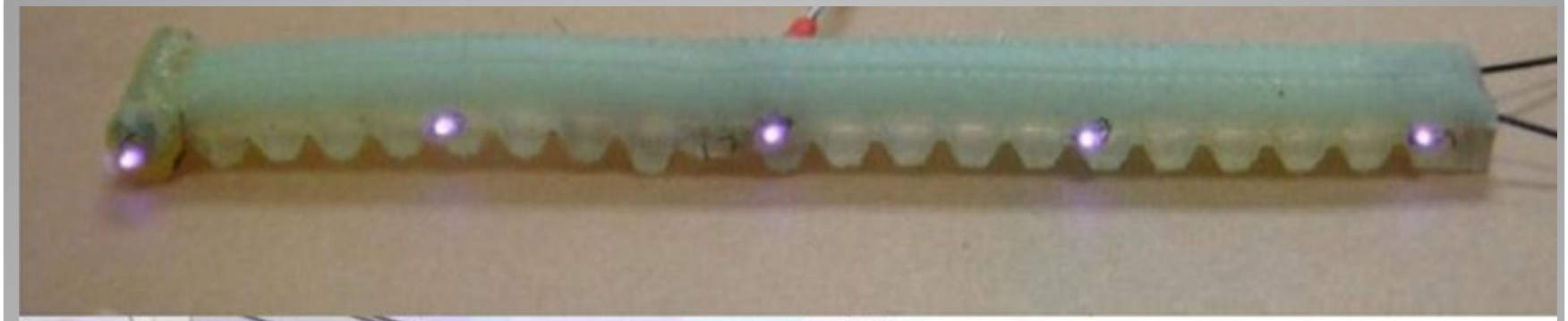
Natural stimulation (f and Φ)

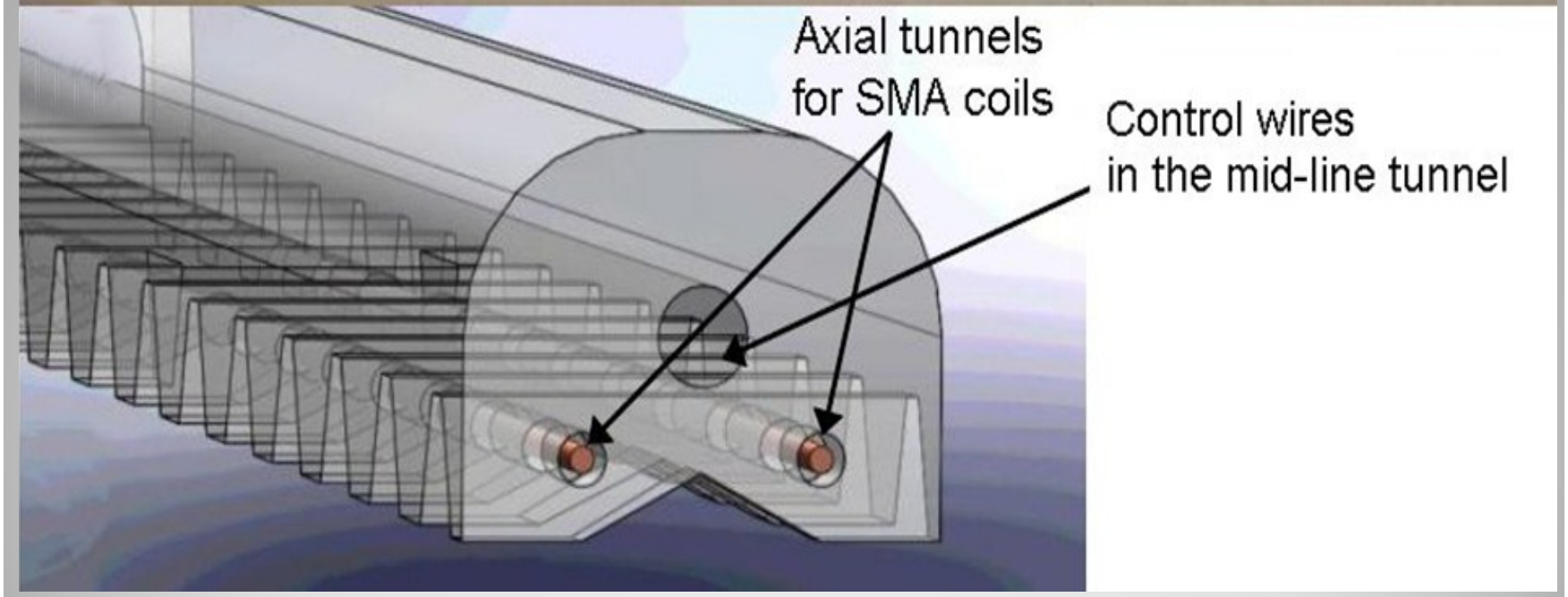




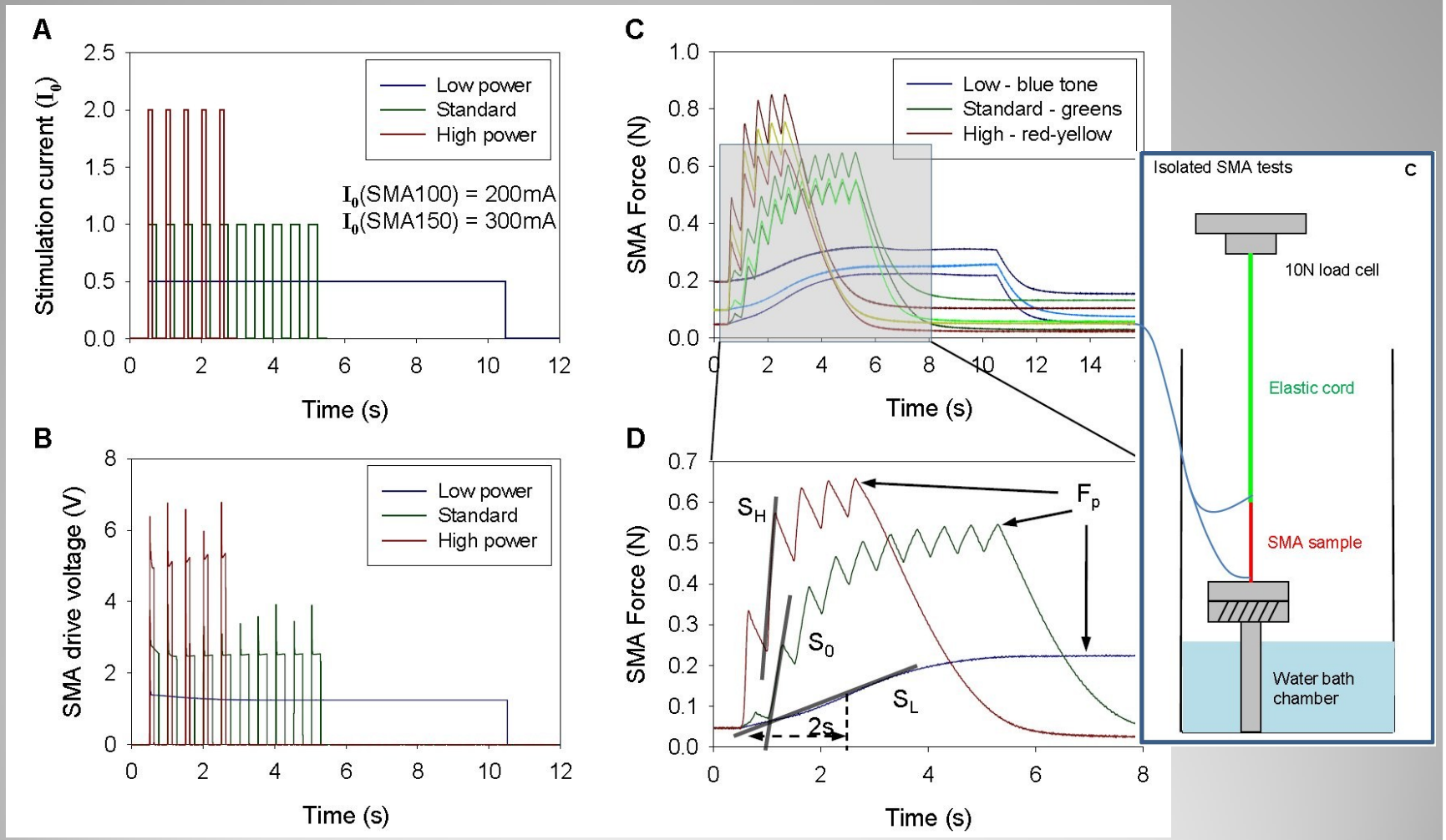
-and a multi-functional material

Movie 2. Muscle cycle



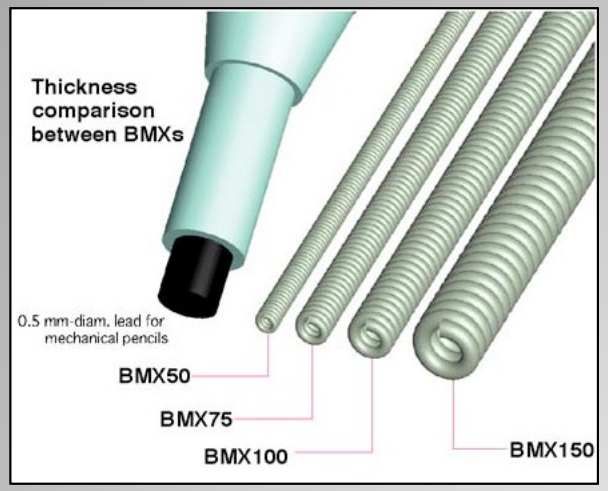


Synthetic Actuators - SMA



Can be muscle-like

- SMA work loops



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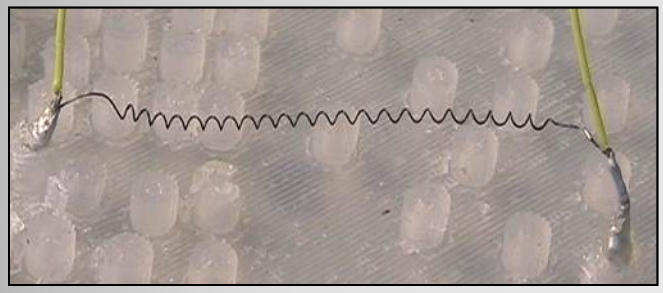
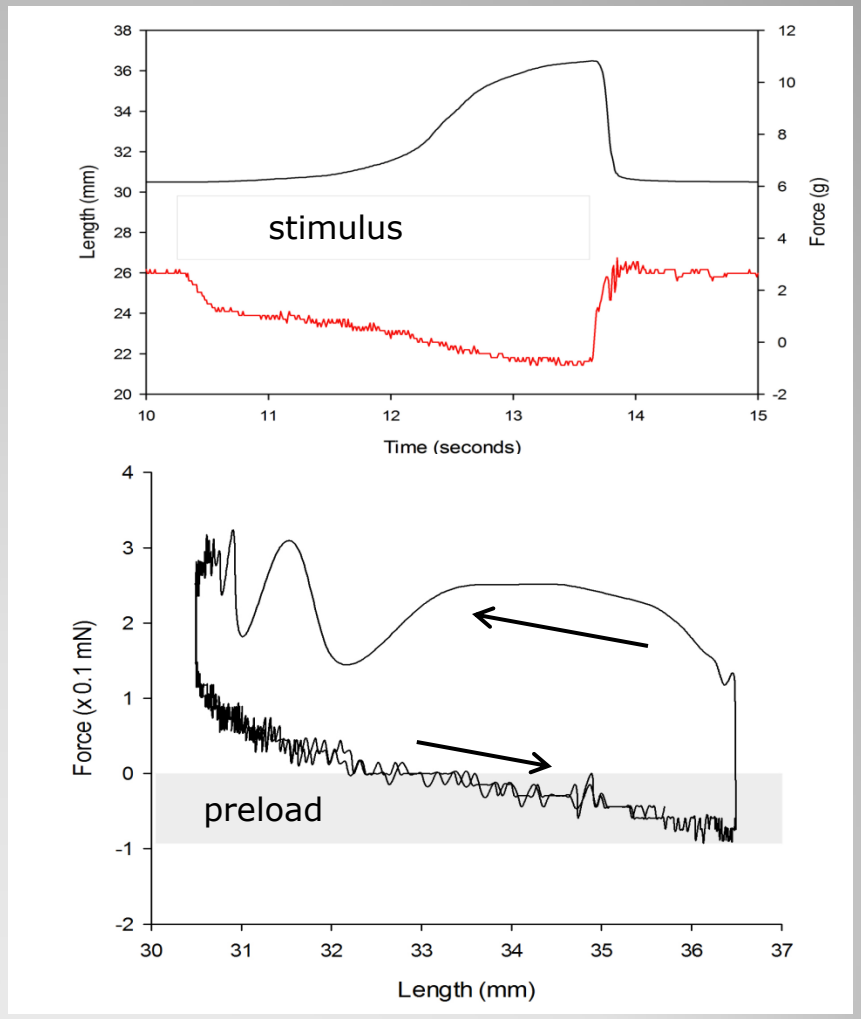
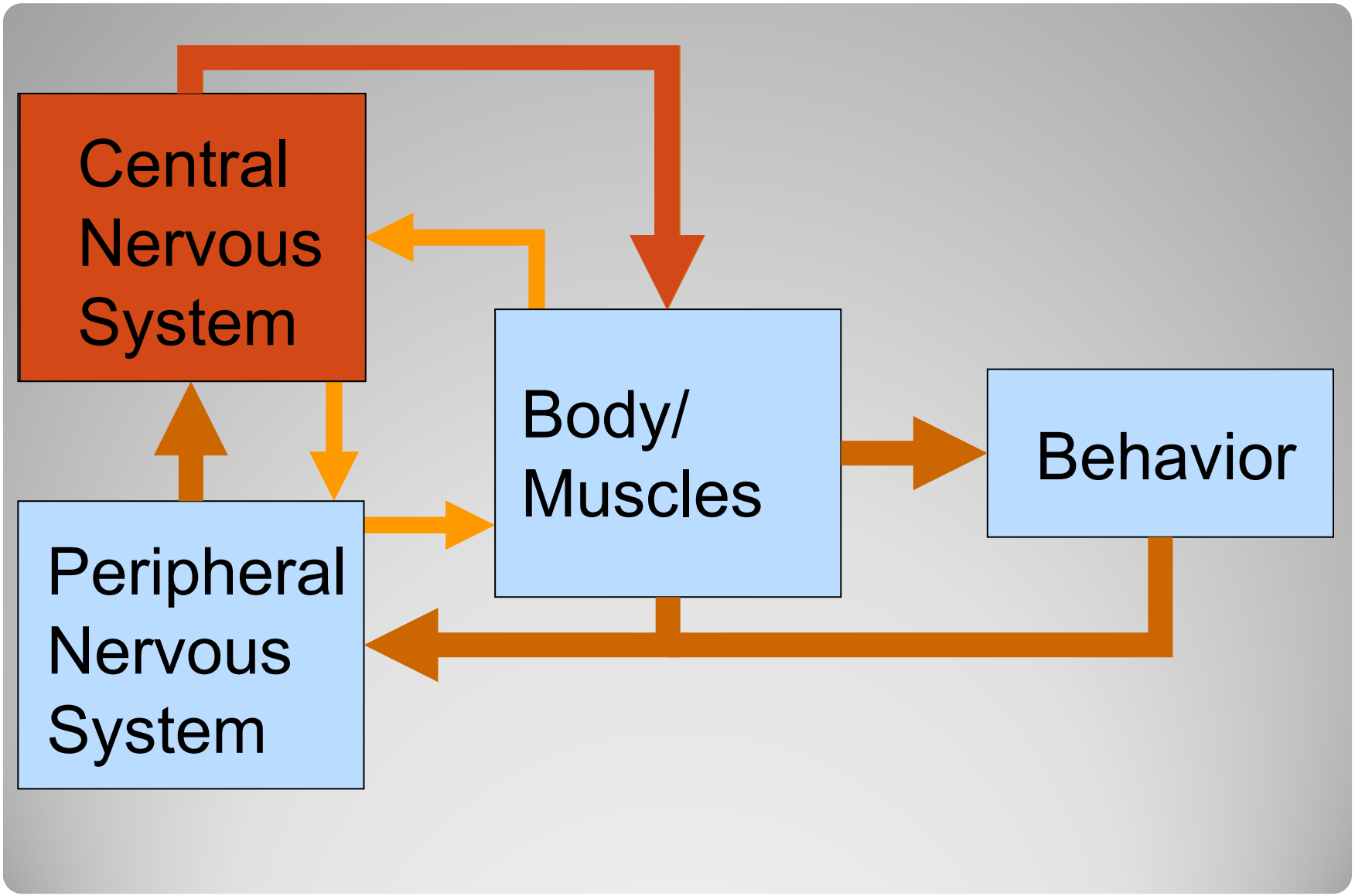
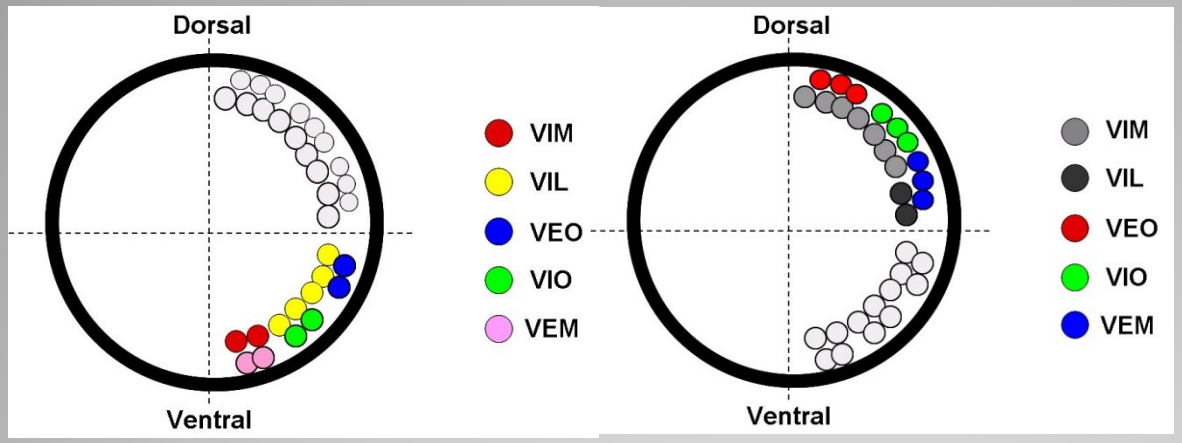
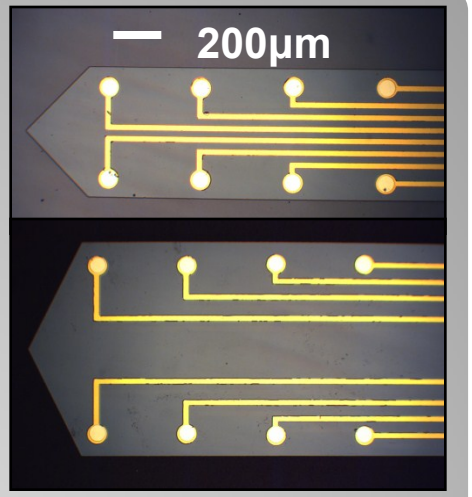


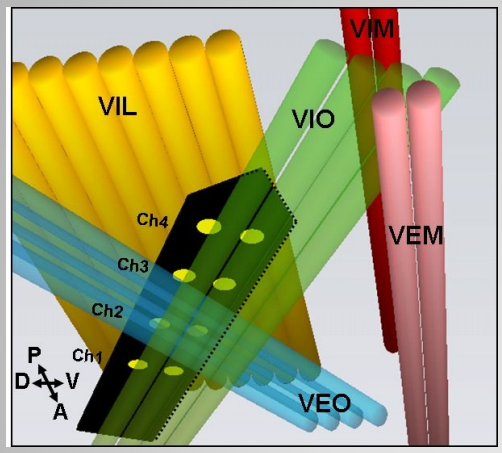


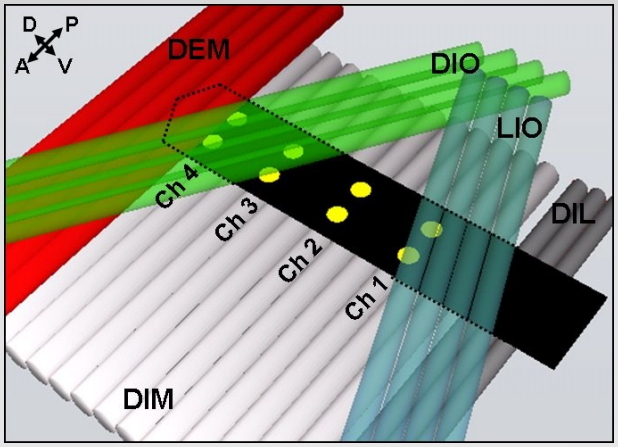
Can be muscle-like

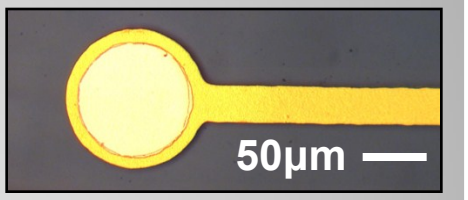

Central Nervous System
Peripheral Nervous System
Body/ Muscles
Behavior

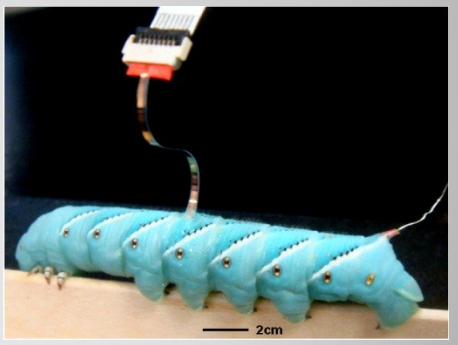






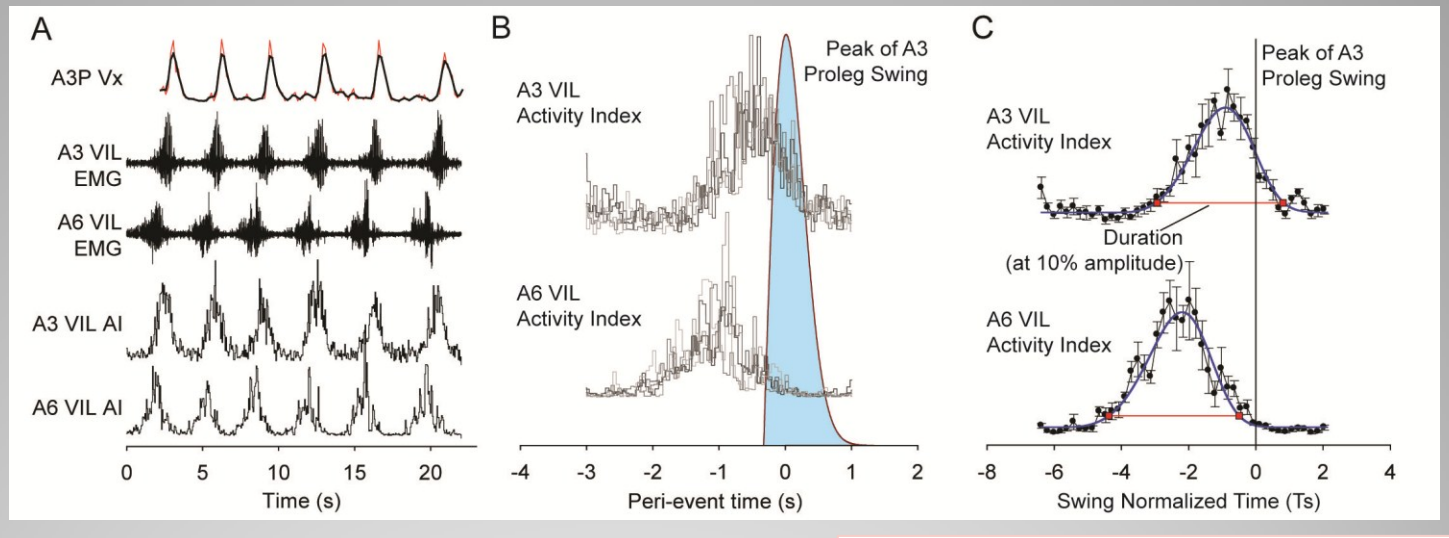


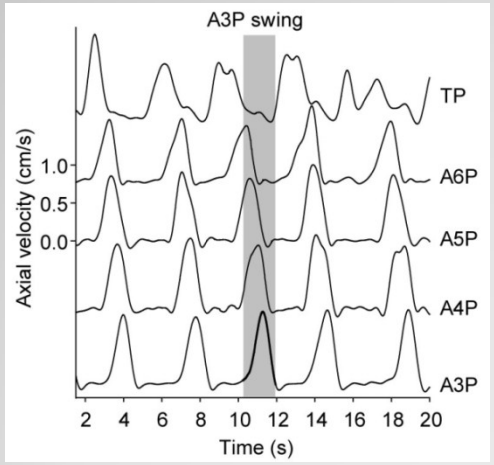


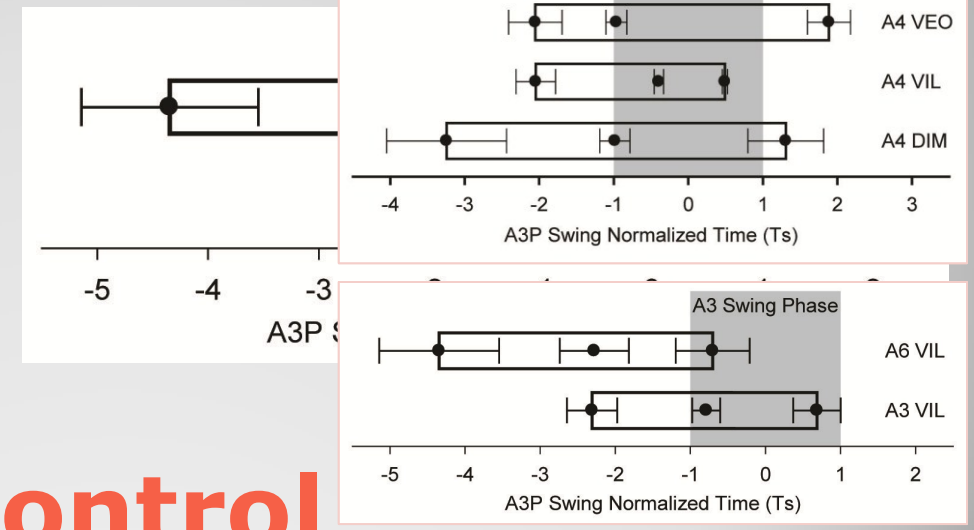


Neural control of crawling

Metallo, C. White, R and Trimmer. B. A. (2011). J. Neurosci. Methods, 195, 176-184.

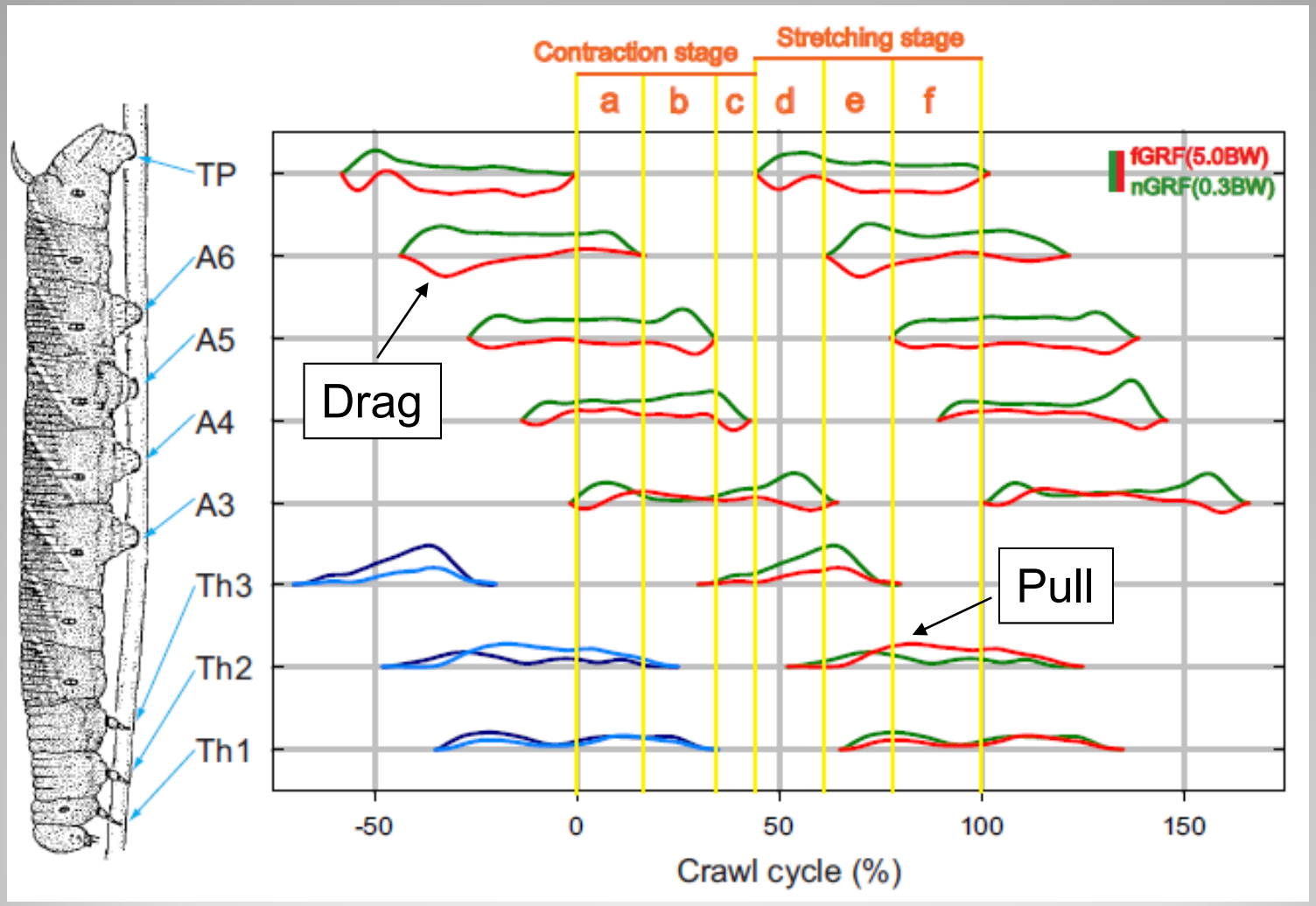






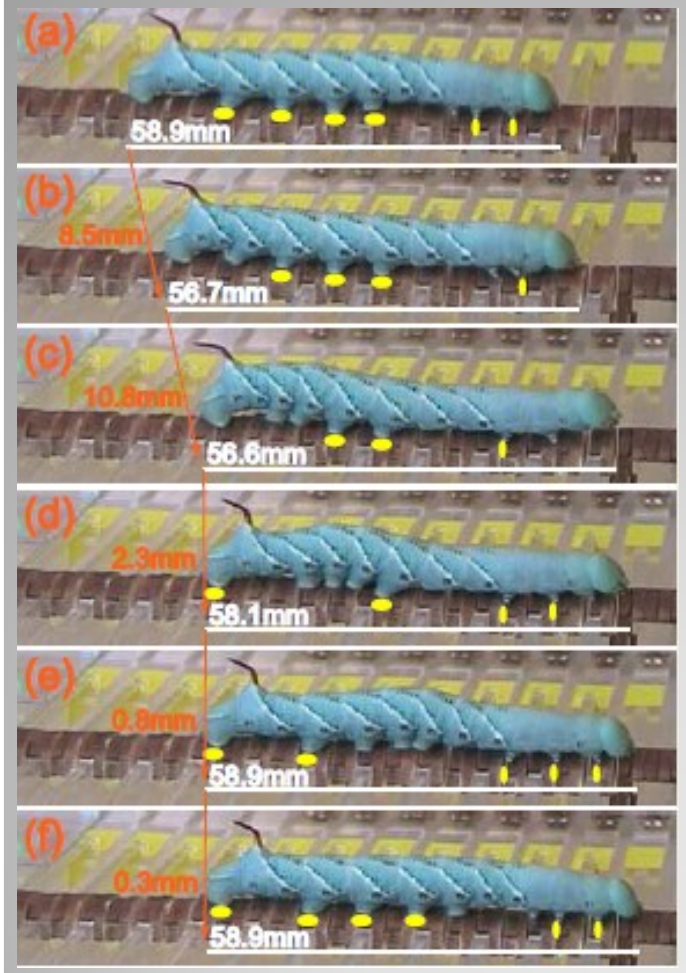
Locomotion control

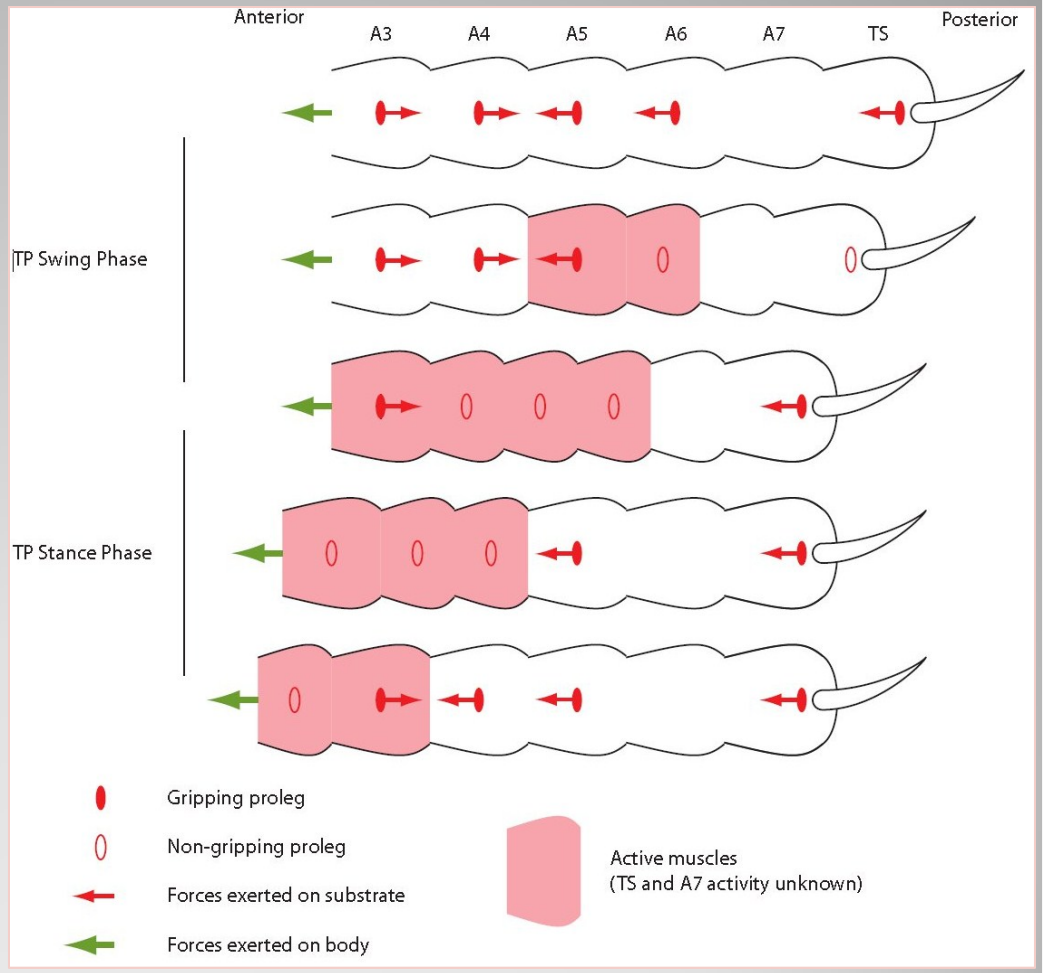
Simon, M., Fusillo, S.J., Colman, K., and Trimmer. B. A. (2010). J. Exp. Biology 213, 2303-9.



Manduca stays in tension

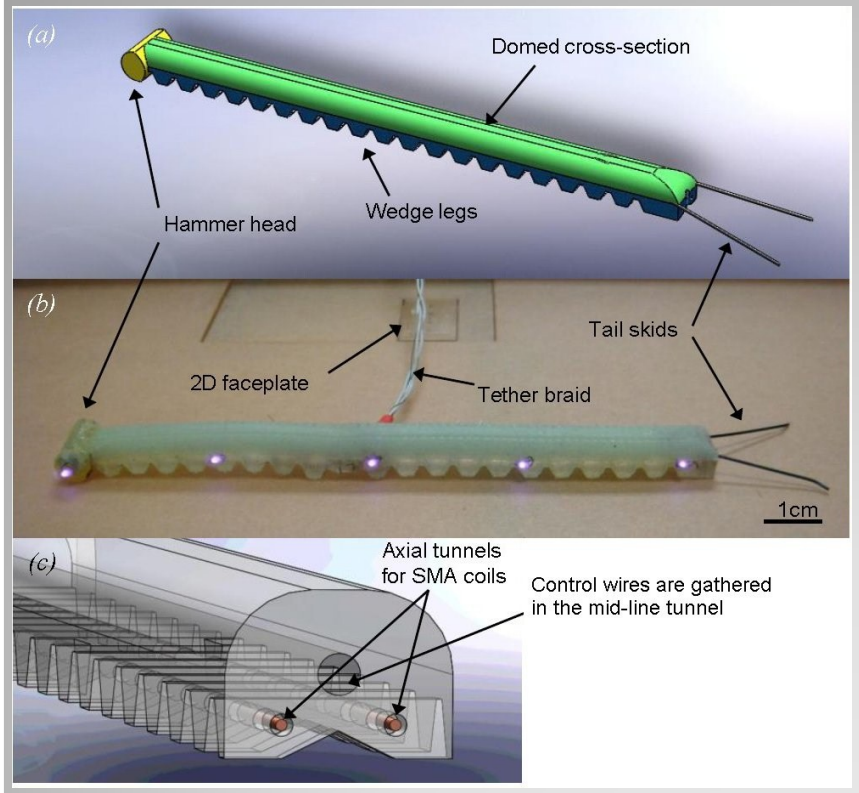
Lin, H-t. and Trimmer, B.A. (2010). J. Exp. Biol. 213, 1133-1142.

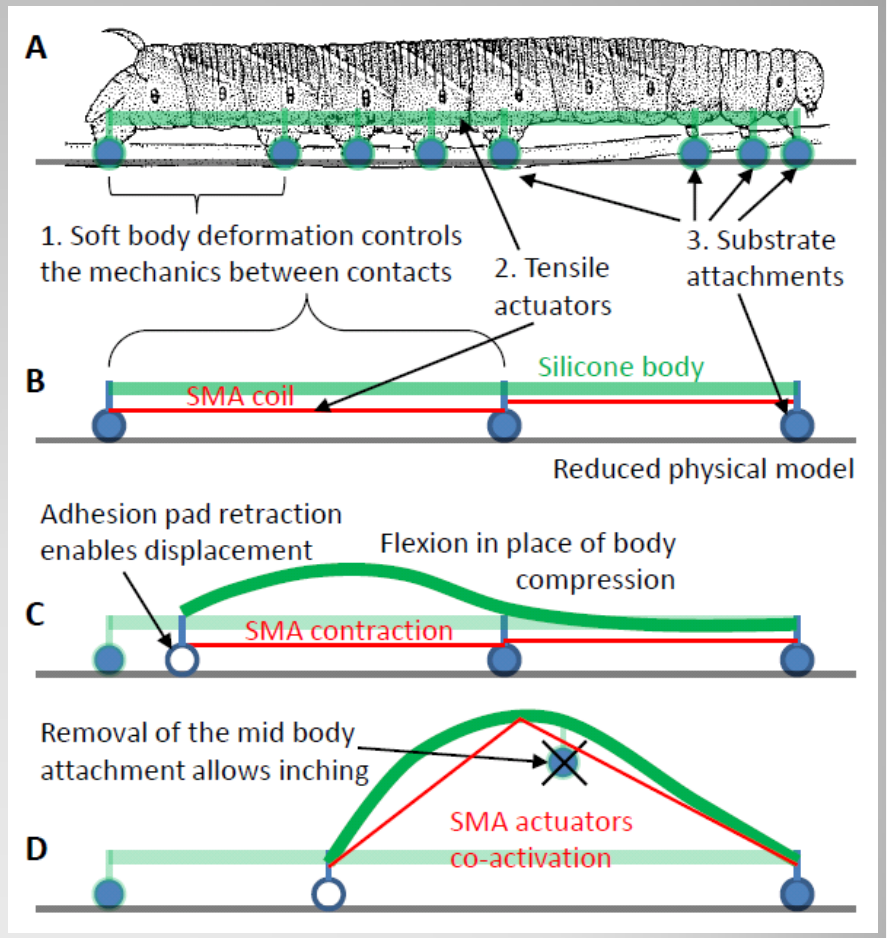




Locomotion Control – animal

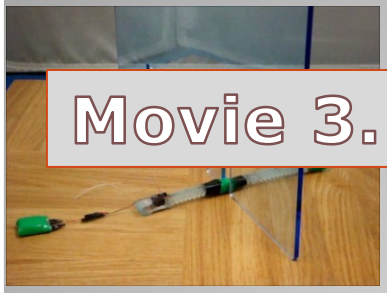
Simon, M., Fusillo, S.J., Colman, K., and Trimmer. B. A. (2010). J. Exp. Biology 213, 2303-9.





Locomotion Control – robot

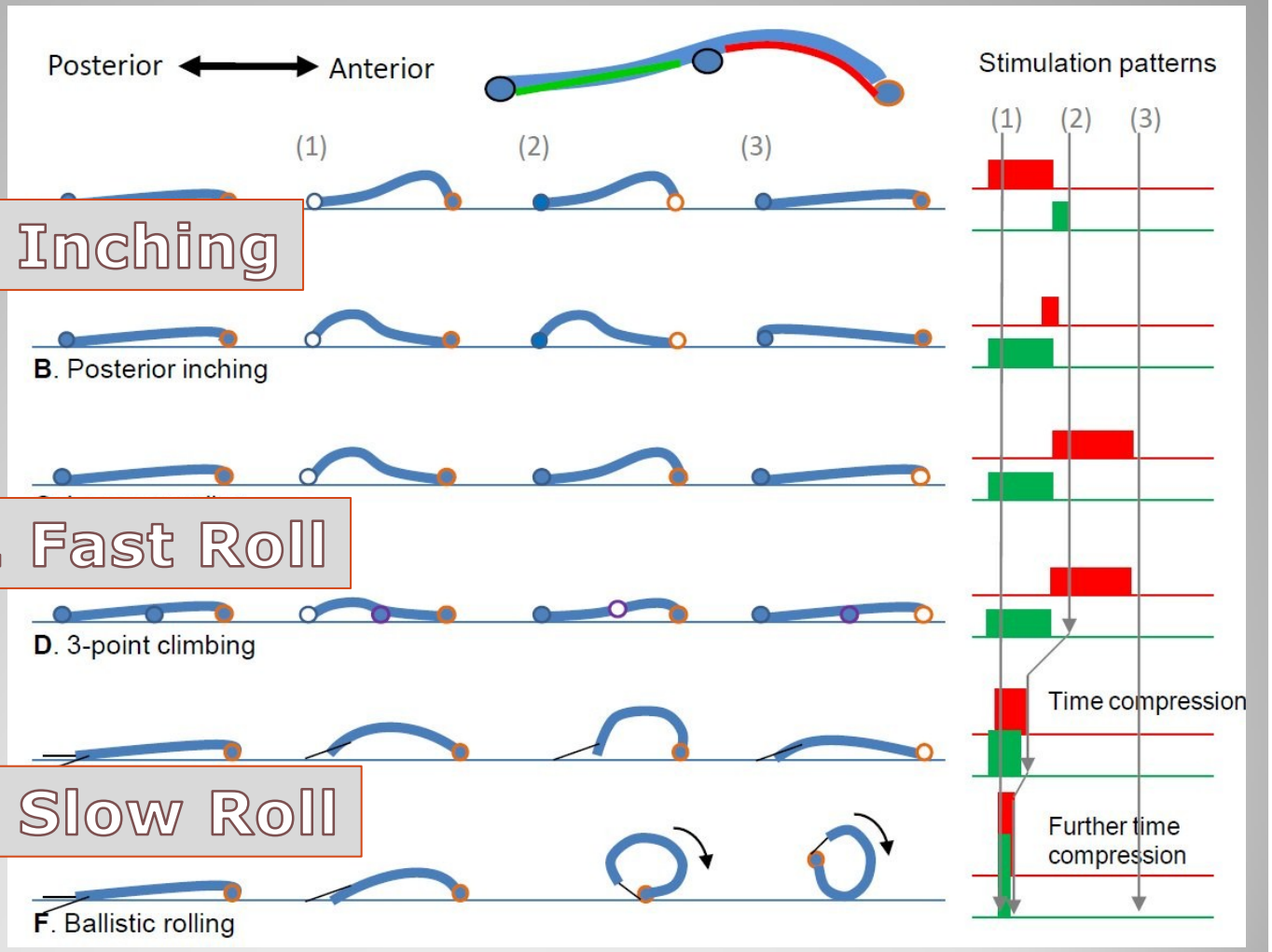
Lin, H.-T., G. Leisk, and B.A. Trimmer (2011) Bioinspiration and Biomimetics. ***6****(2): p. doi1748-3182/6/2/026007*



Movie 3. Inching

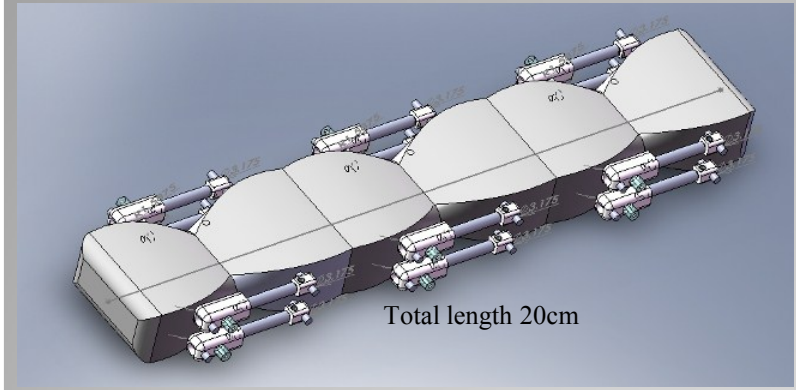
Movie 4. Fast Roll

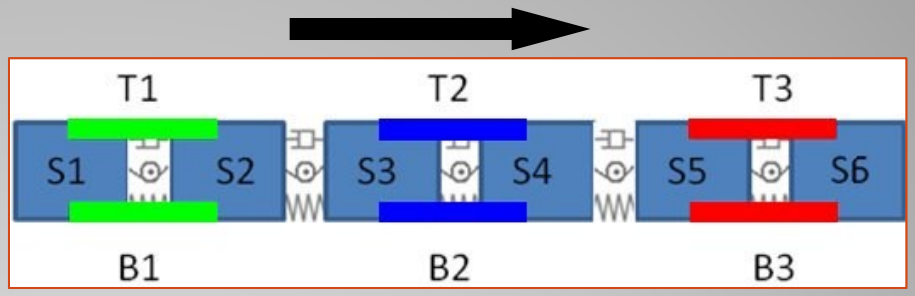
Movie 5. Slow Roll



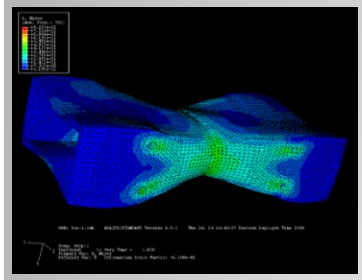
Synthetic gait control

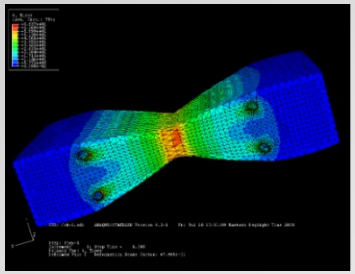
Trimmer, B.A. Lin, H-t, Baryshyan, A., Leisk, G. and Kaplan, D.L (2012) BioRob) Rome, Italy .

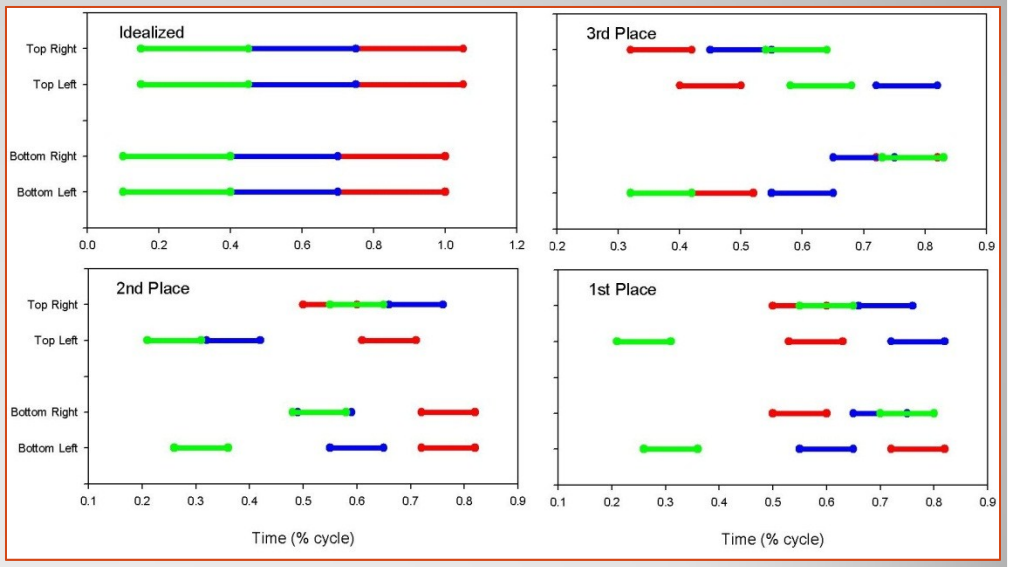




Evolved motor patterns



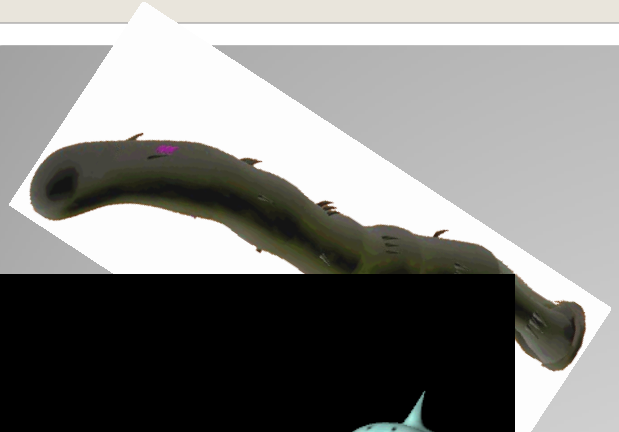


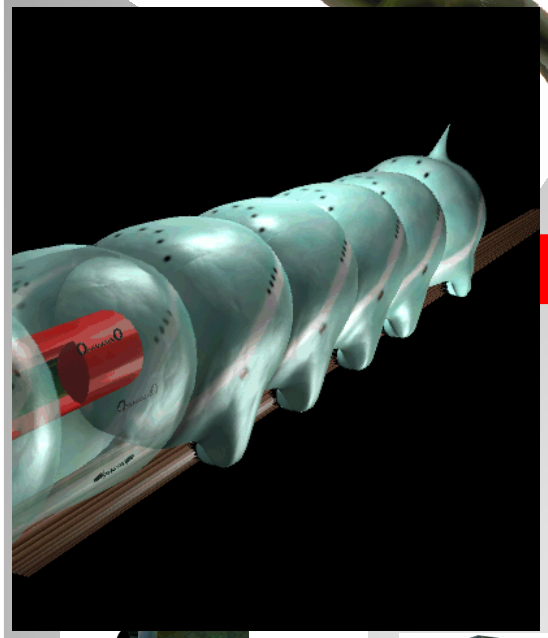


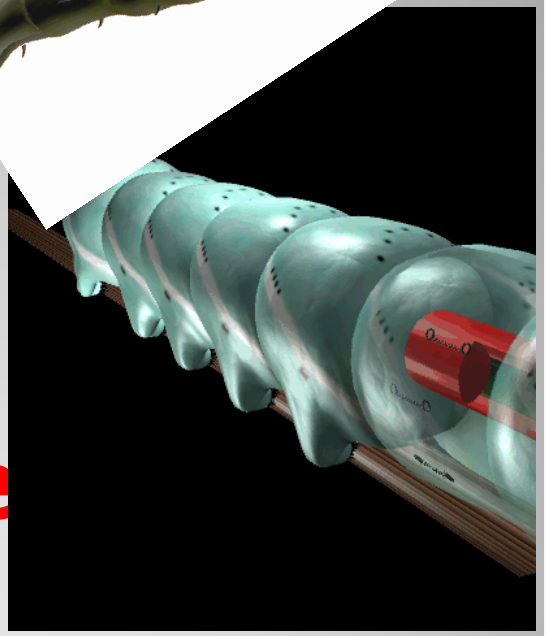
Movie 6. Evolved PneumoBot

Control – validation with PneumaBot

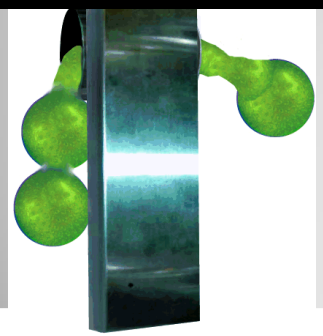
Saunders,F., Golden, E, White, R.D. and J. Rife (2011) Robotica: 1 8

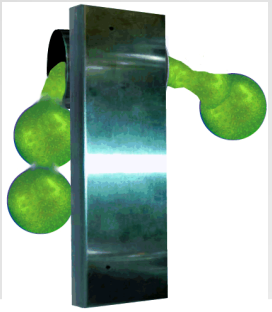


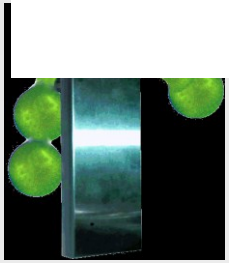




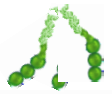
Biosynthetic Robots Initiative



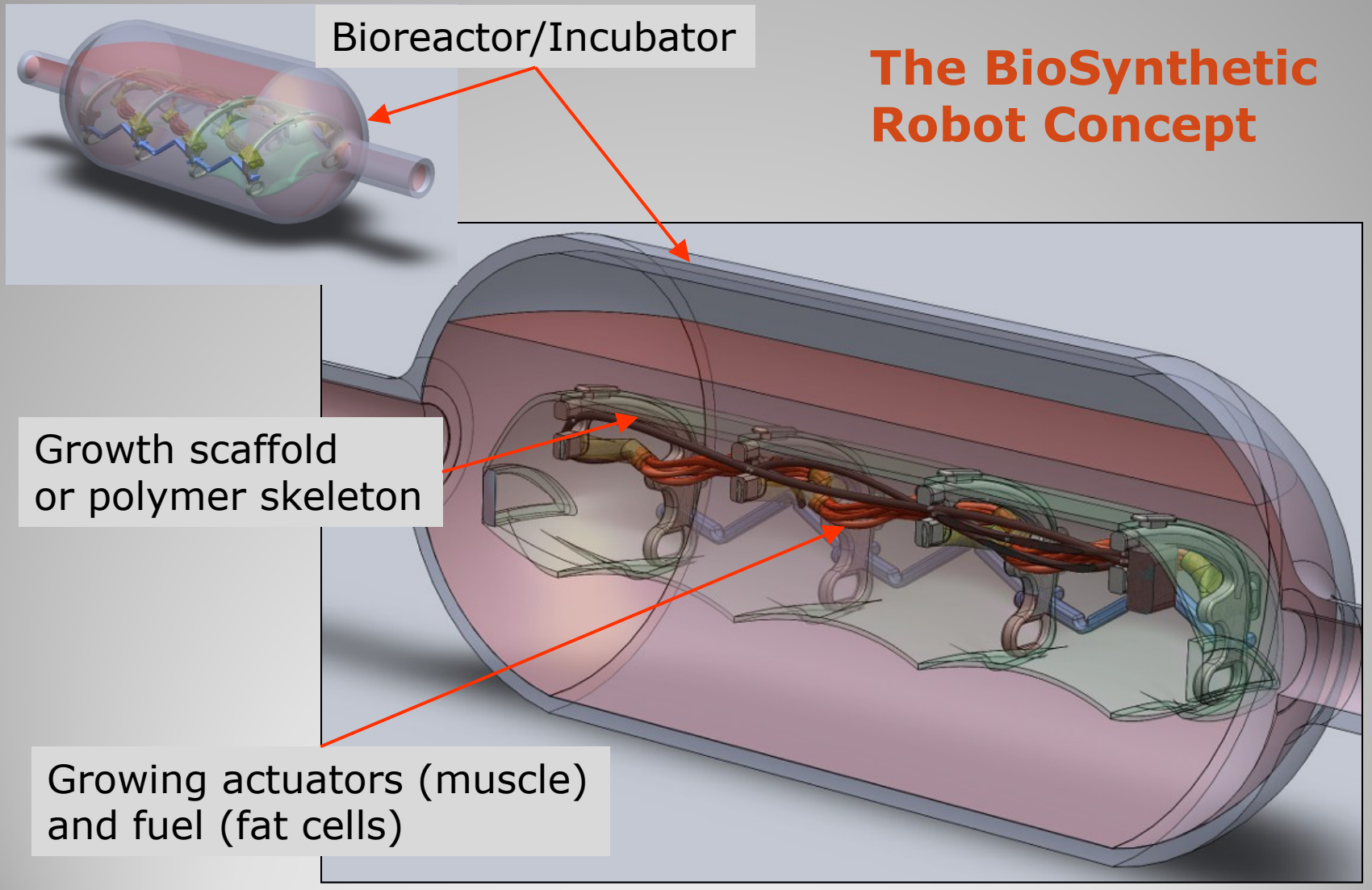




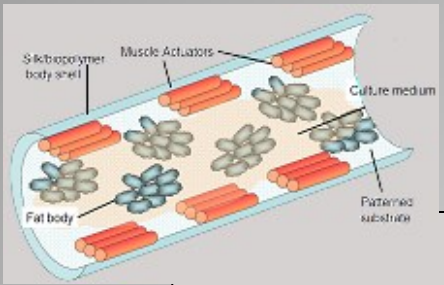
Biosynthetic devices
The next generation of machines will be grown rather than fabricated

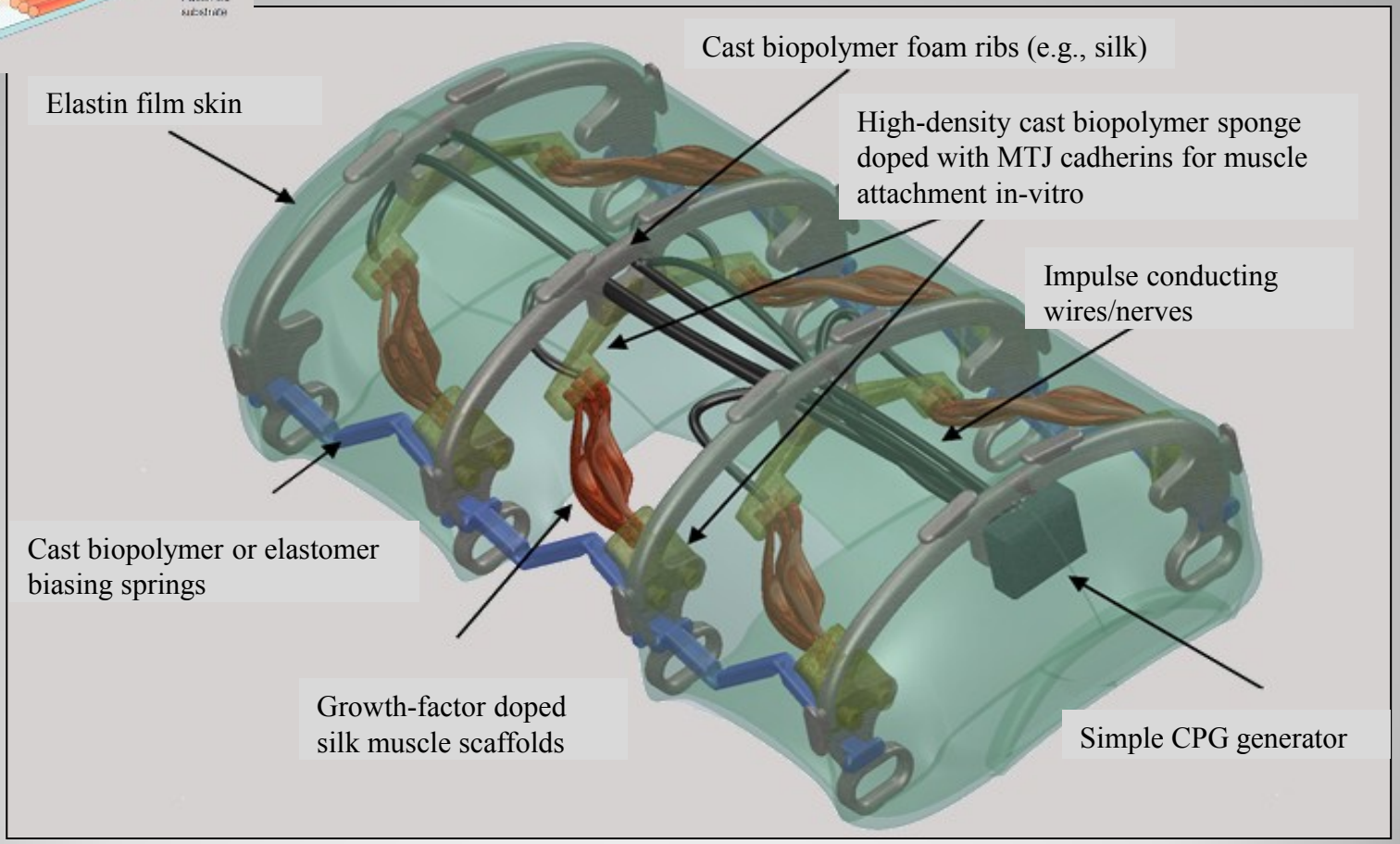


The BioSynthetic Robot Concept



The BioSynthetic Robot Concept





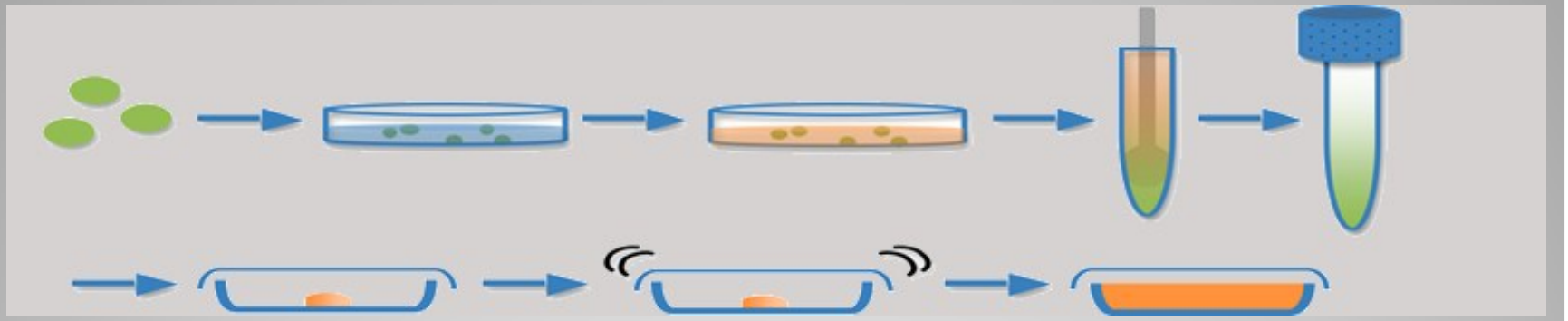
Stage eggs
Wash
Sterilize

Wash with water
Count

Wash with media

Homogenize

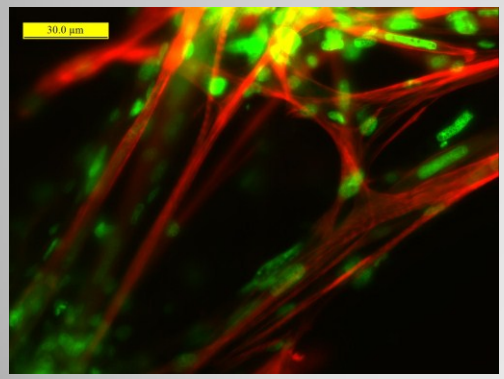
Spin down

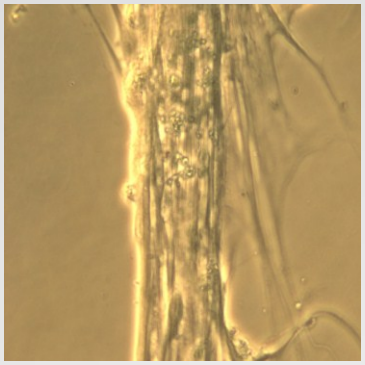


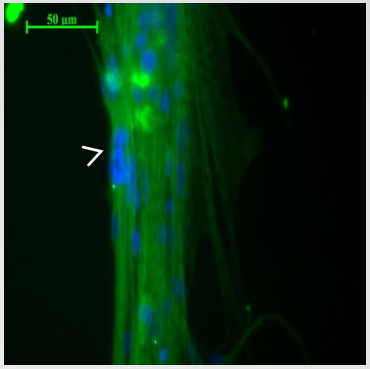
Drop cell
suspension

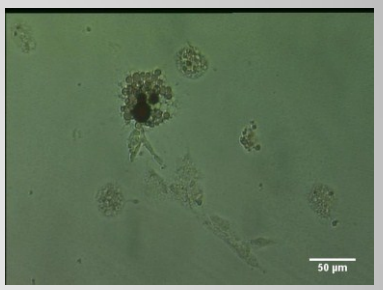
Shake off loosely
adhered cells

Wash
Add fresh media



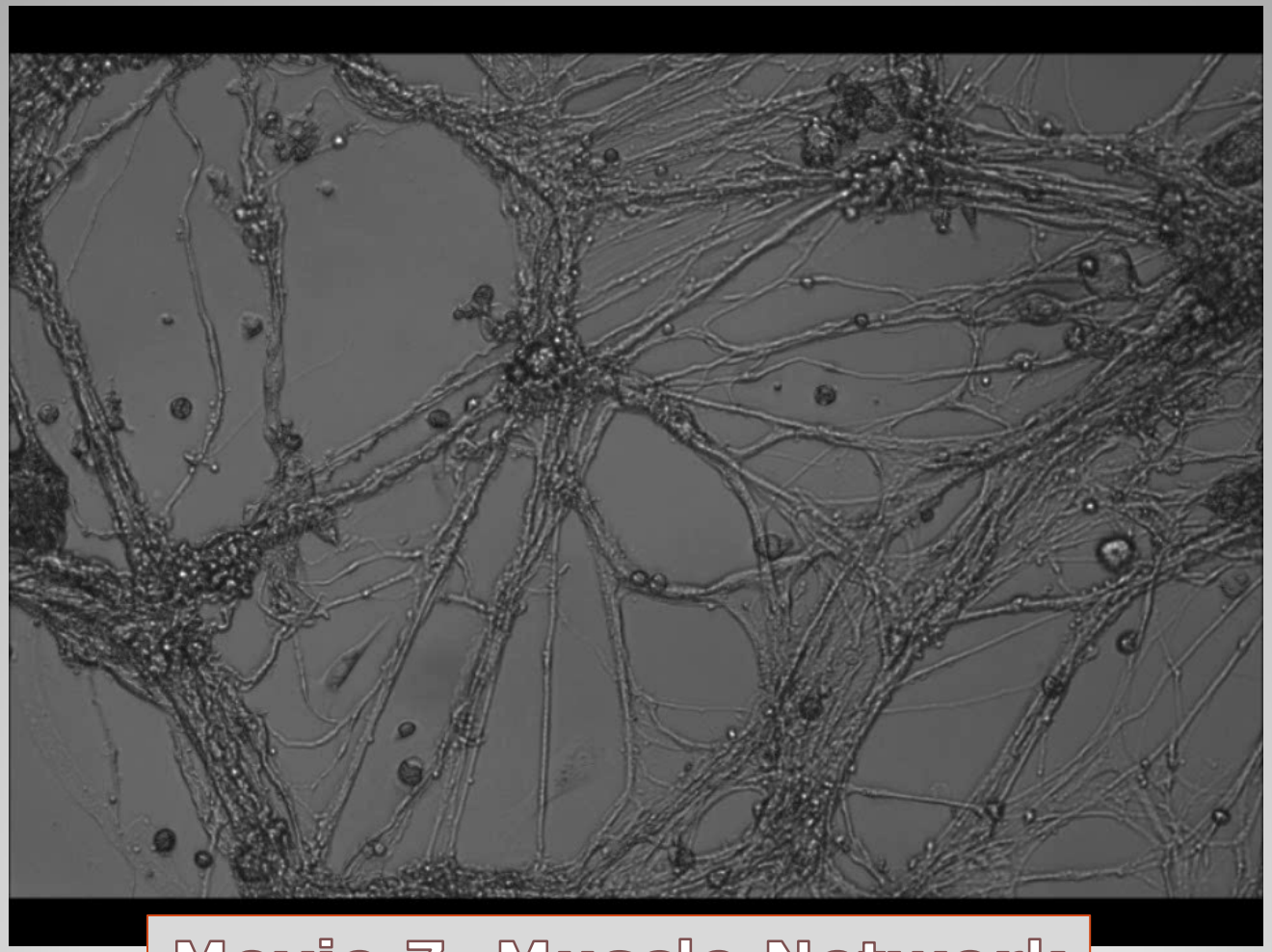






lipid

Cell isolation & characterization

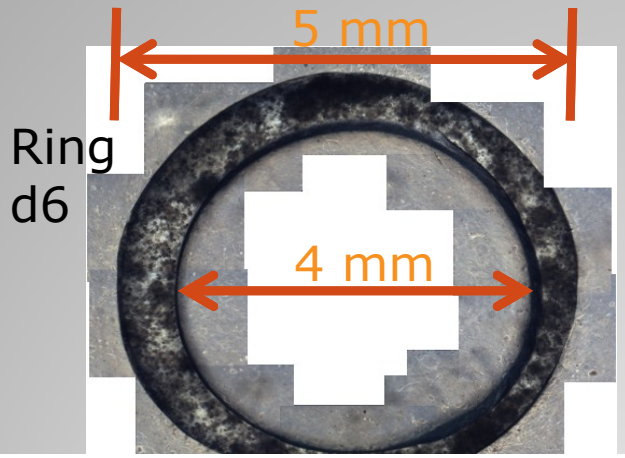


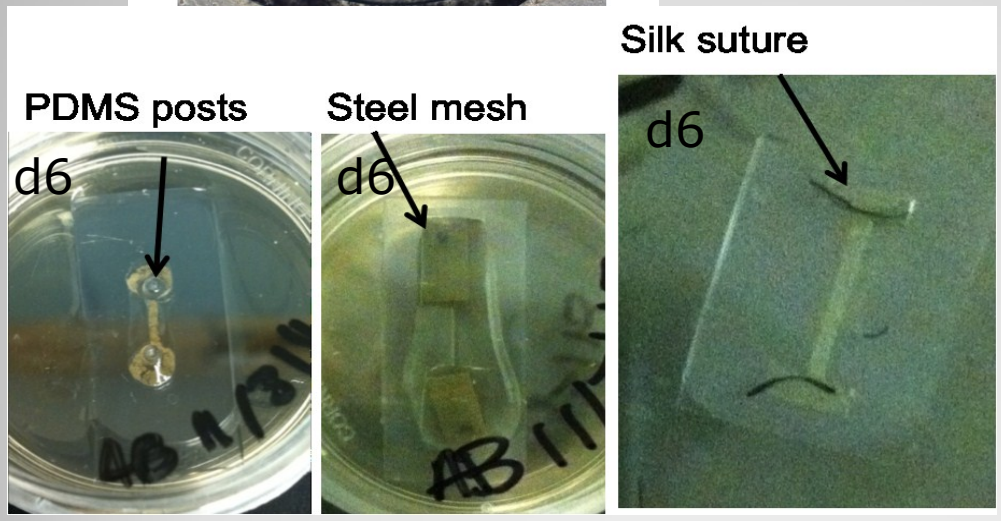
Movie 7. Muscle Network

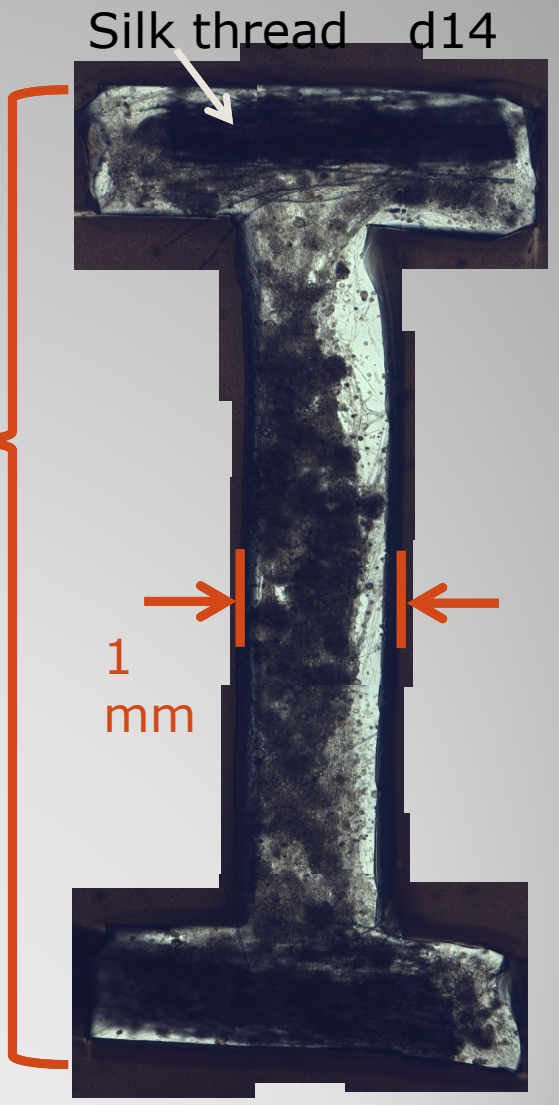
Spontaneously contracting networks

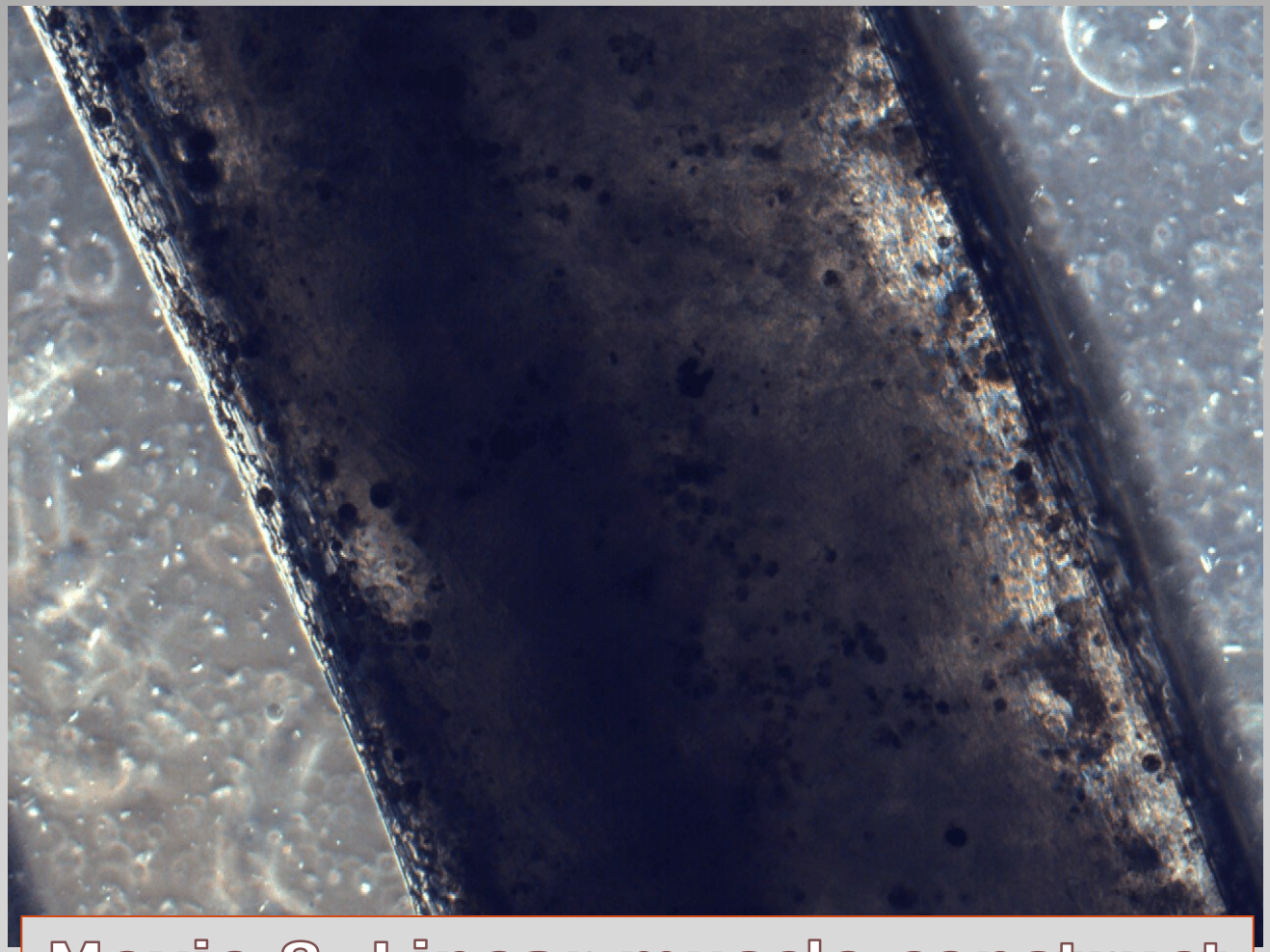
Baryshyan AL, Woods W, Trimmer BA, Kaplan DL. 2012 PLoS One.;7(2):e31598

Construct formats









Movie 8. Linear muscle construct

Co-contracting constructs

Soft Robot Development Team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Woody Woods


Ethan Golden


Vishesh Vikas


Amanda Baryshyan


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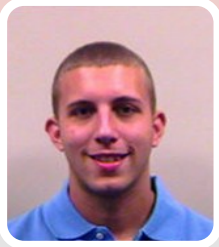
Michael Doire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NSF

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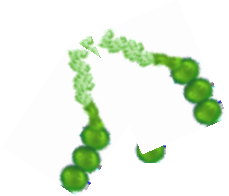
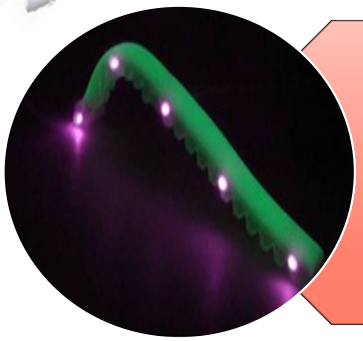
IGERT: Soft Material Robotics

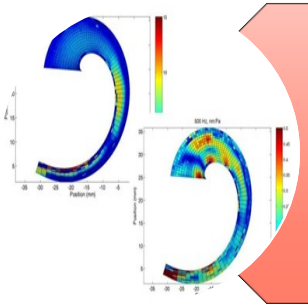
An Interdisciplinary Graduate Program in the New Field of High Deformation Devices





Goal is to develop new types of mobile machines

Through close collaboration between engineers, biologists, and material scientists



Enabling students to work in research teams on complex problems

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