Imiter la nature et comprendre les organismes au travers des robots

Auke Jan Ijspeert

Le meilleur des mondes robotiques
Réseau des scientifiques évangéliques, Suisse Romande
2.6.2018

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Biorobotics Laboratory EPFL

Je me présente

- Né à Genève
- Parents hollandais

- Etudes de physique à l'EPFL, 1995

- Doctorat en Intelligence Artificielle à l'Université d'Edimbourg, 1999

- Postes de recherche à l'EPFL et à University of Southern California

- Professeur à l'EPFL depuis 2002, Laboratoire de Biorobotique

- Chrétien

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Robotics applications

Manufacturing

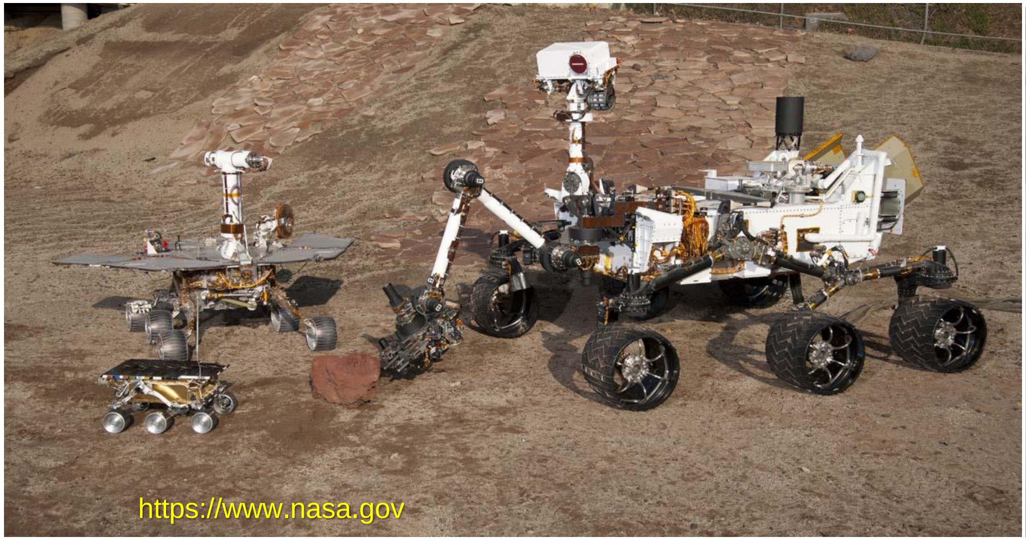
Automated warehouses

House holds

Military applications

Robotics applications

Field/space robotics



Mobility

Surgery / rehabilitation

Entertainment

Biorobotics

=

Biologically-inspired

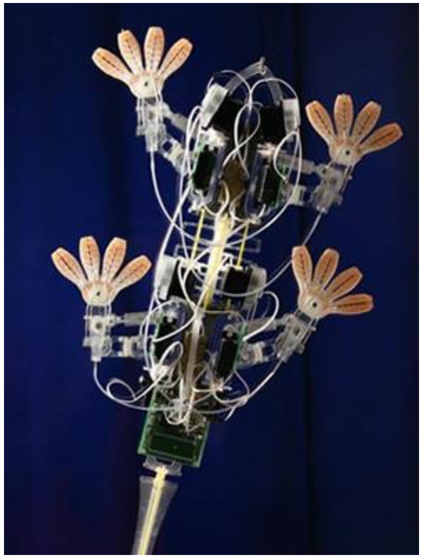
or

Biomimetic robotics

Legged robots

ANYmal
ETHZ, Switzerland

Aibo, SONY, Japan



StickyBot, Stanford, USA

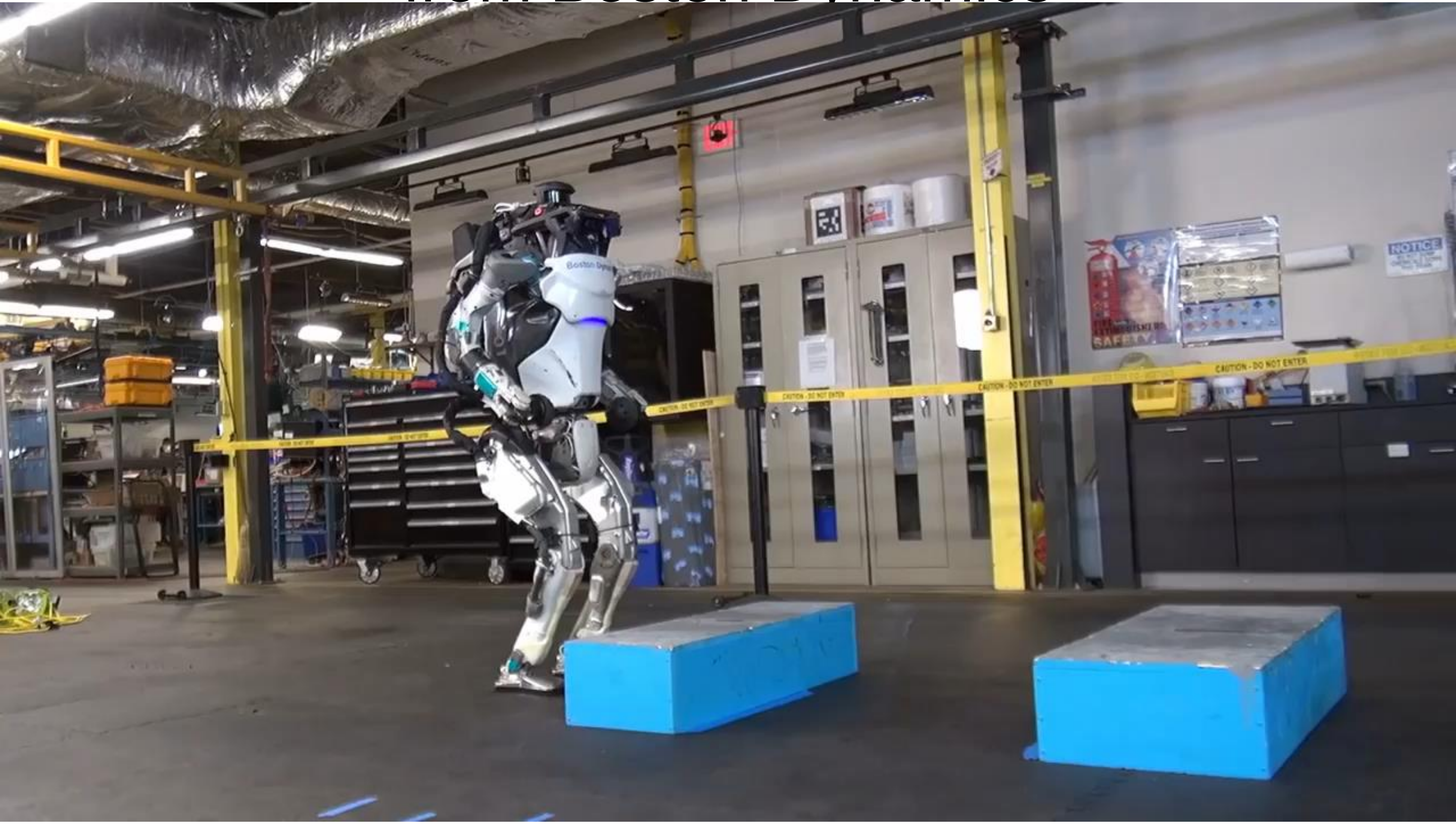
RHex robot, USA

Asimo, Honda, Japan

BigDog,
Boston Dynamics, USA

Impressive recent results from Boston Dynamics

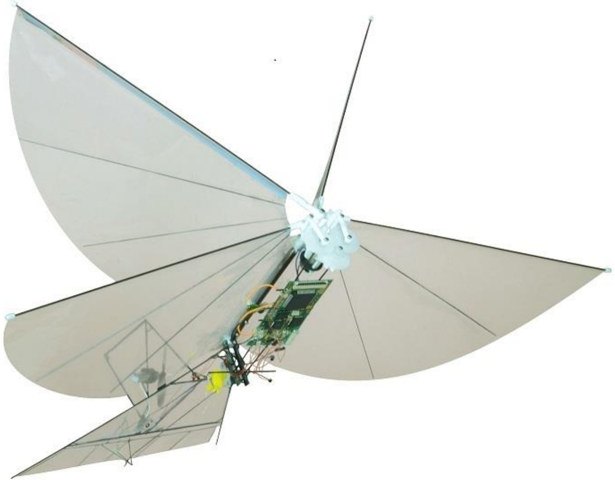
Impressive recent results from Boston Dynamics



Flying robots

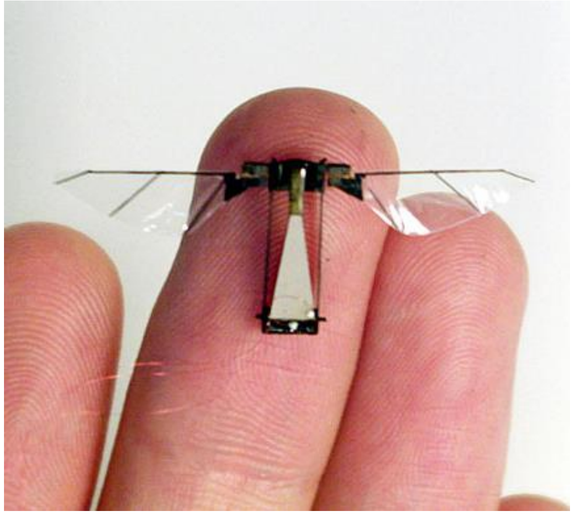
Feathered Drone, LIS, EPFL

Hummingbird, AeroVironment, USA



Ornithopter robot, U. Berkeley, USA

SmartBird, Festo, Germany



Micro aerial vehicle, Harvard Univ., USA

Swimming and crawling robots

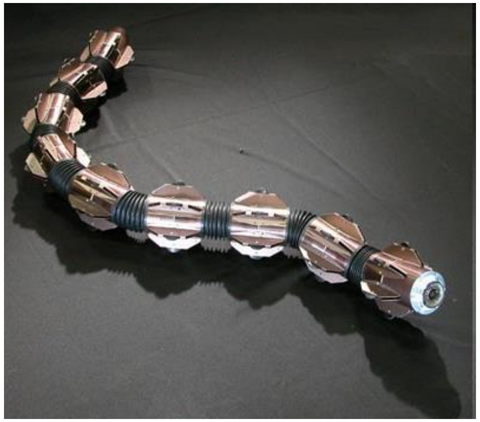
G6 Fish Robot,
University of Essex, UK

Manta Ray
EvoLogics, Germany

Lamprey robot, U. of Northeastern, USA

Lamprey robot, SSSA, Italy

Penguin robot, Festo, Germany



ACM robot, Tokyo Inst of Tech Japan

Snake Robot, CMU, USA

Biorobotics

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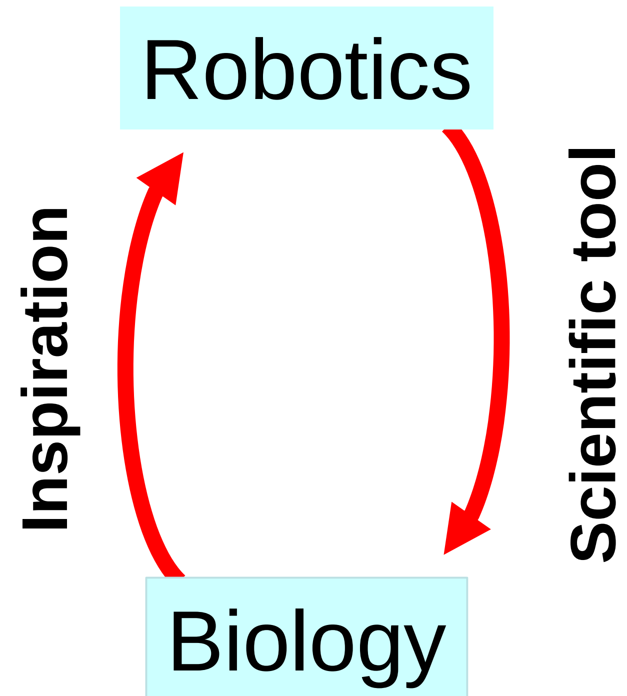
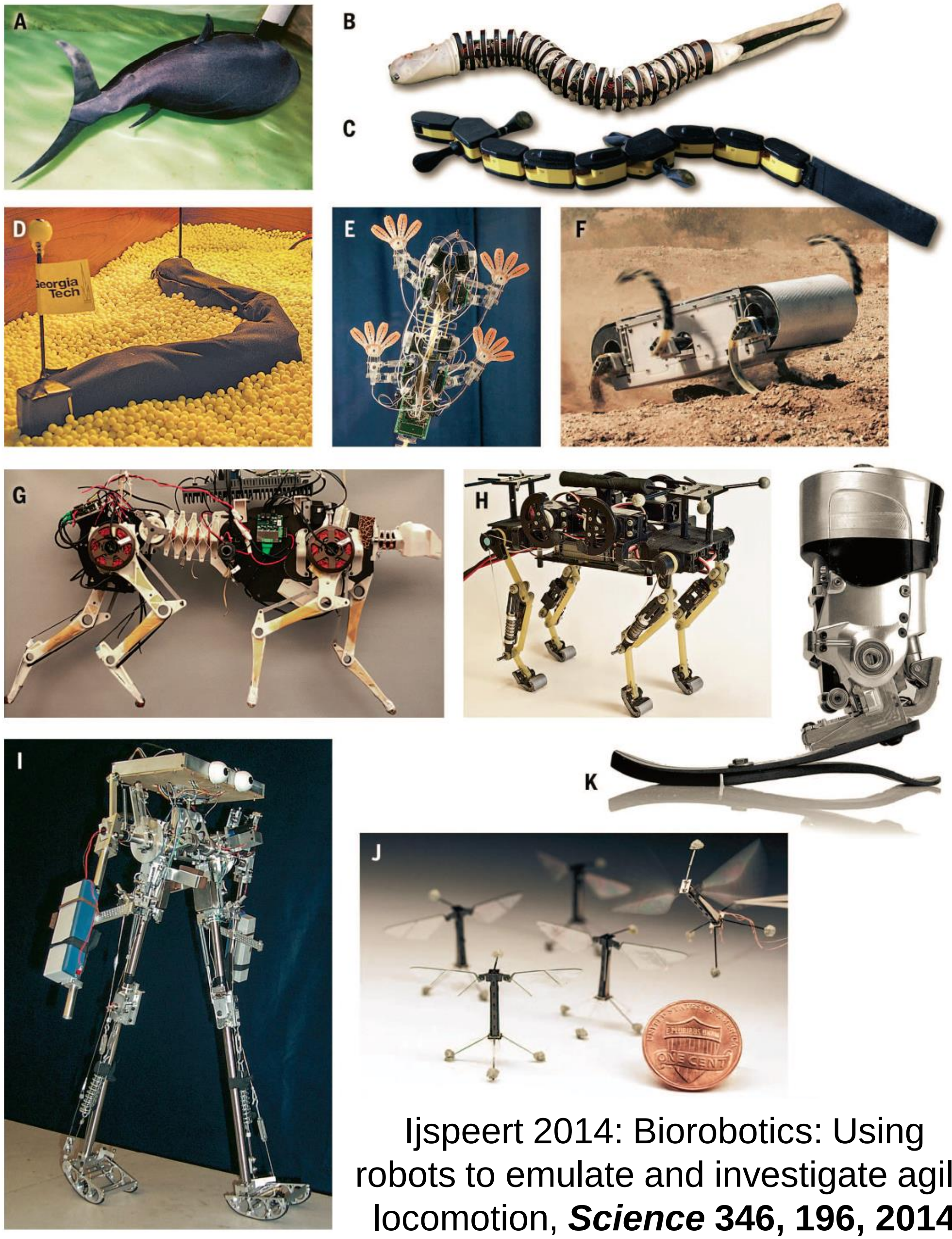
Field robotics
Search and rescue
Transport
Agriculture
Environmental monitoring



Neuroscience
Biomechanics
Hydrodynamics



Ijspeert 2014: Biorobotics: Using robots to emulate and investigate agile locomotion, ***Science*** **346, 196, 2014**

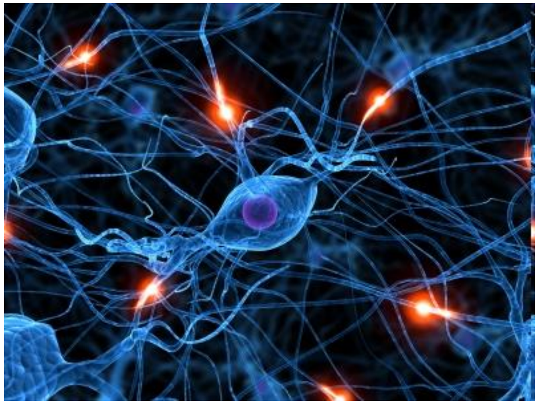
Why is locomotion important?

Engineering:

Having **robots that move better** in unstructured and unknown environments is absolutely **necessary for multiple applications**

Science:

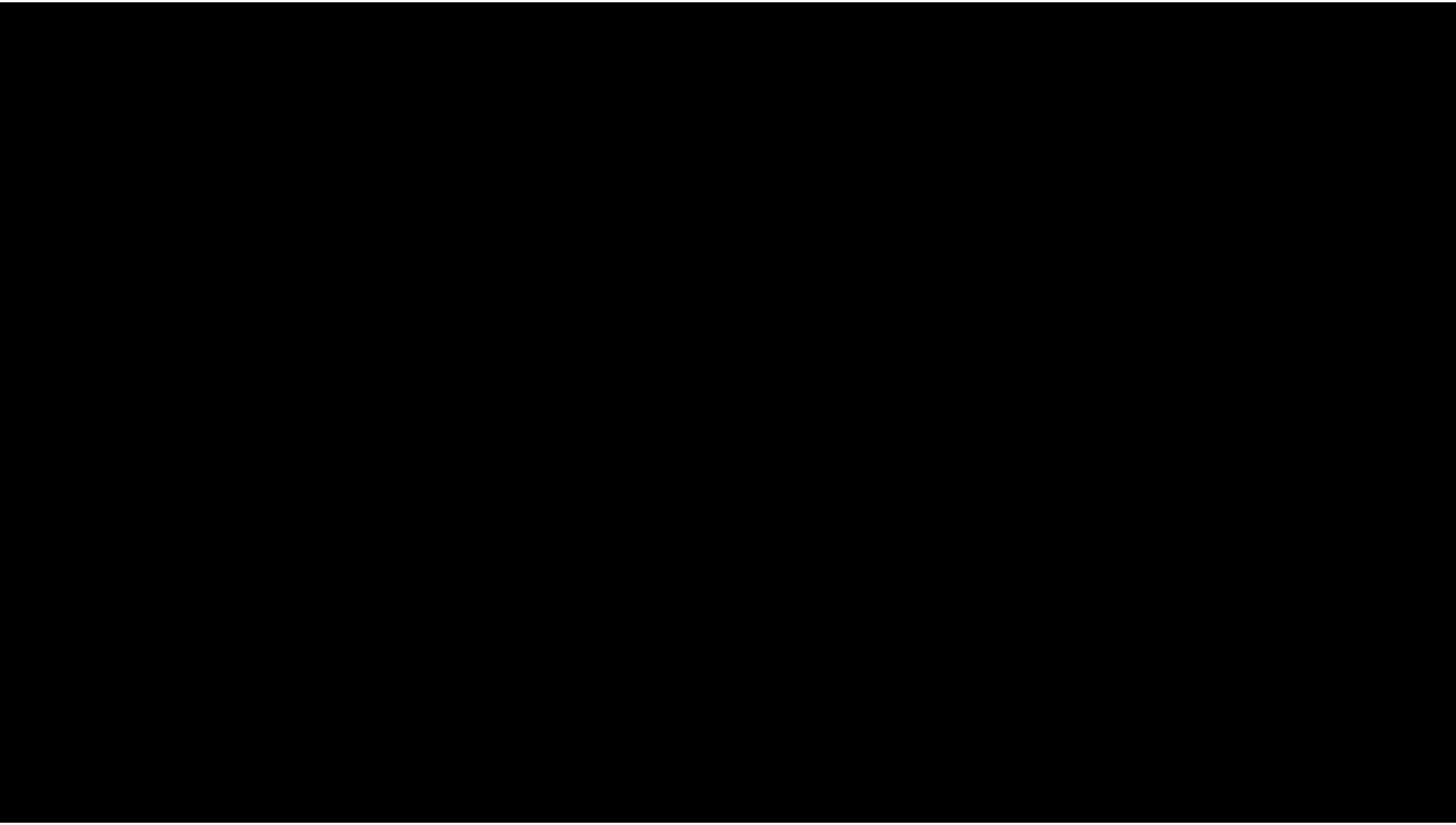
Moving is fundamental to animals.



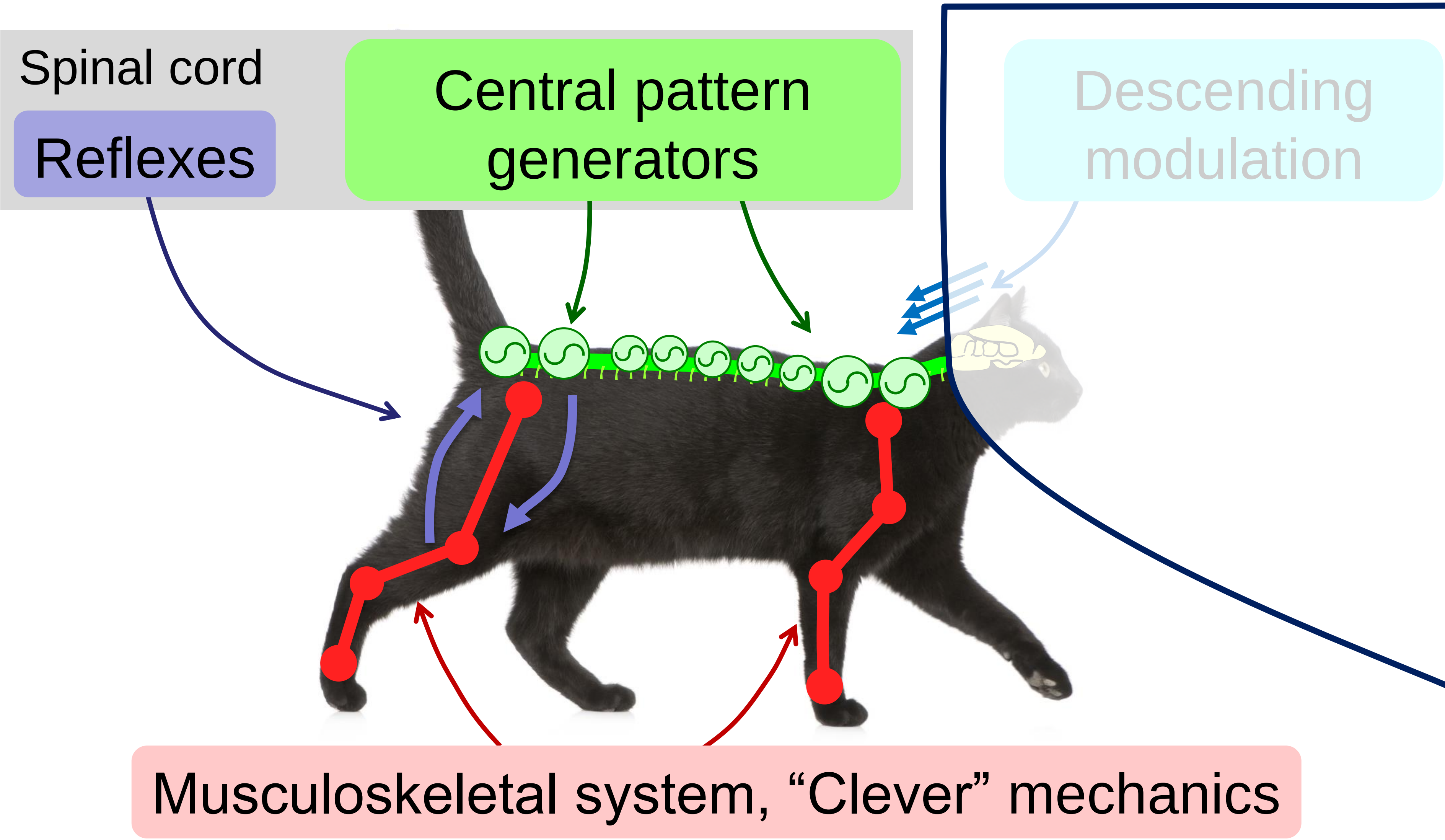
Society:

Having motor deficits is one of the **worst handicaps**

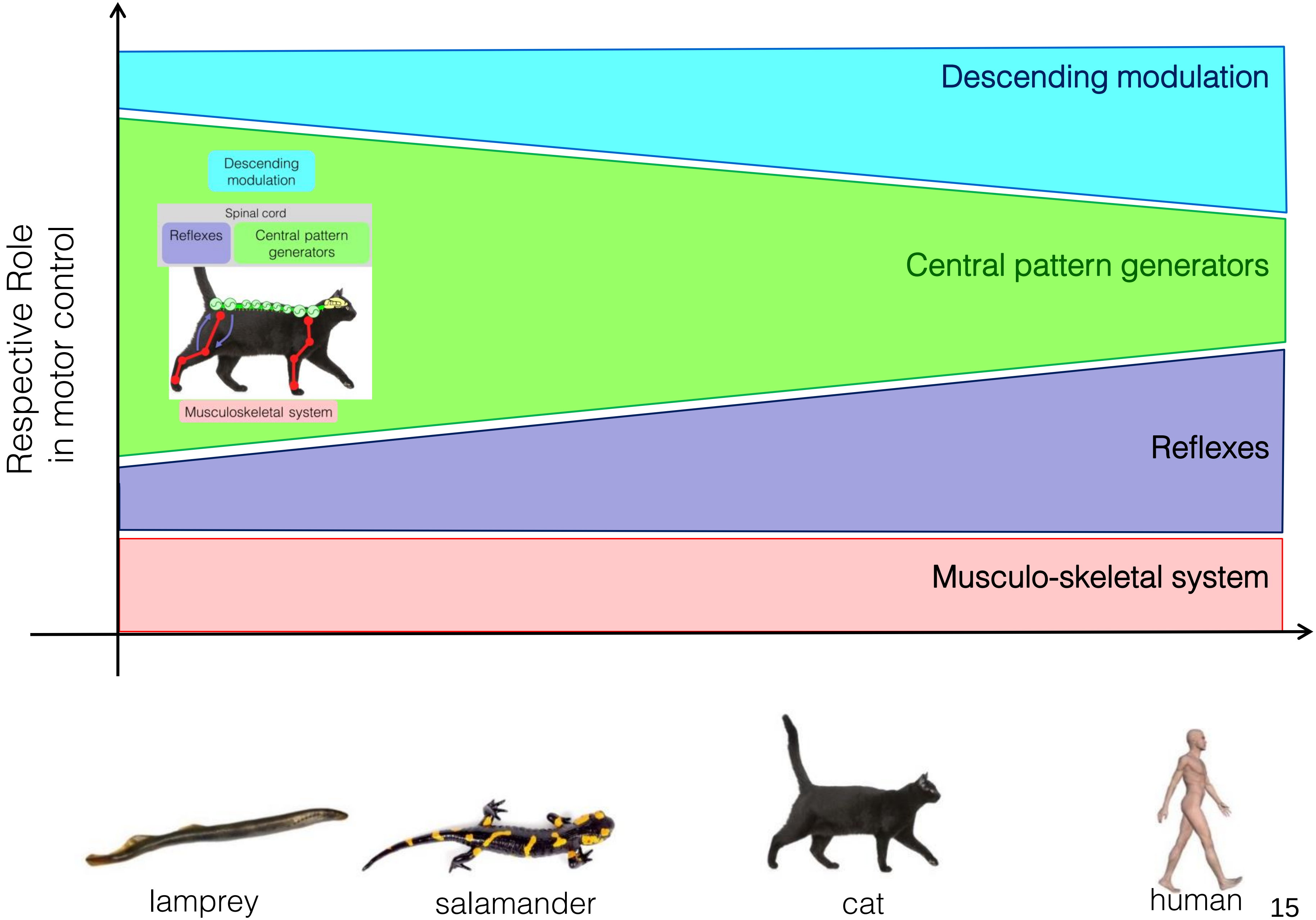
The beauty of animal movement control



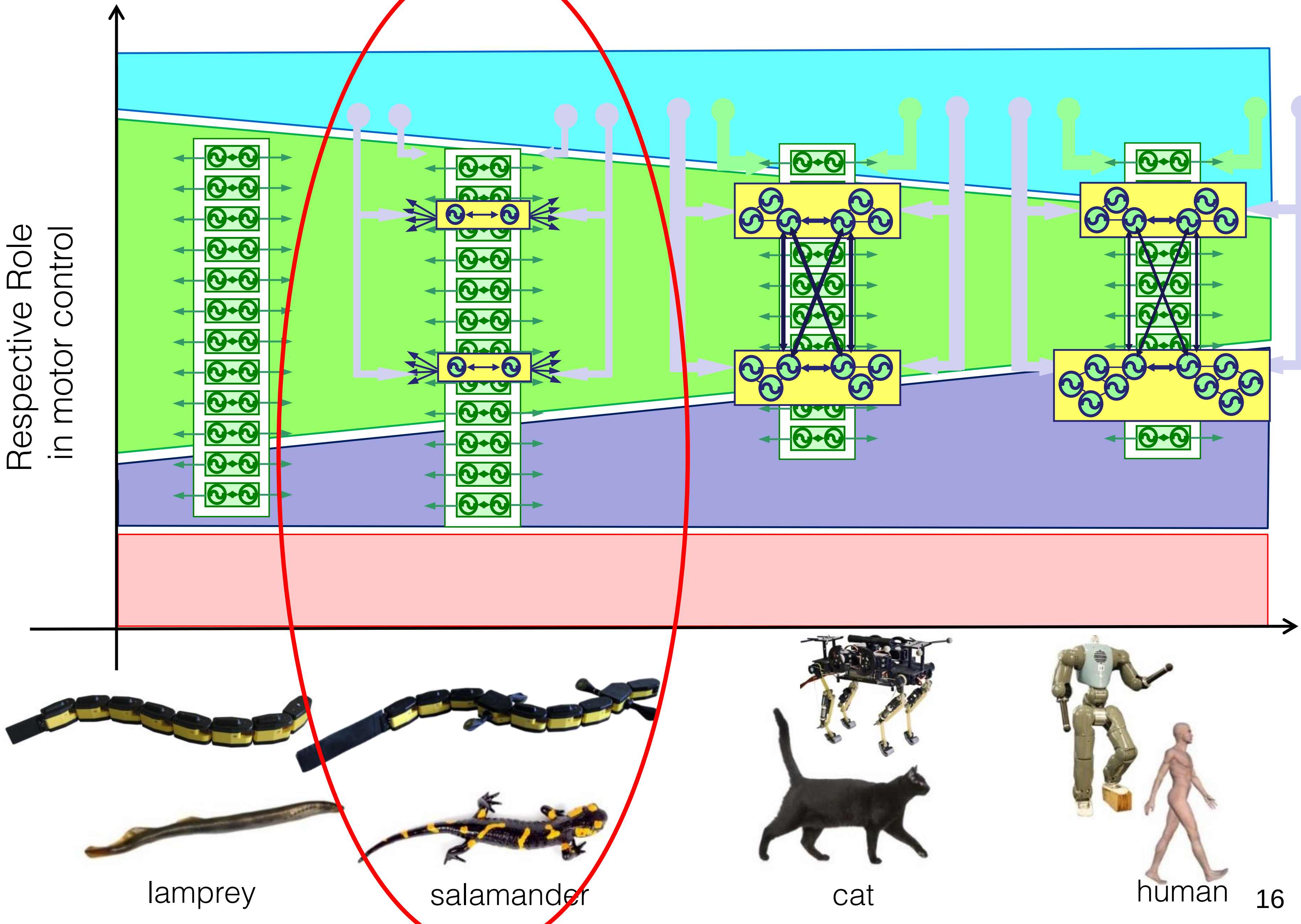
Four essential ingredients in animal motor control



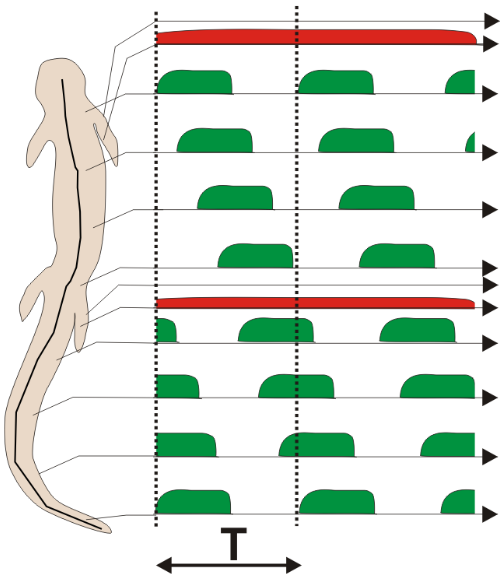
Modeling spinal cord circuits



Modeling spinal cord circuits

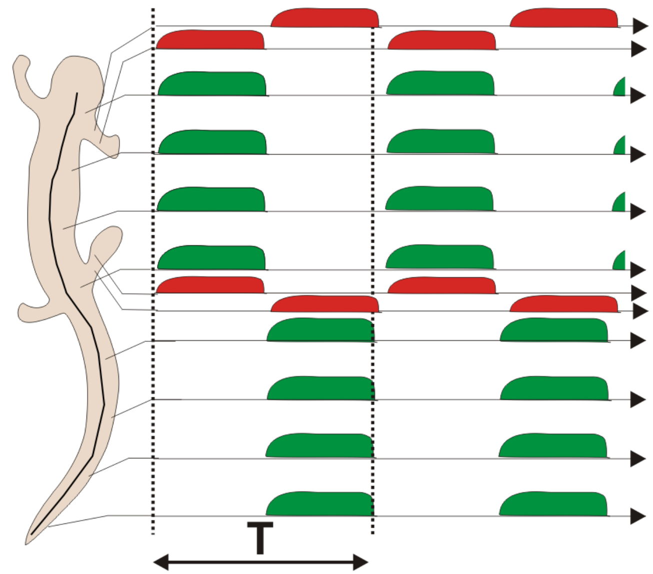


Bimodal locomotion (cartoon)



Swimming:

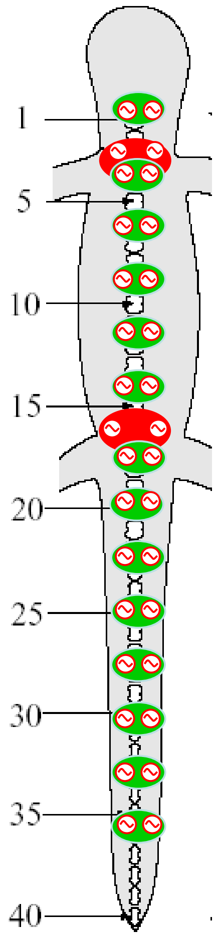
- Traveling wave in axial muscles
- Wavelength ≈ body length
- Limb retractors are tonic
- High frequencies

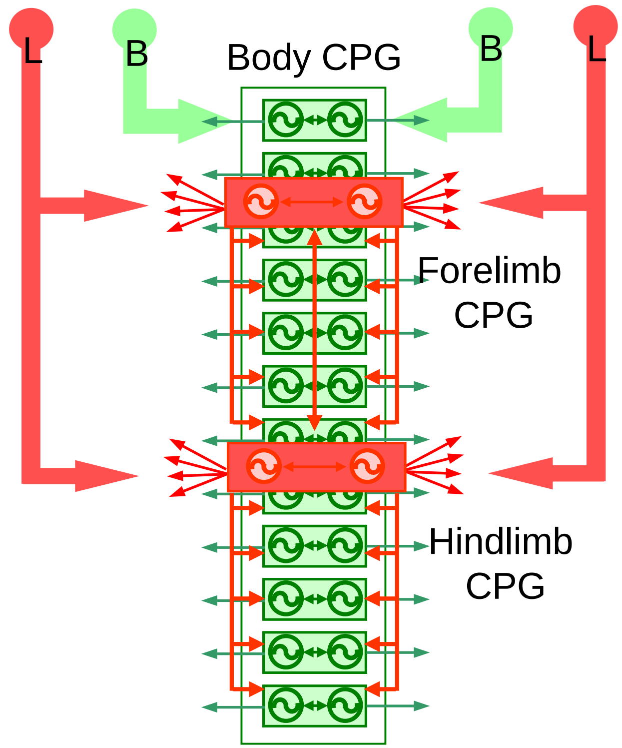


Walking:

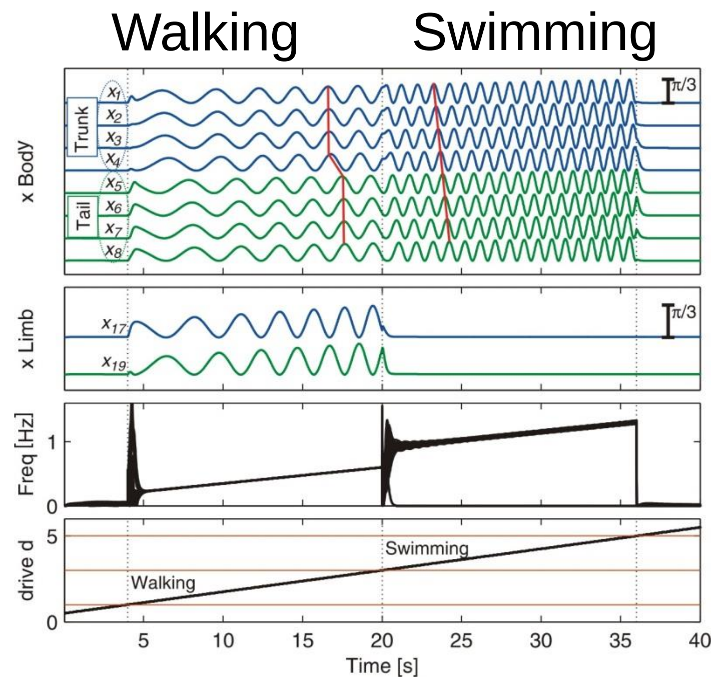
- Standing wave
- Limb retractors/protactors are phasic
- Low frequencies

A mathematical model to study the transition from swimming to walking





System of coupled oscillators

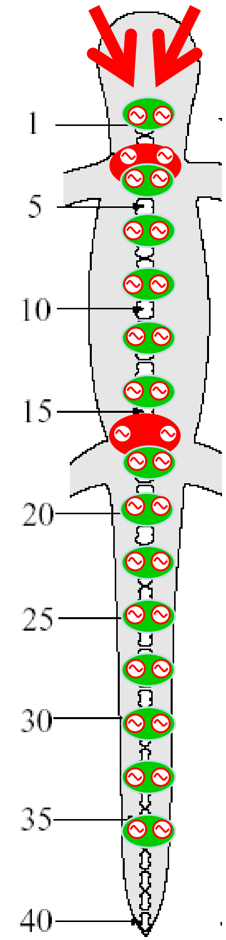


Gait transition due to an increase of the descending drive

[Ijspeert *et al*, *Science*, March 2007].

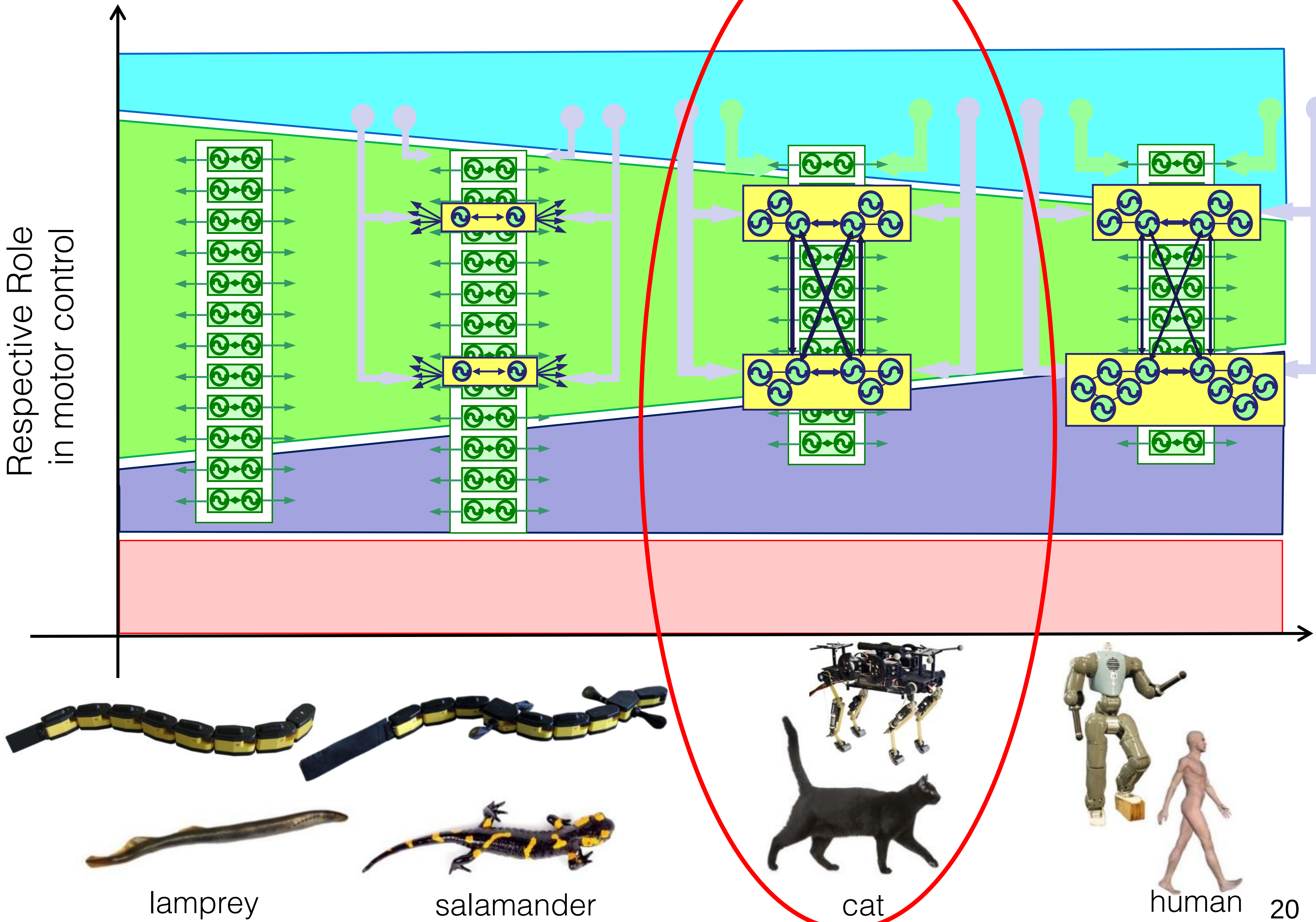
Gait transition in the salamander by modulating descending drive

J.M. Cabelguen
U. of Bordeaux

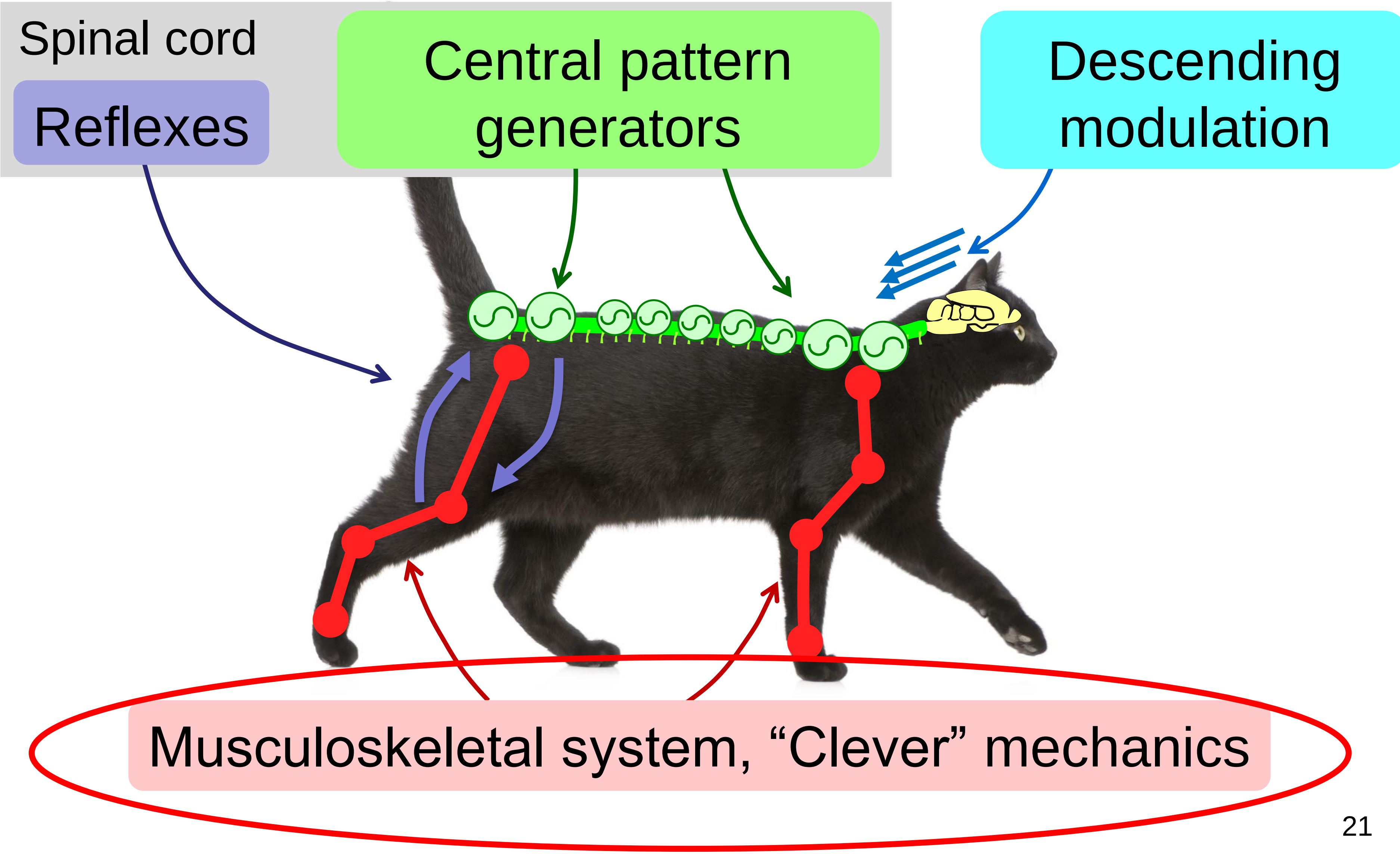


Ijspeert *et al*, *Science*, March 2007.
Crespi et al, *IEEE TRO*, 2013

Modeling spinal cord circuits



Four essential ingredients in animal motor control



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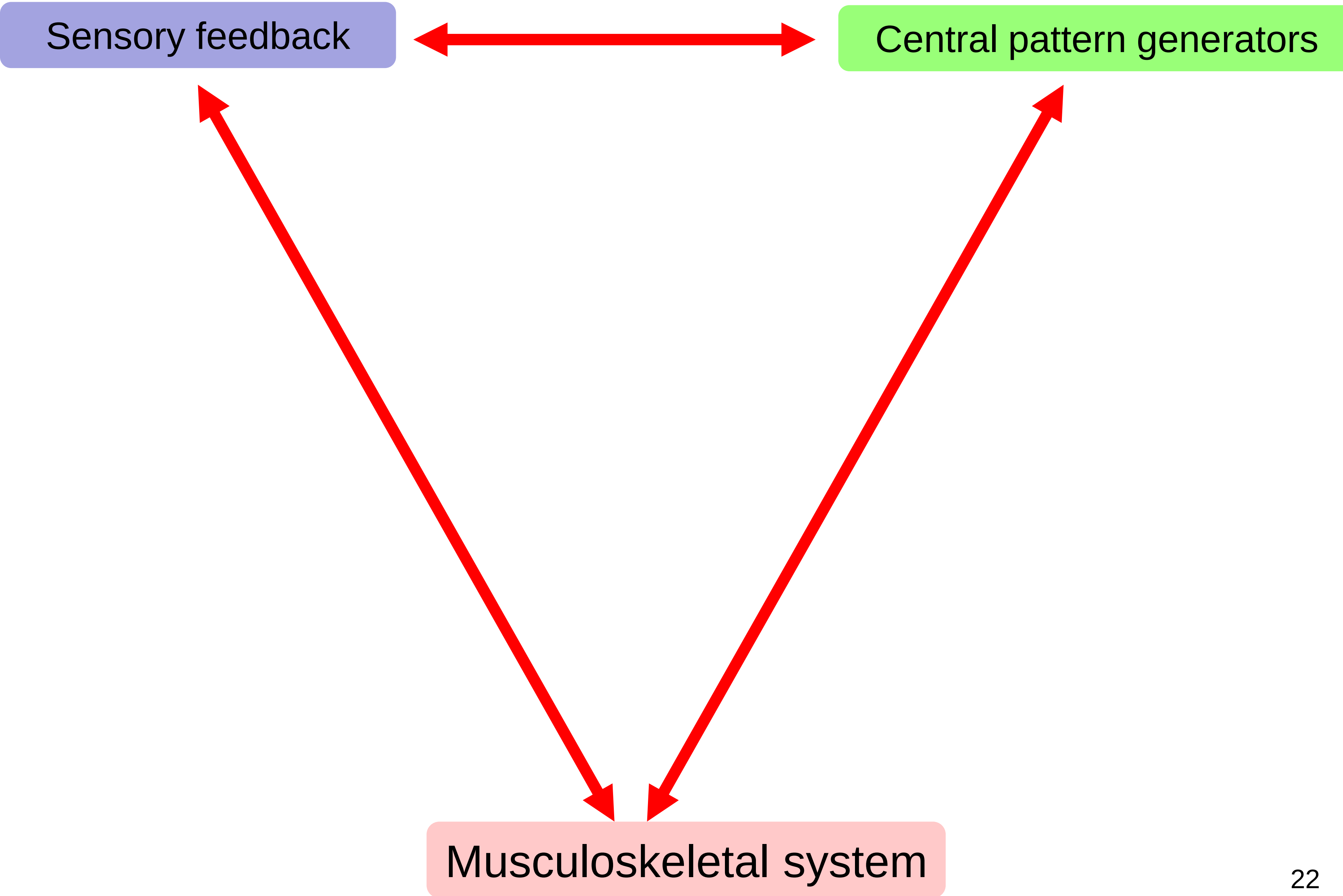
The bridge: Body dynamics



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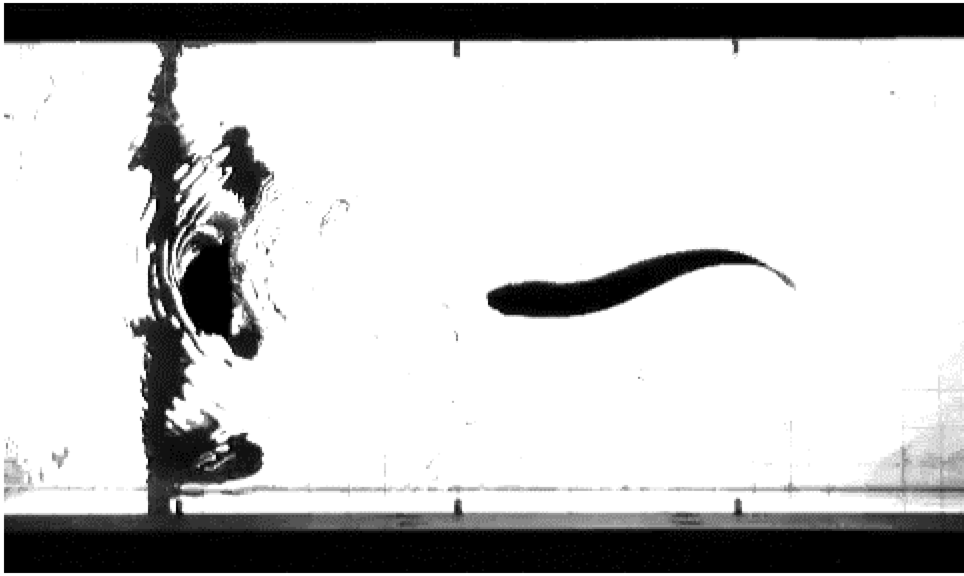
The bridge: Body dynamics

Sensory feedback ↔ Central pattern generators

Passive walker

Collins, S. H., Wisse, M., Ruina, A. (2001)
International Journal of Robotics Research,
Vol. 20, No. 2, Pages 607-615

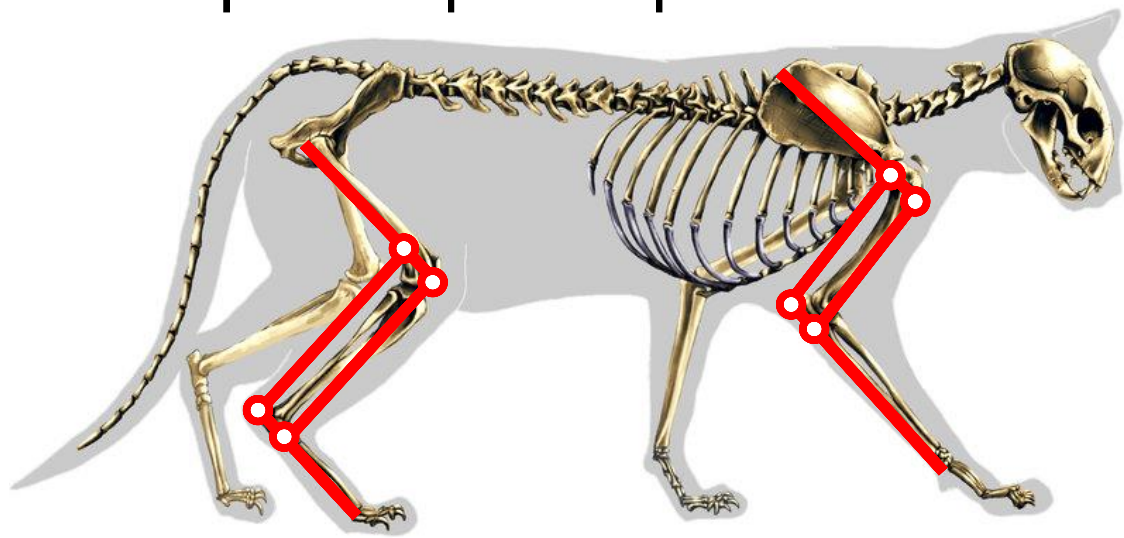
Dead trout swimming



Liao, J. C. (2004).
Journal of Experimental Biology,
Vol. *207*(20), 3495-3506.
MIT tow tank, Lauder Lab Harvard
http://web.mit.edu/towtank/www/

Musculoskeletal system

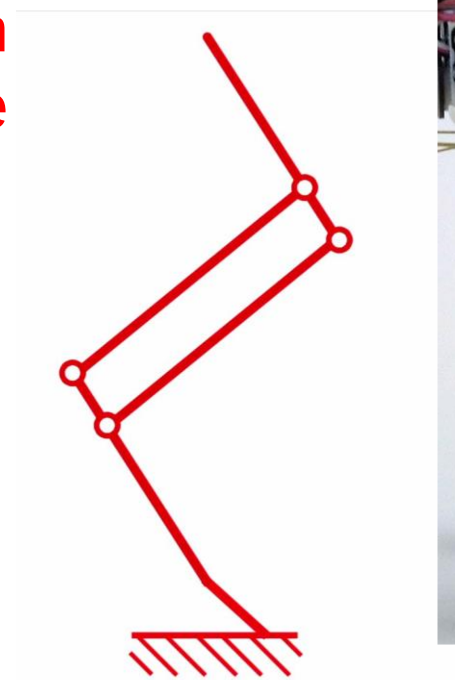
Cheetah-Cub: a compliant quadruped robot

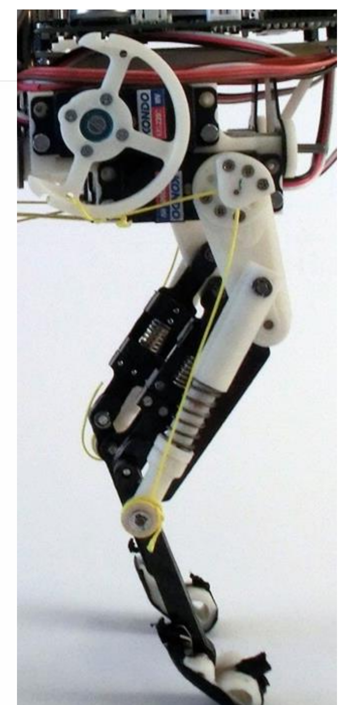


Scientific question:
What are the key principles underlying the agility of cats' locomotion?

Hypothesis:
self-stabilizing property of the musculoskeletal system

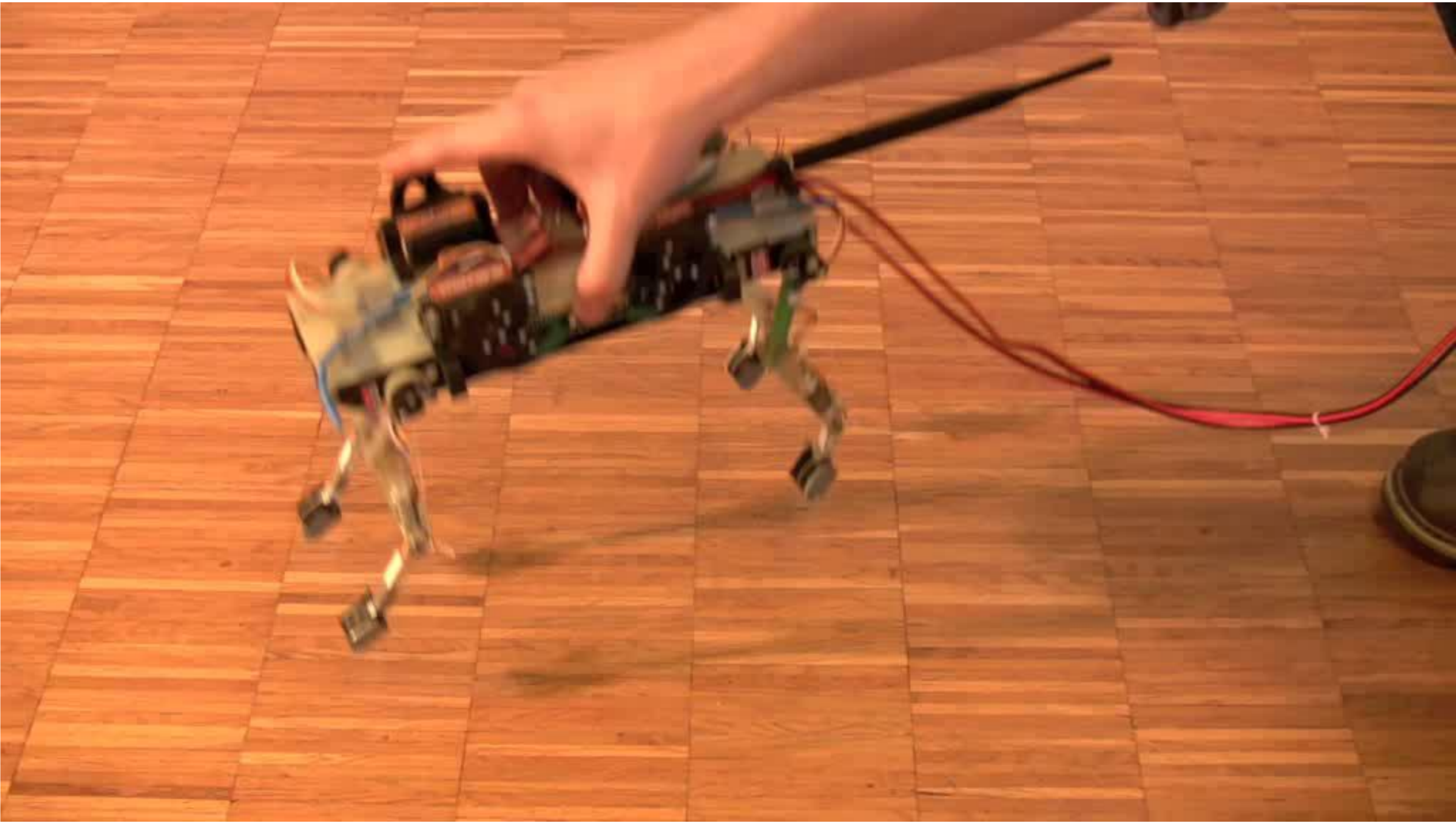
~ Pantograph structure





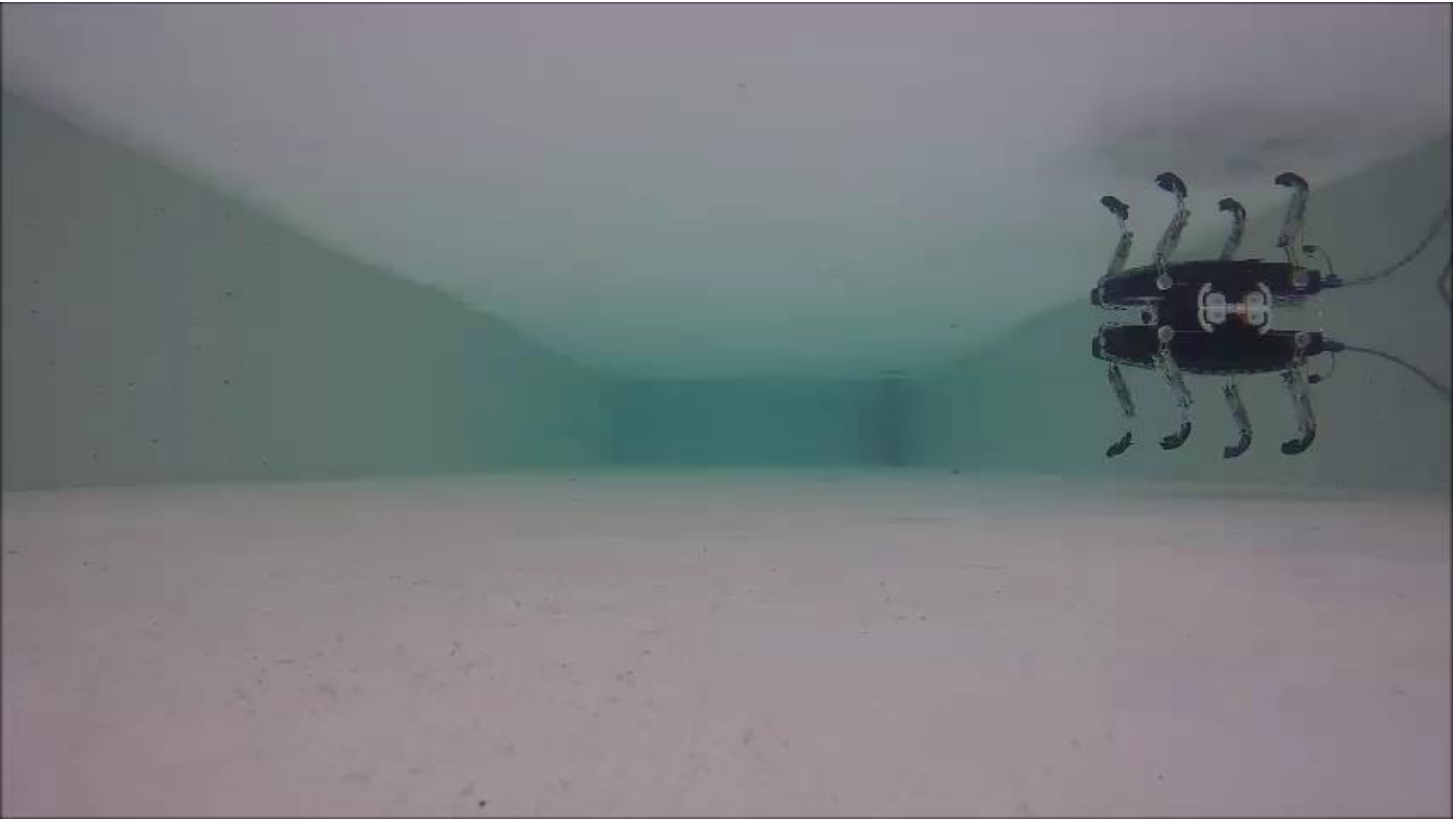
Key properties:
1) light-weight
2) Viscoelastic
3) segmented leg with a **pantograph structure**

Robustness and Self-stabilization



Robustness and Self-stabilization

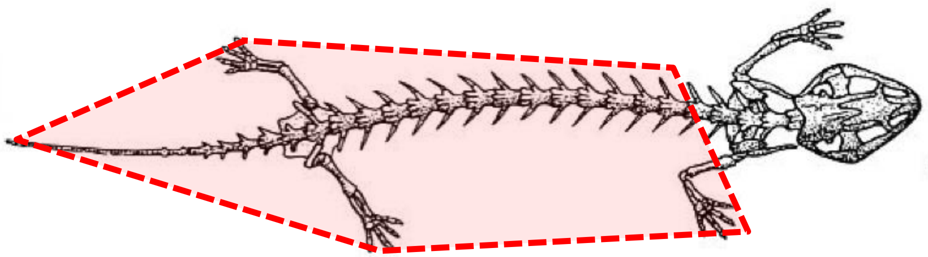
Cheetah-Cub swimming!!



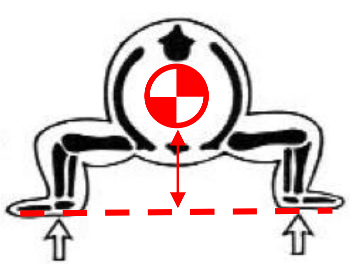
Work of MSc student Andrea Andreoli, together with Peter Eckert, Behzad Bayat

Key transition
from amphibians/reptiles to mammals

Sprawling posture



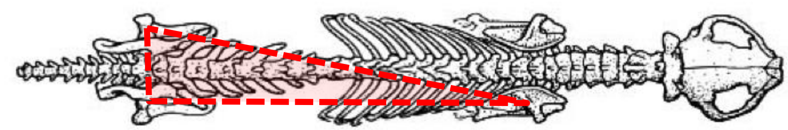
Salamander



Large support polygon

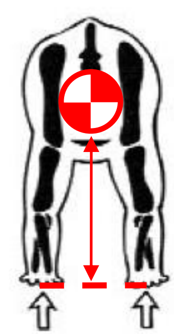
Low center of mass

Upright posture



studyblue.com

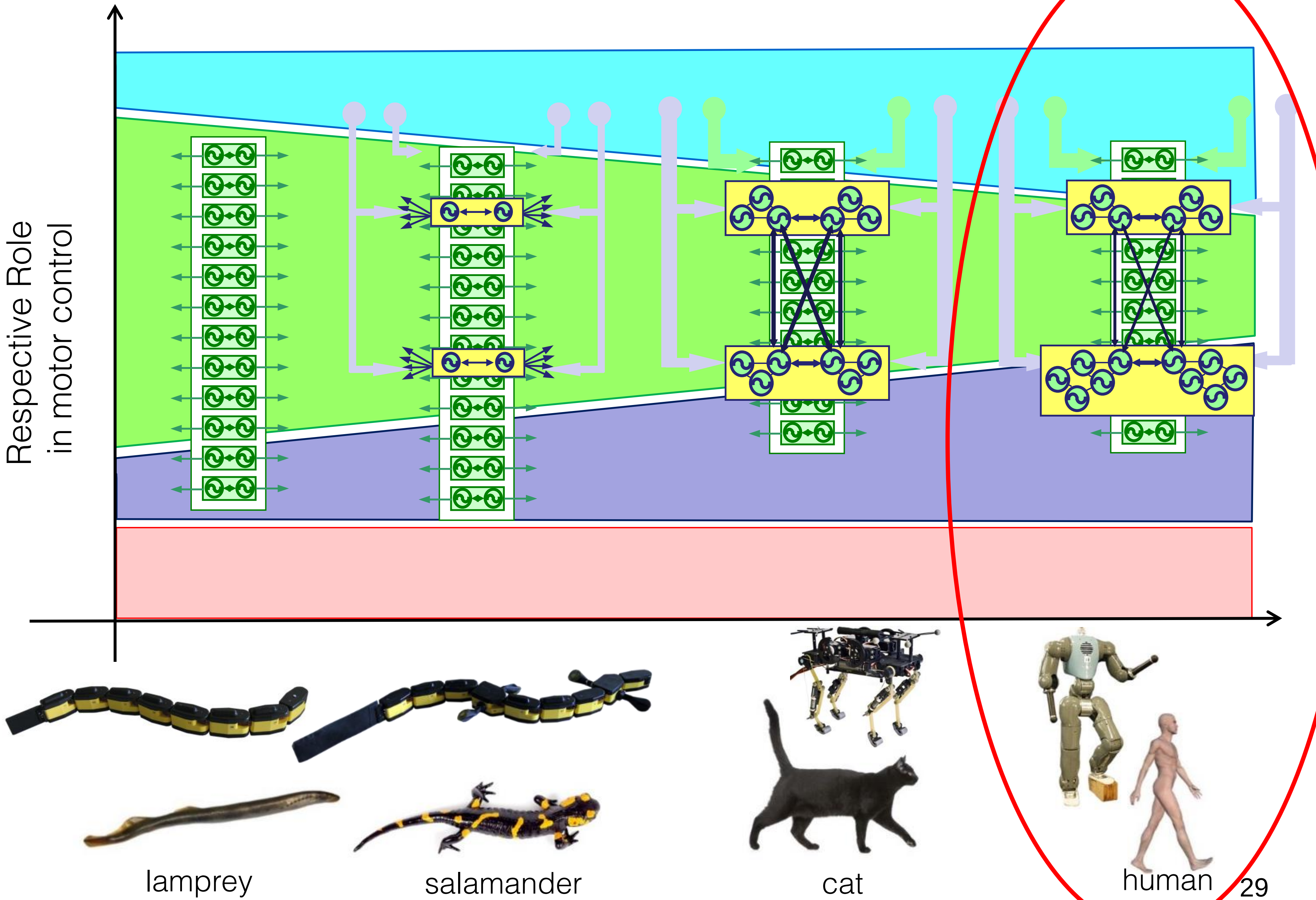
Mammal



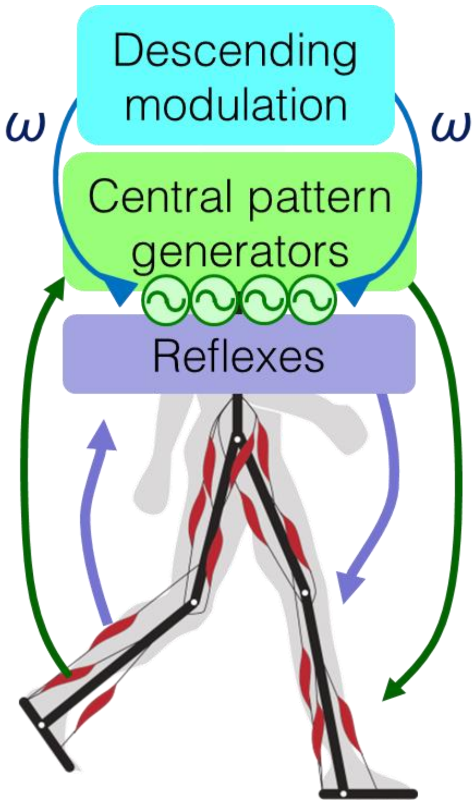
Small support polygon

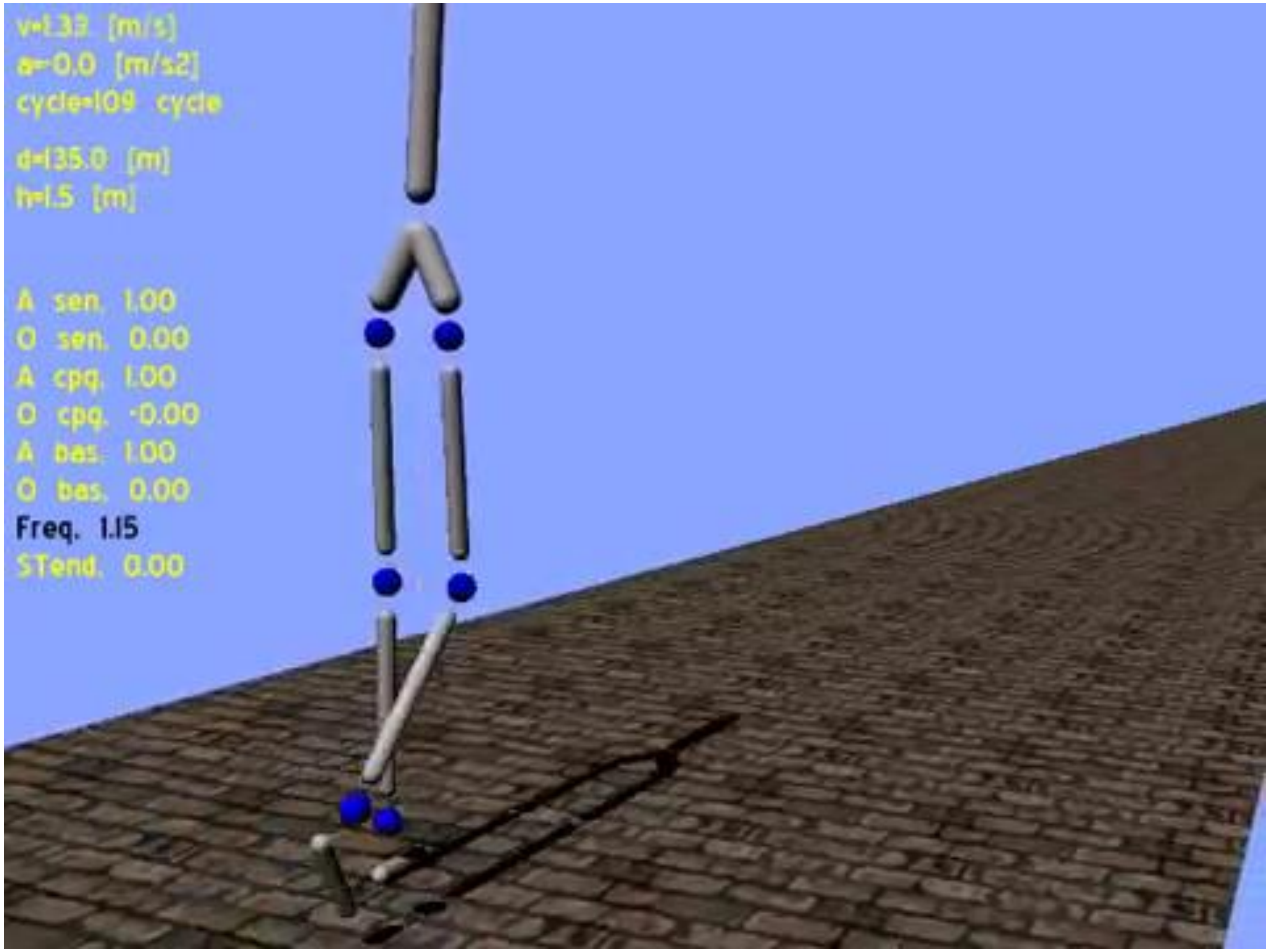
High center of mass

Modeling spinal cord circuits



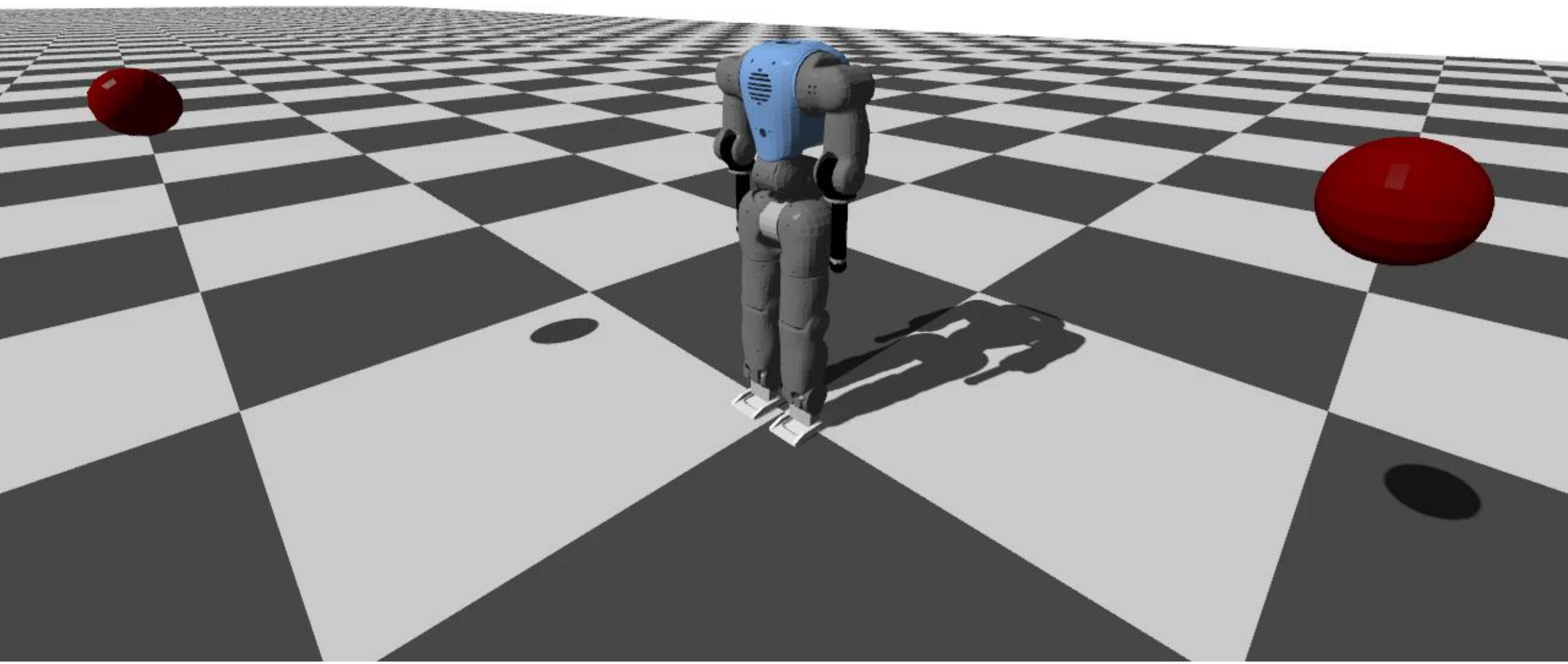
Neuromechanical model of human locomotion



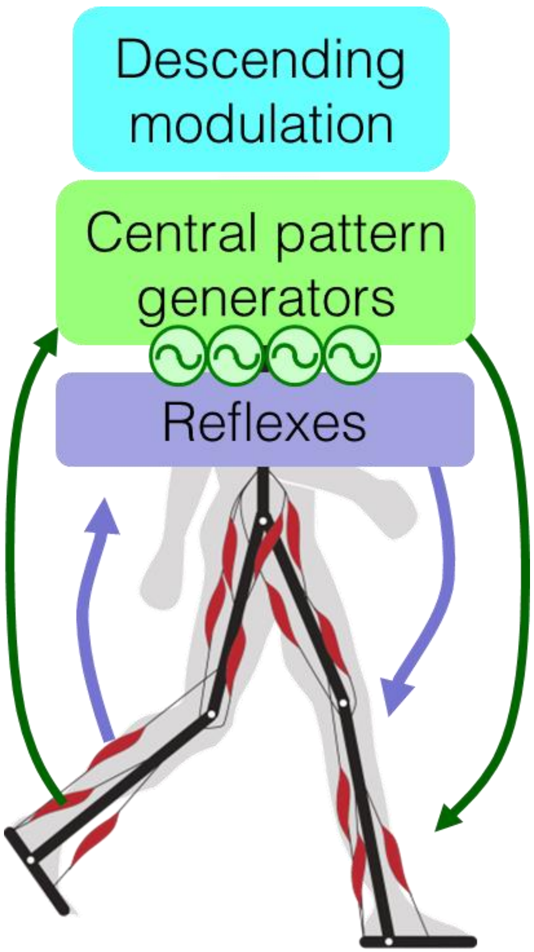


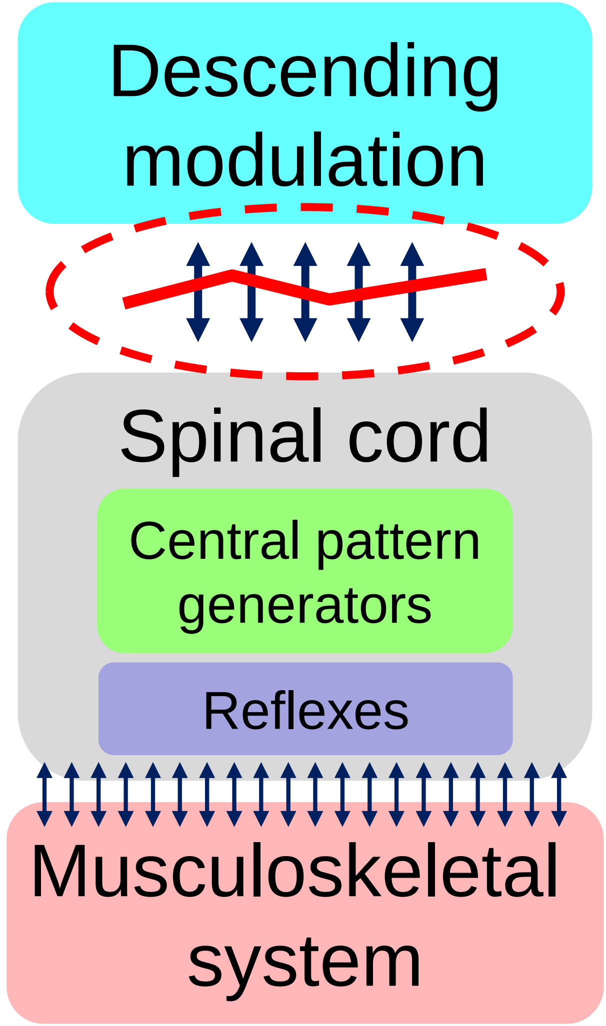
Dzeladini et al, The contribution of a central pattern generator in a reflex-based neuromuscular model, Frontiers in Human Neuroscience, Vol 8, 371, 2014

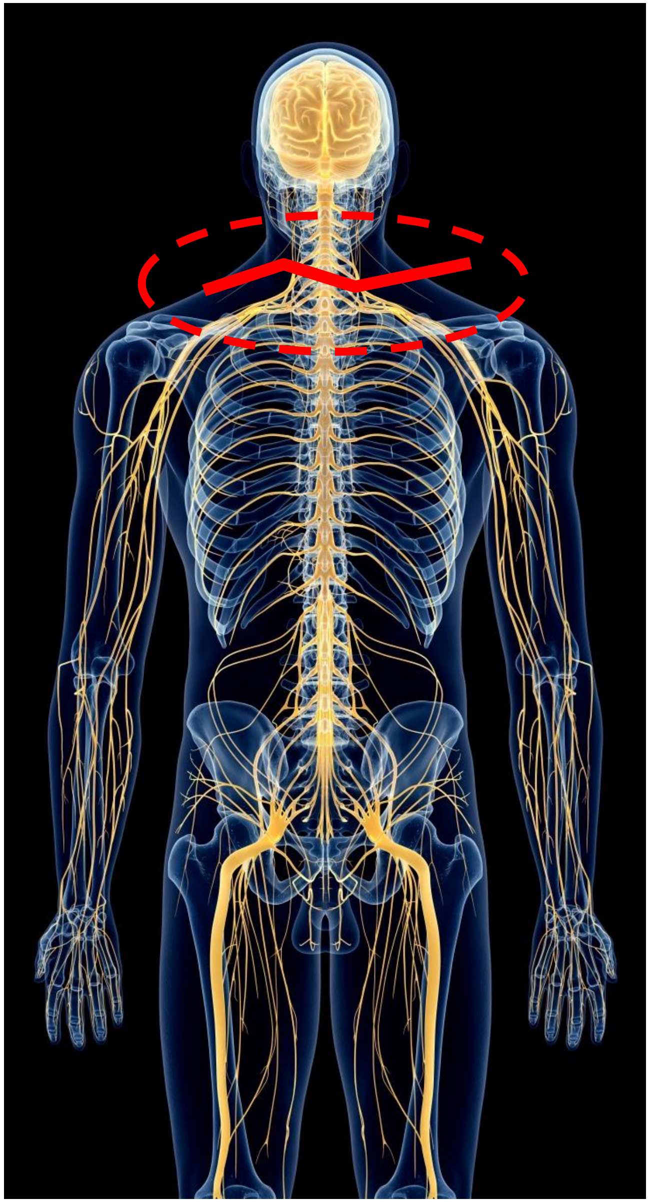
3D CPG-based controller



Link to neuroprosthetics







Zurich, October 2016

Exoskeletons:
ReWalk (ReWalk Robotics, Israel)
Twiice (EPFL), Pilot: Silke Pan

Lower limb exoskeleletons

ReWalk

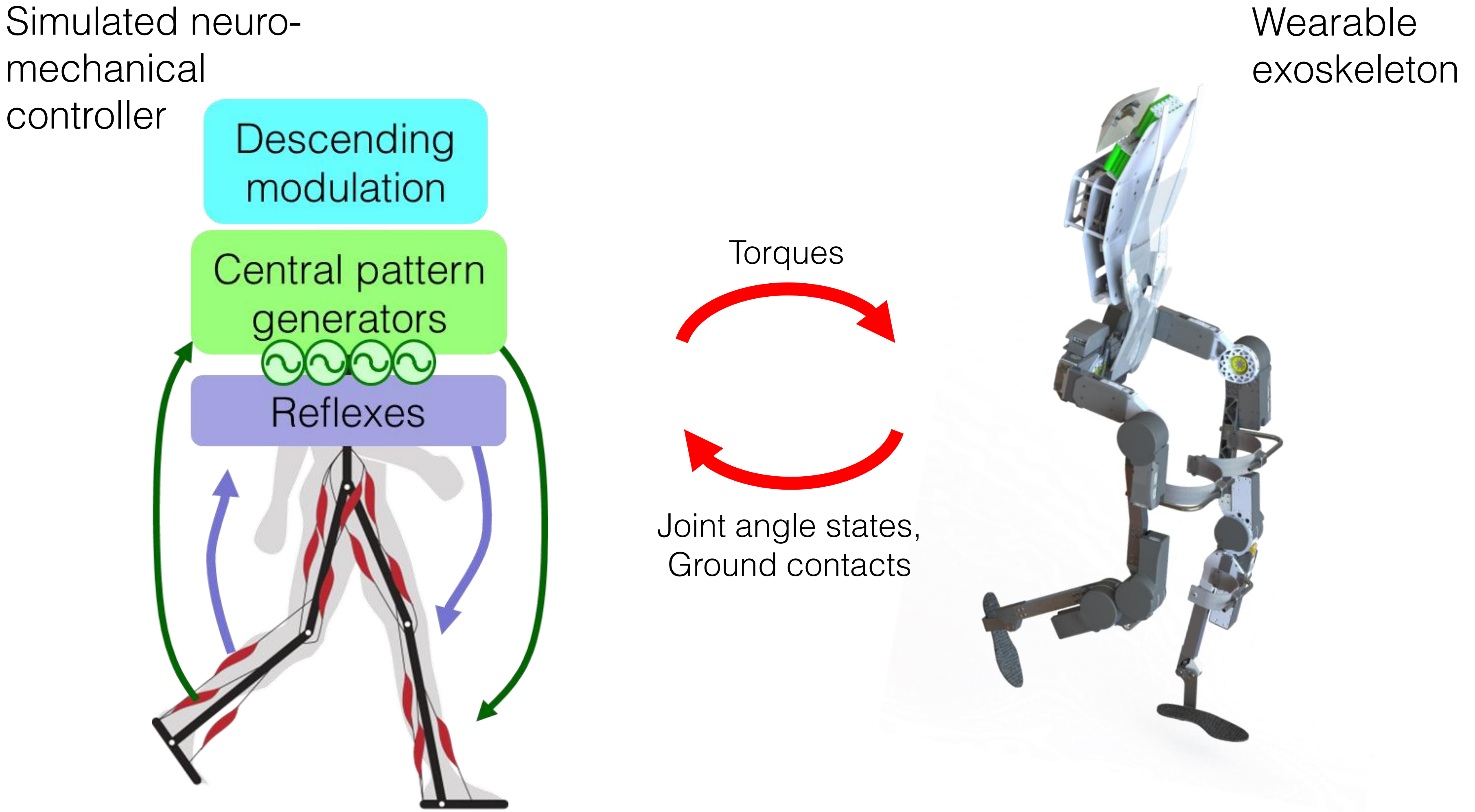
HAL Cyberdine

Ekso Bionics eLEGS

REX

TWIICE

Controllers for exoskeletons



Symbitron project:
U. Twente, TU Delft, Imperial College, Santa Lucia Fondation, Össur, EPFL

Surprisingly fast gaits:

Speed modulation 0.8 m/s to 1.1 m/s

Spinal-cord injured (SCI) subjects with complete lesion and no motor function of legs

Wu et al, WeRob 2016

Robustness against swing foot perturbations

Wu et al, WeRob 2016

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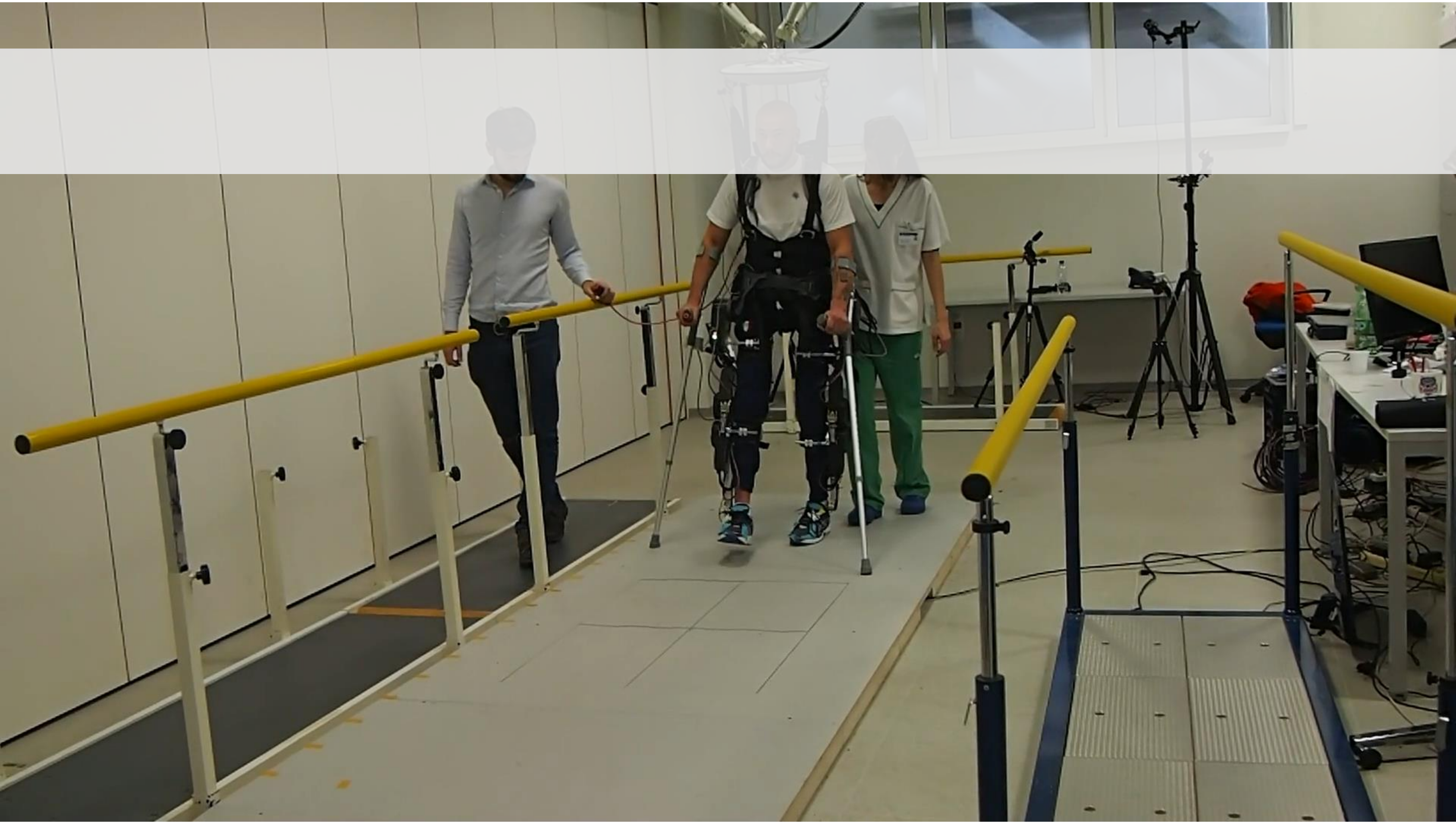
Tests with the wearable exoskeleton

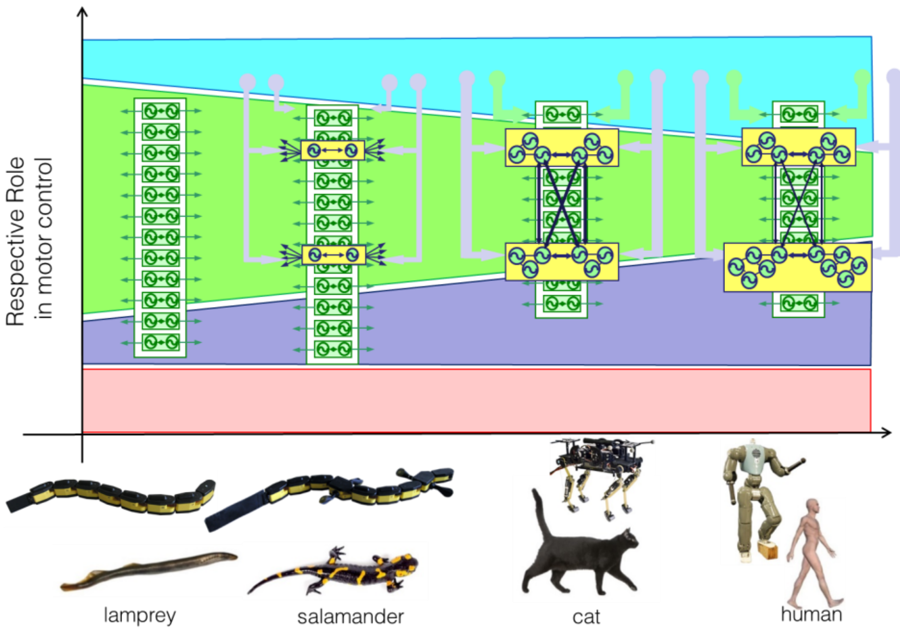
Biorobotics Laboratory EPFL



Symbitron

Beyond biology

Robots for biology



Field robots

Pollution monitoring

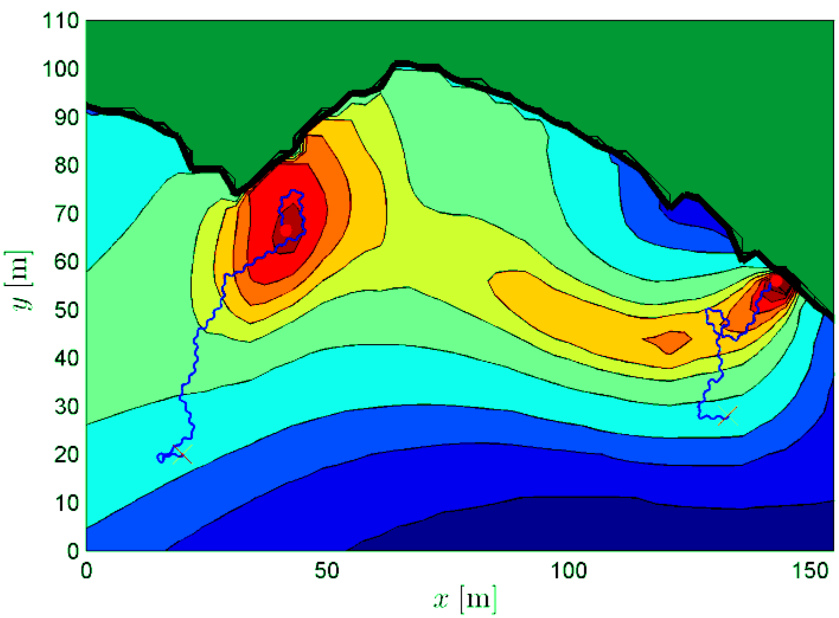
Search and Rescue

Robots for assistance

Envirobot

Modular robot for **pollution monitoring**:

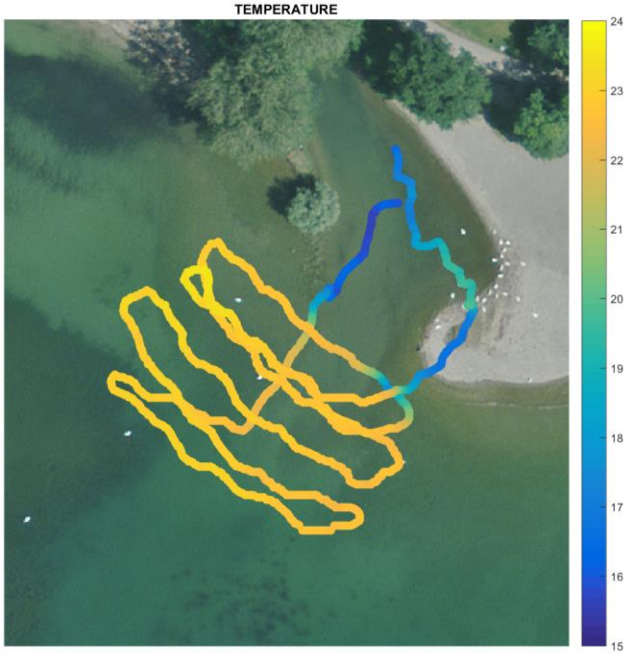
- Dynamic mapping of pollutants
- Gradient-climbing

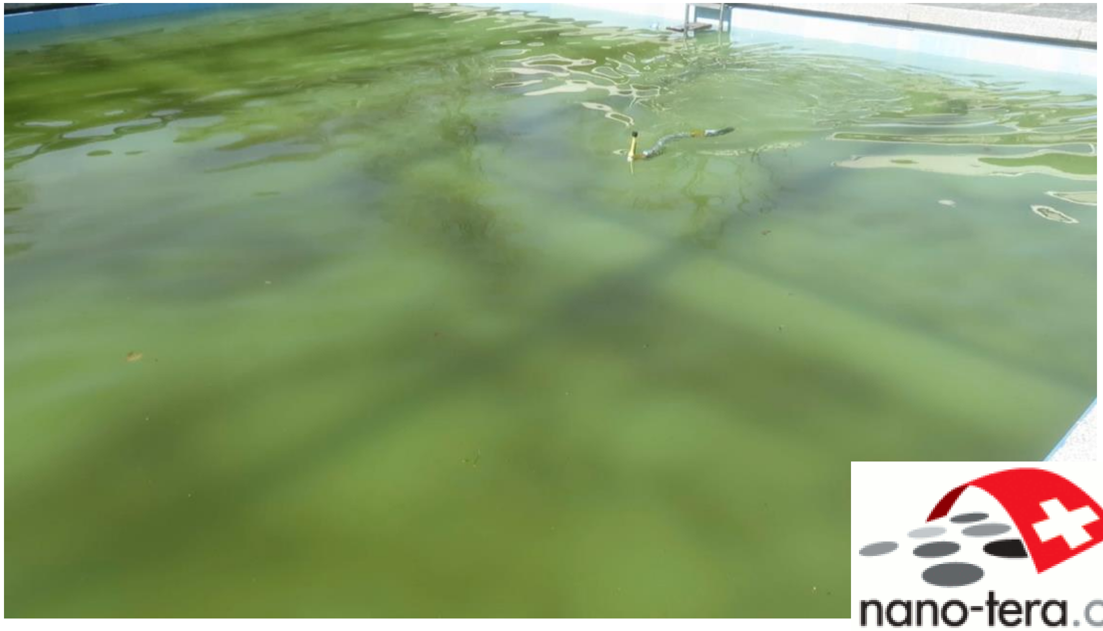


Pollution monitoring, Envirobot

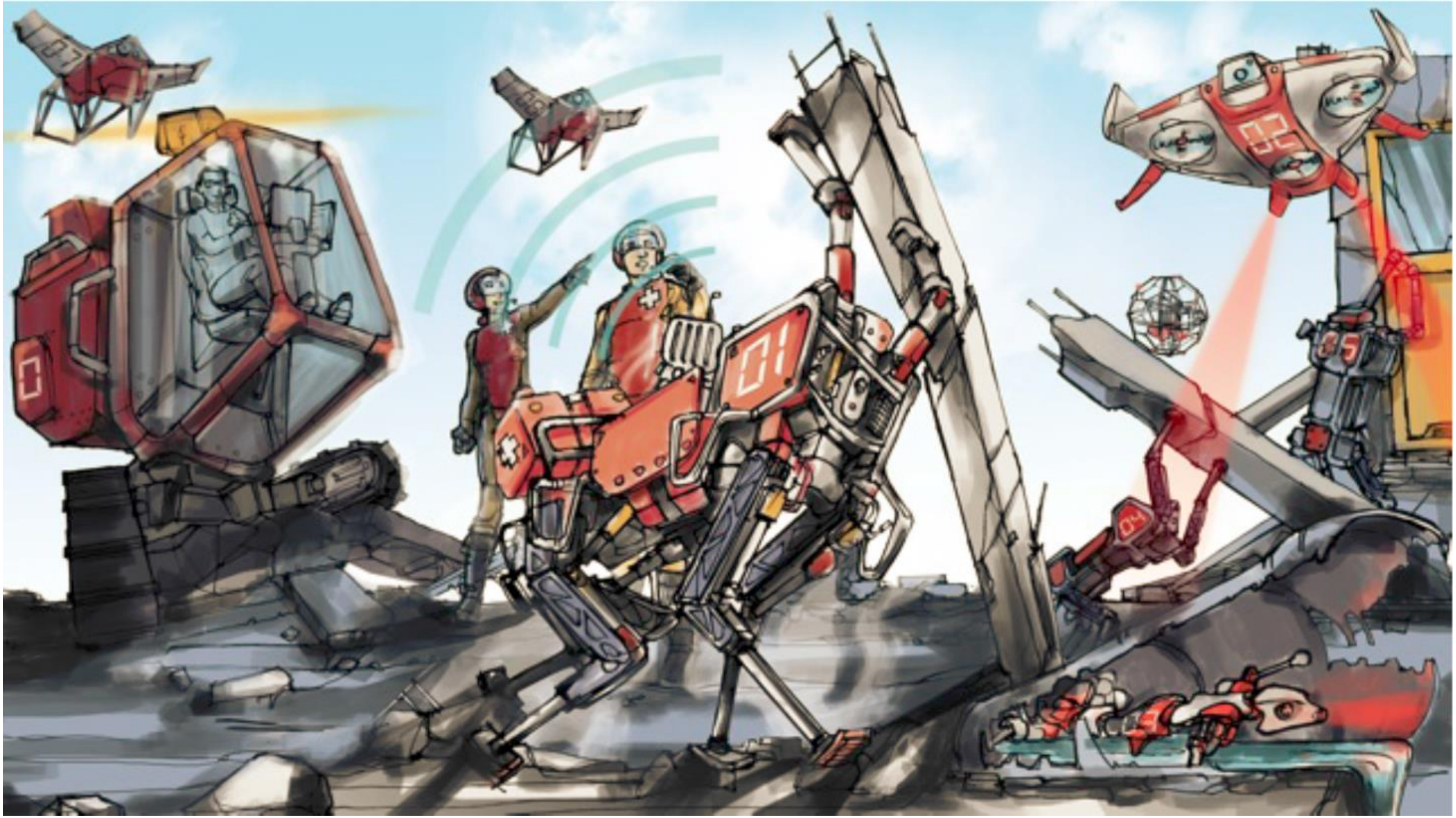
Interesting properties:

- Portable
- Reconfigurable
- Low drag swimming
- Not dangerous
- Low risk of getting stuck





Robots for search and rescue



robotics Swiss National Centre of Competence in Research

Tohoku, Japan, March 2011

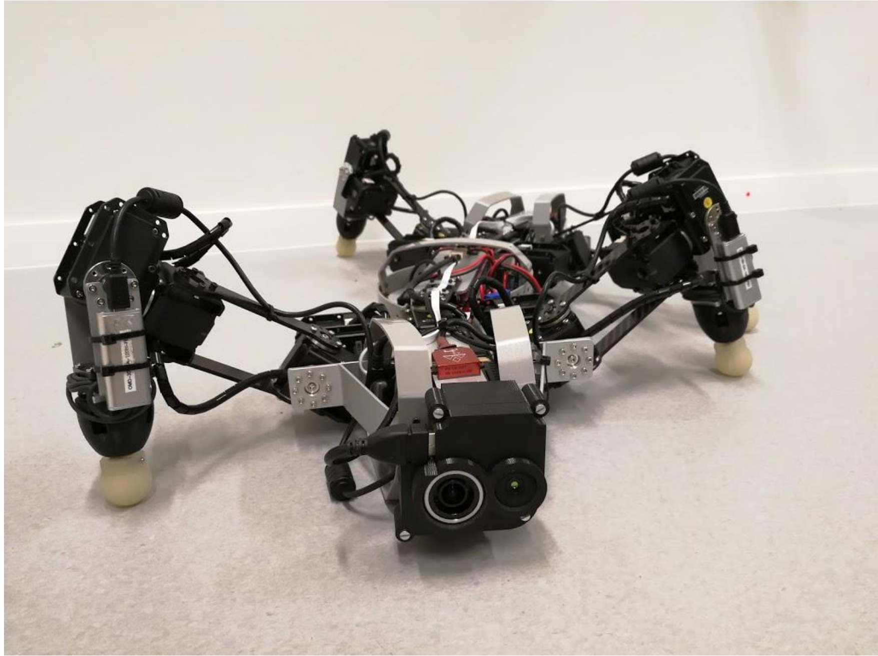
Biorobotics Laboratory EPFL

robotics

Swiss National Centre of Competence in Research

Amphibious robots for rescue

- Multimodal locomotion (swimming/crawling/ walking)
- Ability to move through small holes/pipes



- Stable crouched posture
- Portable
- Reconfigurable

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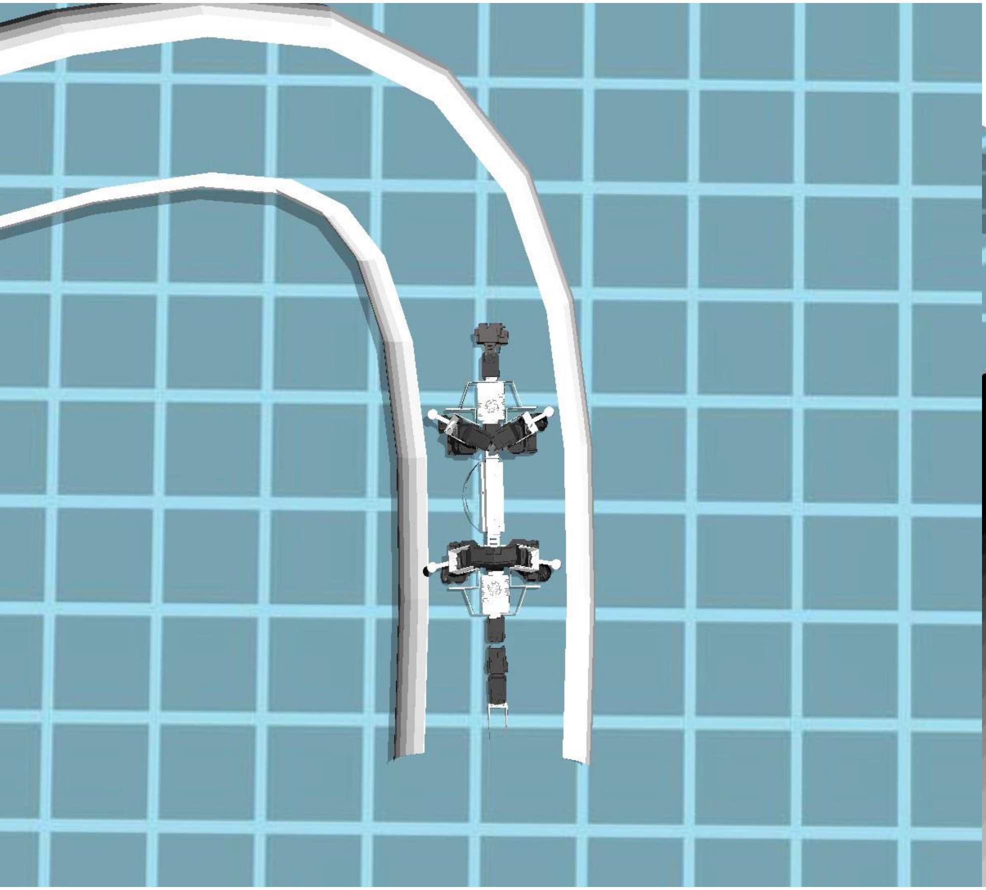
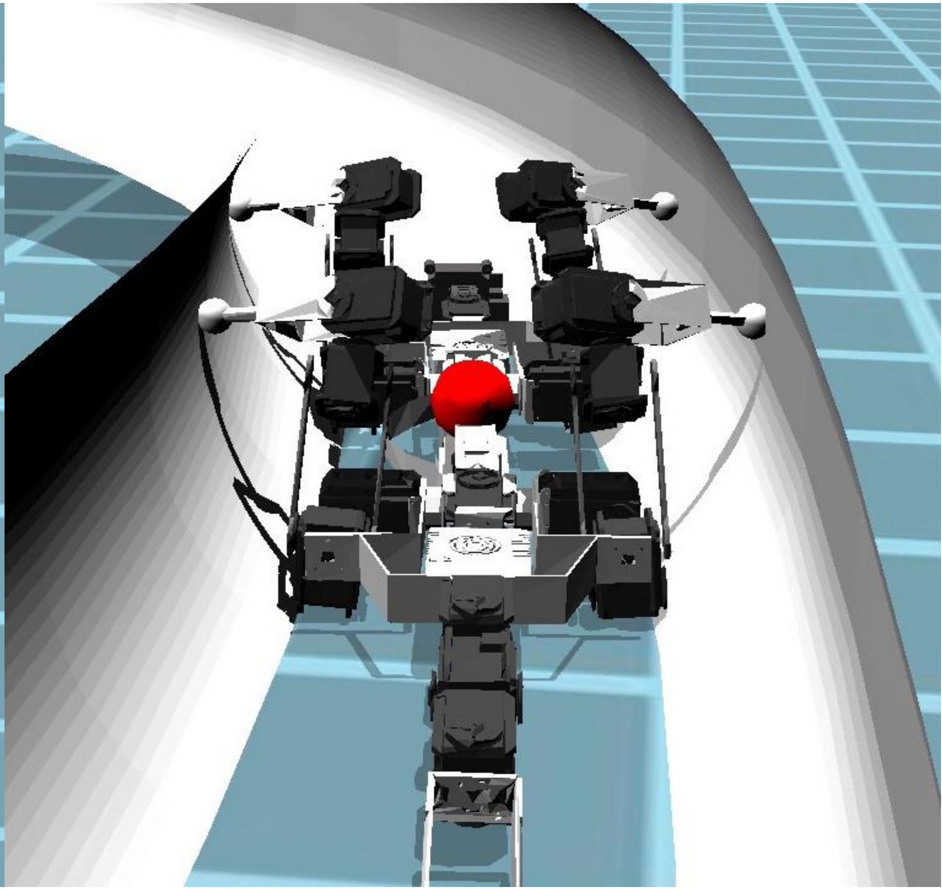
K-Rock2

Locomotion in pipes with K-Rock2





Horvat et al, IROS 20

Biorobotics Laboratory EPFL

Robots for filming wild life

Latest robot: K-Rock Robot developed for «Spy in the Wild» BBC 2017

Biorobotics

Robotics applications

Inspection
Monitoring
Search and rescue
Transport
Pollution monitoring
Agriculture

Scientific applications

Neuroscience
Biomechanics
Sport science
Ethology
Neuroprosthetics
Paleontology

Edutainment applications

Toys
Animatronics
Artificial pets

Filming wild life
Museums
Recreating extinct animals

Quelques réflexions

Emerveillement et humilité

Emerveillement et humilité

Evolution et Création

- L’évolution est un magnifique outil de création
- Genèse 1: 20-21:
- *«Dieu dit:* ***Que les eaux produisent en abondance des animaux vivants****, et que des oiseaux volent sur la terre vers l'étendue du ciel.*
- *Dieu créa les grands poissons et tous les animaux vivants qui se meuvent, et que les eaux produisirent en abondance selon leur espèce; il créa aussi tout oiseau ailé selon son espèce. Dieu vit que cela était bon.»*

Co-evolution of Morphology and CPG Control for Modular Robot Locomotion

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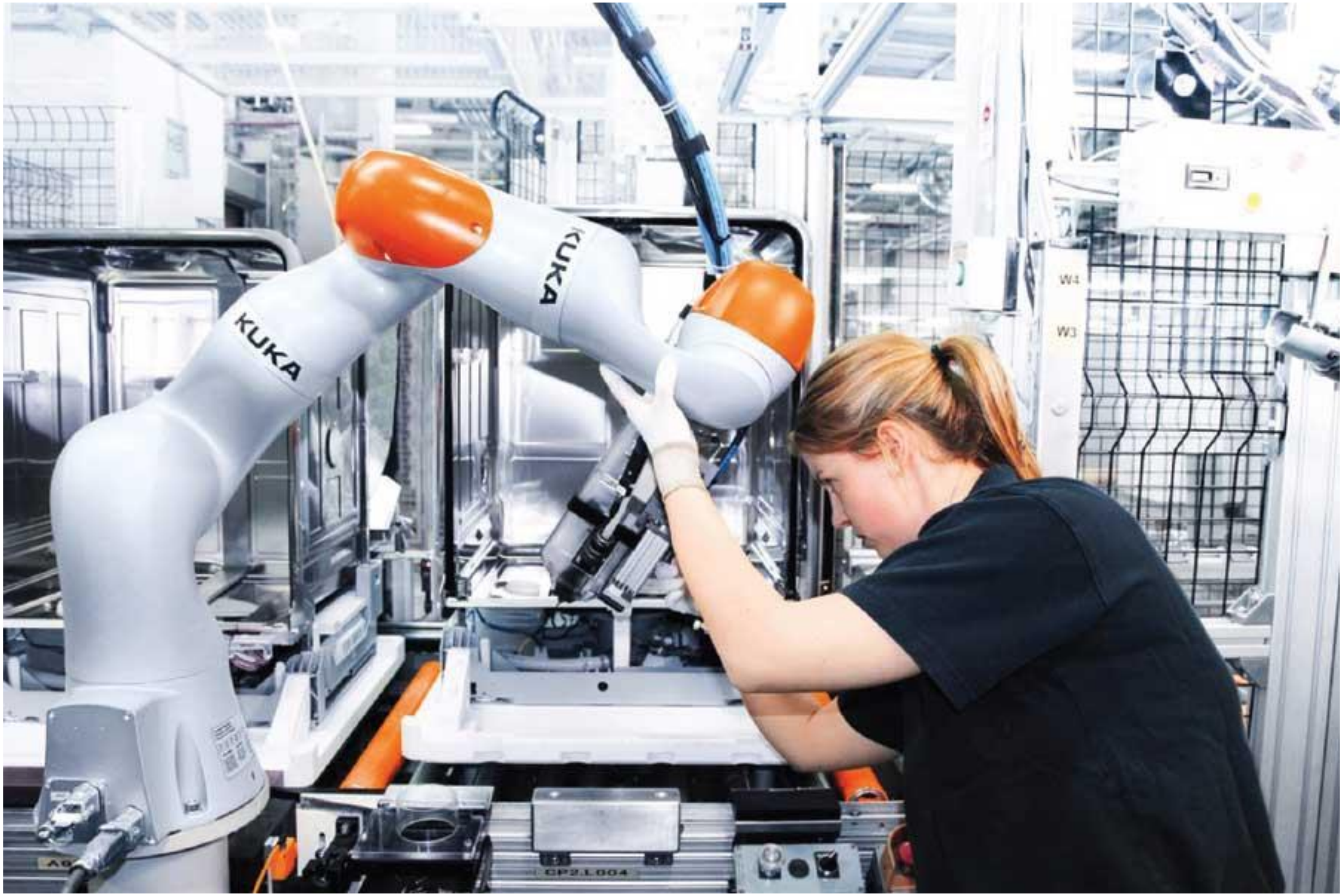
BIOLOGICALLY INSPIRED ROBOTICS GROUP (BIRG)

Daniel Marbach

http://birg.epfl.ch/page56514.html

Les robots augmenteront-ils le nombre de chômeurs ?



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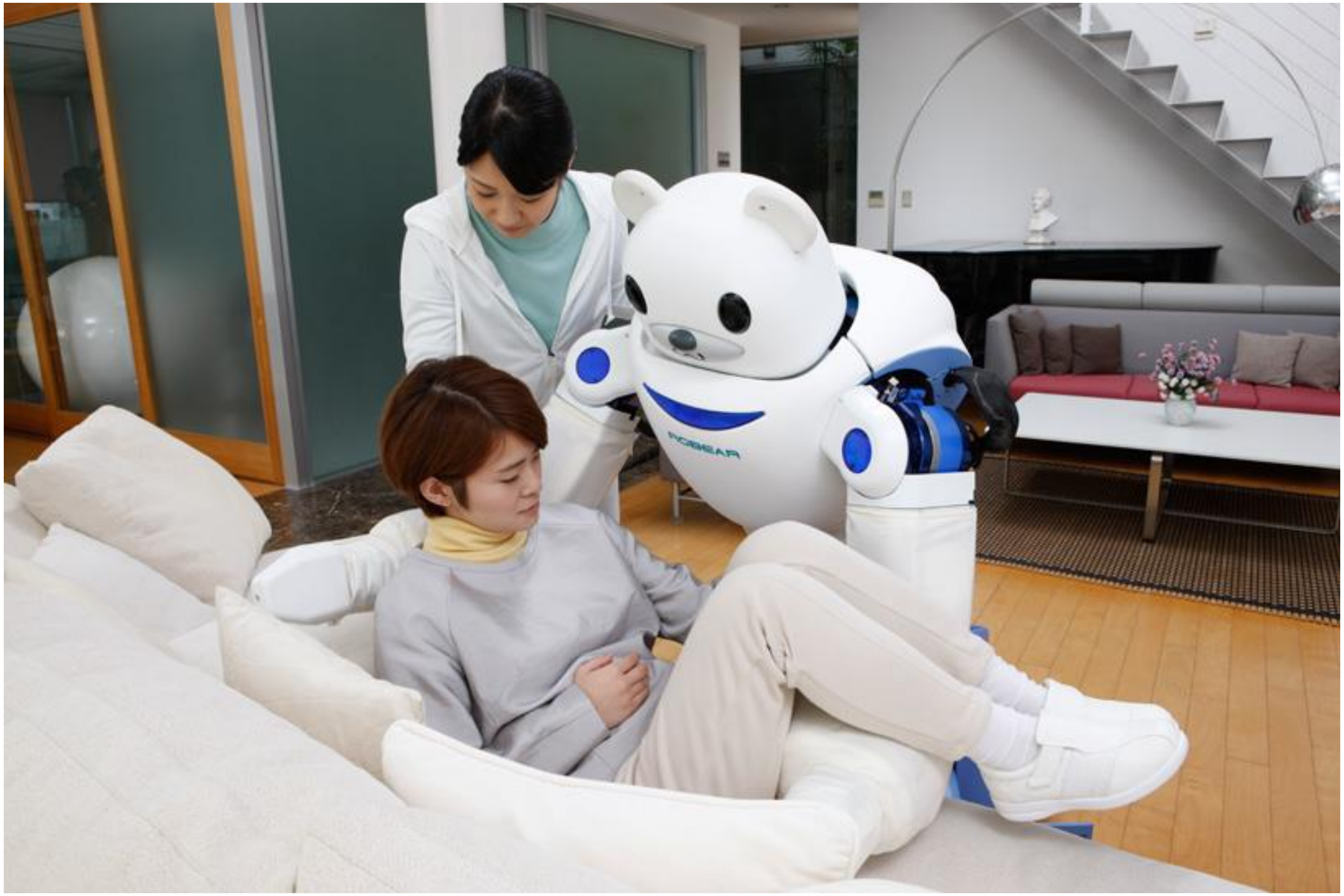
Les robots feront-ils la guerre?

Qui sera juridiquement responsable en cas d'accident?



Riken ROBEAR

Est-ce que les robots vont changer qui nous sommes?

Wall-E, Pixar

La robotique et la religion

International Journal of Social Robotics special issue on "Religion in Robotics". Call for papers, April 2018

Aspects of interest involving religion and robotics include, but are not limited to the following:

* Robots for religious use
* Impact of religion on the history of robotics
* Impact of religion on culturally-aware robotics
* Impact of religion on the Uncanny Valley
* Religion-friendly aesthetic design of robots
* Religion and science
* Religion and AI
* Ethics in robotics
* Anthropological insights on humanoids
* Transhumanism

Deadline June 15 2018

People at BIOROB


A. Ijspeert


A. Crespi


B. Bayat


K. Melo


S. Lipfert


A. Wu


H. Razavi


P. Müllhaupt


R. Baud


T. Horvat


J. Lanini


F. Dzeladini


R. Thandiackal


P. Eckert


A. Tuleu


S. Ramalingasetty


S. Faraji


N. van der Noot


S. Hauser


M. Mutlu


F. Longchamp


A. Guignard


S. Fiaux

ALUMNI

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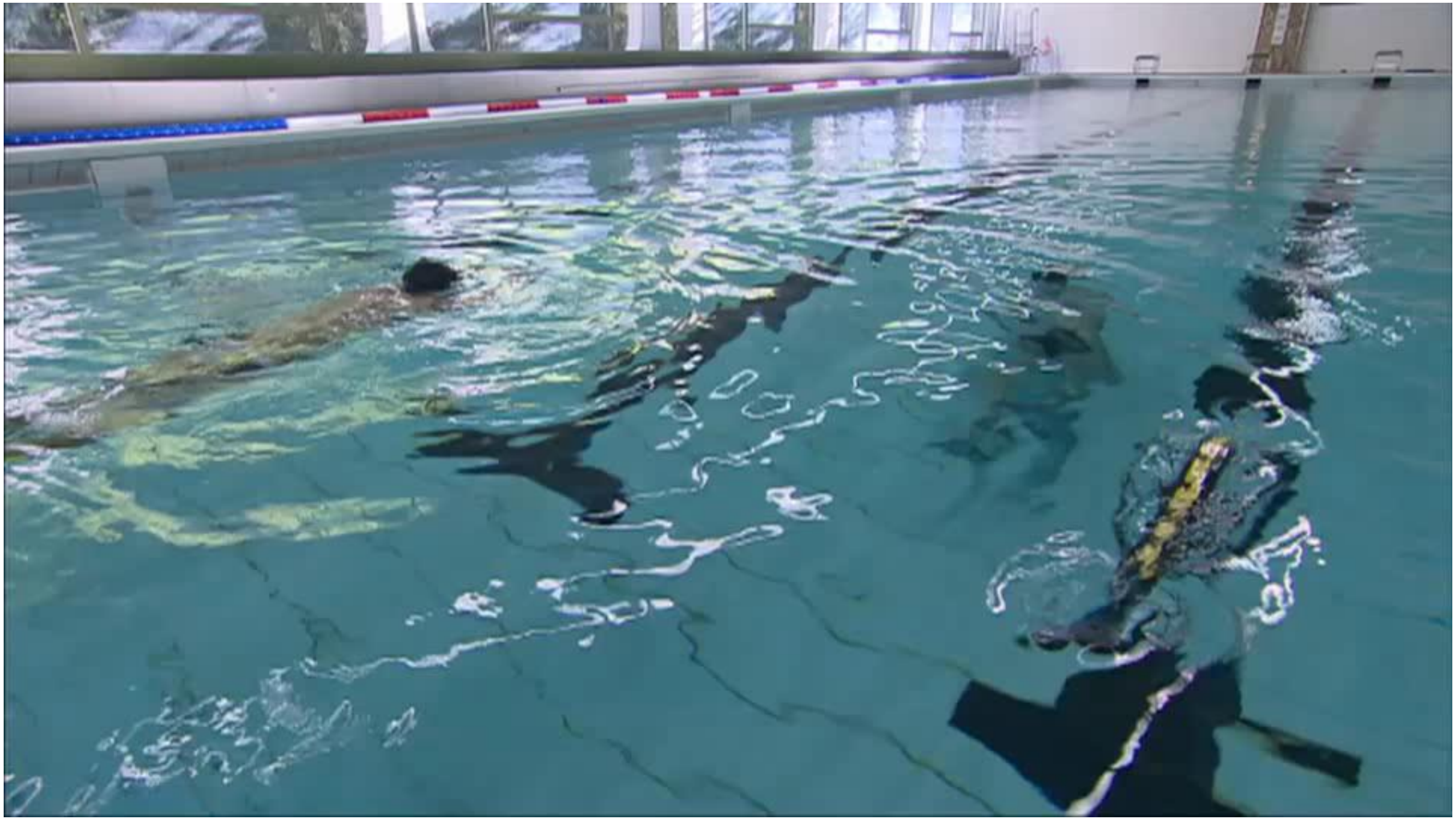
More info: http://biorob.epfl.ch

The human-robot race!!



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