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Germany

Physiological sensing

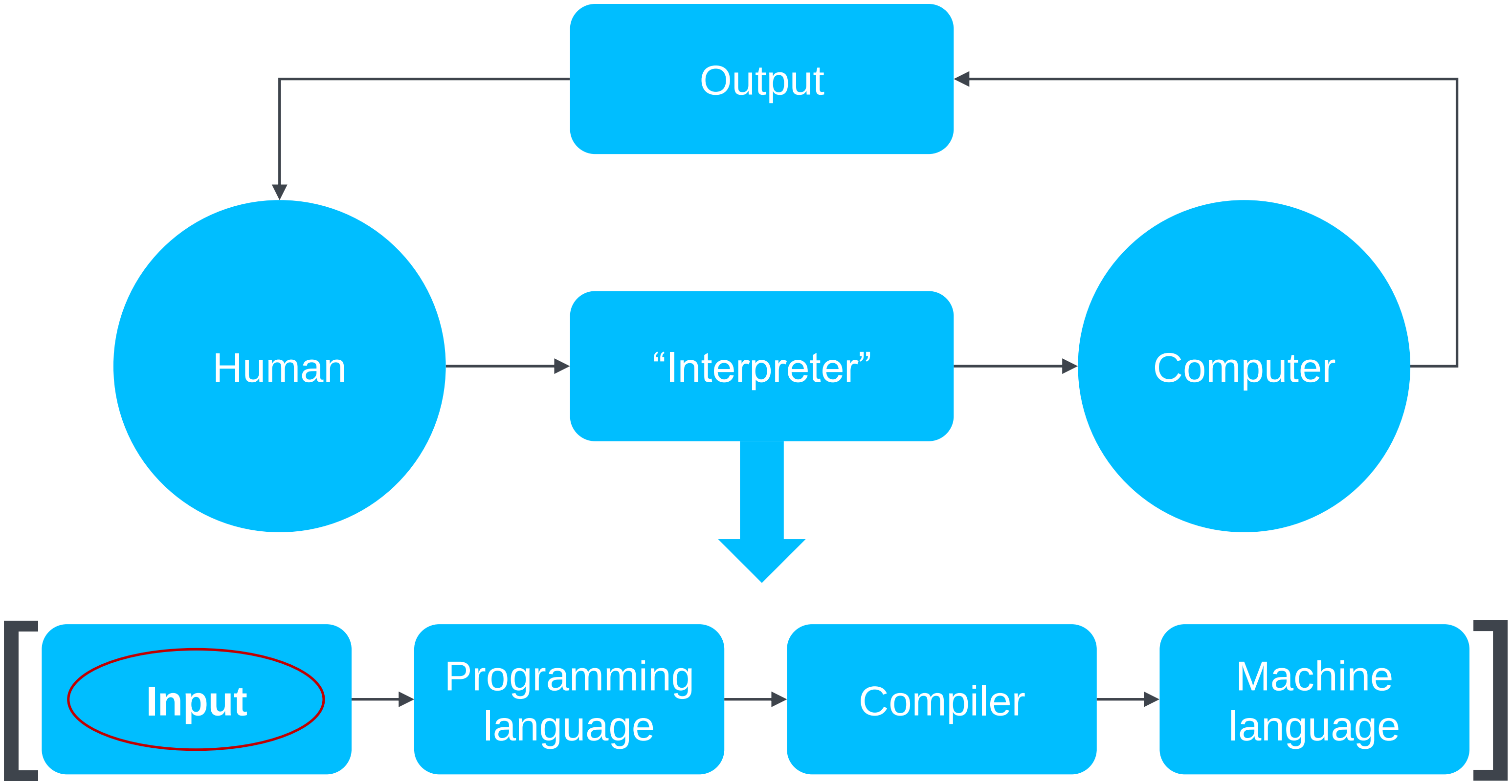
For Human Computer Interaction

Leonardo Gizzi

Motivation

- Physiological sensing = probing a living system
- Tons of information (intrinsic coherence)
- We need to know what we are dealing with
- Reduce the distance between human and computer

Why should we use physiological sensing
… for HCI?



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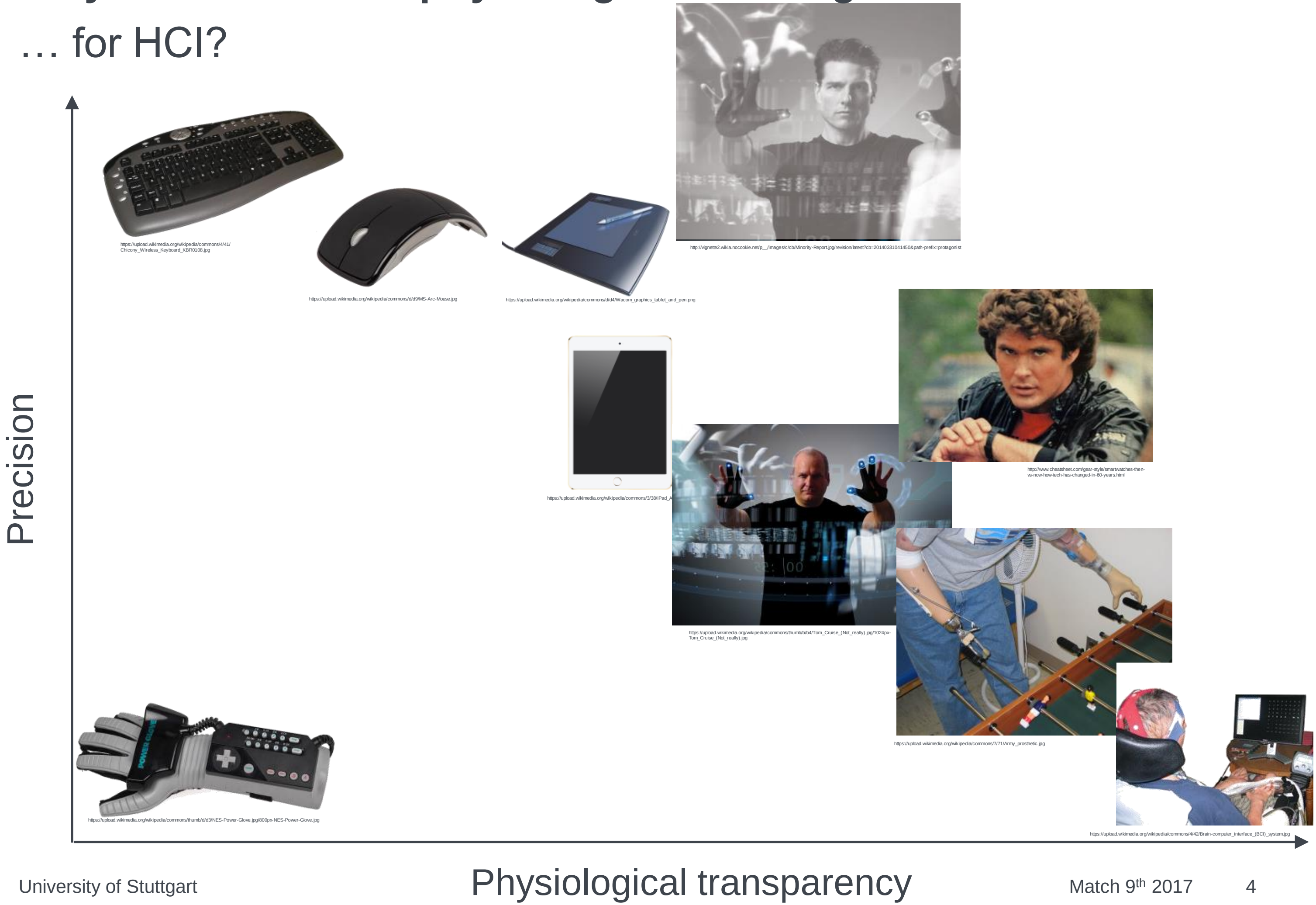

Why should we use physiological sensing

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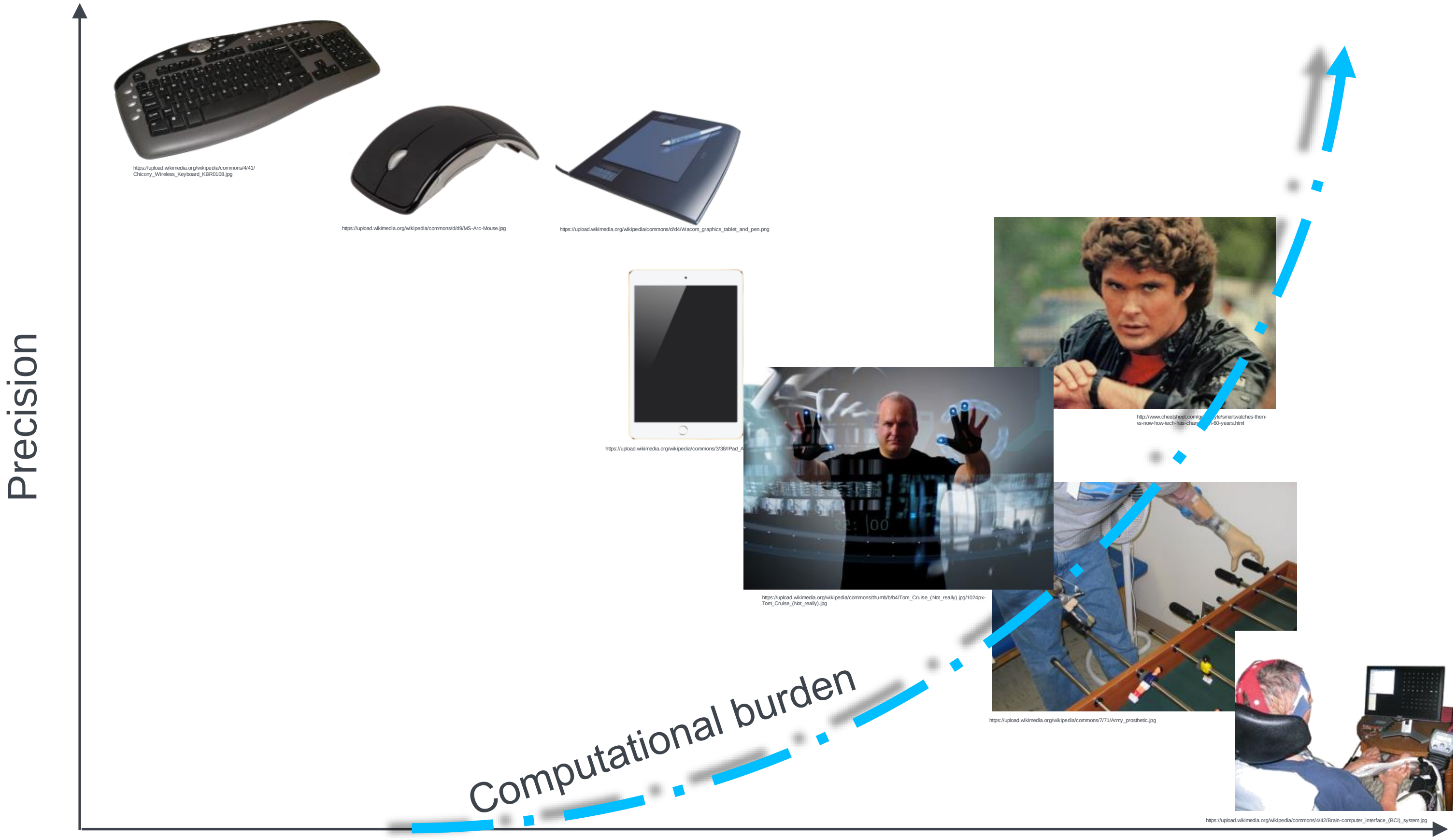


Physiological transparency

Why should we use physiological sensing

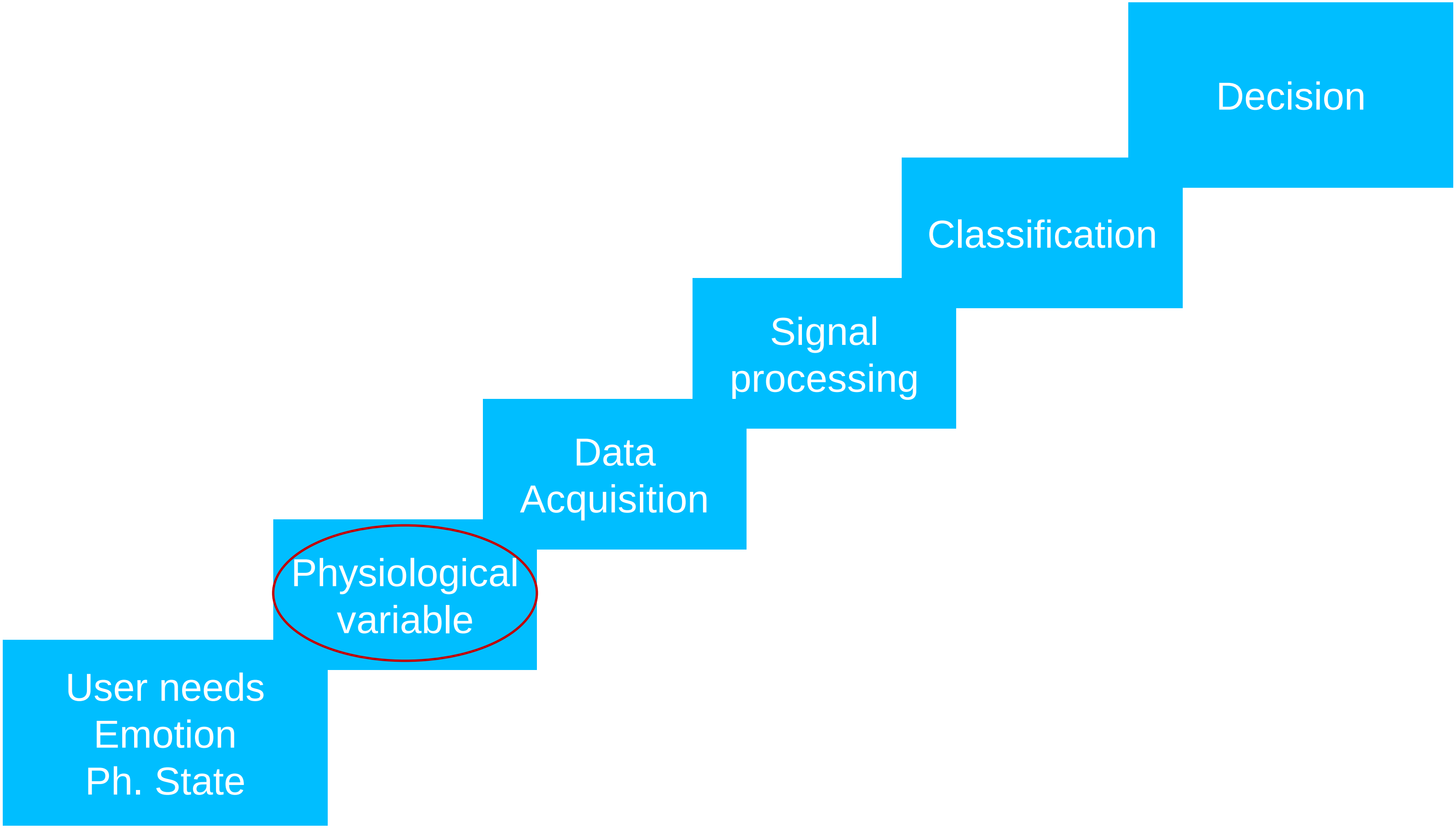
… for HCI?

- Pros
  - Intuitive / Trainable
  - Voluntary / Involuntary
  - Applicable with non-cooperative subjects
  - Subject-tailored

- Cons
  - Prone to errors:
    - Measurement
    - Misclassification
    - Misinterpretation
  - Computational burden
  - Privacy

What do we need

…for a happy physiological sensing?



Behaviour and Physiological variables

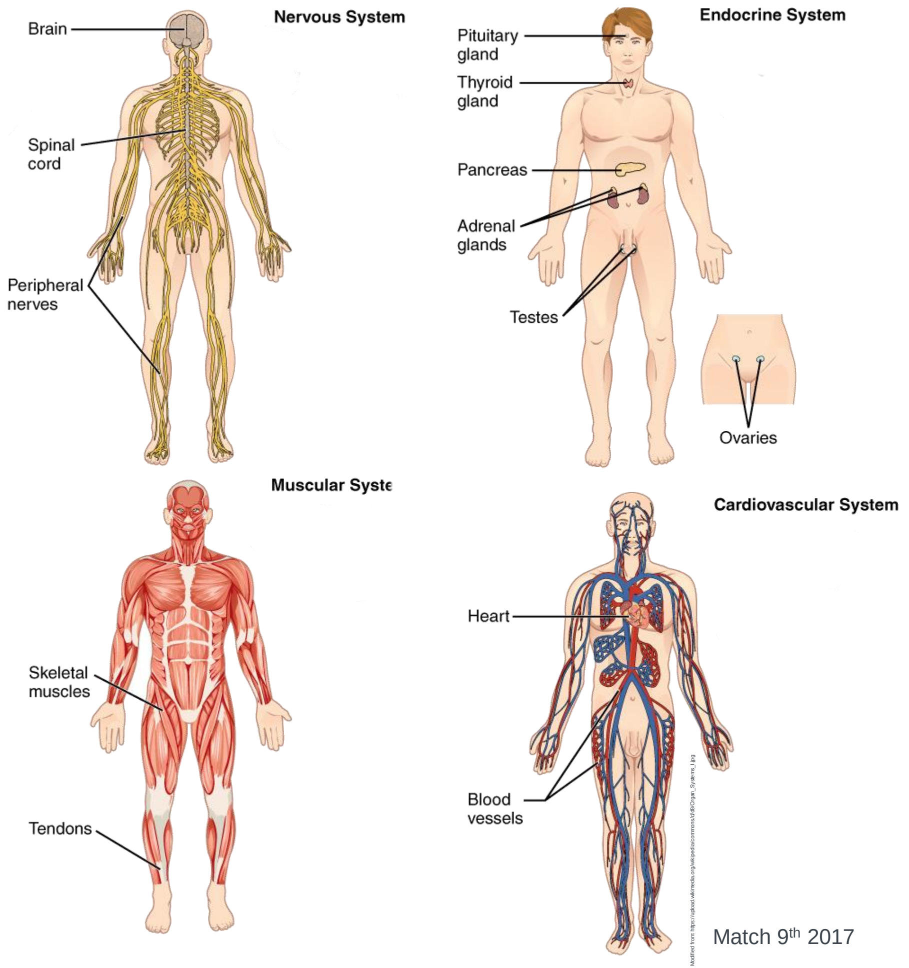
Behaviour to model

↓

System

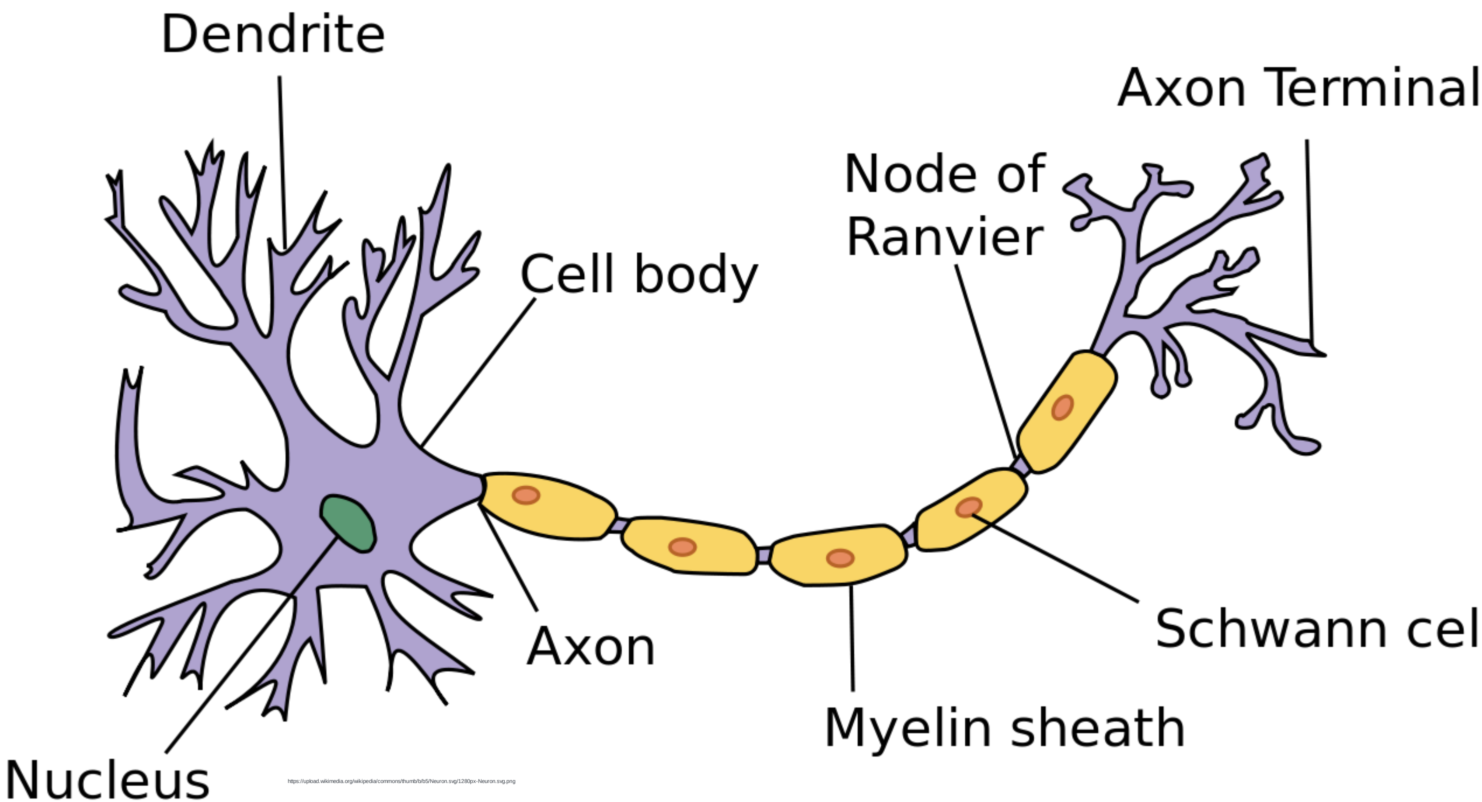
↓

Physiological variable



Excitable cells

Anatomy of a neuron



https://upload.wikimedia.org/wikipedia/commons/thumb/b/b5/Neuron.svg/1280px-Neuron.svg.png

Excitable cells

Kyudo = Archer + Bow

. . . + target

Inagaki Genshiro

Provides trigger

Stores energy

https://upload.wikimedia.org/wikipedia/commons/2/29/Professor_Inagaki_Genshiro.jpg

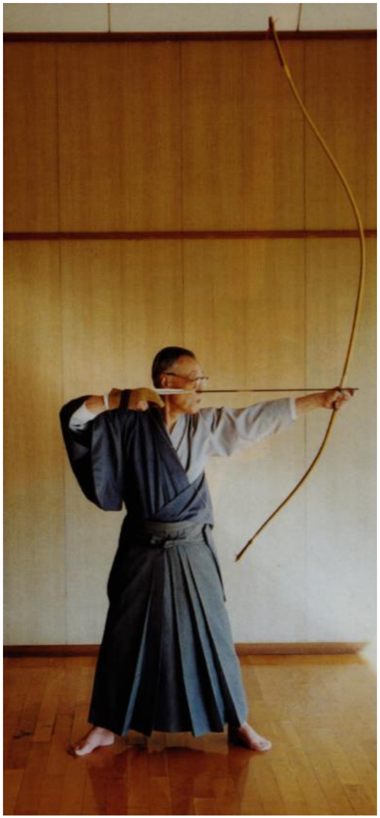
Provides energy

Ready to shoot!

Excitable cells

Kyudo and Neurons

Inagaki Genshiro



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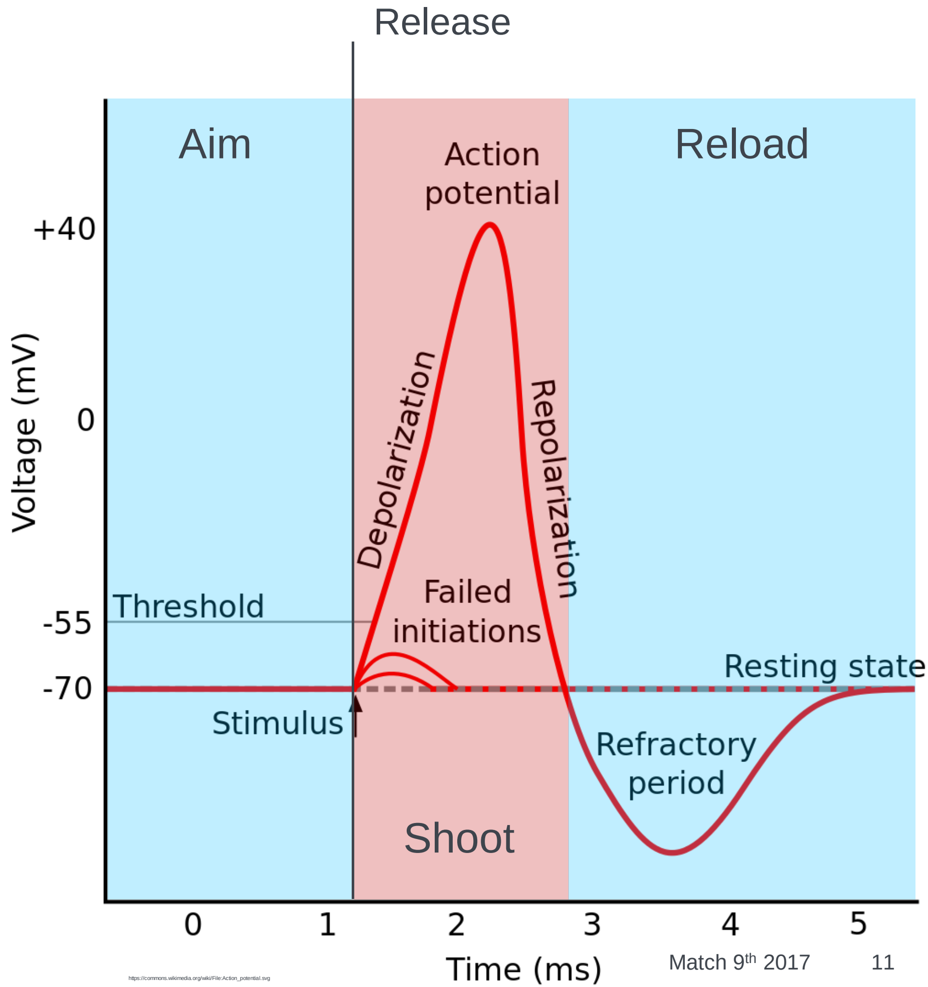


https://commons.wikimedia.org/wiki/File:Action_potential.svg

Excitable cells

Resting potential

Provides trigger
(other neurons*)

Provides energy
ATP
(sodium-potassium pump)

Inagaki Genshiro

https://upload.wikimedia.org/wikipedia/commons/2/29/Professor_Inagaki_Genshiro.jpg

Stores energy
(The cell membrane)

Resting potential ≠ 0
(faster)

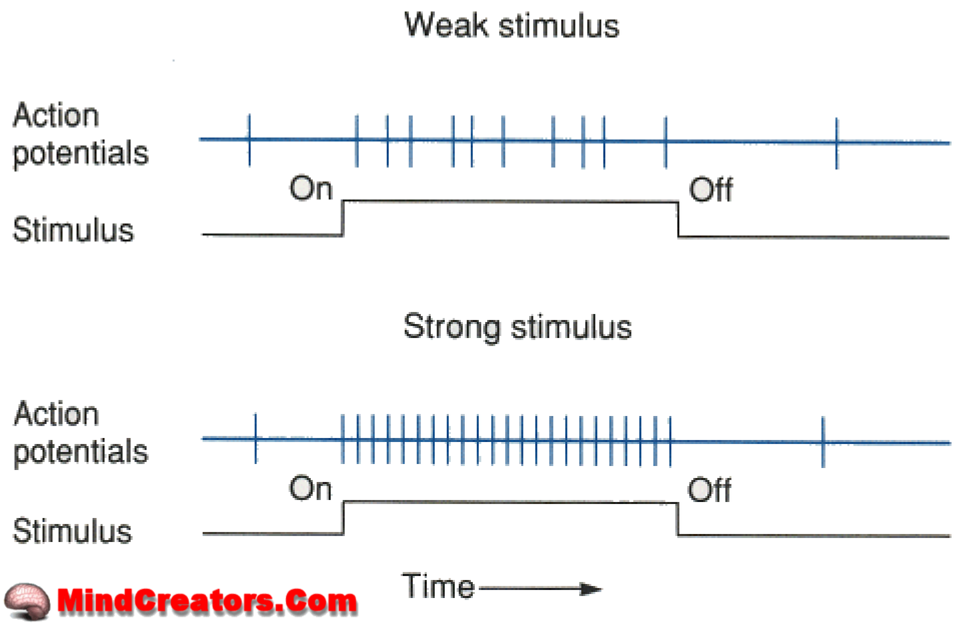
Moving ions = fun!

Excitable cells

Rate-coded

Maintaining potential
(Cheaper and faster)

No news, good news!



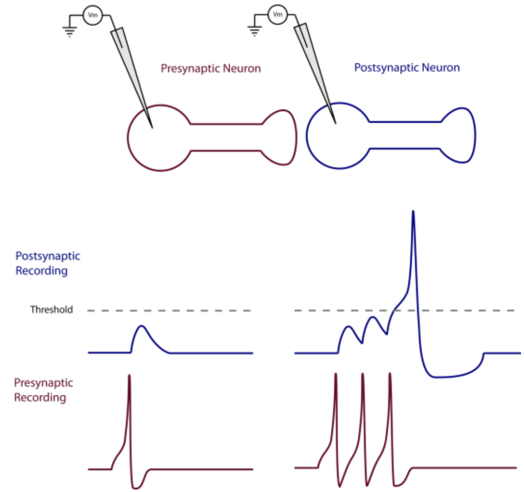
Do you see your nose?
Can you feel your clothes?

Now you do.

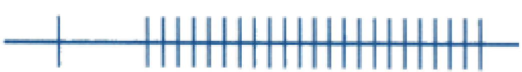
Excitable cells

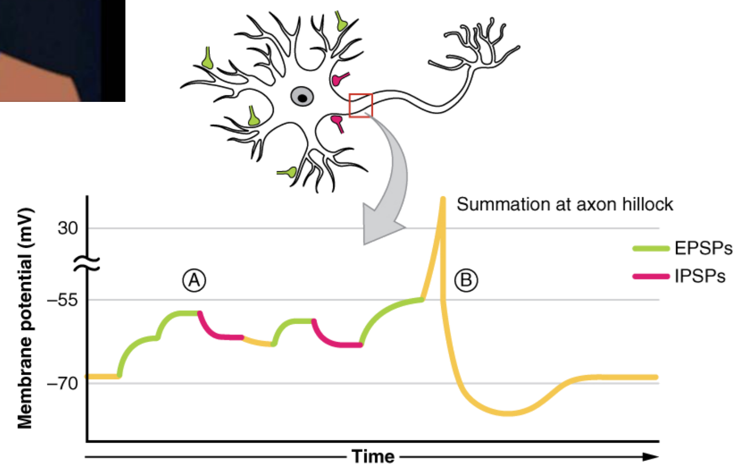
“Integrate and fire”

Dindal 2000



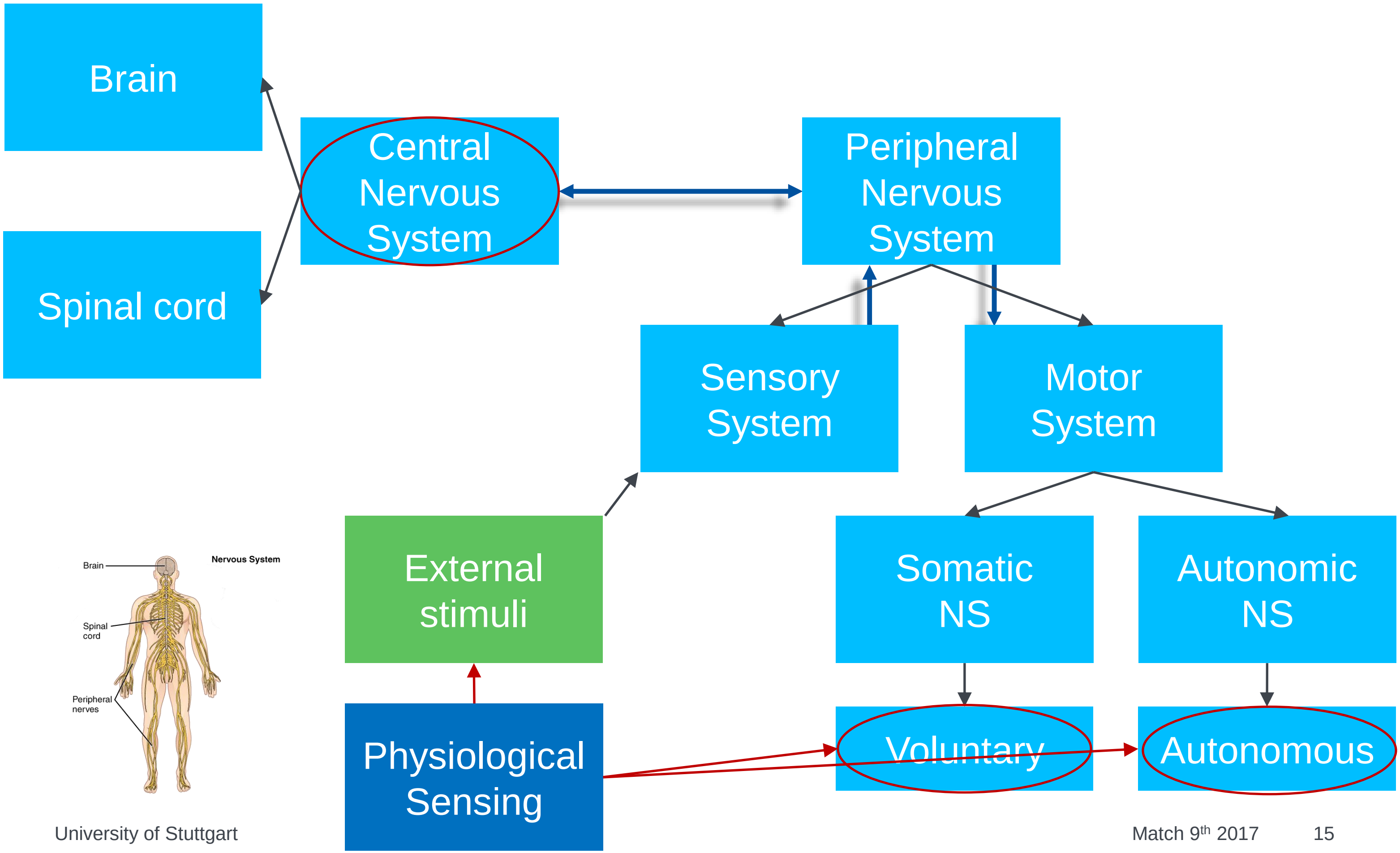
Action potentials





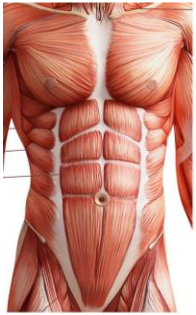
https://upload.wikimedia.org/wikipedia/commons/thumb/b/b5/Neuron.svg/1280px-Neuron.svg.png

Target: The Nervous System



Autonomic Nervous System

https://cdn.pixabay.com/photo/2016/02/01/16/10/eye-1173863_960_720.jpg



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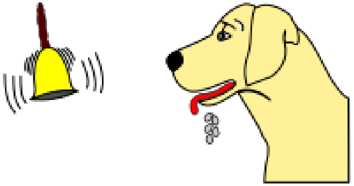

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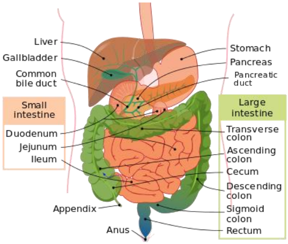
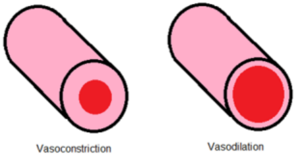
https://upload.wikimedia.org/wikipedia/commons/c/c5/Digestive_system_diagram_en.svg

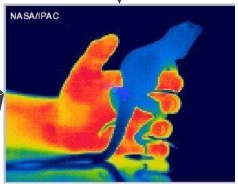




https://upload.wikimedia.org/wikipedia/commons/b/b2/Vasoconstriction_and_Vasodilation.png

https://upload.wikimedia.org/wikipedia/commons/d/d6/Heartbeat.jpg

https://upload.wikimedia.org/wikipedia/commons/c/c3/TranspirationPerspirationCommonsFL.jpg



http://coolcosmos.ipac.caltech.edu/image_galleries/ir_zoo/images/lizard2_ir.jpg

https://upload.wikimedia.org/wikipedia/commons/thumb/2/23/Goose_bumps.jpg/1024px-Goose_bumps.jpg

Autonomic Nervous System

Fight or Flight!

https://cdn.pixabay.com/photo/2016/02/01/16/10/eye-1173863_960_720.jpg

https://bg.wikipedia.org/wiki/%D0%A4%D0%B0%D0%B9%D0%BB:%D0%9C%D0%A3%D0%A1%D0%9A%D0%A3%D0%9B%D0%98_%D0%9D%D0%90_%D0%A7%D0%9E%D0%92%D0%95%D0%A8%D0%9A%D0%9E%D0%A2%D0%9E_%D0%A2%D0%AF%D0%9B%D0%9E_%D0%91%D0%93.png

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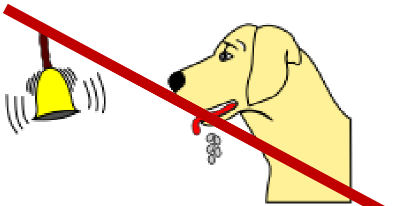

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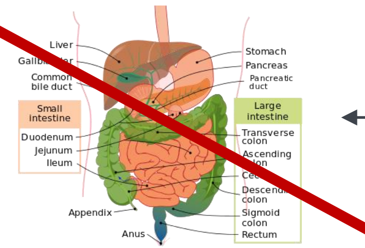

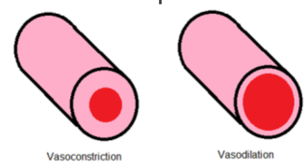

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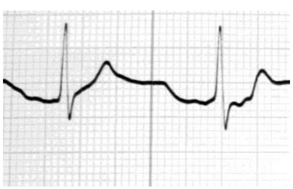

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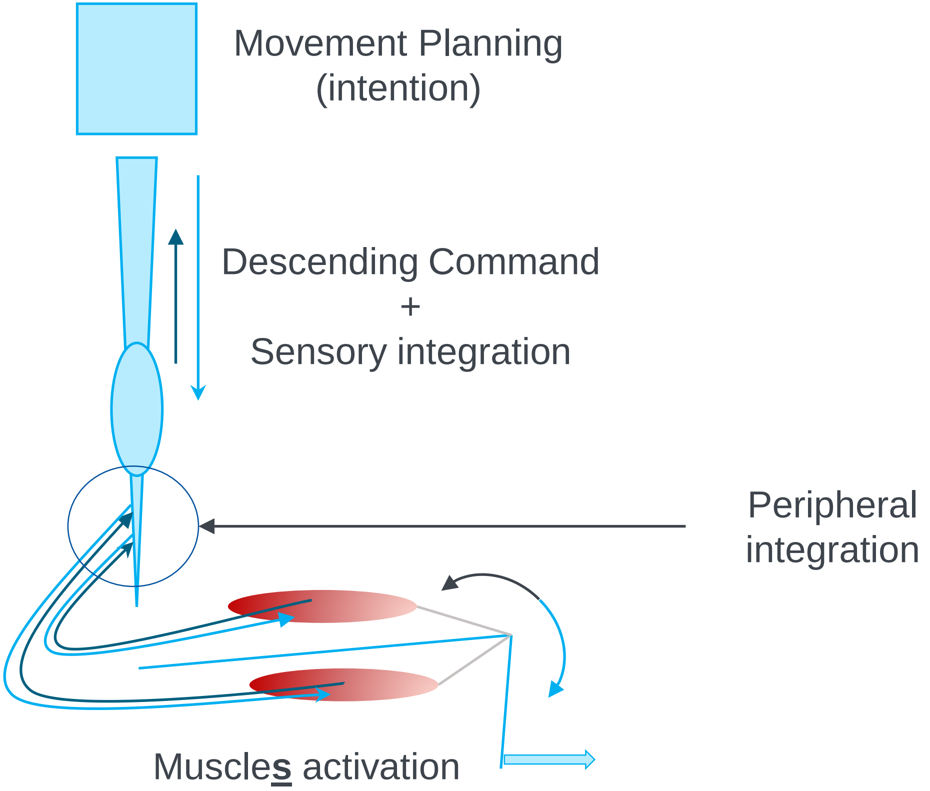
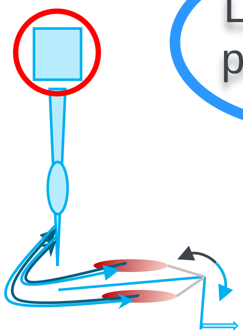
Motor Nervous system (AKA: Neuromuscular system)

From an idea to a movement

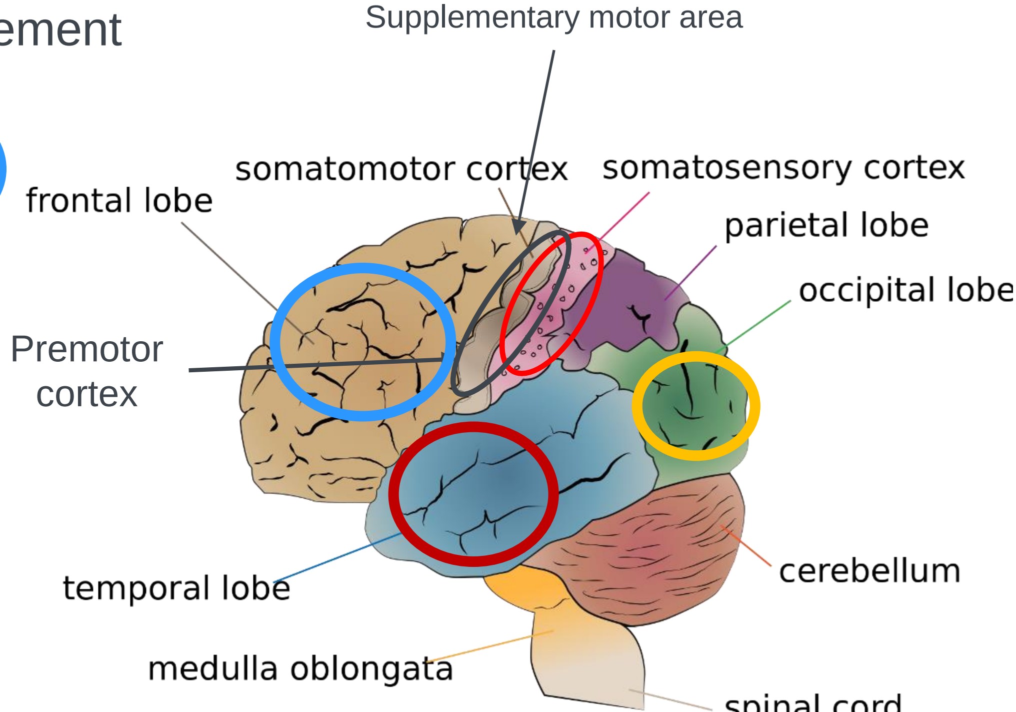


Neuromuscular system

From an idea to a movement



Language processing



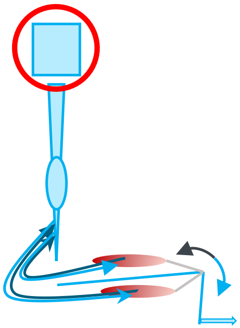
Audio processing

Video processing

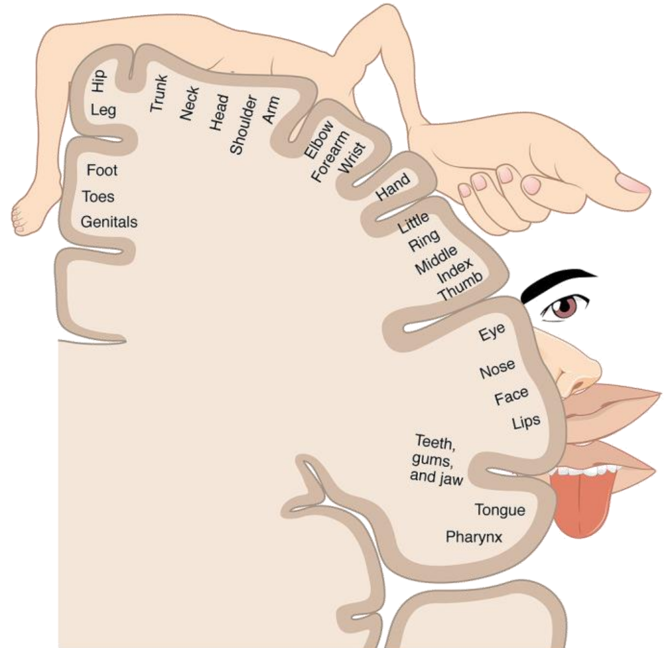
ttps://en.wikipedia.org/wiki/Cortical_remapping

Neuromuscular system

From an idea to a movement



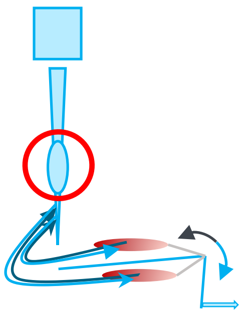
Sensory Cortical Map
(Penfield and Boldfrey 1937)

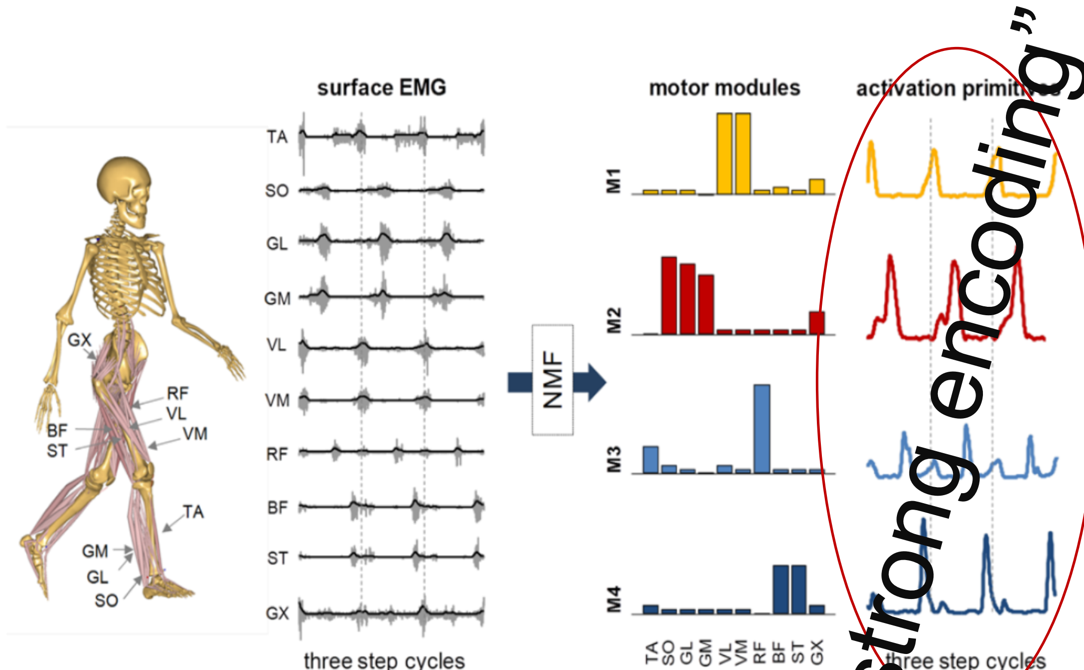


Sensory Homunculus
(Price-James S. 2016)

Neuromuscular system

From an idea to a movement

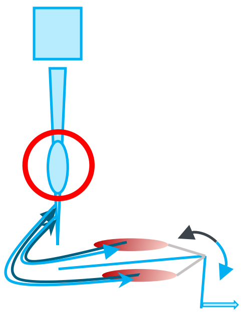




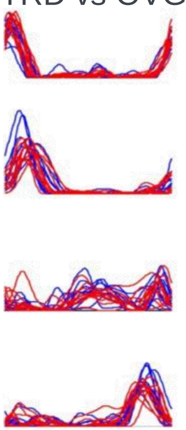
Holobar and Farina 2014

Neuromuscular system

From an idea to a movement

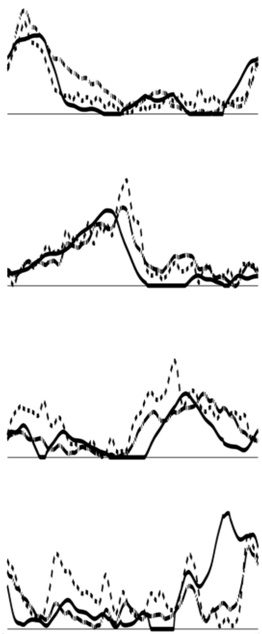


TRD vs OVG

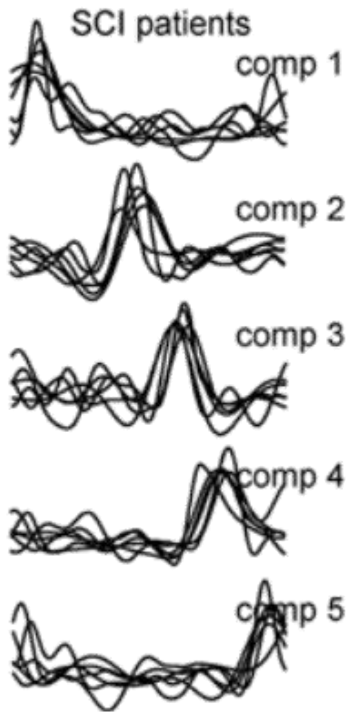


Oliveira 2016

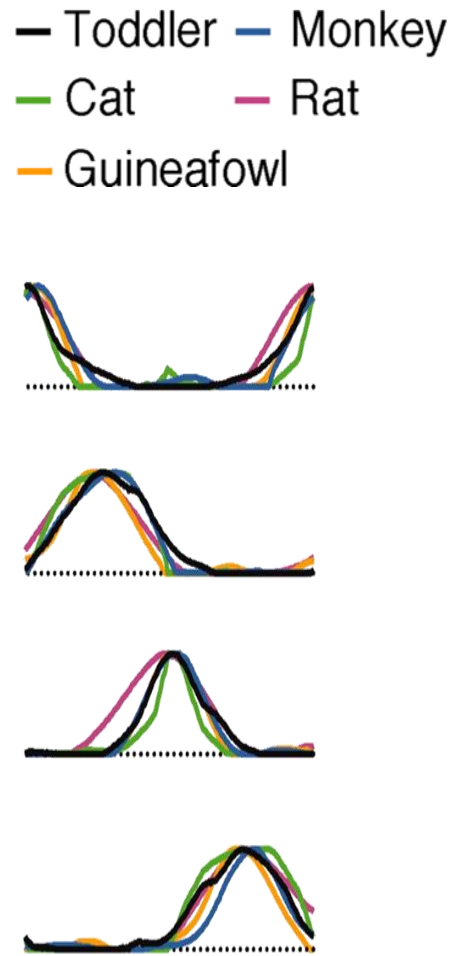
Stroke



Gizzi 2011



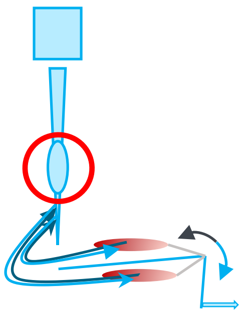
Ivanenko 2003

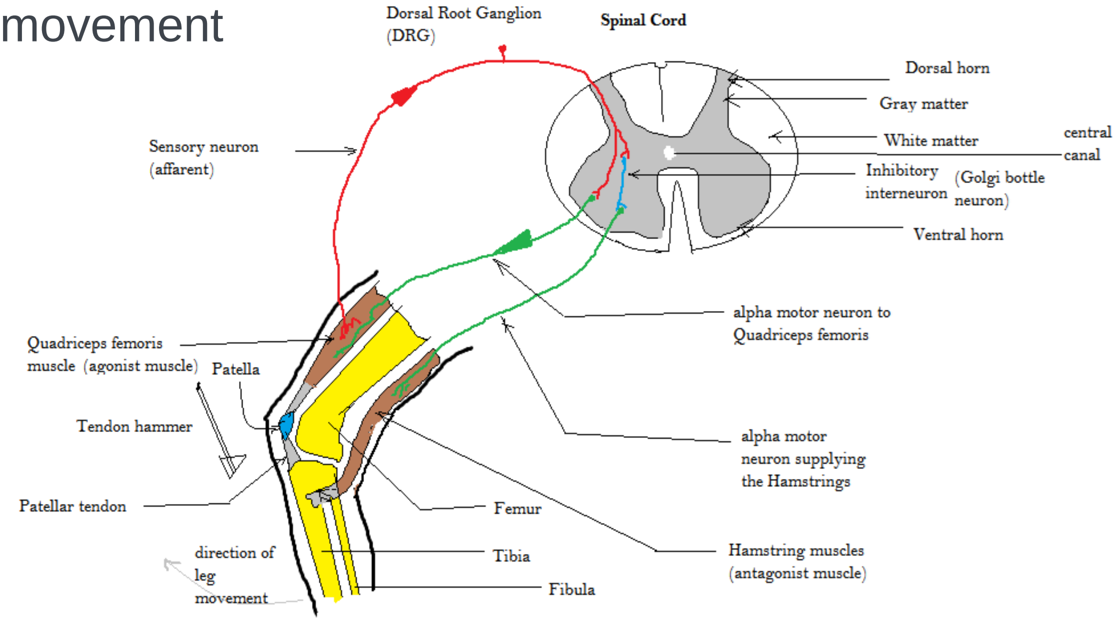


Dominici 2012

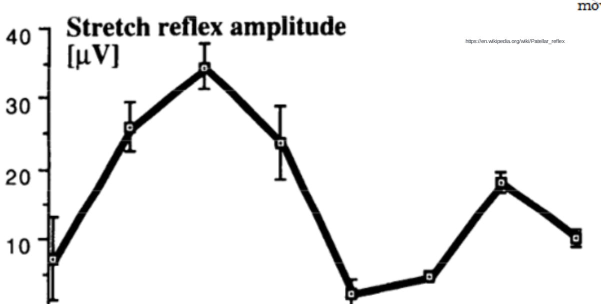
Neuromuscular system

From an idea to a movement

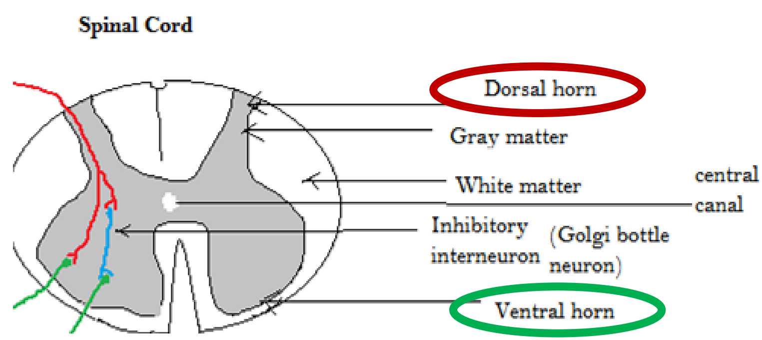




https://en.wikipedia.org/wiki/Patellar_reflex

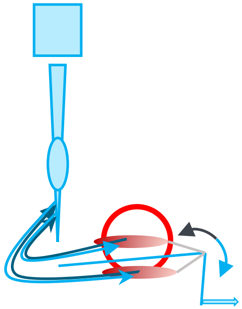


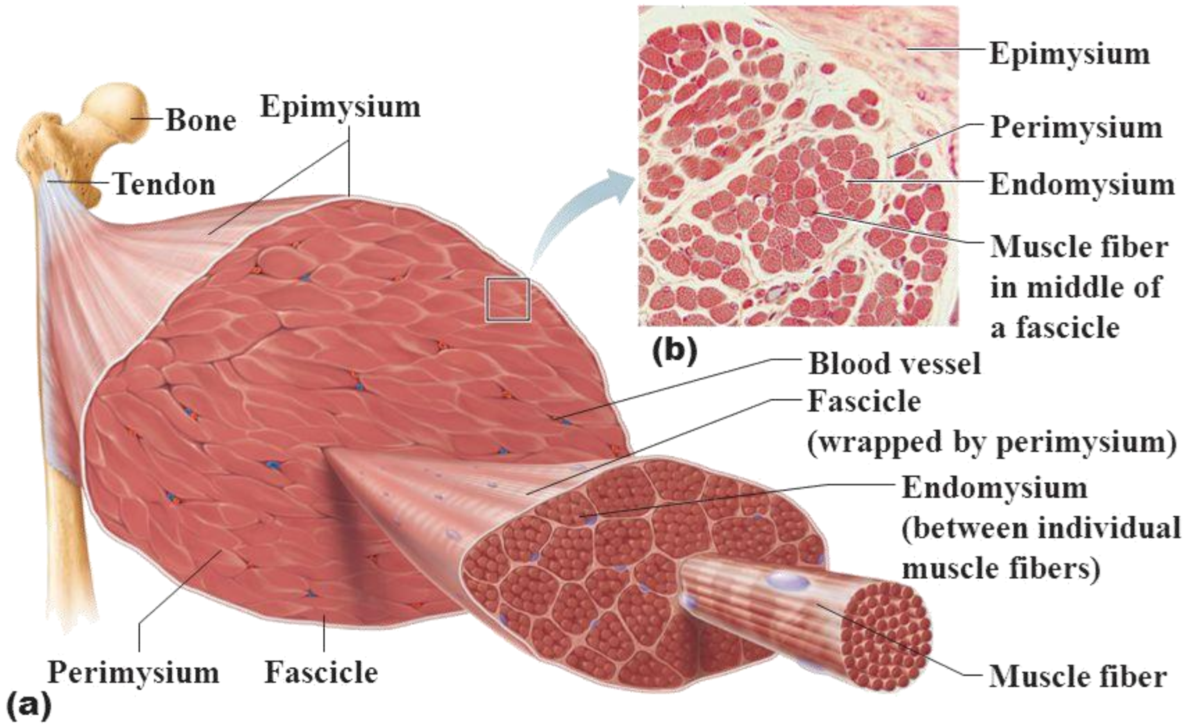
Sinkjær 1996



Neuromuscular system

From an idea to a movement

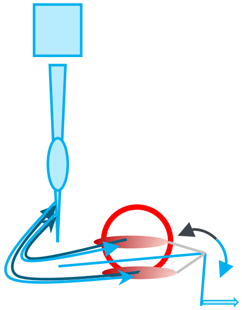


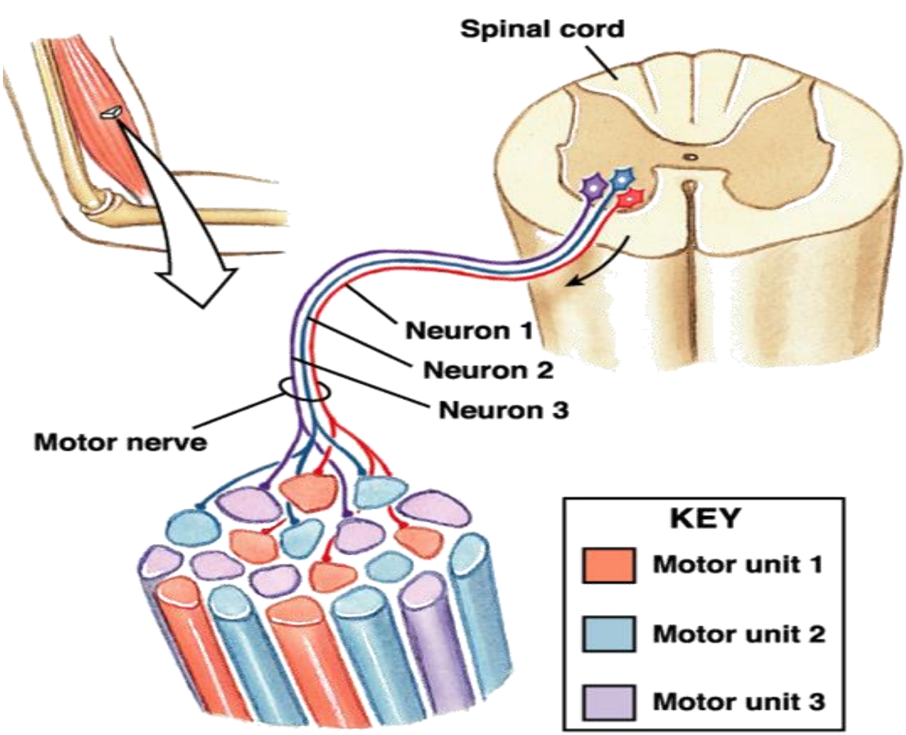


http://images.slideplayer.com/26/8554656/slides/slide_2.jpg

Neuromuscular system

From an idea to a movement



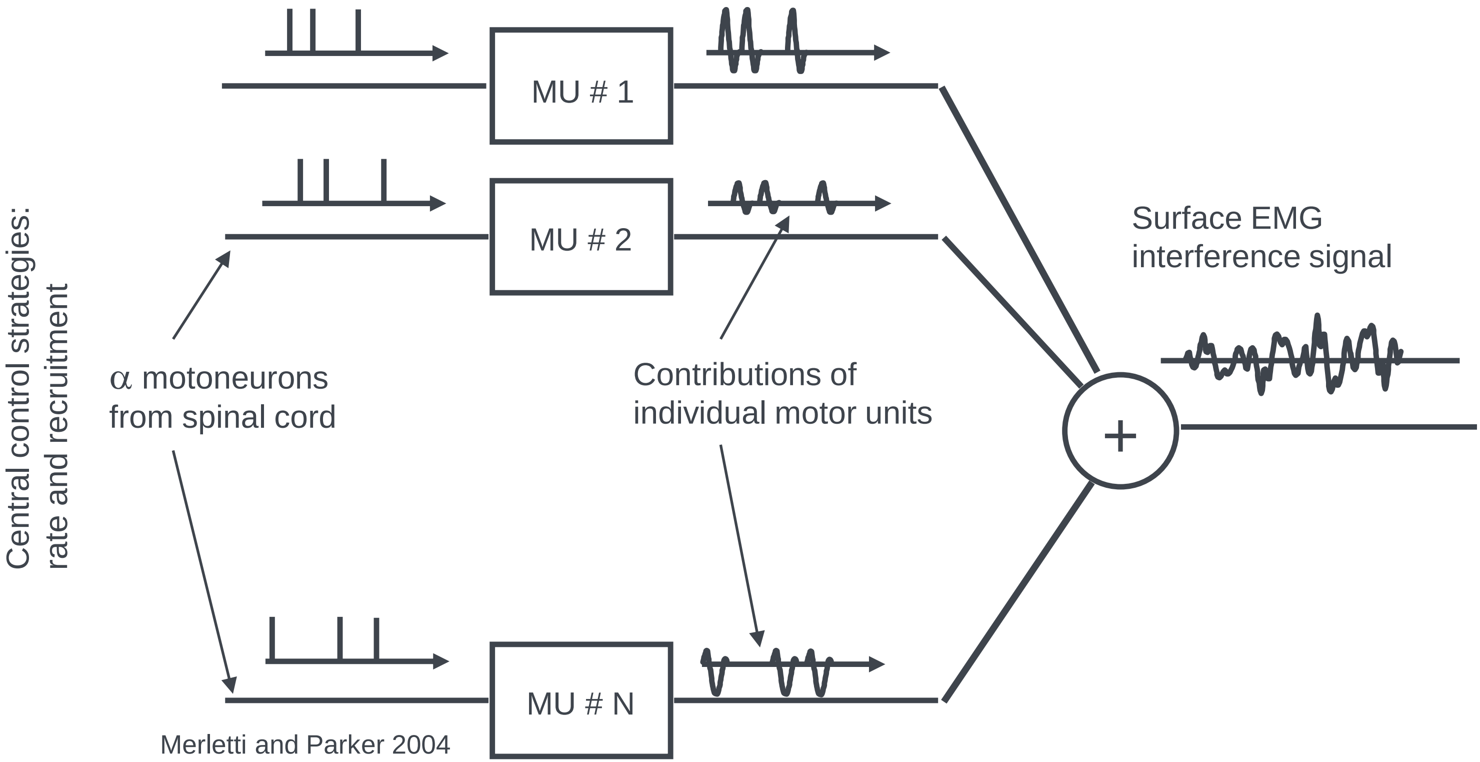


Moving ions = fun!

http://faculty.pasadena.edu/dkwon/chapt_11/textmostly/slide47.html

Neuromuscular system

From an idea to a movement



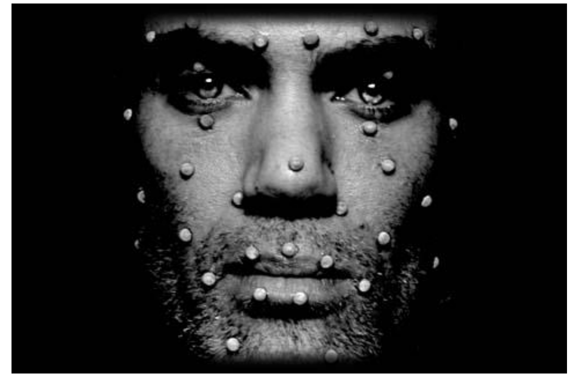
Merletti and Parker 2004

Probing the Human Body

- Metabolism
    - Gas analysis (a)
    - NIRS (a)
    - Temperature (a)

- Electrophysiology
  EMG (s)
  ECG (a)
  EEG (s)
  Skin impedance(a)
  Arc Reflex (s)

https://upload.wikimedia.org/wikipedia/commons/thumb/0/0f/Three_quarter_view_of_EEG_subject.jpg/400px-Three_quarter_view_of_EEG_subject.jpg



https://upload.wikimedia.org/wikipedia/commons/9/95/Motion_capture_facial.jpg

- Movement analysis
  Motion capture (s)
  IMU (s)
  Actigraphy (s)
  Pupillary reflex (a)

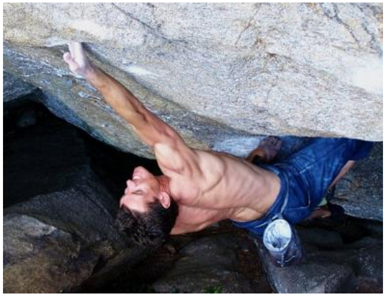
Example: myoelectric prosthesis control

- Human hand: 27DOF
- Robotic hand: 27DOF*

- Myoelectric control: 3DOF

Example: prosthesis control

The task at hand…



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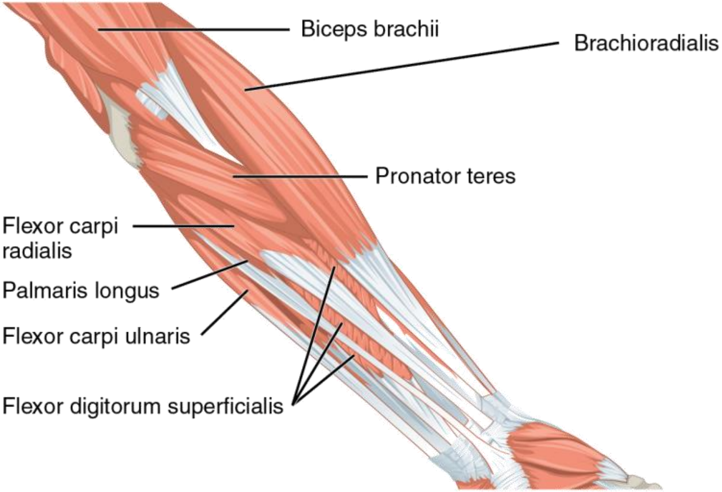
https://upload.wikimedia.org/wikipedia/commons/c/ca/Playing_the_piano.jpg

https://fogsmoviereviews.files.wordpress.com/2011/09/20110925-114643.jpg

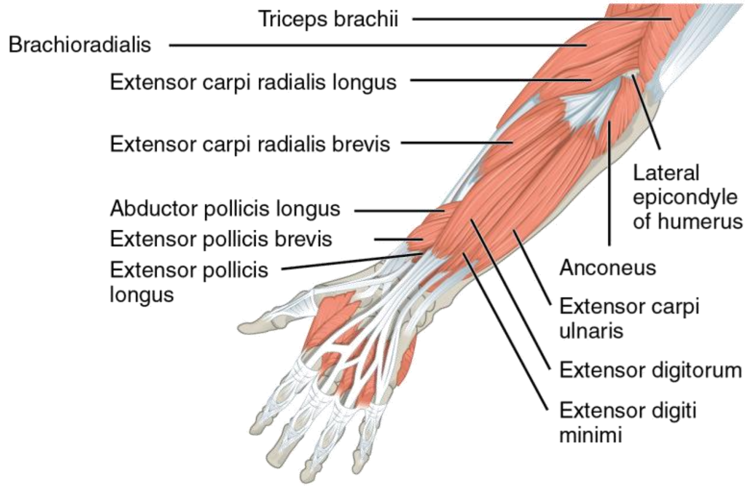
https://upload.wikimedia.org/wikipedia/commons/0/08/Surgeons_at_Work.jpg

Example: prosthesis control

Why is it so complicated?

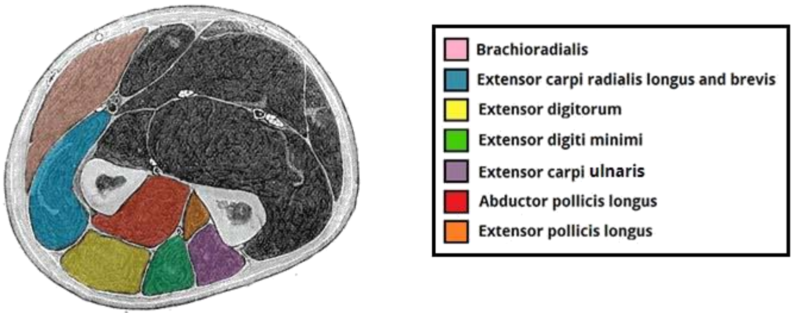


https://upload.wikimedia.org/wikipedia/commons/5/57/1120_Muscles_that_Move_the_Forearm_Antebrach._Sup._Flex._Sin.png



https://upload.wikimedia.org/wikipedia/commons/8/89/1120_Muscles_that_Move_the_Forearm_Antebrach._Sup._Ext._Sin.png

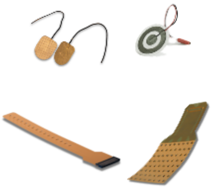
- EMG detection
- Flexible control
- Multiple solutions



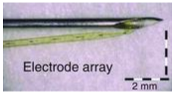
http://teachmeanatomy.info/upper-limb/muscles/posterior-forearm/

Example: prosthesis control

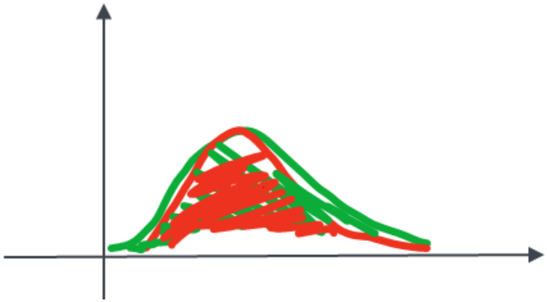
Mitigation



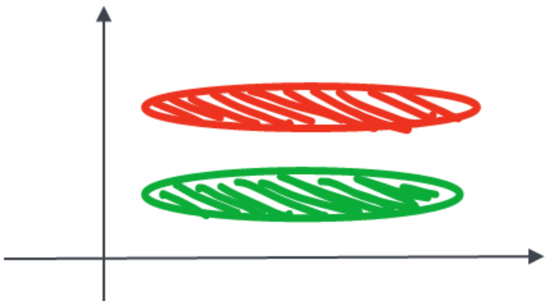
Muceli 2015



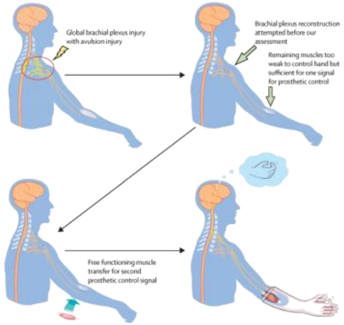
- EMG detection (bipolar, high density, multimodal)



- Classification algorithms



- Get 'creative' – Quality of life first!



http://www.sciencedirect.com/science/article/pii/S0140673614617761

Aszmann 2015

Example: myoelectric prosthesis control

Put things in perspective: neural plasticity and learning

http://www.nagehu.org/content/Projekte.html

www.goettinger-tageblatt.de/

http://www.goettinger-tageblatt.de/Goettingen/Uebersicht/Alimatou-Bamba-zu-Forschungsuntersuchungen-in-Goettingen

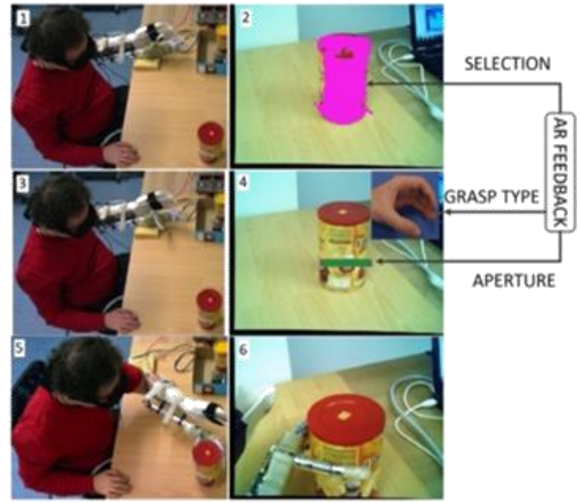
NGH

Nachhaltig gegen Hunger
http://www.nagehu.org/content/Projekte.html

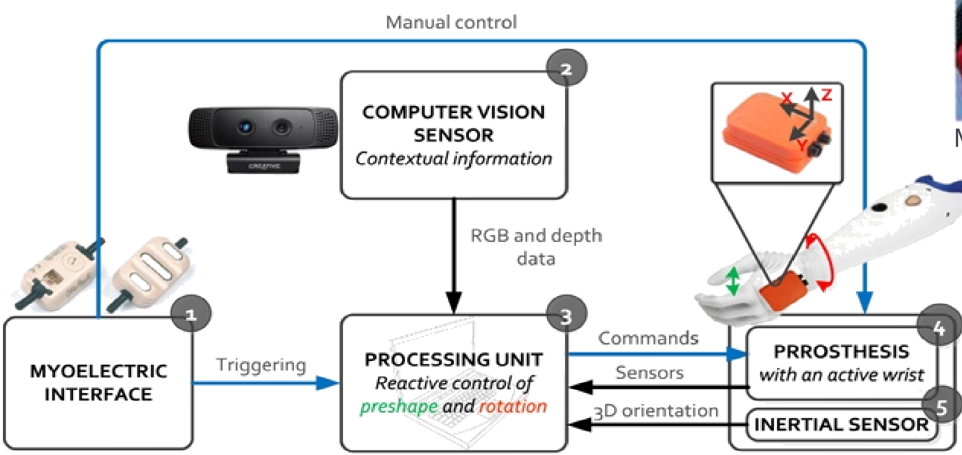
Example: myoelectric prosthesis control

Put things in perspective: machine intelligence

Prosthesis awareness



Markovic 2014

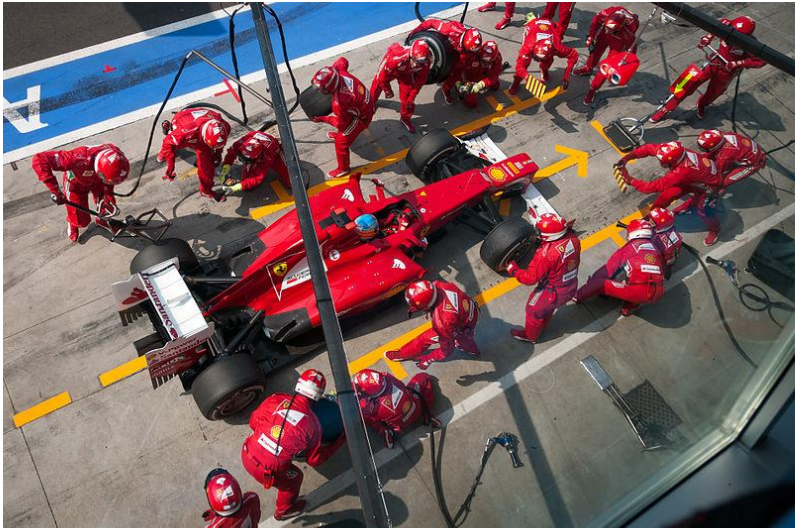


Markovic 2015

Probing the Human Body

Summary

- There is a lot of measurements that we can use
- We need to keep in mind the user's needs
- Signal quality is crucial
  - Physiology = ally
  - Noise = enemy
  - Multimodal rocks!
- We must get creative
  - Neural plasticity
  - Machine intelligence
  - Teamwork



https://upload.wikimedia.org/wikipedia/commons/c/c9/2012_Italian_GP_-_Ferrari_pit.jpg

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Thank you!

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