Snakes in Space: Limbless Biomimetic Snake Robots for Extraterrestrial Exploration

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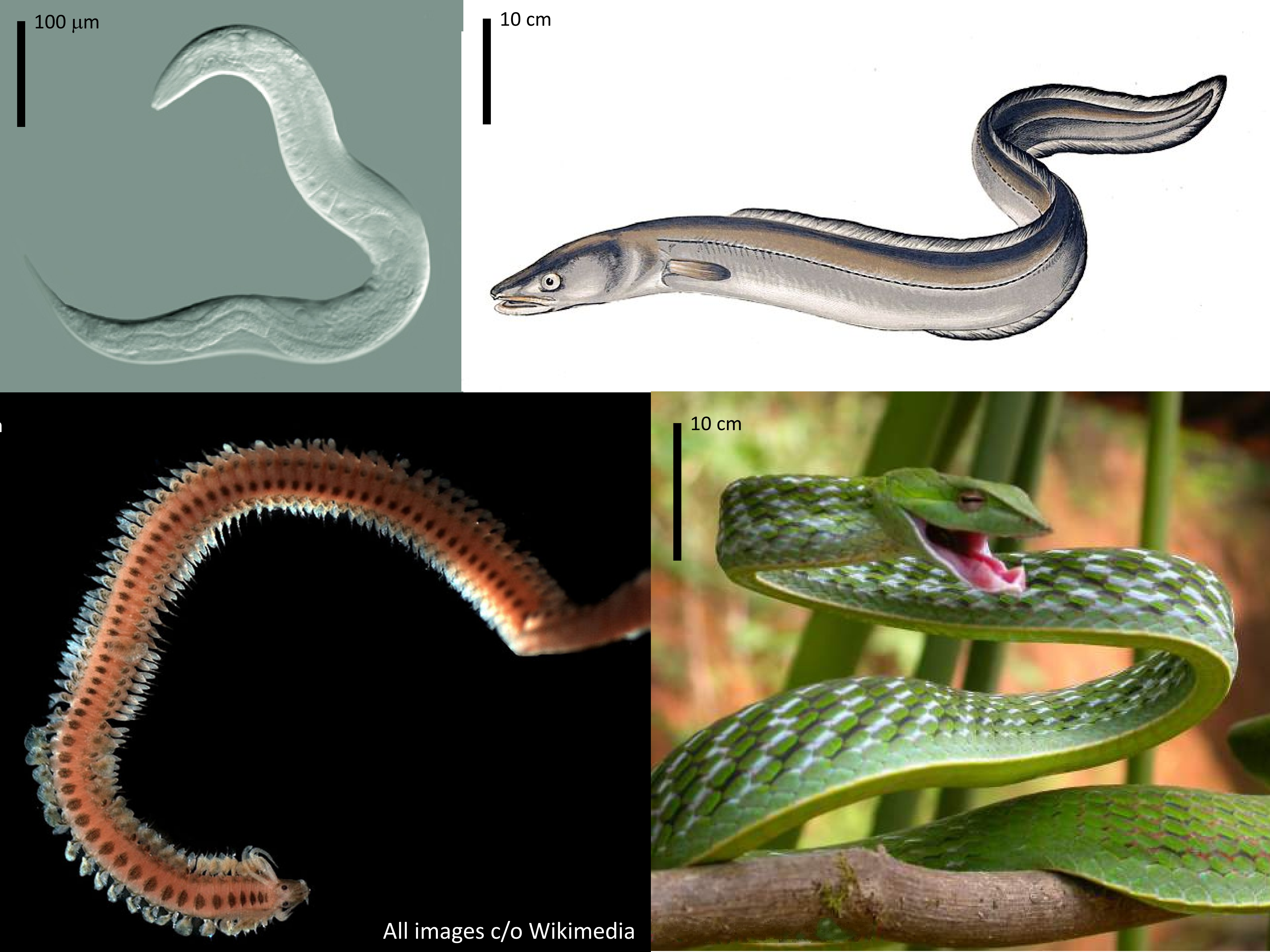
Butte 'M9a' in 'Murray Buttes' on Mars
NASA's Curiosity Mars rover


NASA's Curiosity Mars rover


Wikimedia
Opheodrys aestivus


100 μm
10 cm
10 cm
All images c/o Wikimedia


Armand Kok
2009

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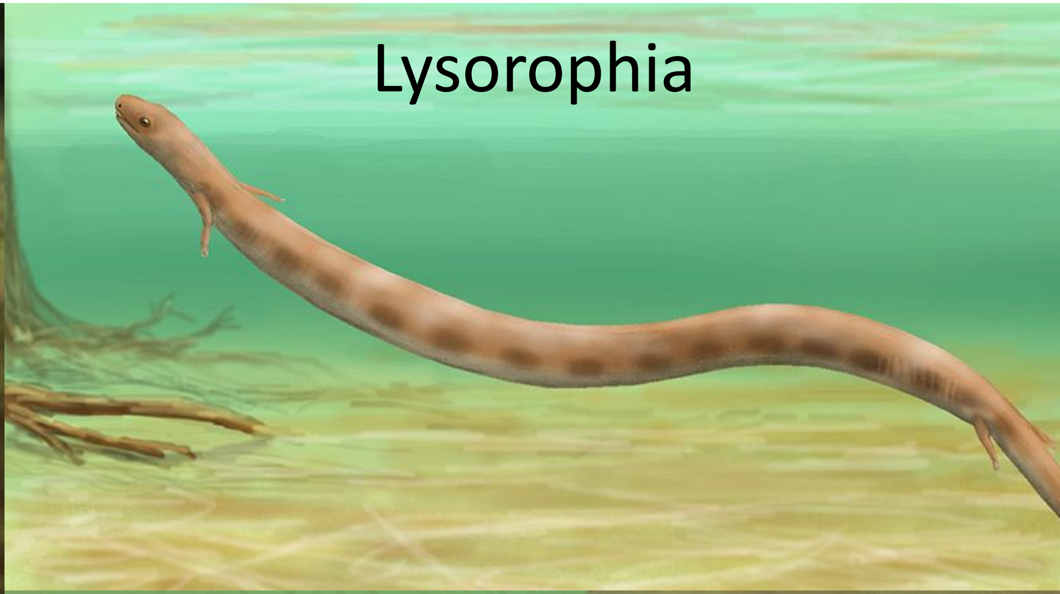
John D. Willson

(c) Philipp Wagner, Chamaesaura miopropus, Zambia, Ikelenge, Hillwood Farm



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Wikimedia *Opheodrys aestivus*

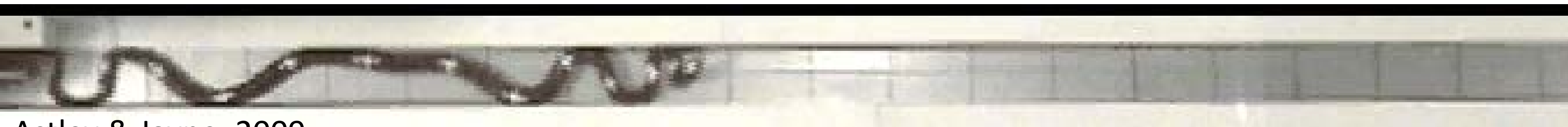
Wikimedia *Pantherophis obsoletus*


Choset Lab

Astley & Jayne,
unpublished data

4x speed

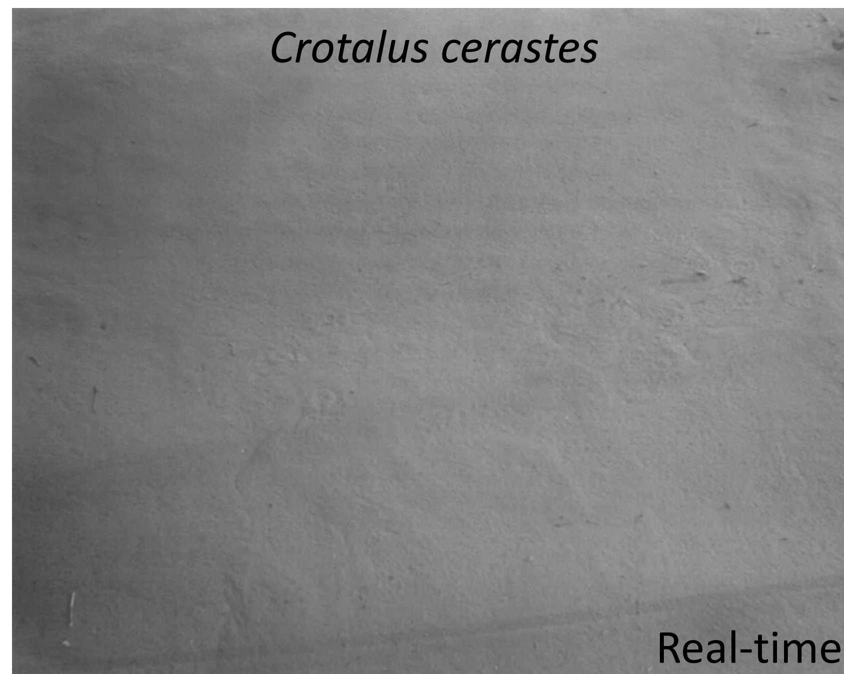
Pantherophis guttatus



Astley & Jayne, 2009

Real-time

Real-time

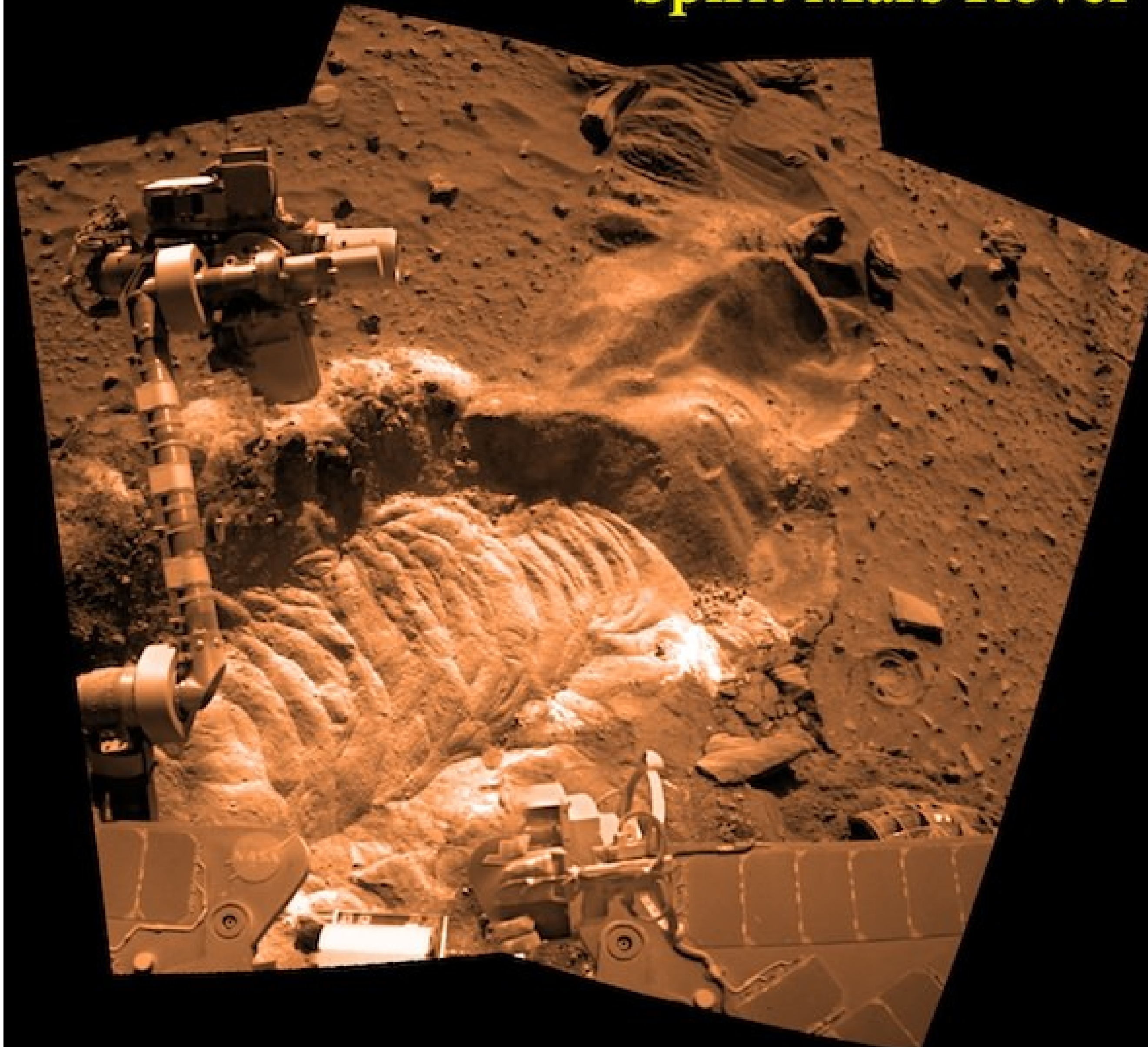


El Dorado Dune Field, Mars
NASA Spirit Rover

Rainbow Beach, Queensland, AUS

NATO Exercise in Portugal

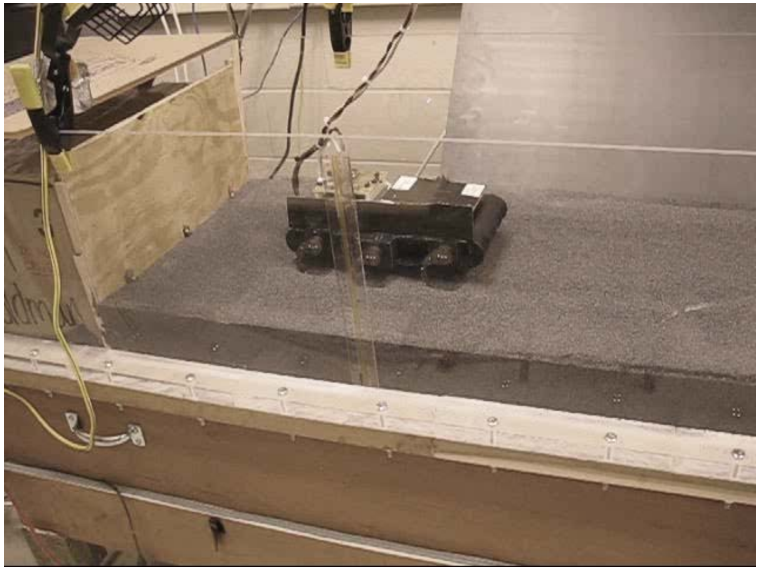
Spirit Mars Rover



Robotic arm and sand trap at Troy in Gusev Crater Mosaic

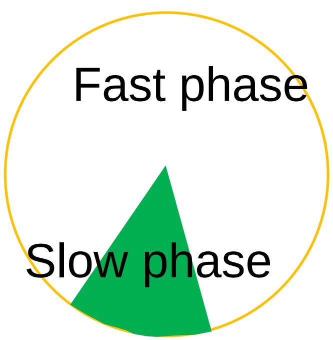
Sol 2174 February 2010 Credit: Marco Di Lorenzo, Kenneth Kremer NASA/JPL/Cornell

Locomotor sensitivity on simple flowing ground

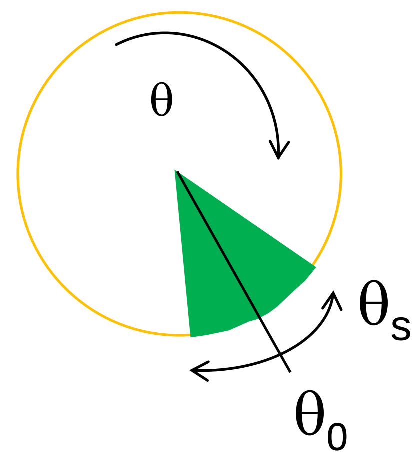


SandBot, ~2 kg

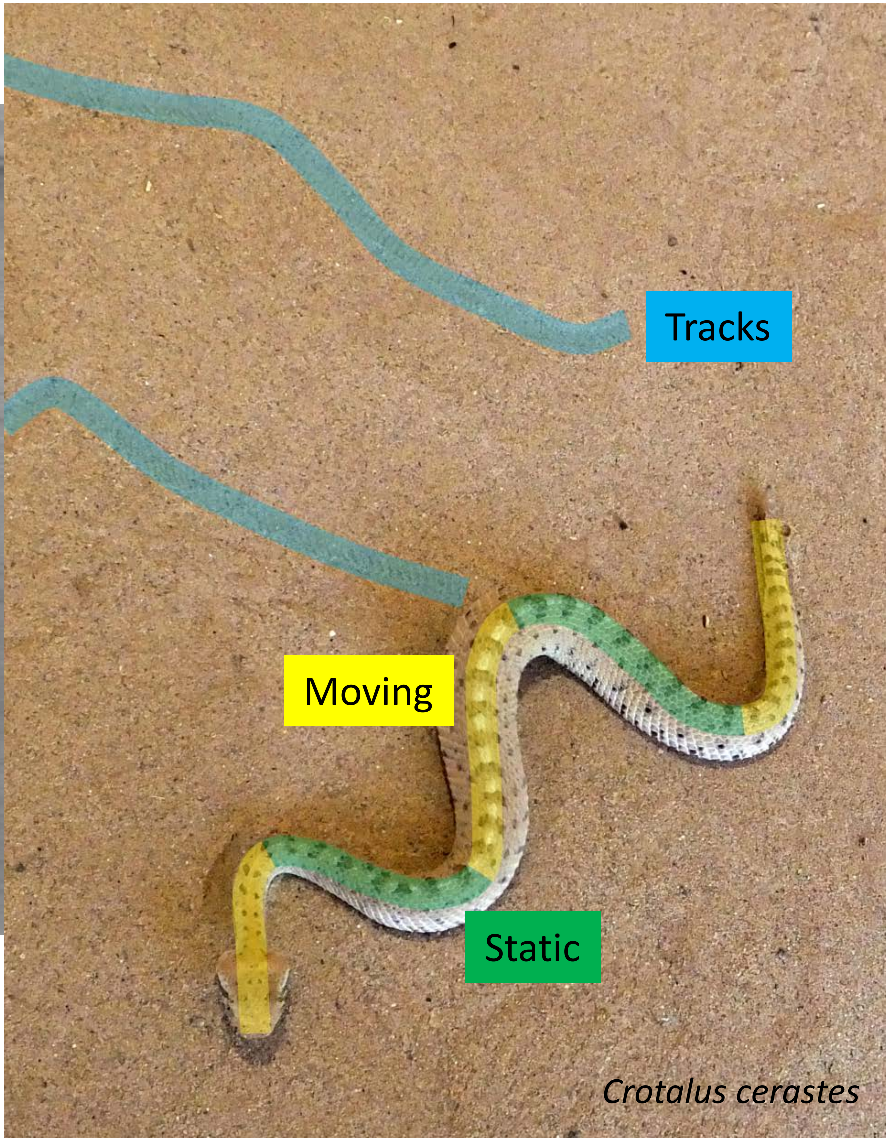
Tuned for hard ground kinematics

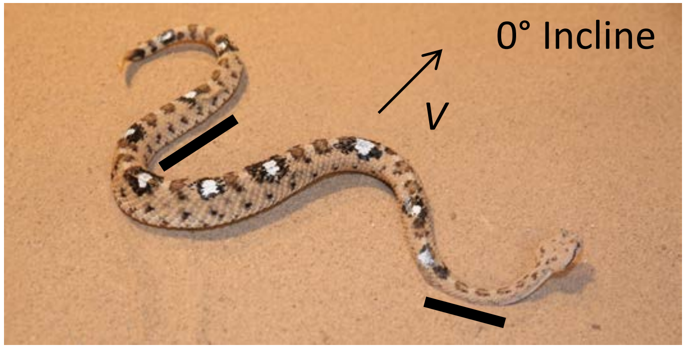


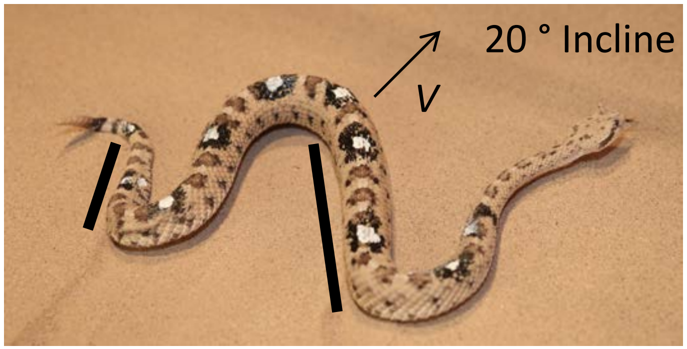
Tuned for soft ground kinematics



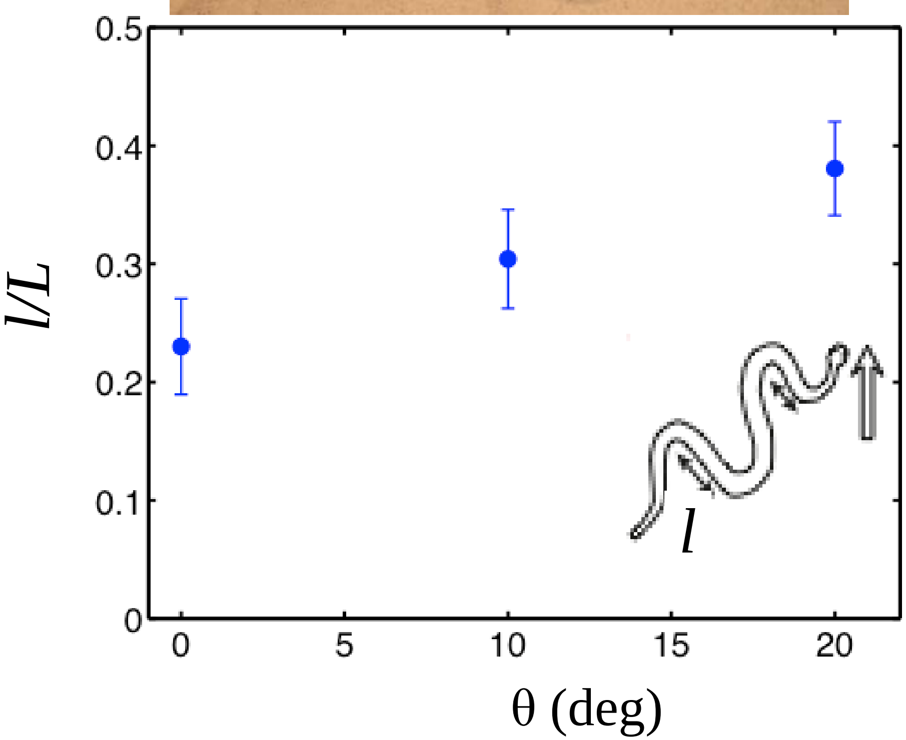
Li, Umbanhowar, Komsuoglu, Koditschek, Goldman, *PNAS*, 2009, *Exp. Mechanics*, 2010.

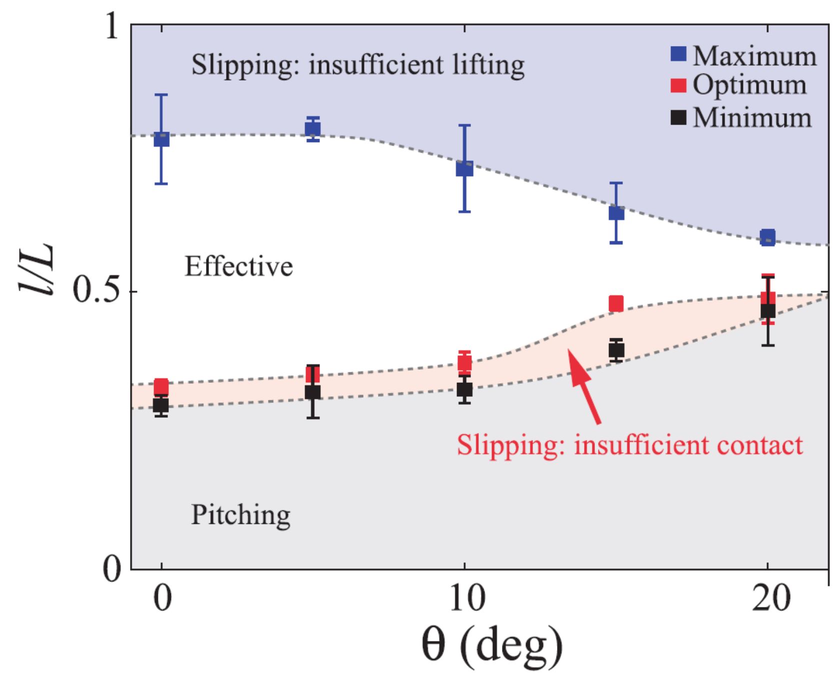

Tracks
Moving
Static
Crotalus cerastes





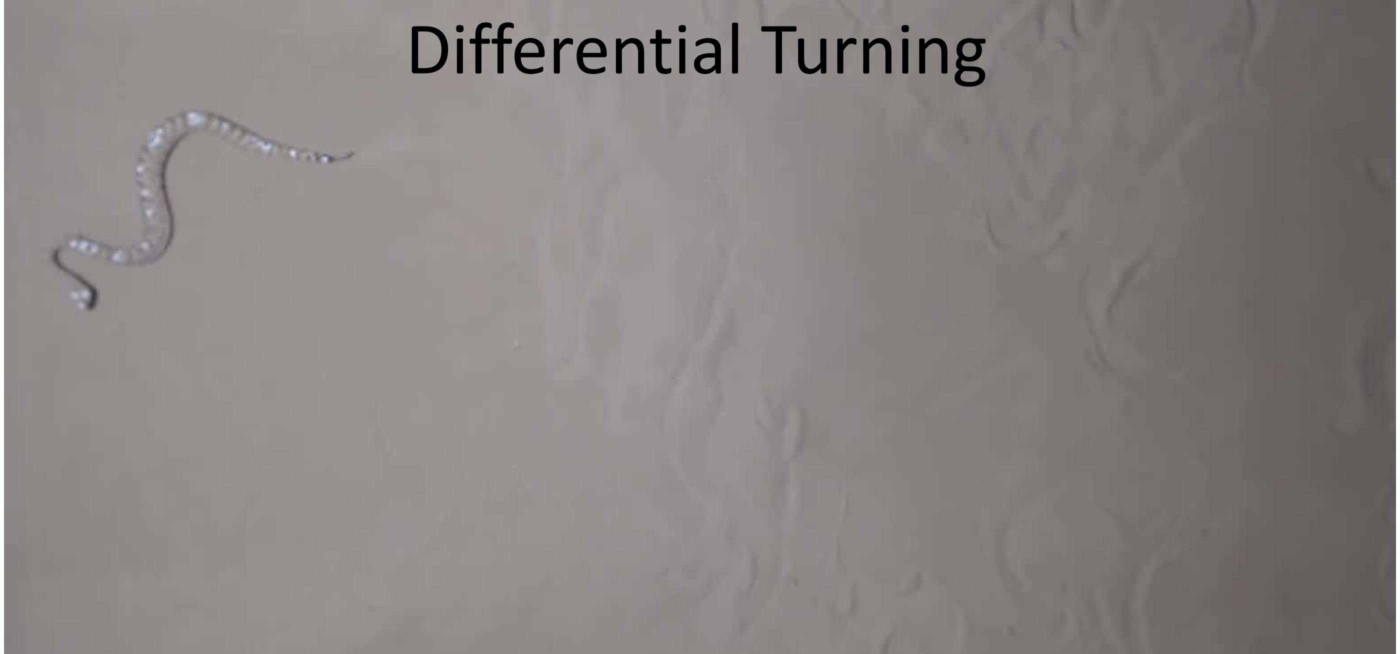
10 ° Incline

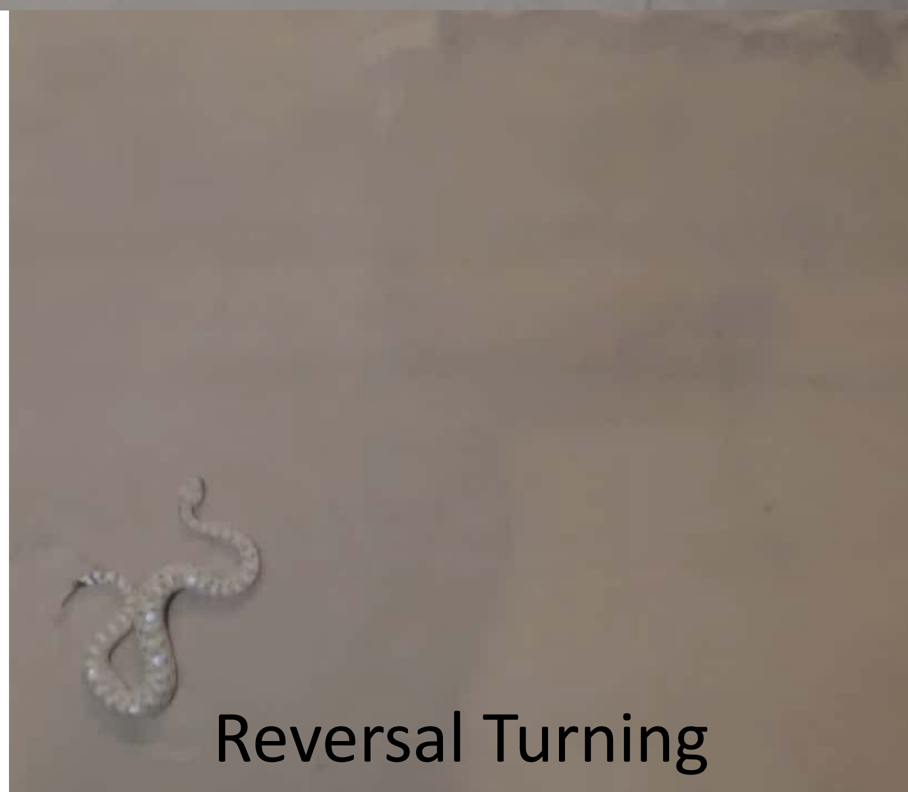




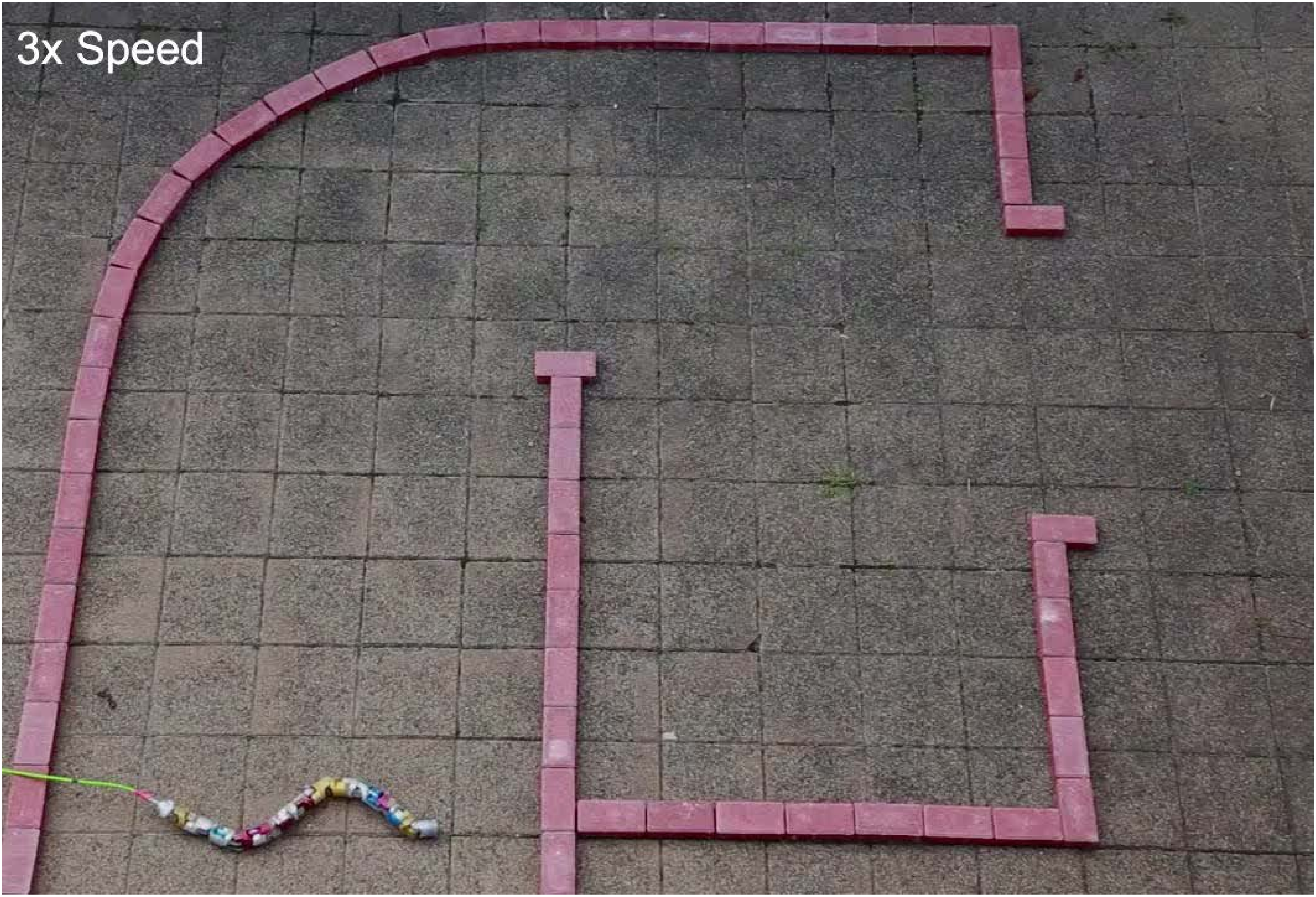
Marvi et al 2014

Differential Turning





Reversal Turning


3x Speed

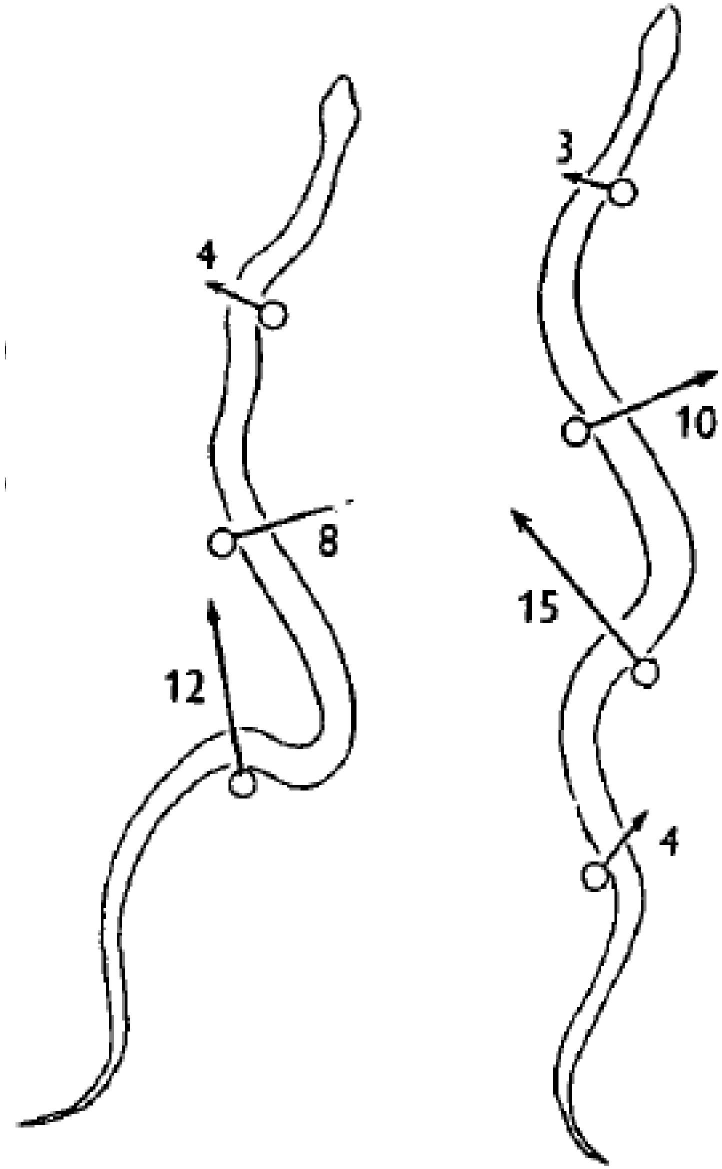

Butte 'M9a' in 'Murray Buttes' on Mars

NASA's Curiosity Mars rover

Lateral Undulation

Corn Snake (*Pantherophis guttatus*), Astley Lab

- Snakes use obstacles as "push points" to generate propulsive force
- **Increased obstacle density allows snakes to move faster, while limbed animals go slower!**
- Most common, but control is least understood.
- Lateral Undulation is a dialogue between the snake and its environment



Gray & Lissman 1950

Sharpe et al 2014


Murray Buttes, Mars
NASA Curiosity Rover
What’s in there?

Concertina Locomotion

Corn Snake (*Pantherophis guttatus*), Astley Lab

- Concertina locomotion allows snakes to move through tunnels effectively across a wide range of diameters
- Slow and expensive (in part due to anchoring forces), but versatile across many situations
  - Lateral anchoring can be replaced with medial gripping for narrow arboreal branches.
- Bends in tunnels or obstructions can serve as anchor points to switch to lateral undulation.

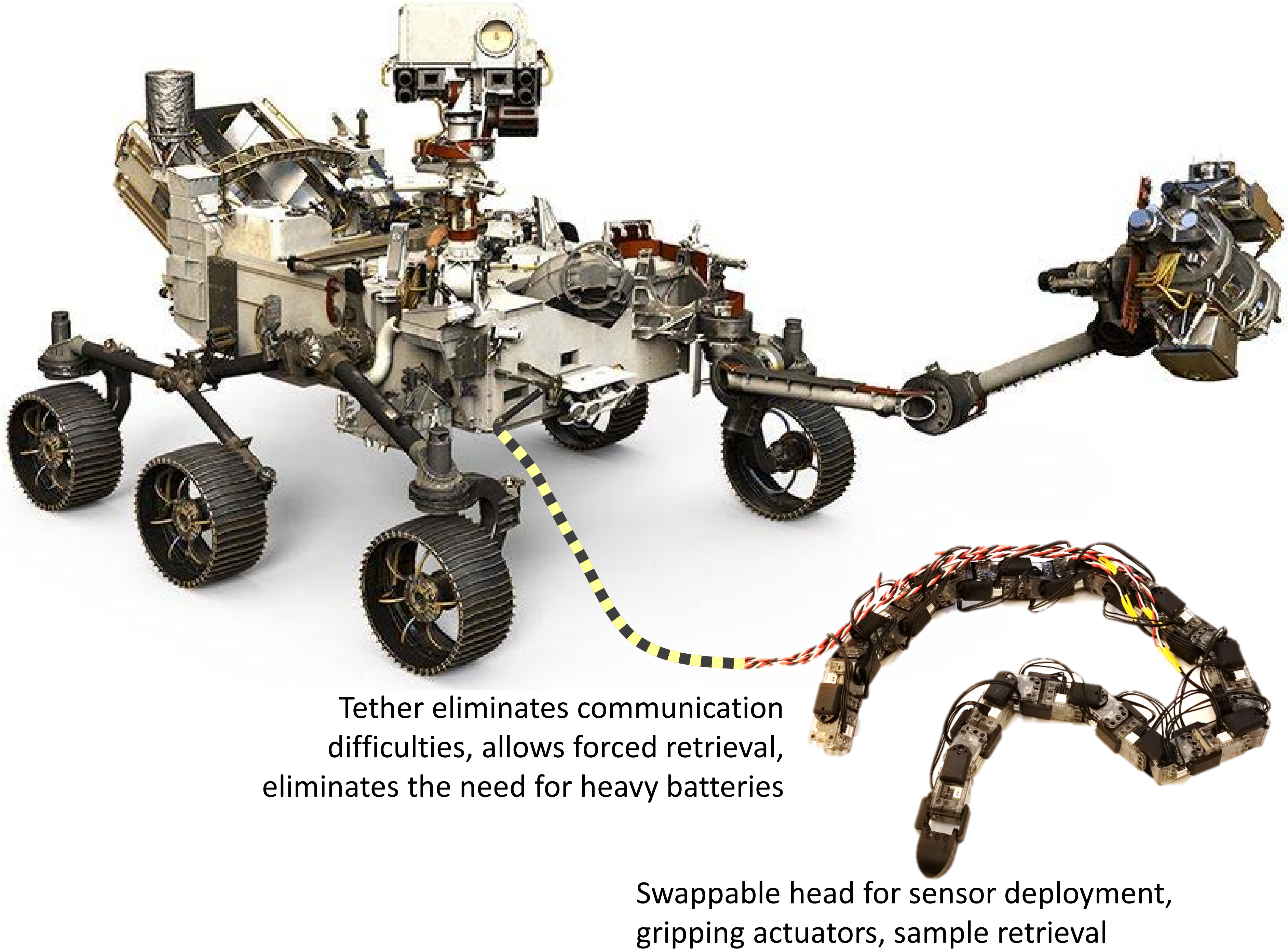
Bio-inspired Adaptive Snakebot Concertina Locomotion, 3x speed, Astley Lab

Astley & Jayne, unpublished data

Rectilinear Locomotion

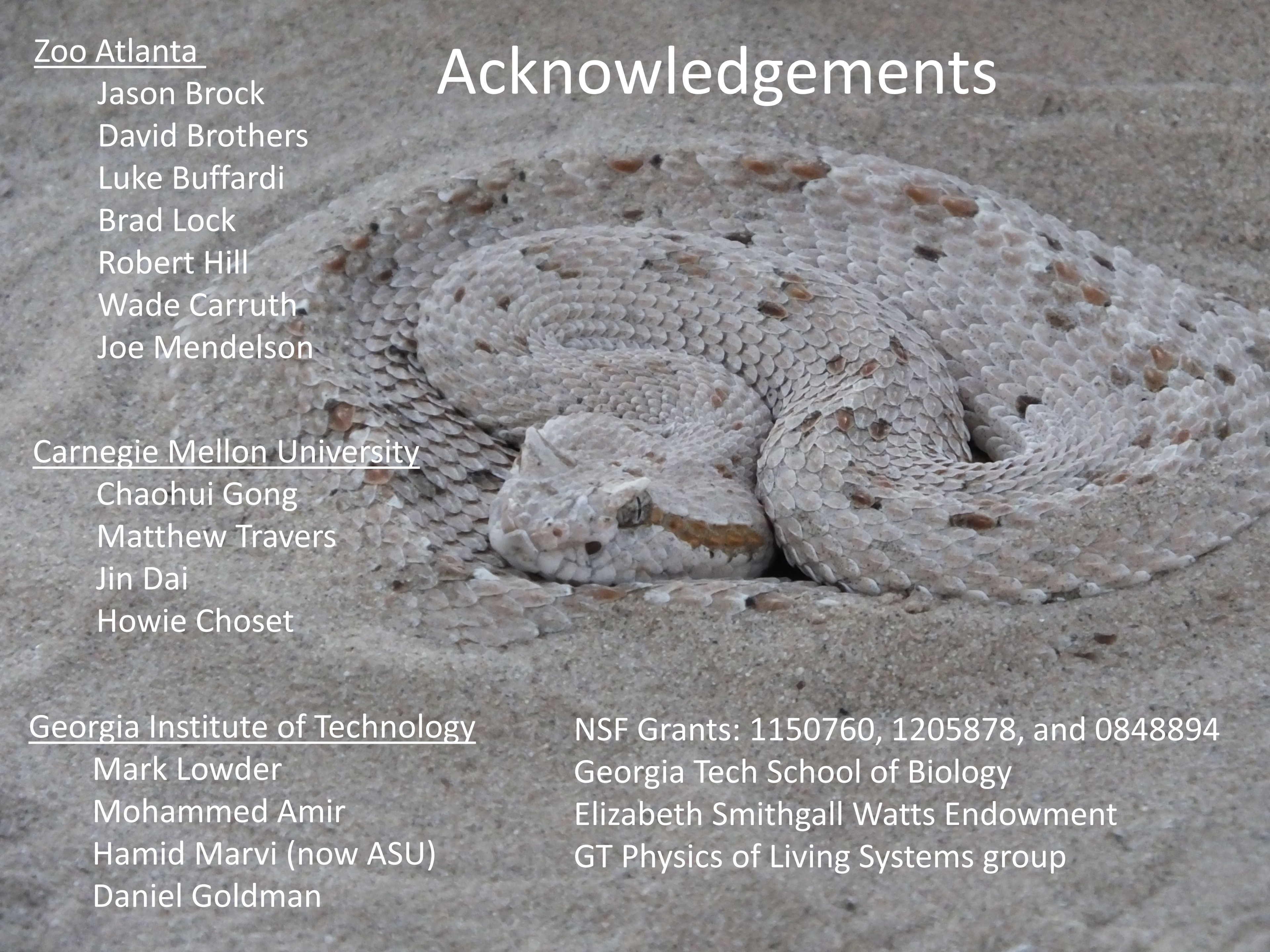
4x speed

- Rectilinear locomotion can allow snakes to move through any hole or tunnel the body can fit through
- Body scales are cyclically lifted, moved forward, and lowered into static contact with the ground, just like the body segments in sidewinding
- Preliminary trials show no-slip locomotion on loose sand, even at steep inclines
  - Alternative to tracks and wheels for rovers?


Tether eliminates communication difficulties, allows forced retrieval, eliminates the need for heavy batteries
Swappable head for sensor deployment, gripping actuators, sample retrieval

Slithering Into The Future: Next Steps?

- Biomimetic replication of snake locomotor modes
  - Current snakebot can do 3 / 4 modes, but only sidewinding really well
- Need understanding of snake control algorithms
  - High DOF system, yet snakes have rapid control including environmental feedback
  - Snake nervous system is completely "black box"
- Improved actuators
  - Better torque and power
  - Smaller/more vertebrae



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