Understanding how activity in the brain produces movements

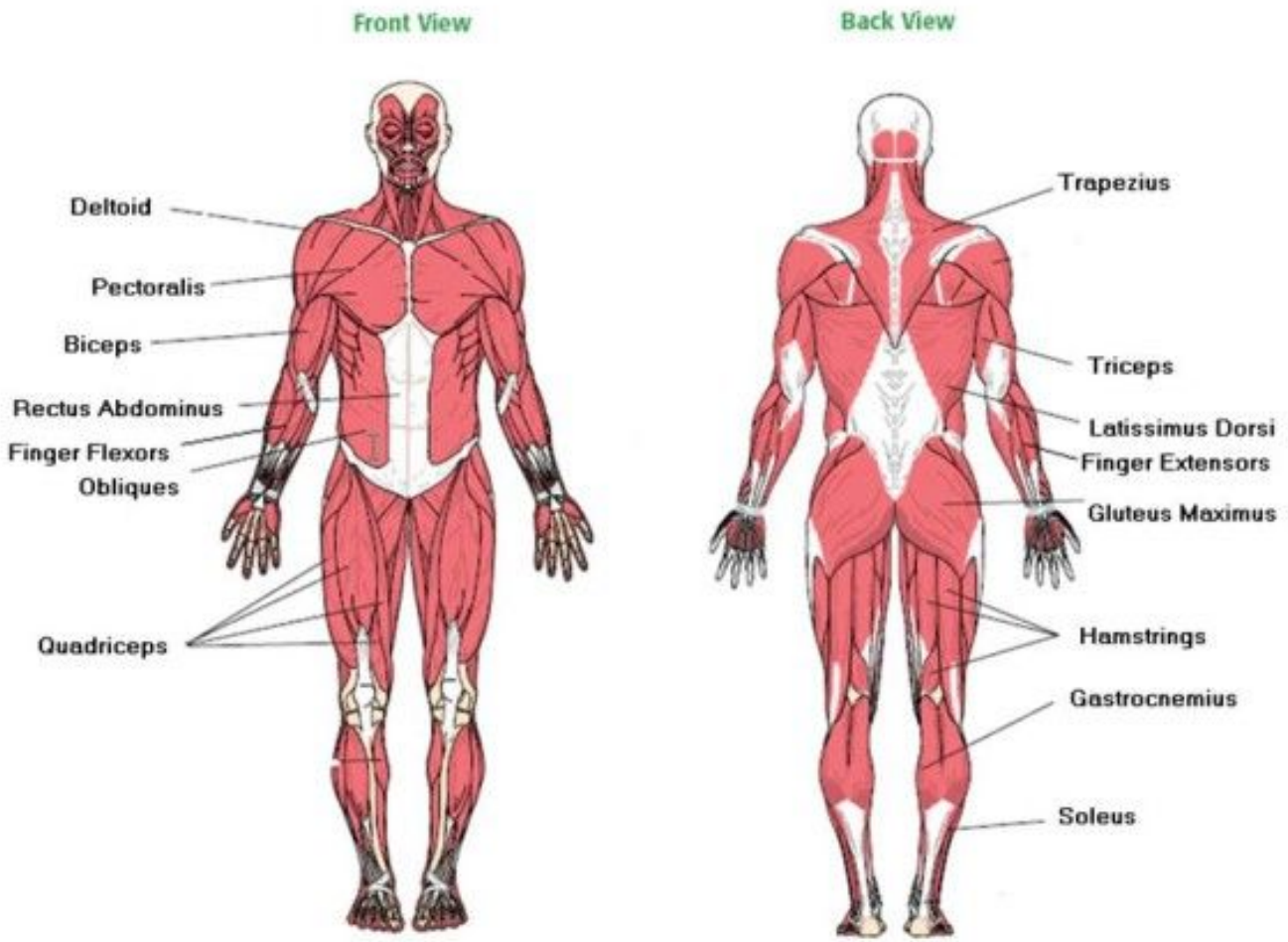
Raghav Rajan, IISER Pune

Nov 29th 2015

We all make many different movements every day

- How do we make these movements?

Skeletal muscles in our body help us move our body parts



- We have ~640 skeletal muscles in our body
- Are required for different movements
- Muscles contract/relax to cause the movement
- How do these muscles work?

http://cdn.runningmagazine.ca/wp-content/uploads/2015/02/Muscles.jpg

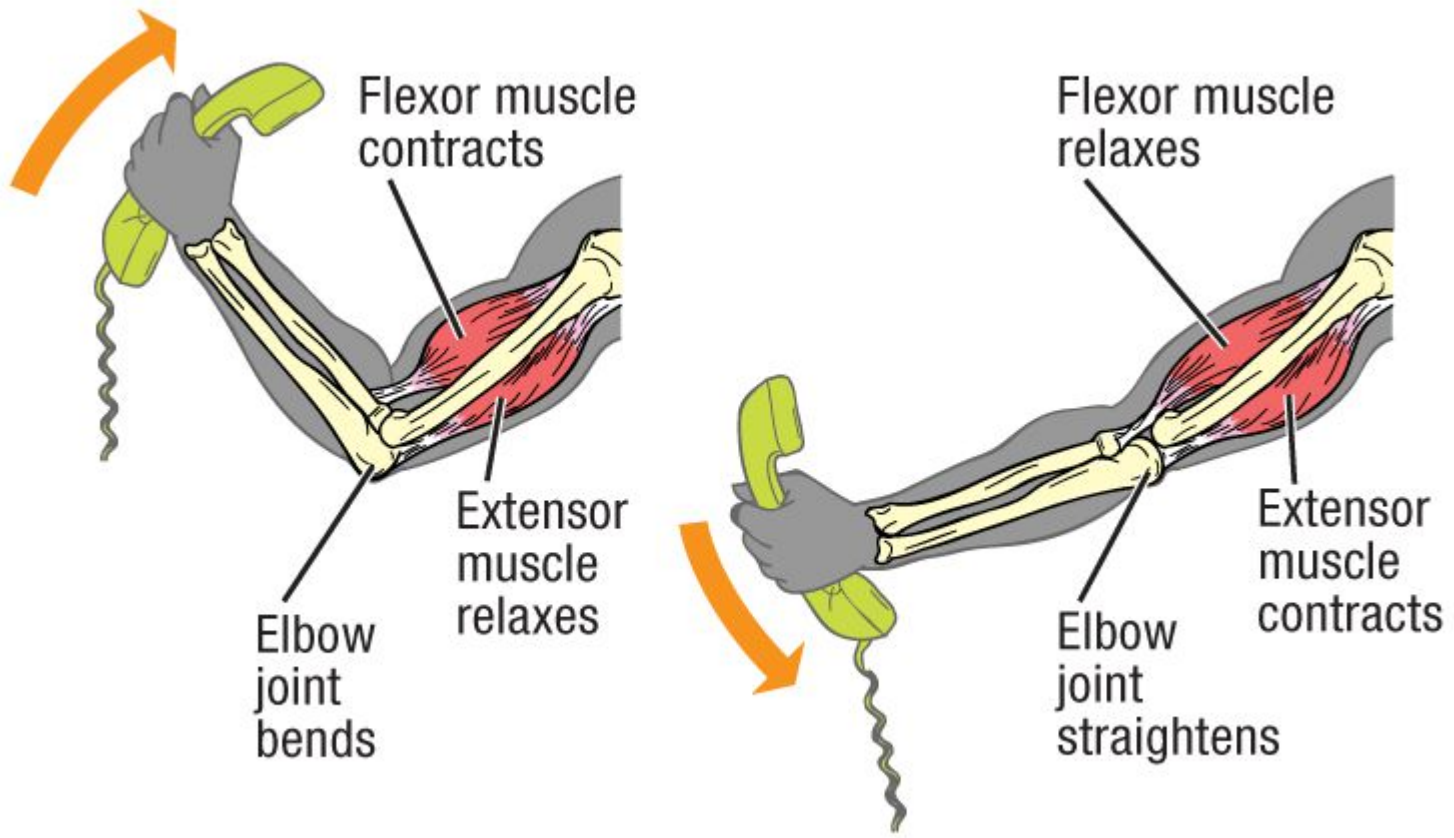
Skeletal muscles work in pairs to “flex” or “extend”

https://www.youtube.com/watch?v=C6u0u_59UDc

Skeletal muscles work in pairs to “flex” or “extend”

https://www.youtube.com/watch?v=C6u0u_59UDc

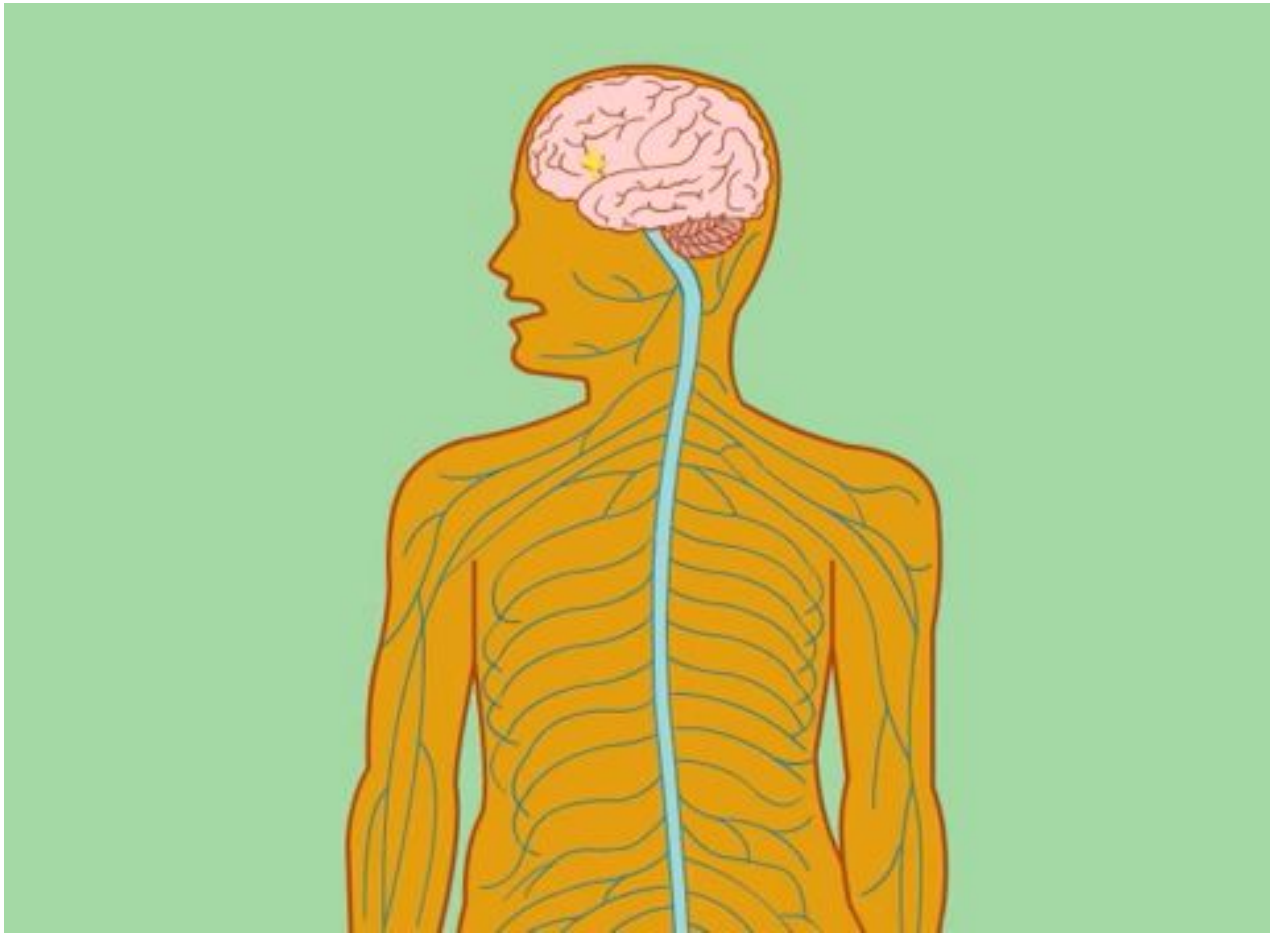
Flexor-Extensor muscle pairs help to move different parts of the body



- What causes them to contract or relax?

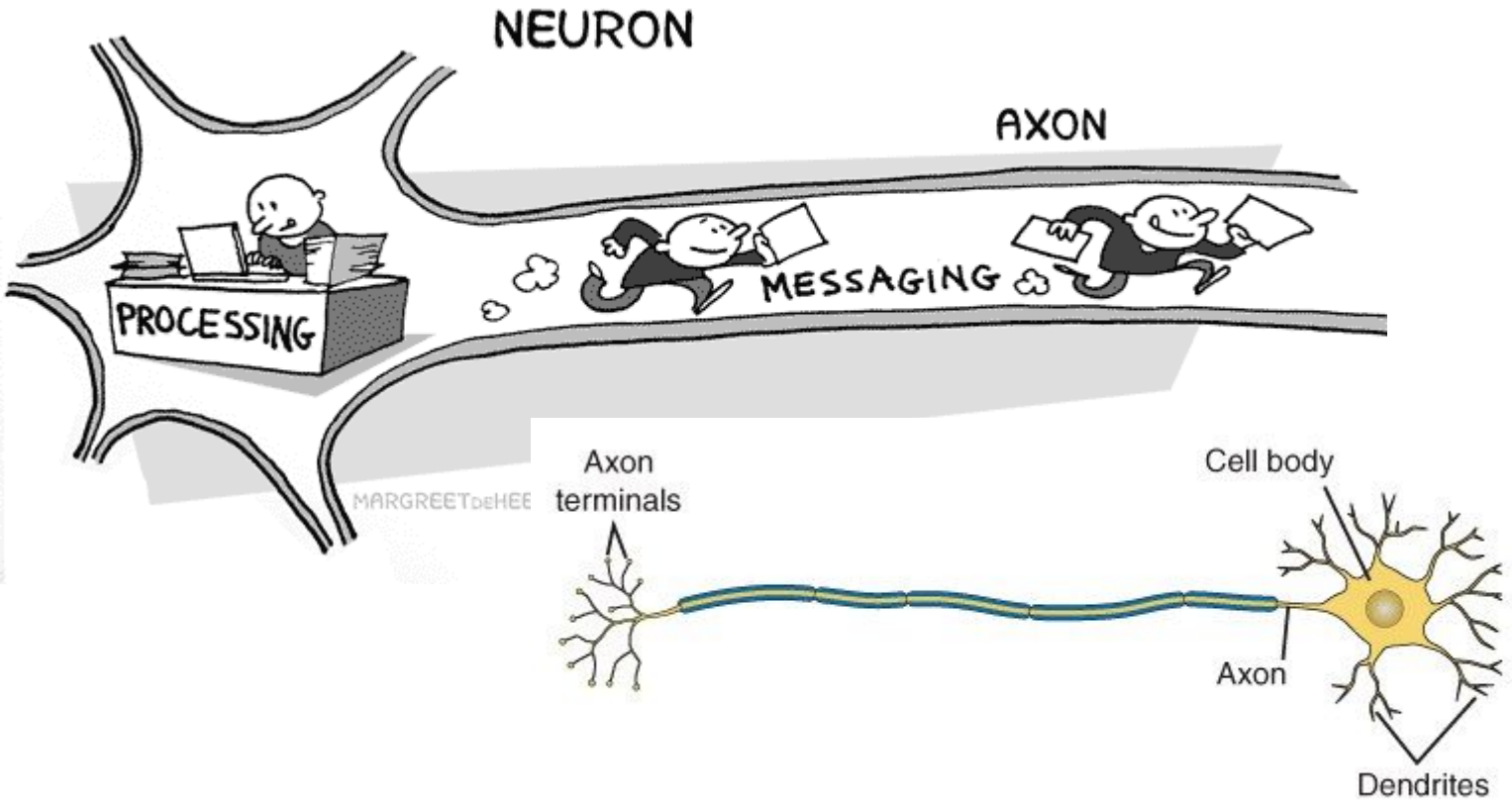
http://www.benjaminreece.com/source_images/ill31_lg.html

Nerves provide the signals to make muscles contract or relax



https://www.youtube.com/watch?v=C6u0u_59UDc

What is a neuron?



- Neurons are the basic units of the nervous system
- The brain has about 1 billion (1, 000, 000, 000) neurons
- Neurons transmit electrical signals

http://nbmpub.com/blog/wp-content/uploads/2013/08/17neuron-axon.gif

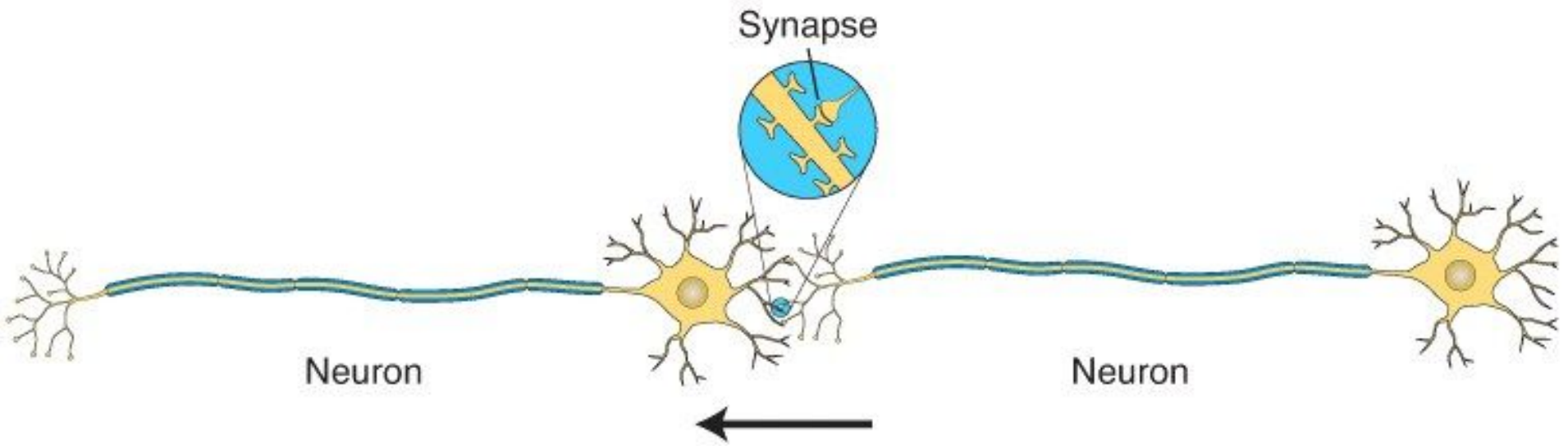
LIGHTS, CAMERA, ACTION POTENTIAL!!

https://www.youtube.com/watch?v=XdCrZm_JAp0

Neurons connect with each other and pass messages to each other

https://www.youtube.com/watch?v=XdCrZm_JAp0

Neurons connect with each other and pass messages to each other



- Electrical signals from one neuron are passed on to other neurons
- 1,000,000,000 neurons
- 100,000,000,000,000 connections between neurons

http://rise.duke.edu/seek/pages/0105.html

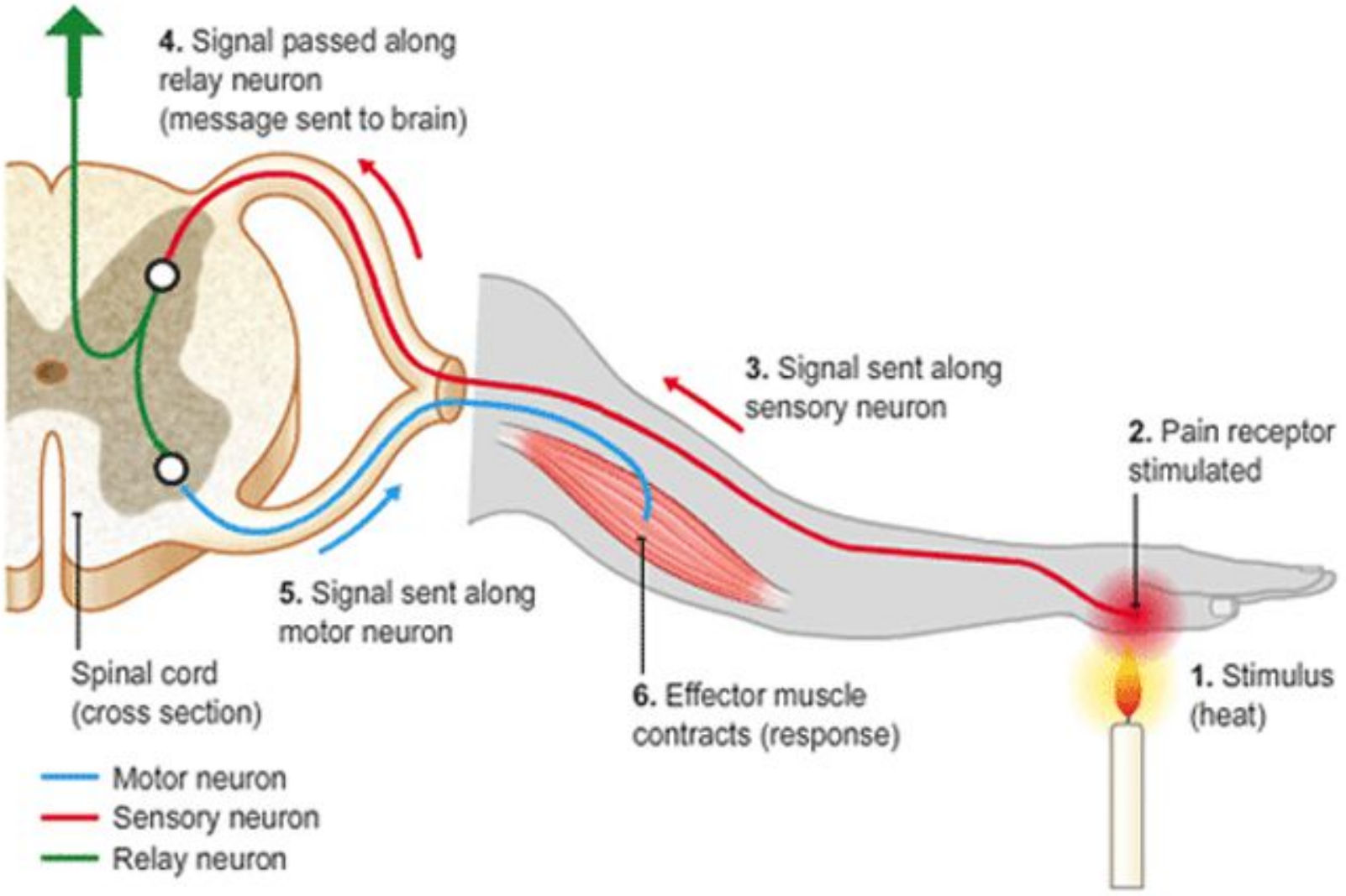
So now, how are movements produced?

- What are the different types of movements?
  - Reflex actions – very basic movements
  - Voluntary actions
  - Movement sequences

Reflex actions are controlled from the spinal cord – No thinking involved!

Whenever we happen to come close to an object that is capable of harming us, we immediately withdraw the part of the body that is the most vulnerable. This is called reflex action.

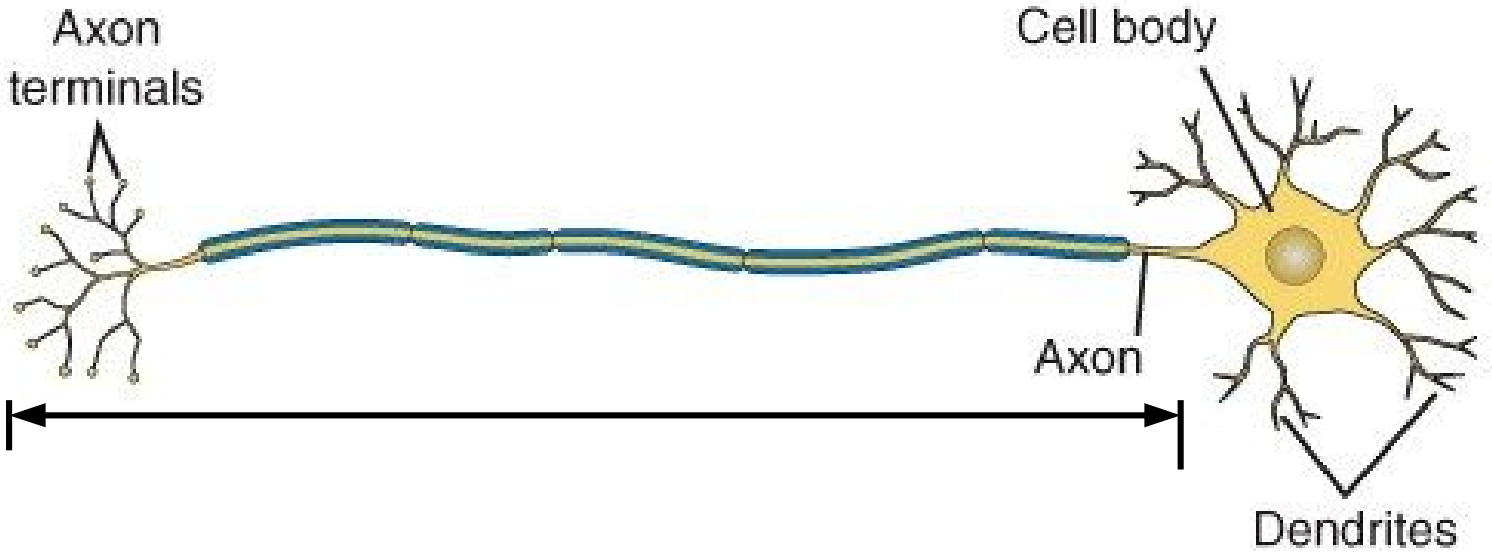
How long does it take to remove your hand?



- Has to travel from from finger tip to spinal cord and back

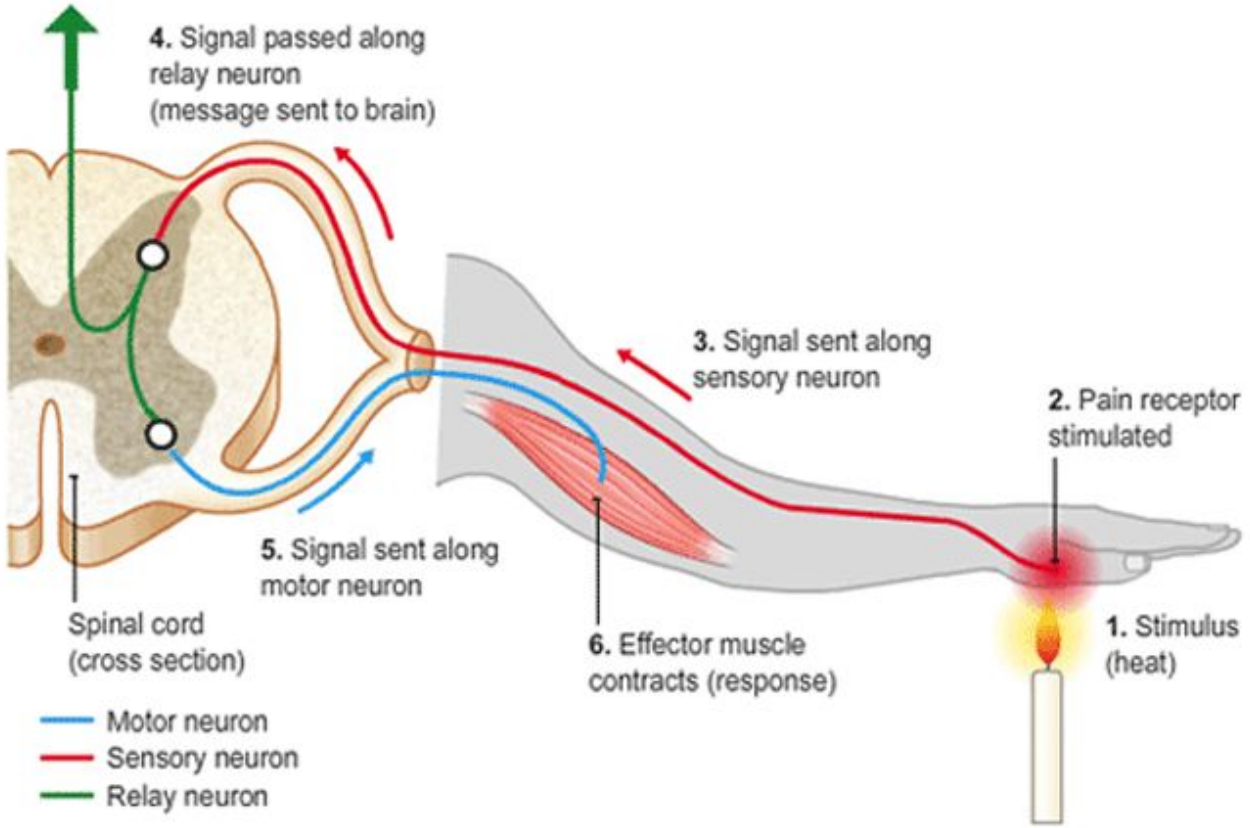
http://georgi-georgiev.com/demo/websites/nervous-system/img/Reflex.gif

Electrical signals travel very fast



- Action potential lasts ~ 1ms (1/1000th of a second)
- Speed at which one electrical signal travels – 0.5 – 100m/s
  - Or 1.8 km/hr – 360 km/hr
- As fast as a car on the road!!

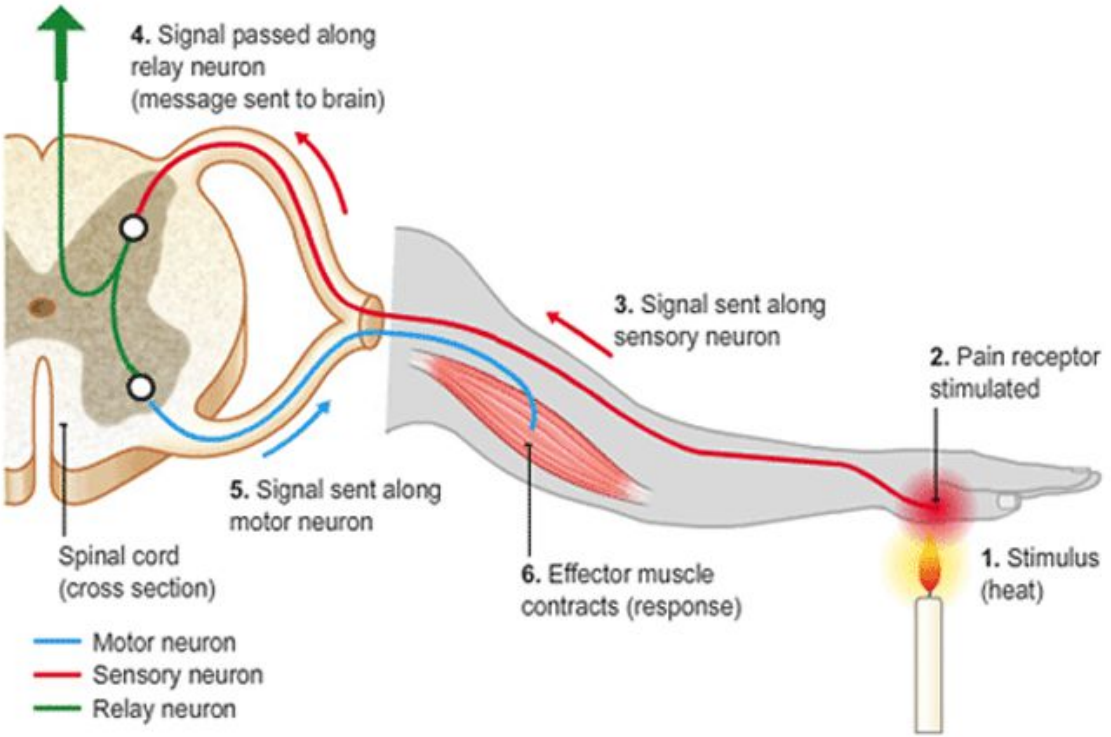
So, this reflex action must take about 0.5s or sometimes as little as 0.05s!!

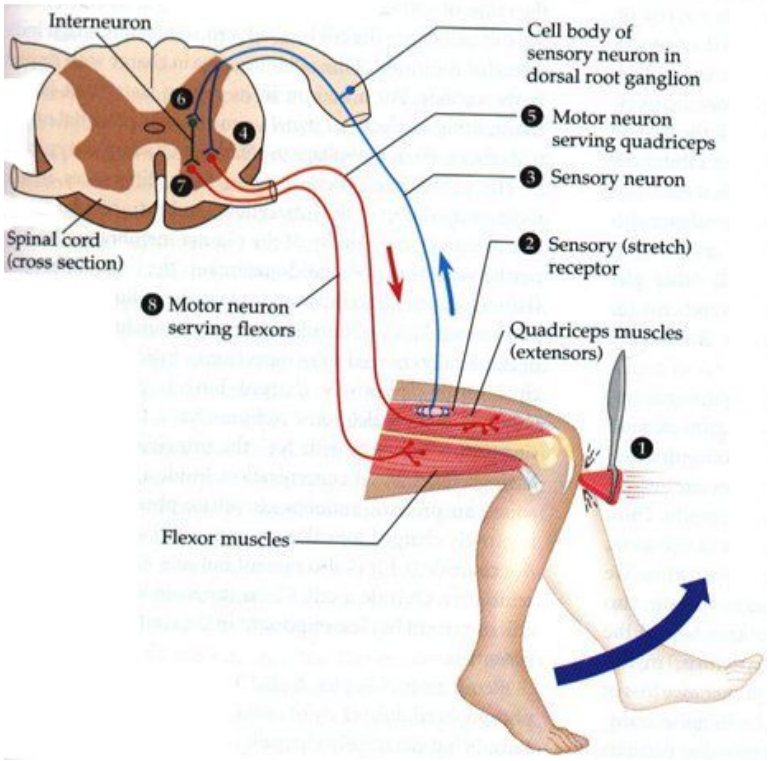


- Has to travel from from finger tip to spinal cord and back
- 0.5 second
  - Time for one eye-blink!

http://georgi-georgiev.com/demo/websites/nervous-system/img/Reflex.gif

Very specific response since Sensing Neuron is directly connected to Motor Neuron

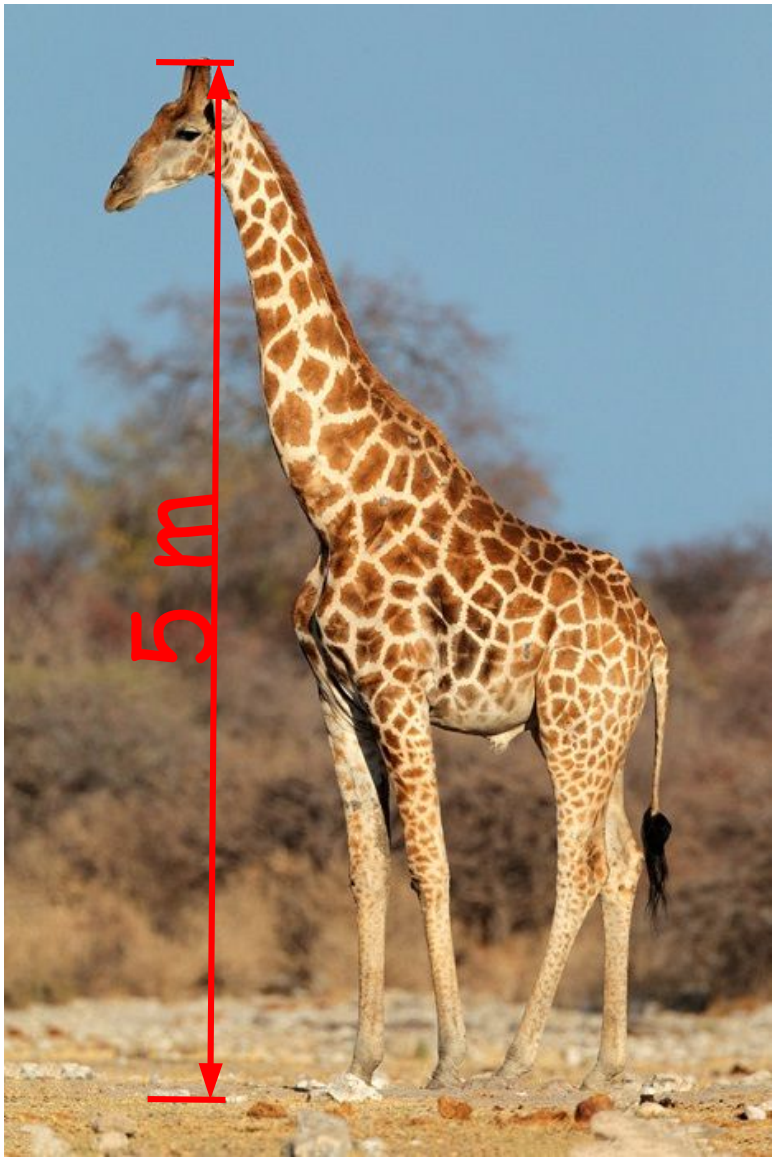


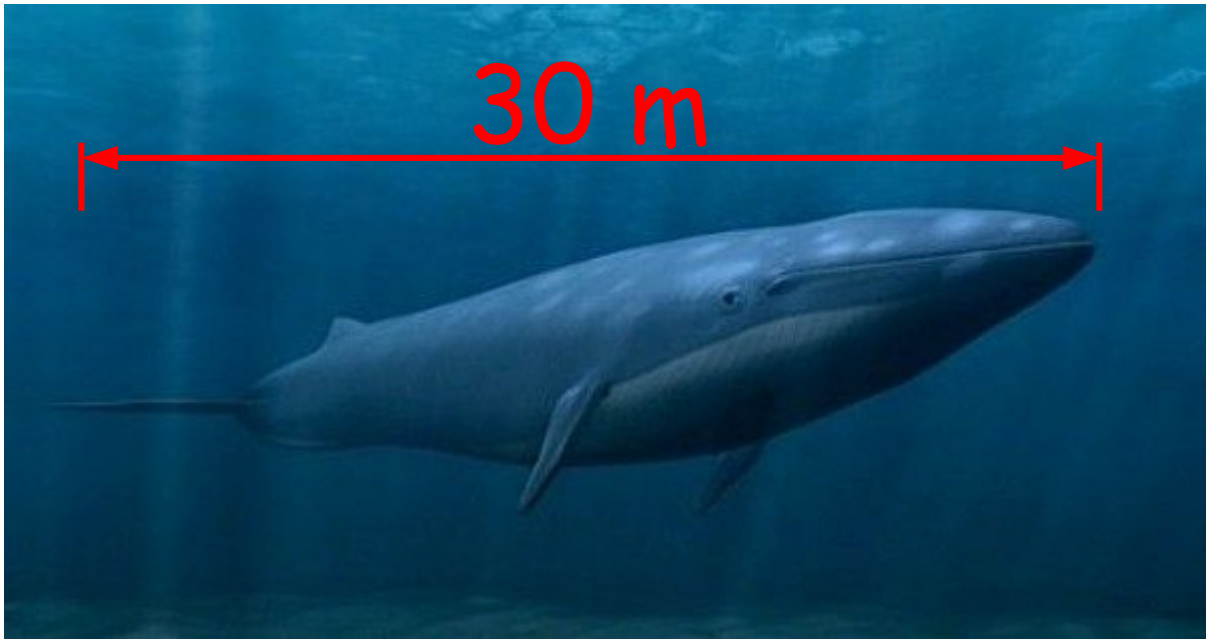


- Other reflexes are also produced by direct activation of specific motor neurons

http://georgi-georgiev.com/demo/websites/nervous-system/img/Reflex.gif
http://e08595.medialib.glogster.com/rachelrainsforyou/media/2b/2b9f020b0e019620e3cb693f24336793e136b995/reflex-arc.jpg

In a giraffe or a whale, how long would it take?!

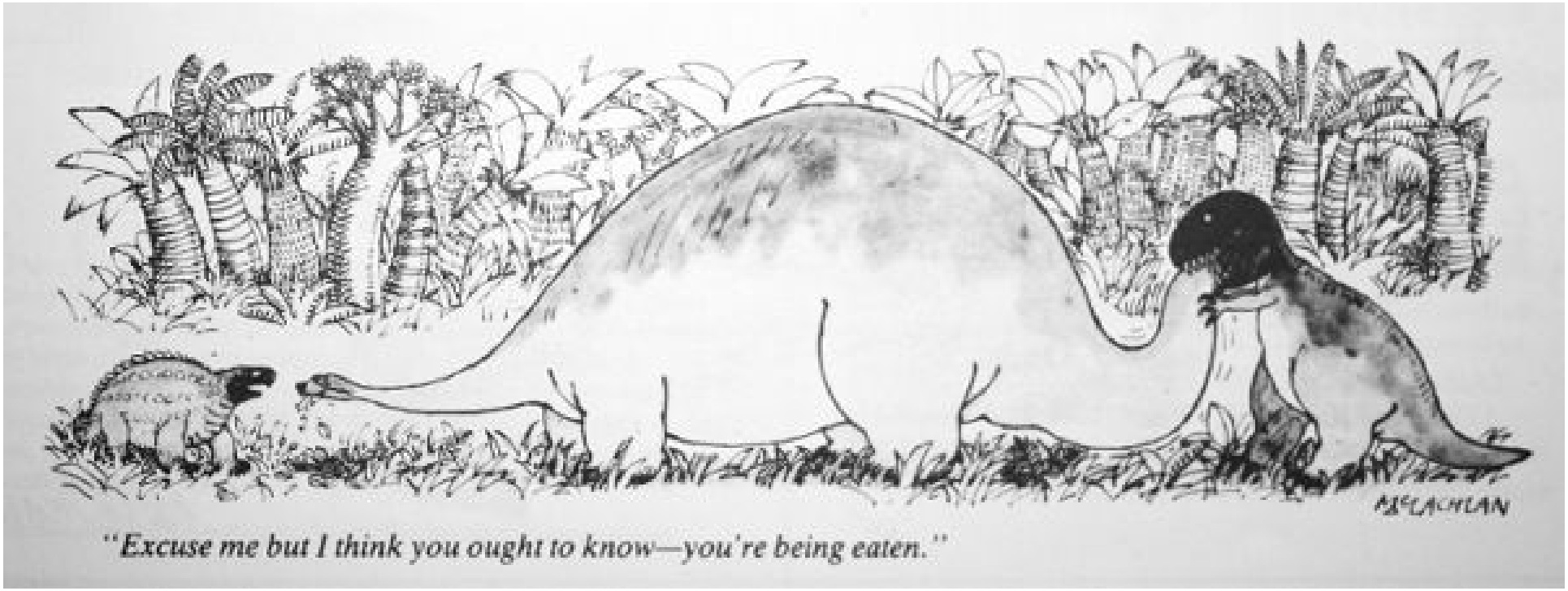




http://guardianlv.com/2014/06/endangered-species-blue-whales-are-the-largest-mammals-that-ever-lived/

http://www.livescience.com/27336-giraffes.html

And what about dinosaurs?



https://svpow.files.wordpress.com/2013/01/being-eaten-600.jpg

So now, how are movements produced?

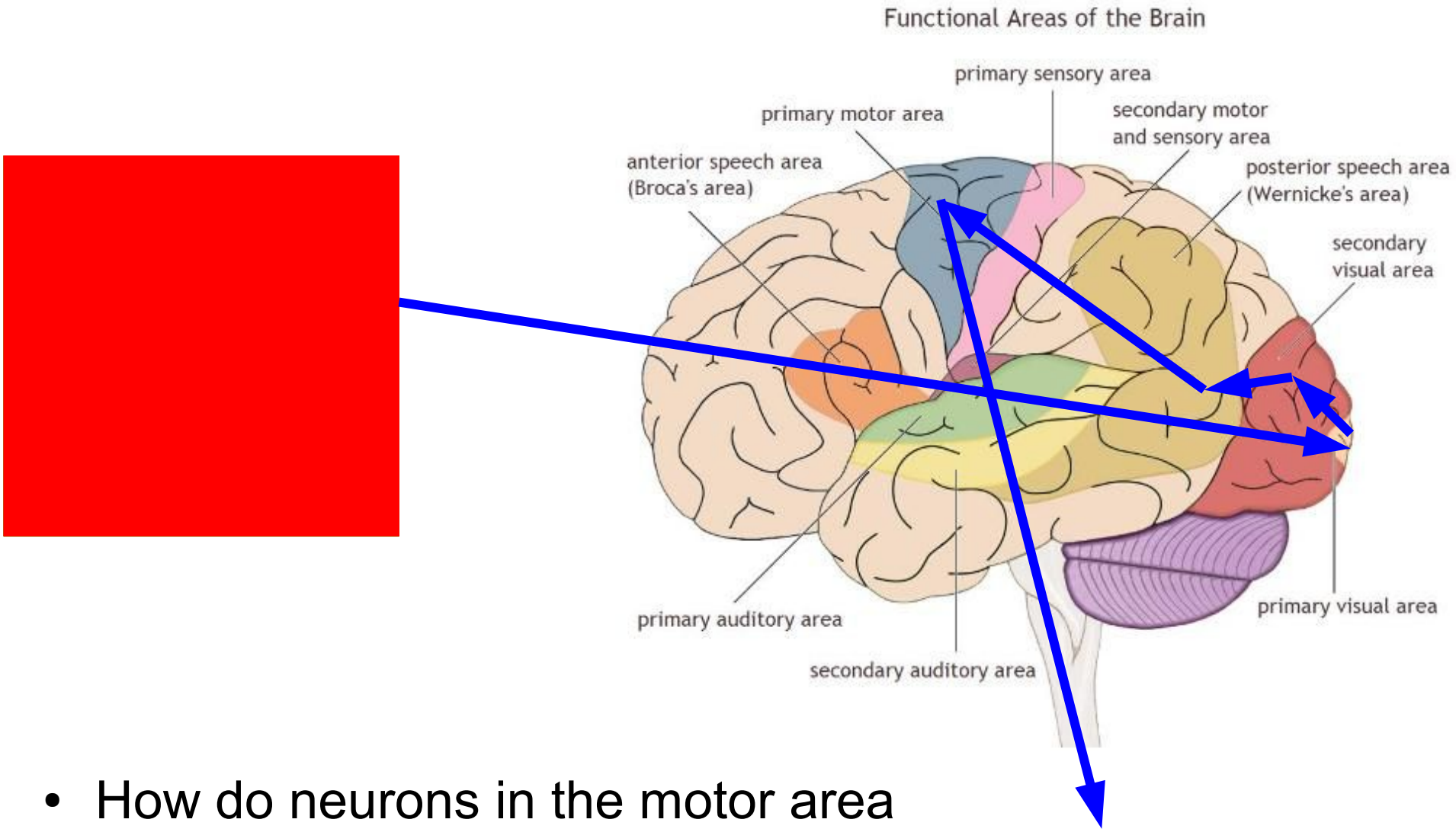
- What are the different types of movements?
  - Reflex actions – very basic movements
  - Voluntary actions
  - Movement sequences

How fast are our voluntary movements?

- Reaction time
  - http://www.humanbenchmark.com/tests/reactiontime

What happens during voluntary movements?

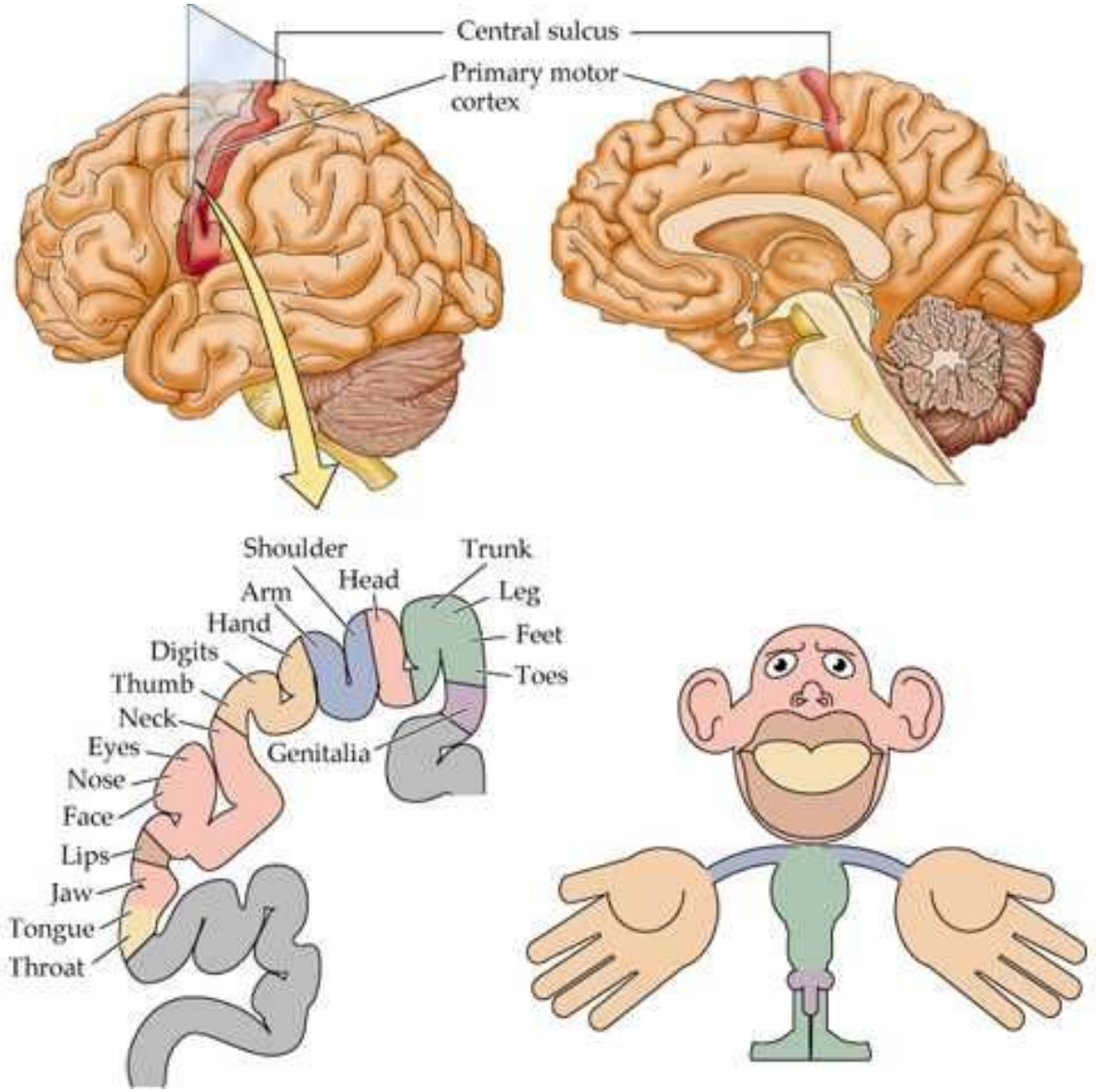
What happens during voluntary movements?



- How do neurons in the motor area control different body parts?

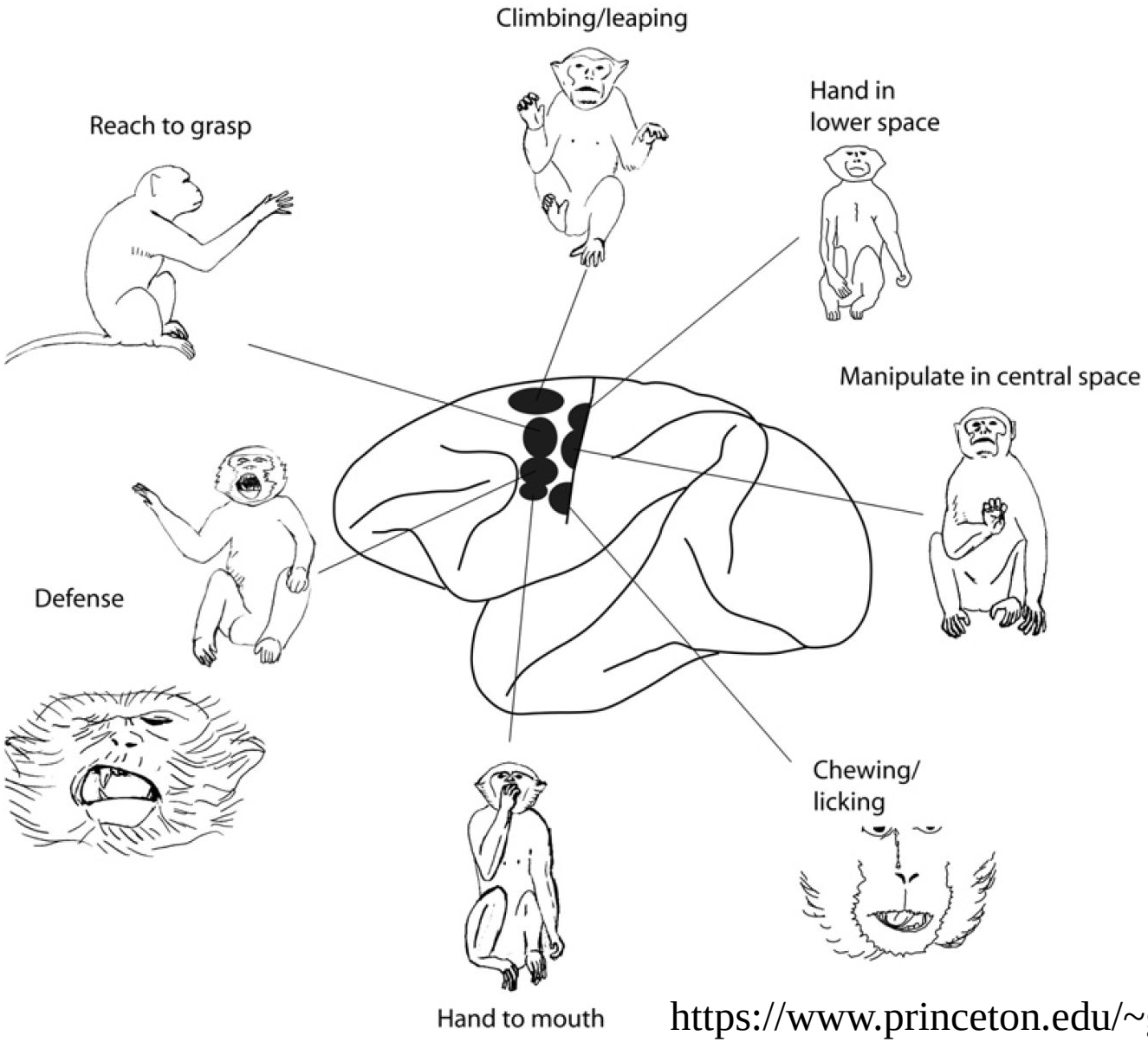
http://my-ms.org/images/brain_functional_areas_600px.jpg

Neurons in different parts of the motor area of the brain control movement of different body parts



http://www.utdallas.edu/~tres/integ/mot2/2_08.jpg

Current view – neurons in different parts of motor cortex control different behaviorally relevant movements

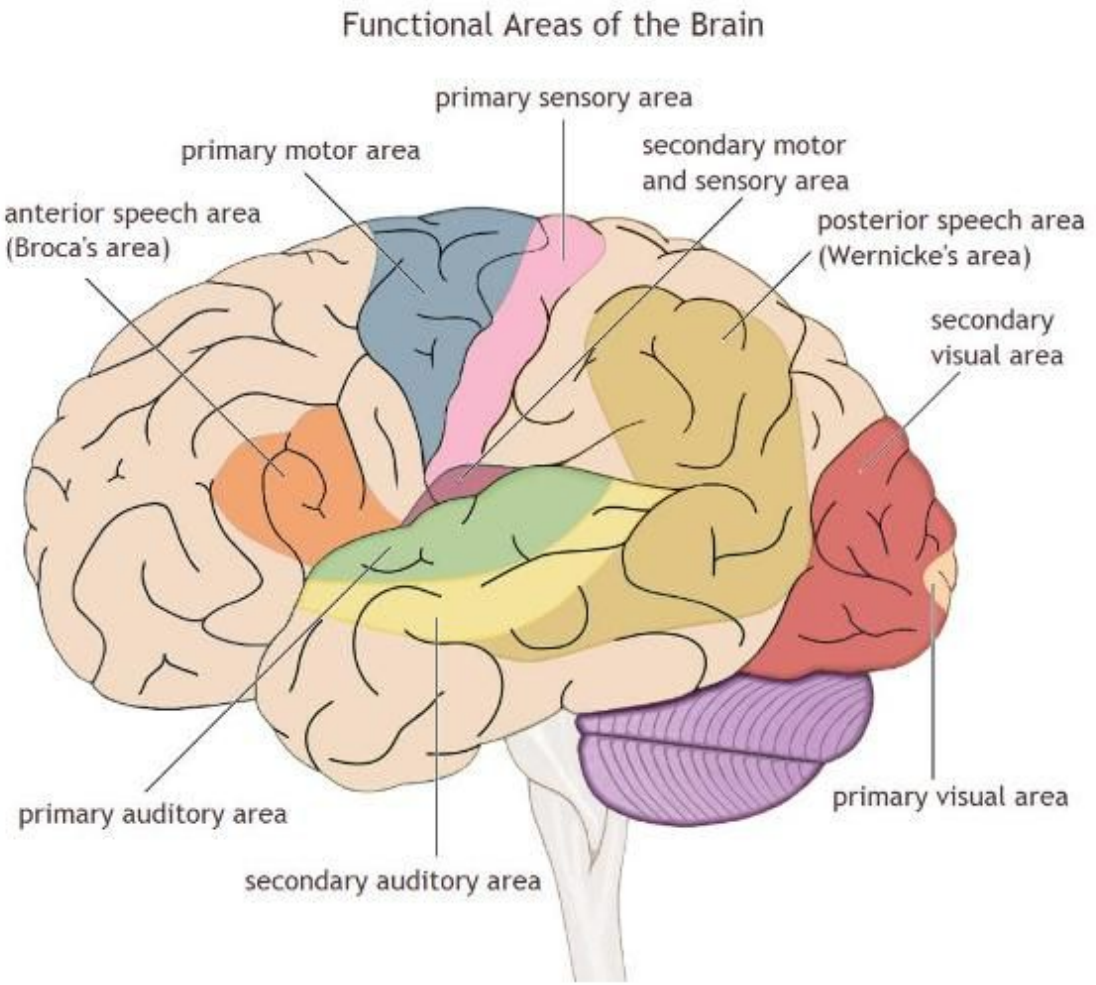


- So then to produce a movement or movement sequence, CORRECT set of neurons need to be activated

https://www.princeton.edu/~graziano/neuron_07.pdf

Why so many other motor areas?

- Not fully understood
- Maybe for planning movements
- Or for executing movement sequences



http://my-ms.org/images/brain_functional_areas_600px.jpg

Men ought to know that from the brain, and from the brain only, arise our pleasures, joys, laughter and jests, as well as our sorrows, pains, griefs and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant

Hippocrates 460-370 BC (2400 years ago!)

Music of the brain – Action Potentials

How I became a scientist

Completed school with Maths, Physics, Chemistry, Biology – 1995

Did my Bachelors in Mechanical Engineering – finished in 1999

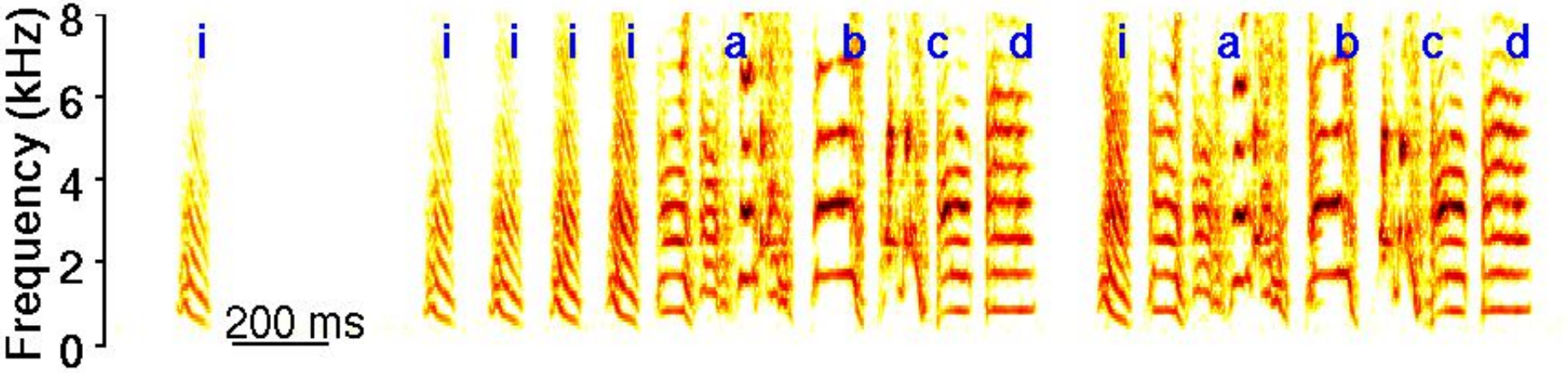
Did my PhD from National Centre for Biological Sciences, Bangalore (TIFR) – 1999-2006

Postdoctoral studies on songbirds at University of California at San Francisco (UCSF) – 2006 – 2012

Joined IISER Pune in 2013

My lab at IISER Pune

Our model system is the zebra finch, a songbird



We are interested in understanding how movements are initiated in the brain?

What happens in the bird-brain to make him sing?

Science/Research as a career – early stages

- IISERs – Integrated BS/MS immediately after school

http://www.iiseradmission.in/


- Fellowships available – KVPY, DST-INSPIRE
- http://kvpy.iisc.ernet.in/main/index.htm

  http://www.inspire-dst.gov.in/

Science/Research as a career – later stages

- MSc by research
  - TIFR, Mumbai
- Integrated MSc/Ph.D program (after BSc)
  - NCBS, Bangalore
  - IISERs
  - IISc, Bangalore
- PhD program (after BTech/MTech/MSc)
  - All research institutes

“The most important thing is to not stop questioning. Curiosity has its own reason for existence. One cannot help but be in awe when he contemplates the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if one tries merely to comprehend a little of this mystery each day.

- Albert Einstein