CICADA
IST-2001-34718

Cricket Inspired perCeption and Autonomous Decision Automata

IRBI CNRS- U. Tours

MESA+

Forschungszentrum Jülich

Coordinator: Jérôme CASAS
Tours, F

The University of Reading

Project funded by the Future and Emergent Technologies arm of the IST Programme - FET Keyaction Life-like perception

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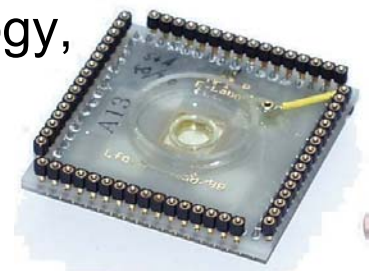
CICADA

Cricket Inspired PerCeption and Autonomous Decision Automata

- Increase the advancement of **biomimetic** life-like perception systems by providing novel data and concepts on a ‘sensing-perception-action’ chain using highly innovative technologies.

- Combine first rate European expertise in sensory ecology, material sciences, MicroElectroMechanicalSystems (MEMS) and living computers



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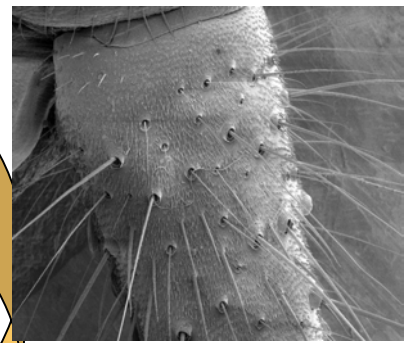
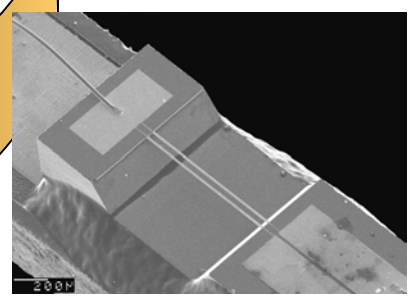
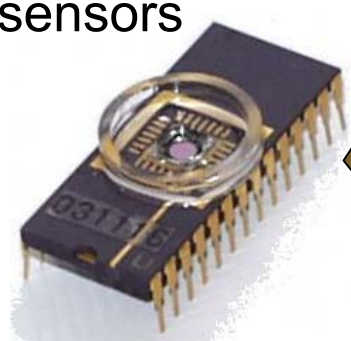
Approach

- Investigate air current perception and escape action of crickets responding to attacking predators
- Characterize and model mechanical and functional properties of mechanoreceptor hairs and hair canopy
- Design large arrays of MEMS sensors
- Build a miniature demonstrator using living computers







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Participants

- ✓ Université Francois-Rabelais Tours - **FRANCE** – *Sensory ecology*
  Leader: J. Casas
  Danger sensing and perception

- ✓ The University of Reading - **UNITED KINGDOM** - *Material science*
  Leader: G. Jerondiminis
  Mechanics of single sensors

- ✓ Universiteit Twente - **NETHERLANDS** – *Nanosensors*
  Leader: G. Krijnen
  MEMS flow sensors

- ✓ Forschungszentrum Juelich - **GERMANY** – *Hybrid systems*
  Leader: A. Offenhaüser
  Bioelectronic devices, Hybrid demonstrator

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Performance of single insect mechanoreceptors

- *Displacement detection threshold of $2x10^{-7}$ m at 1kHz (spiders)*
- *Acceleration detection threshold of $0.3x10^{-11}$ m/s^2 at 0.01 Hz (spiders)*
- *Load sensitivity between 0.5 and 20 $\mu\varepsilon$ / mN*
- *Displacement sensitivity of less than 1 nm [CICADA]*
- *Angular displacement (hairs) 10^{-3} degrees [CICADA]*

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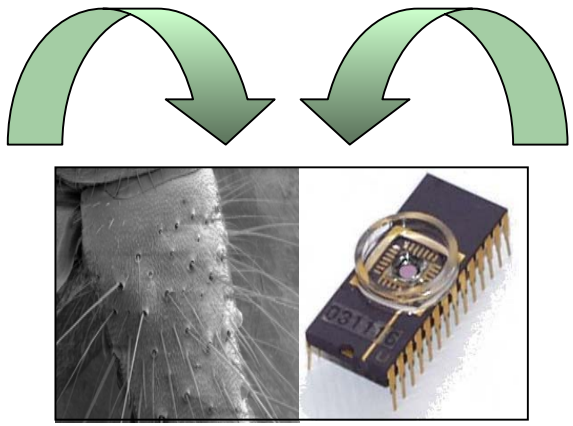
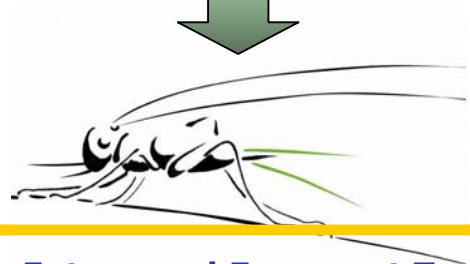
Which cricket species to mimic? Adaptation to what ?

Neurophysiological and biomecanical background

?





Ecological relevance

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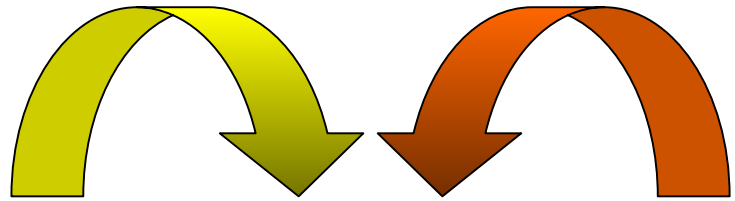
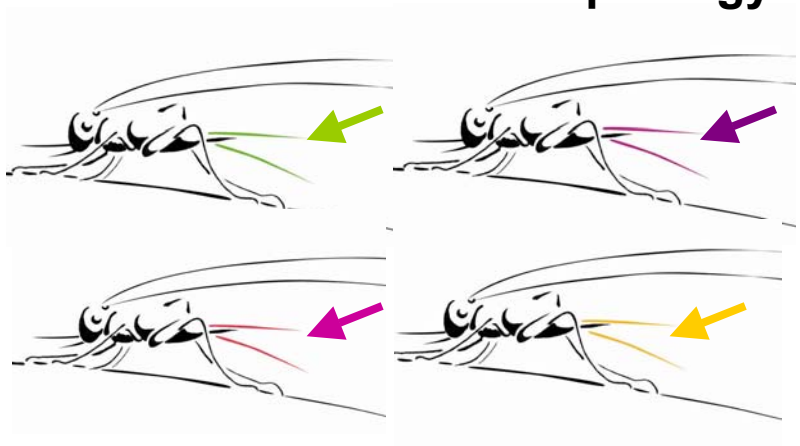
Which cricket population to mimic?

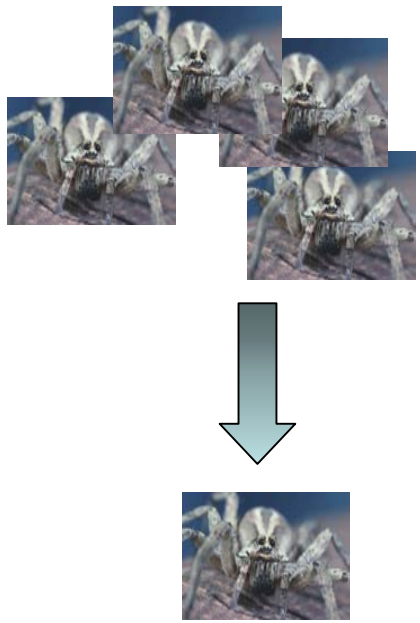
Local adaptation?

Environmental heterogeneity



Differences in cerci morphology?





Predation pressure

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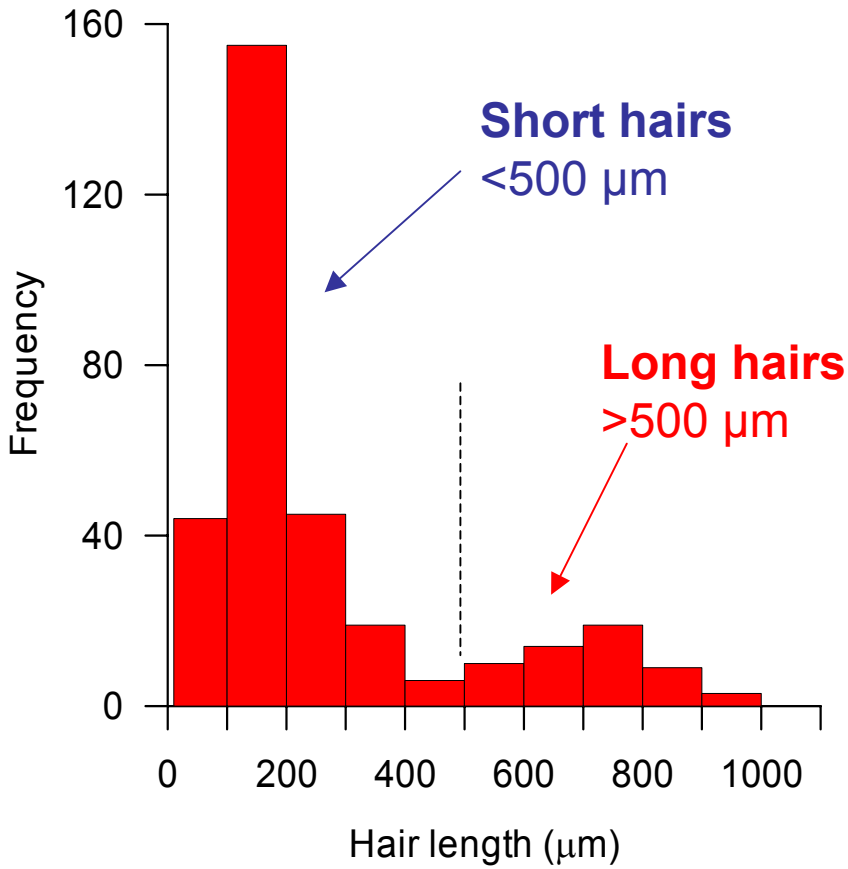
Hair length distribution



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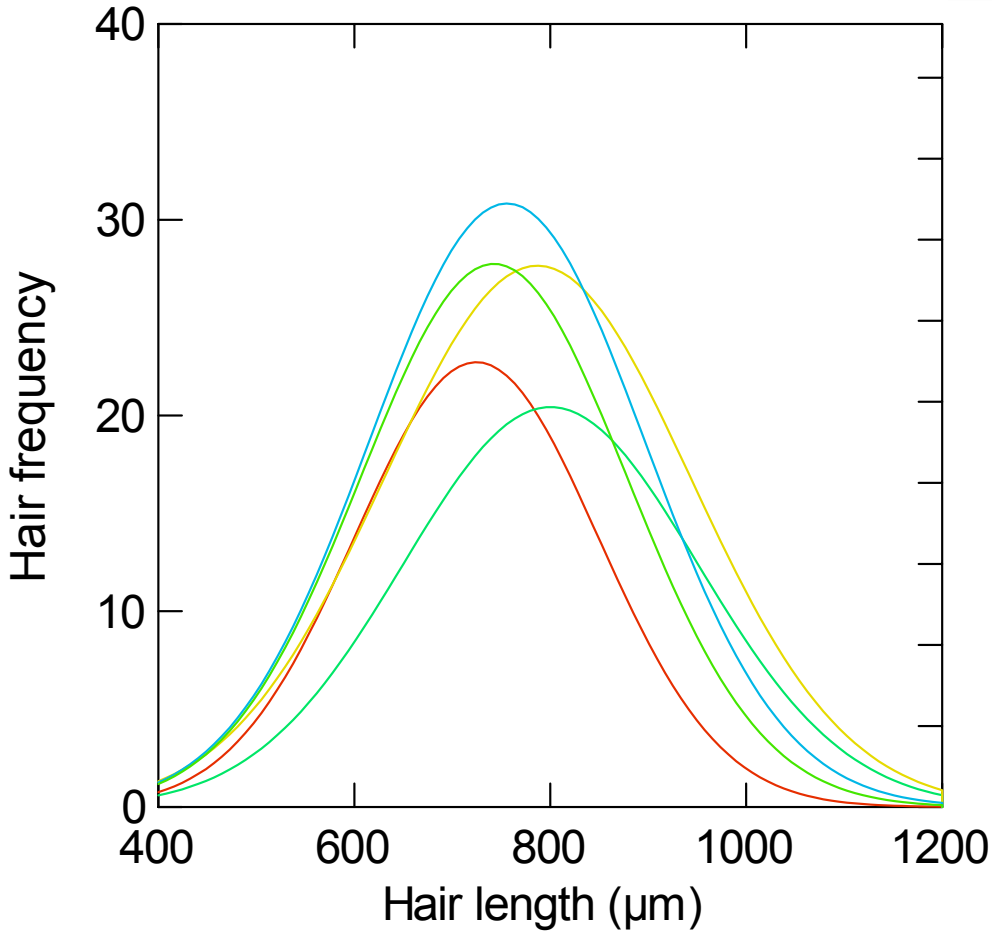
Filiform hairs > 500 µm



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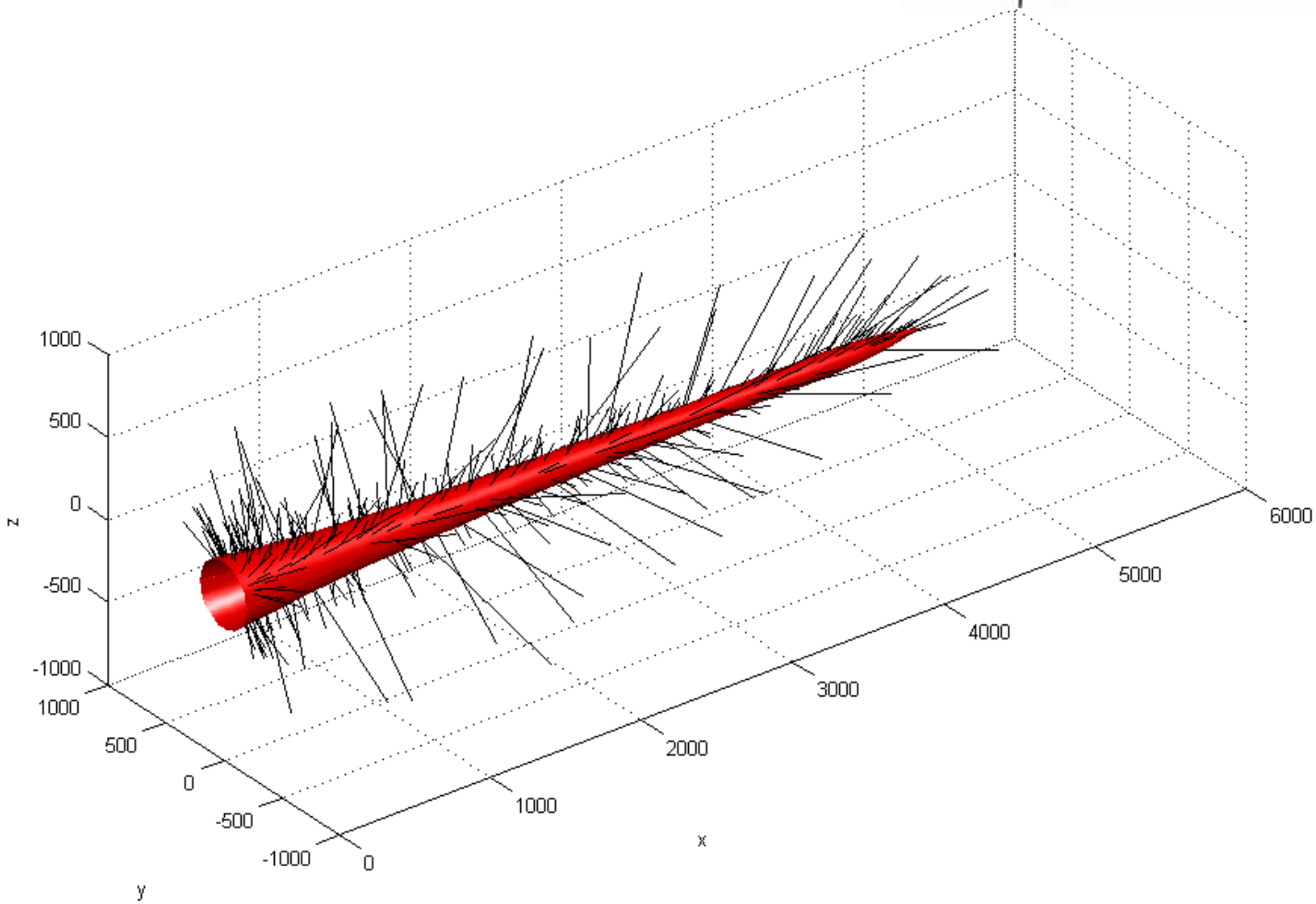
Complete mapping of the cercus



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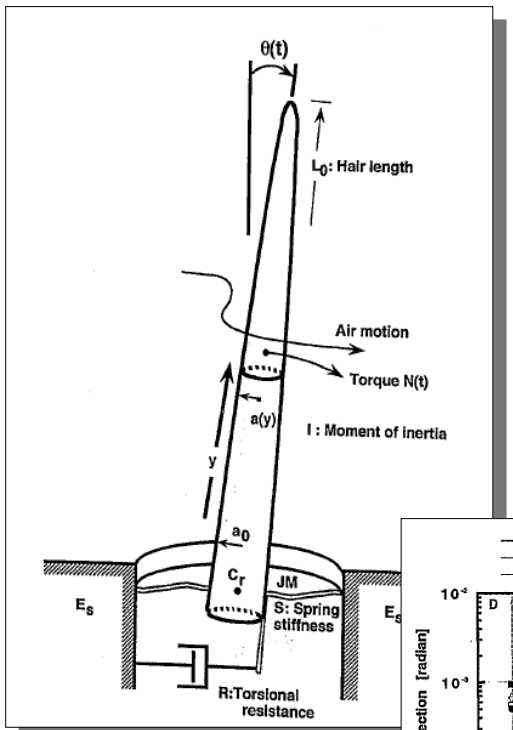
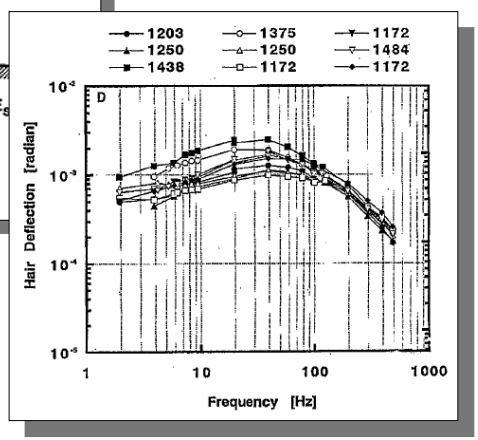
Cricket Receptor Hairs

"mimicking is not that easy"



$$\alpha \propto \frac{1}{k}$$

$$f_0 \propto \sqrt{\frac{k}{m}}$$



- Damped second-order system *(low-pass filters)*
- Weak torsional springs *(low Youngs modulus material)*
- Strong light hairs *(low-density material)*
- Large torsional resistance *(wet tissue at the base of the hairs)*
- Impedance matching maximizes energy transfer to the base.

T. Shimozawa, et al.
Journal of Comp. Physiol. A, 183, pp. 171-186, 1998

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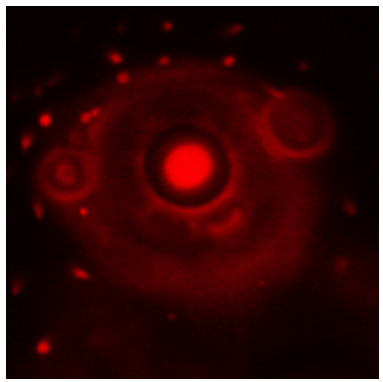
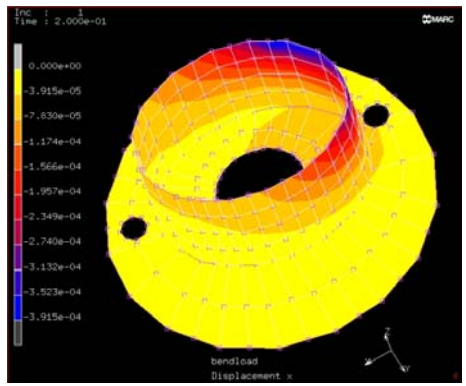
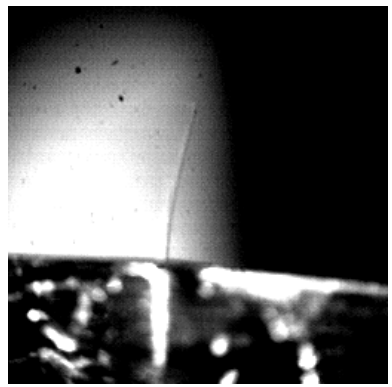
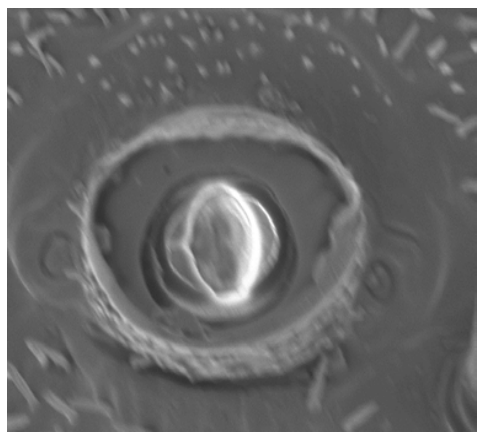
INTEGRATION OF INFORMATION







Biological System ⟷ Reconstruction ⟷ Modelling ⟷ System Response



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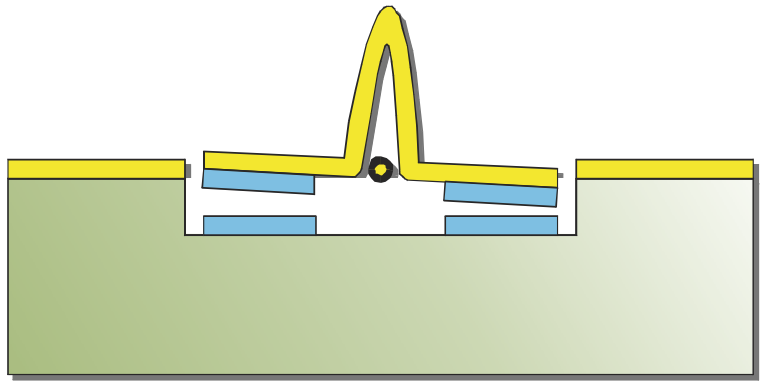
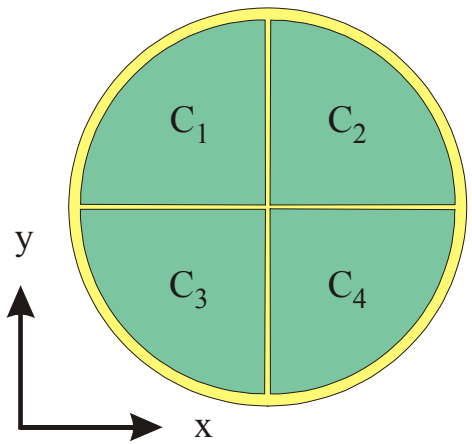
Capacitive read out

- High sensitivity
- Generator or modulator type
  (Low power consumption)
- Measures displacement
- Relative complex read out electronics
- Ability for 2 dimensional sensing
  and common mode rejection





$S_x=(C_1 + C_3) - (C_2 + C_4)$

$S_y=(C_1 + C_2) - (C_3 + C_4)$

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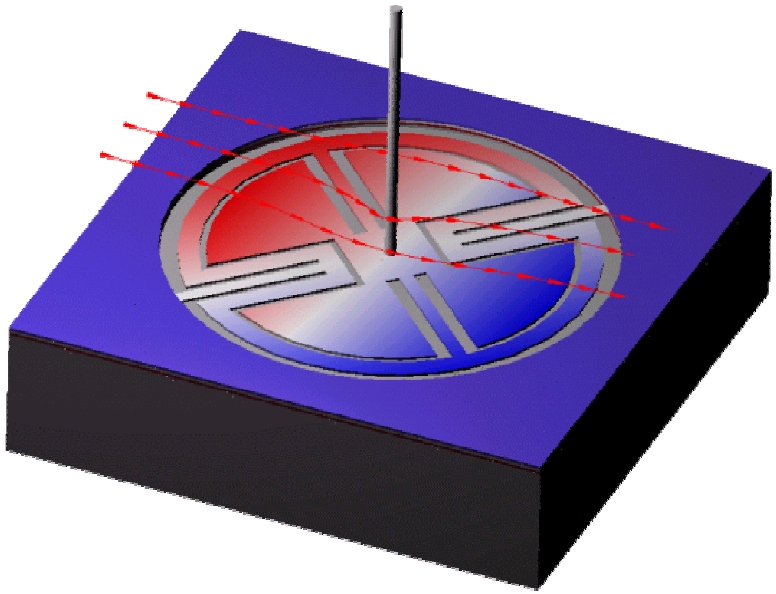
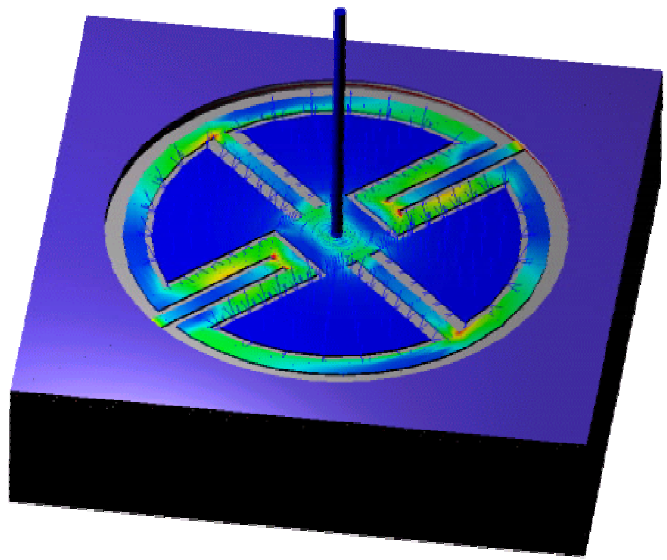
Simulations
Double Gimbal





- Developed flow at 3 $m \cdot s^{-1}$ as input
- Maximum deflection 3.6 nm at edge of the plate
- 0.61 nm deflection by 1 V attraction
- Capacitance $0.15 \cdot 10^{-12}$ F

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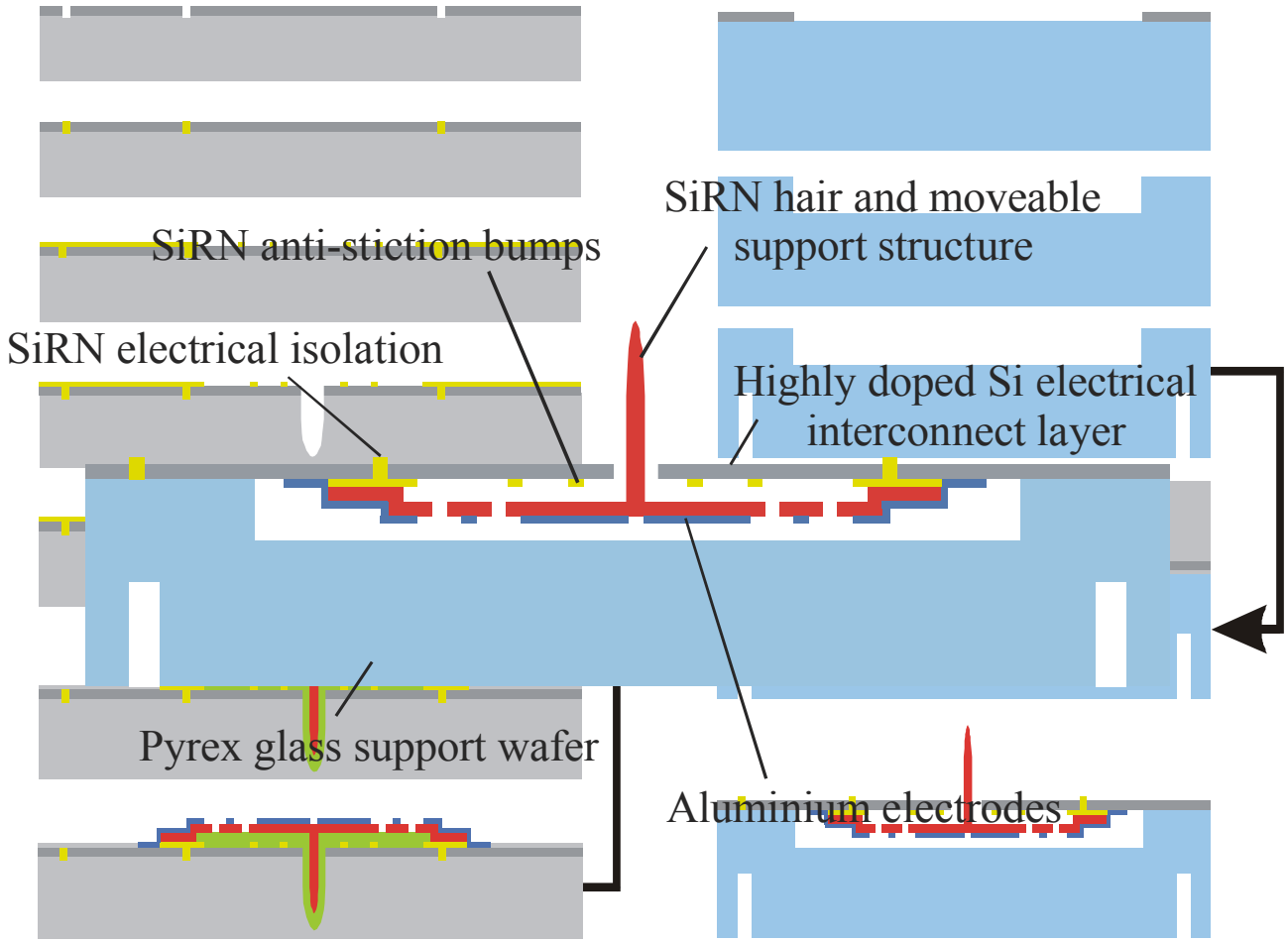
The Technology

"if we only could use DNA"

- Etching control by Boron doping
- Wafer dissolving
- 7 masks
- 7 layers top
  2 layers bottom
- 40 - 50 clean-room steps



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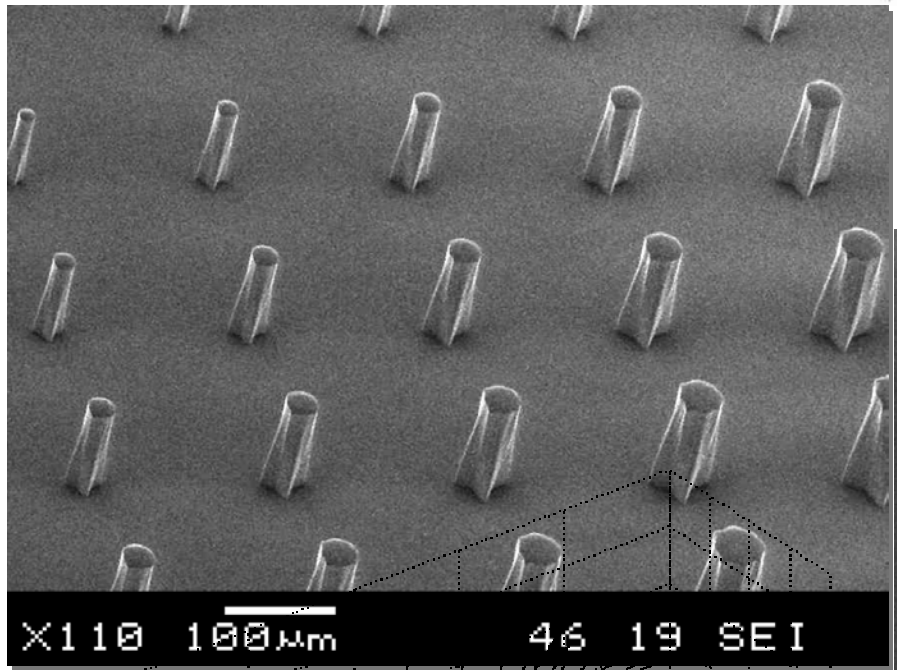
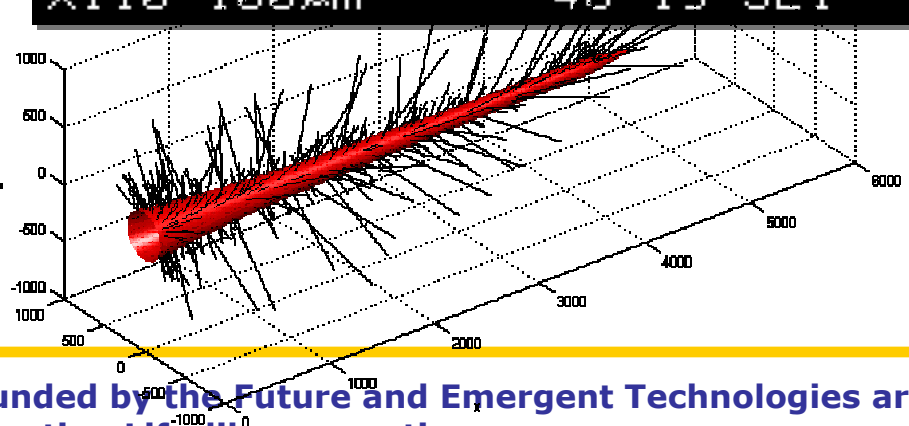
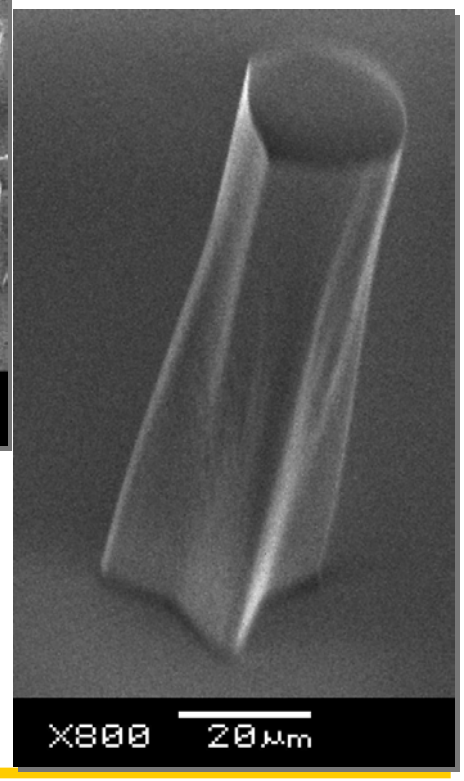
Test fabrication of hairs

- Star shaped masks
- Anisotropy
- >80 μm long 25 μm wide
- Flat top ⇒ hairs can be made longer







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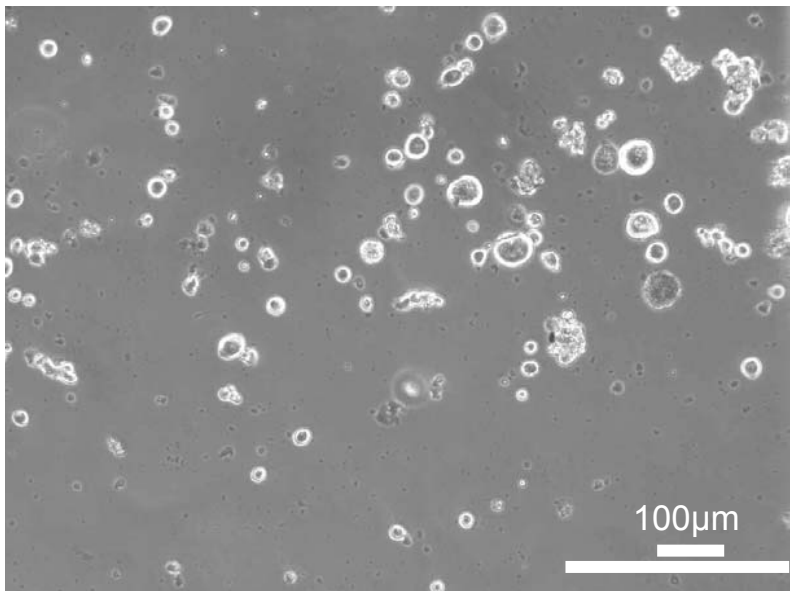
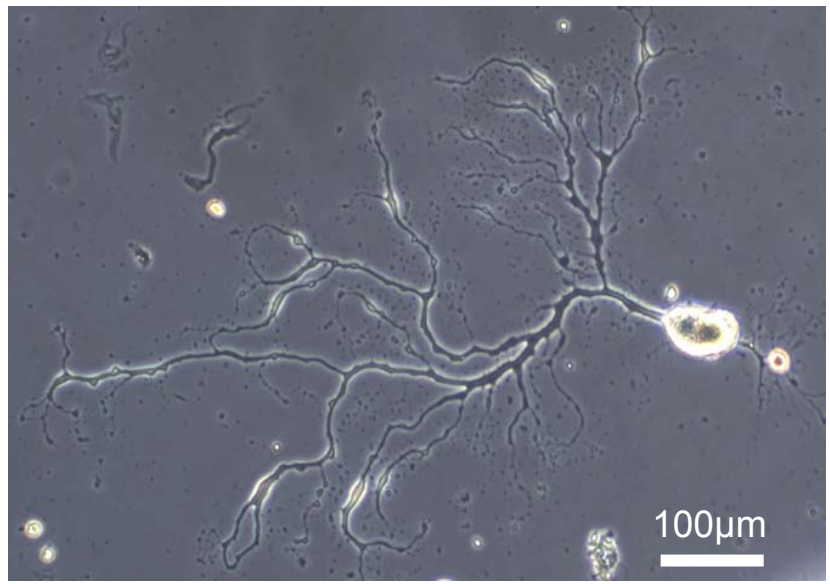
Morphological differentiation





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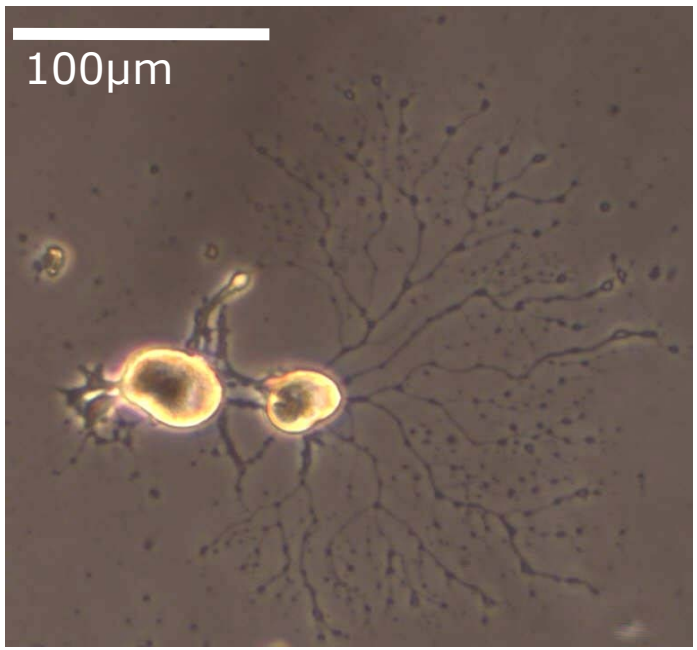
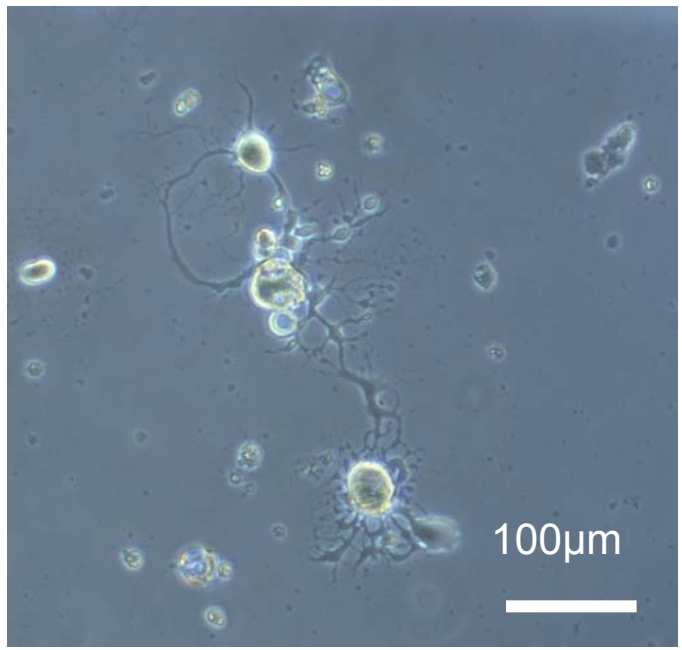
Network formation





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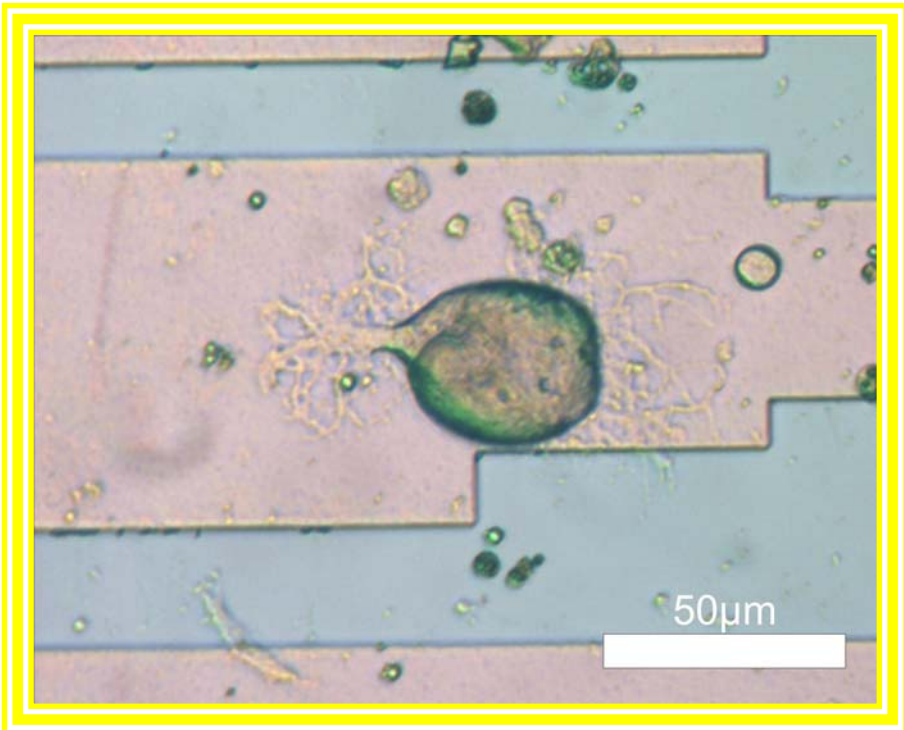
culture of insect neurons on microelectronic devices



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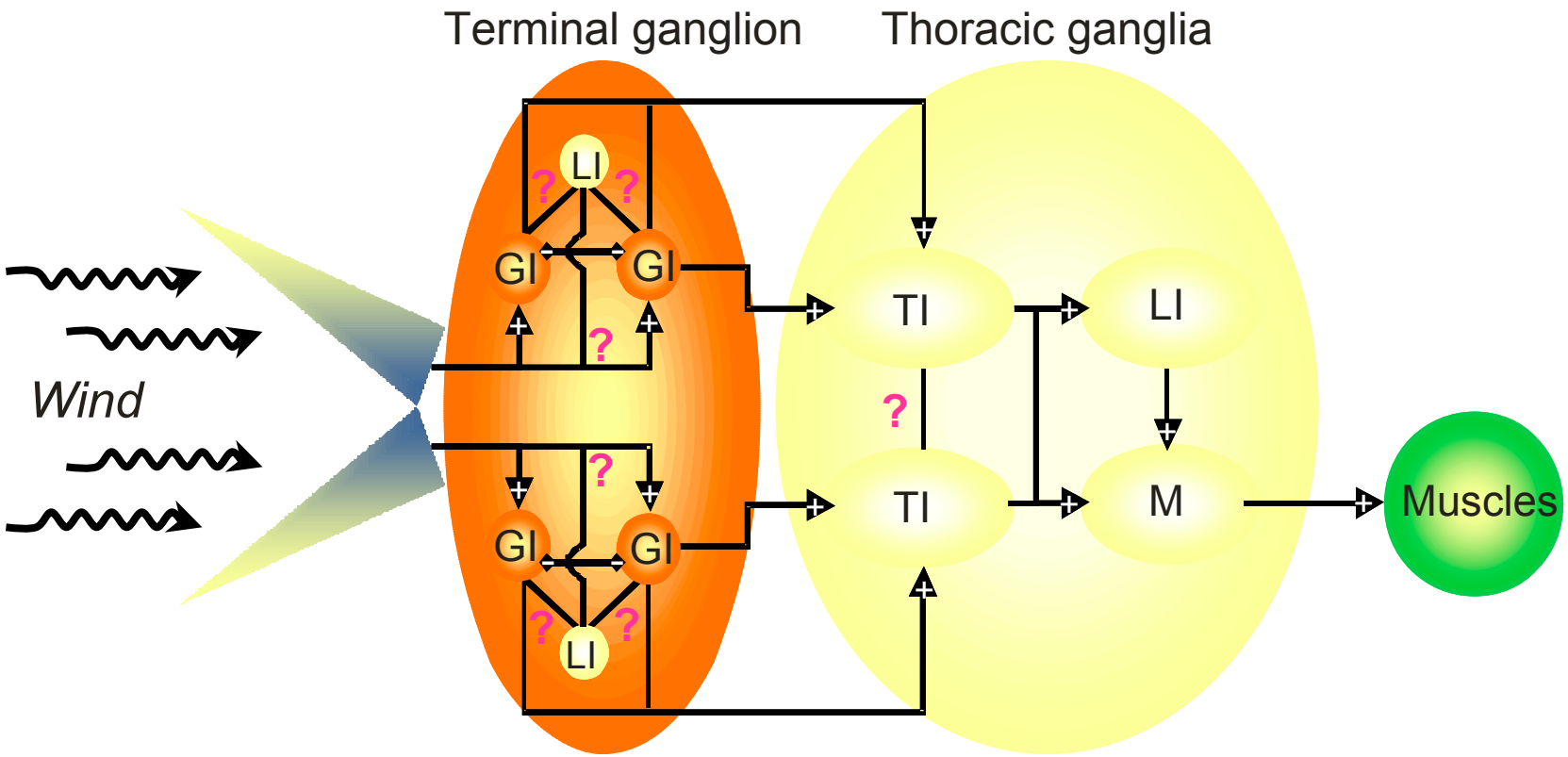
Escape circuit of crickets



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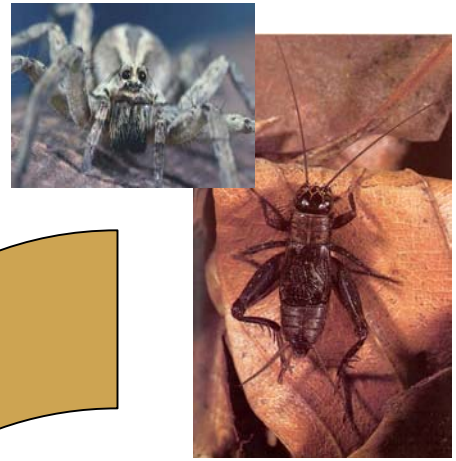
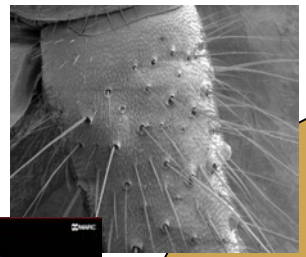
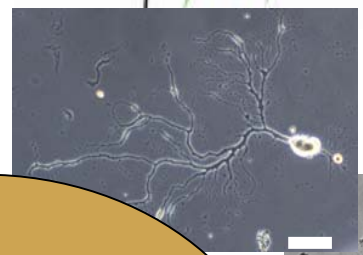
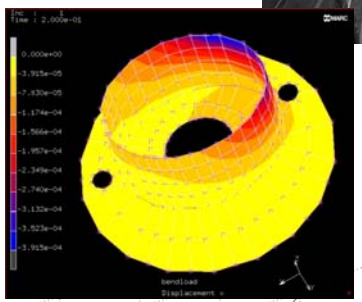
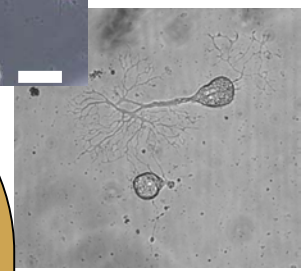






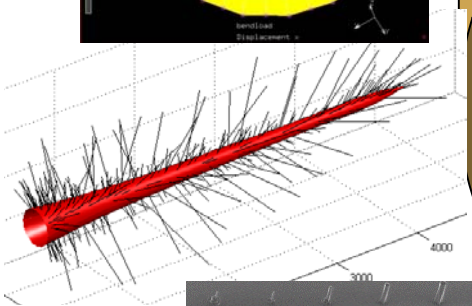


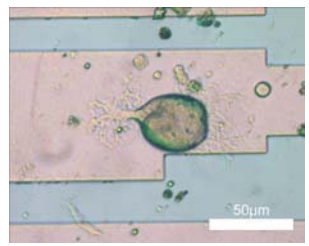


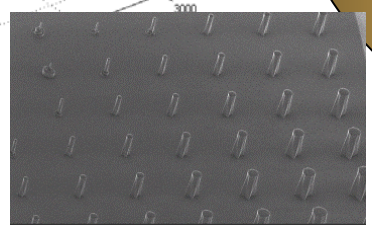
Sensing

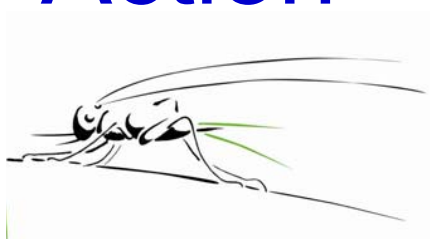
Perception

Action









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