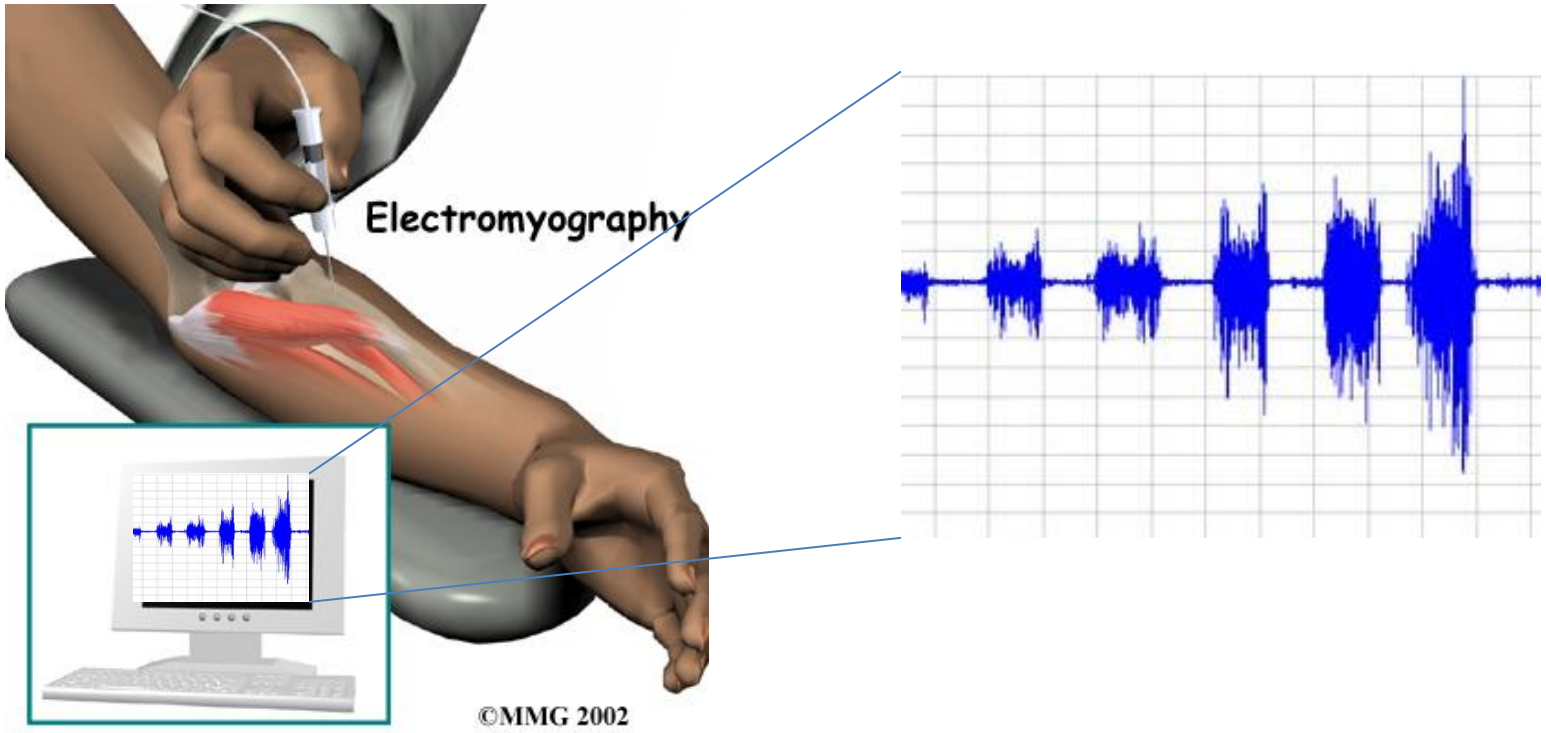
Introduction to Electromyography (EMG)



Hands-On Research School
Shanghai Jiao Tong University
Daniel Goldman, Sarah Sharpe, Nick Gravish

Muscles:

Motors of the human body

Act to generate force and produce movement

3 Types of Muscle

(1)Skeletal ⟶ Only skeletal can be controlled voluntarily

(2)Cardiac

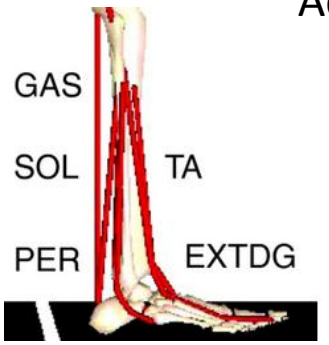
(3)Smooth

Two broad types of voluntary muscle fibers

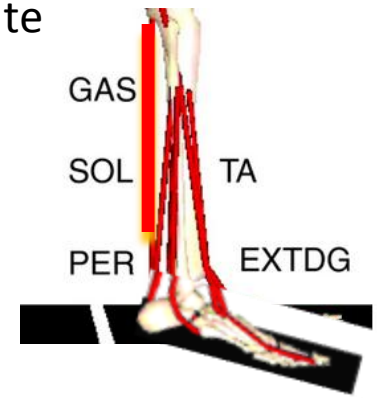
(1) Slow twitch: *contract for long periods of time but with little force*

(2) Fast twitch*: contract quickly and powerfully but fatigue very rapidly*

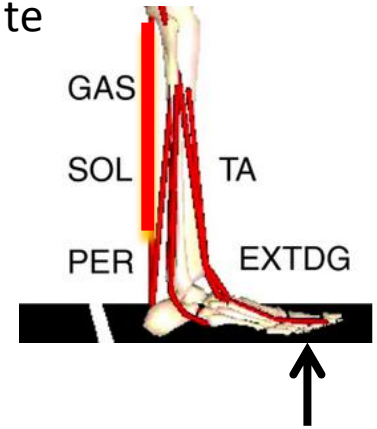
Muscle: Produce or resist motion



Activate

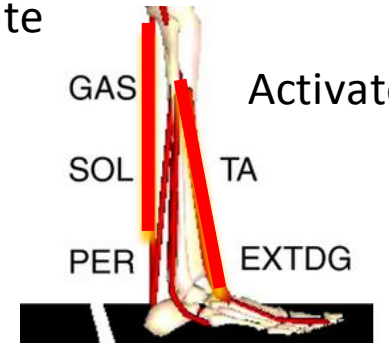


Activate



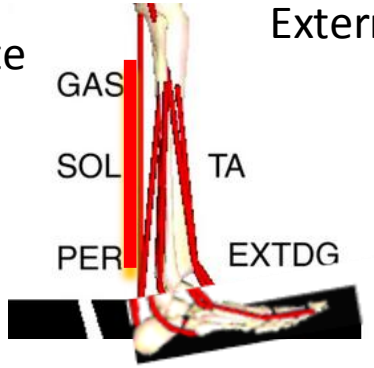
External Force

Activate



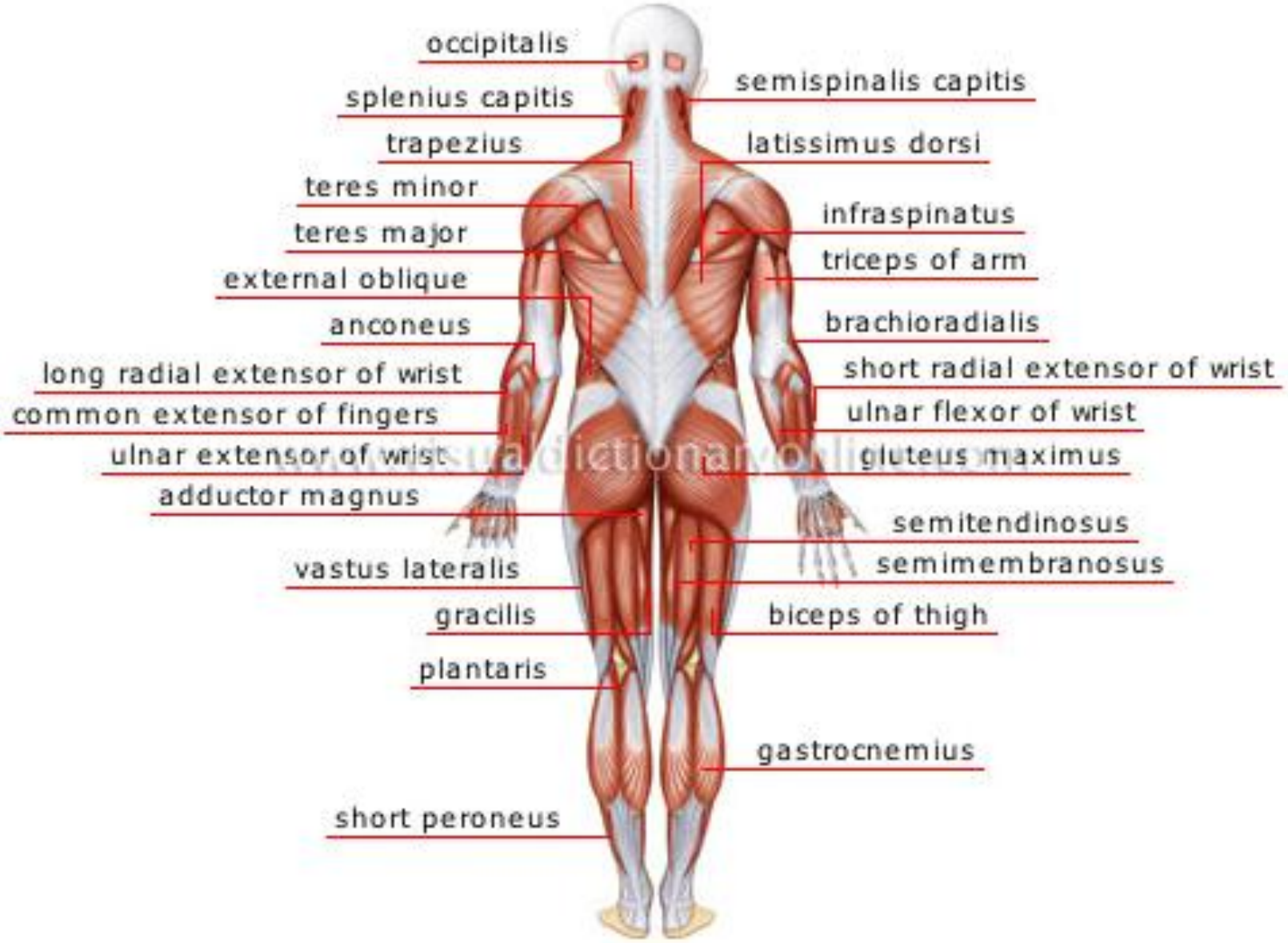
Activate

Activate

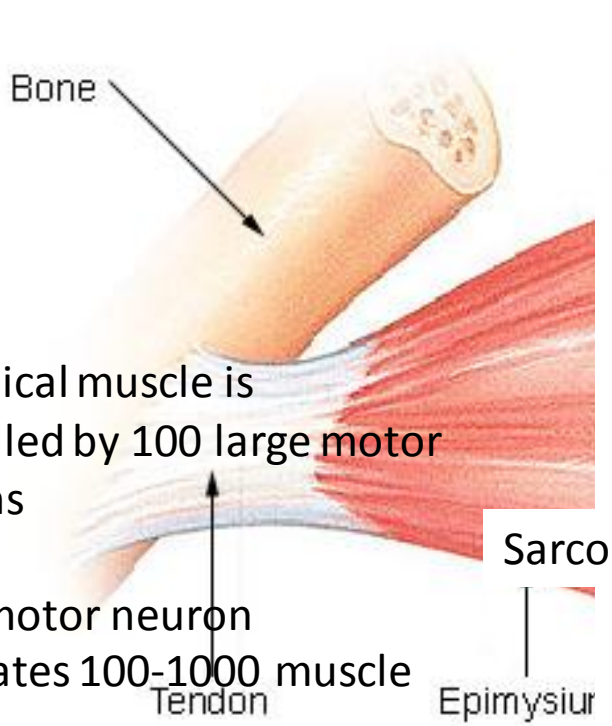


External Force (>)


frontalis
orbicularis of eye
masseter
sternocleidomastoid
trapezius
deltoid
pectoralis major
biceps of arm
external oblique
brachialis
rectus abdominis
pronator teres
brachioradialis
long palmaris
tensor of fascia lata
ulnar flexor of wrist
adductor longus
short palmaris
sartorius
vastus lateralis
rectus femoris
vastus medialis
peroneus longus
gastrocnemius
anterior tibialis
soleus
extensor digitorum longus
extensor digitorum brevis
plantar interosseous


occipitalis
splenius capitis
trapezius
teres minor
teres major
external oblique
anconeus
long radial extensor of wrist
common extensor of fingers
ulnar extensor of wrist
adductor magnus
vastus lateralis
gracilis
plantaris
short peroneus
semispinalis capitis
latissimus dorsi
infraspinatus
triceps of arm
brachioradialis
short radial extensor of wrist
ulnar flexor of wrist
gluteus maximus
semitendinosus
semimembranosus
biceps of thigh
gastrocnemius

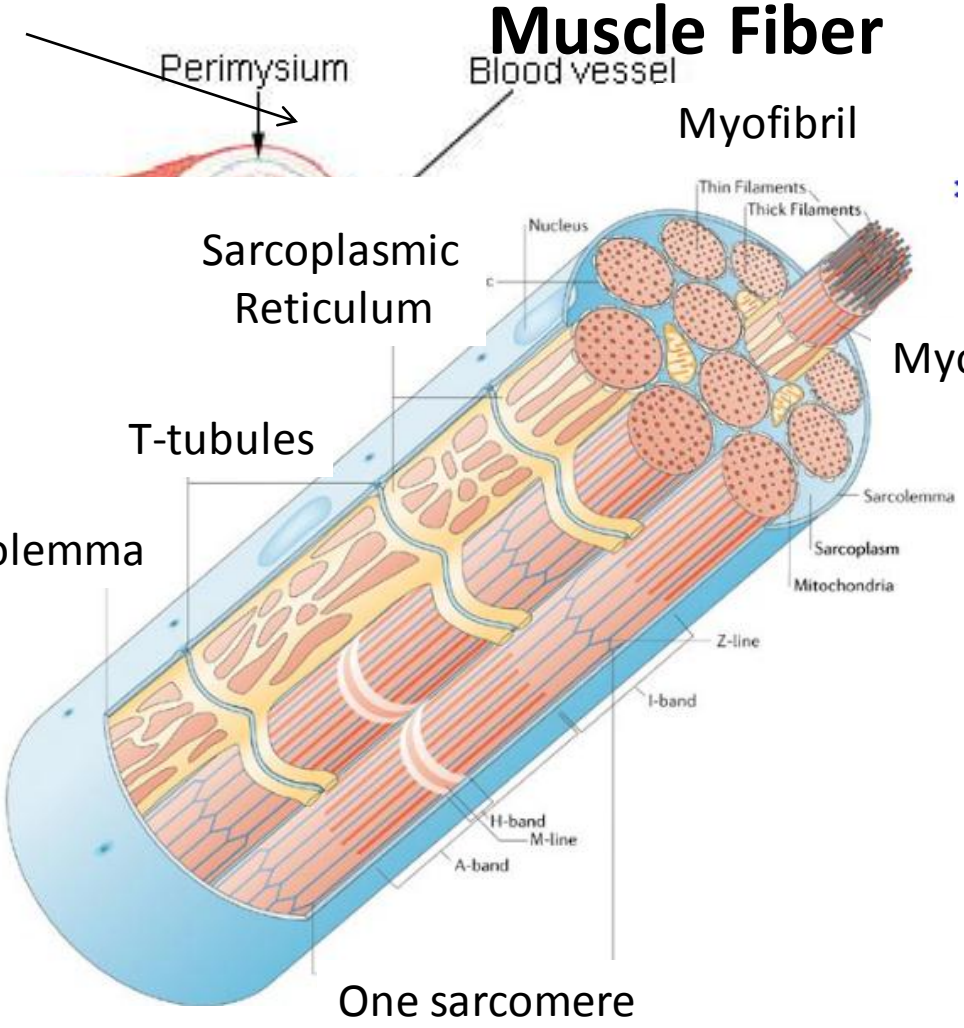
Detailed structure of skeletal muscle



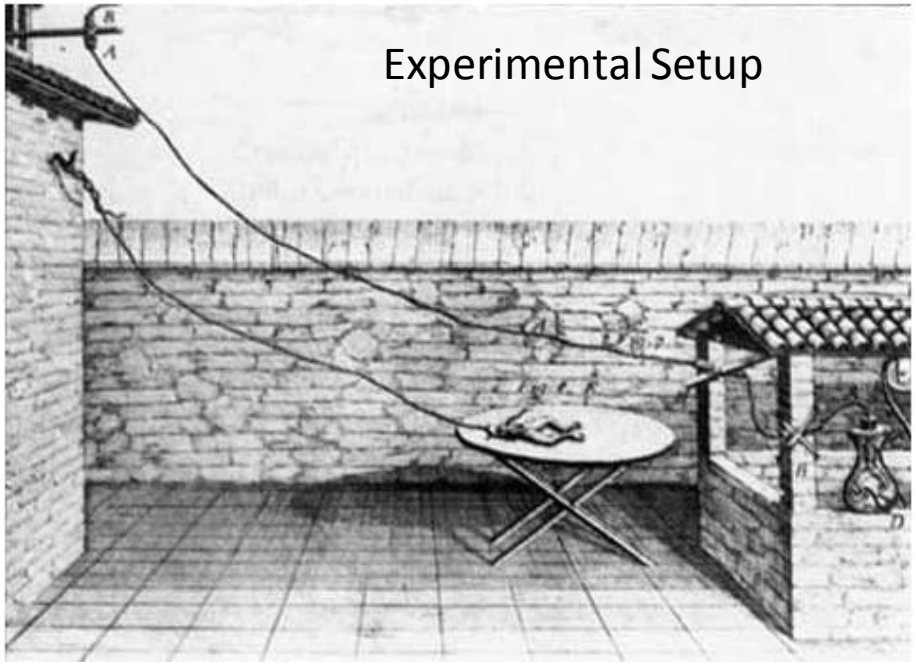
- A typical muscle is controlled by 100 large motor neurons

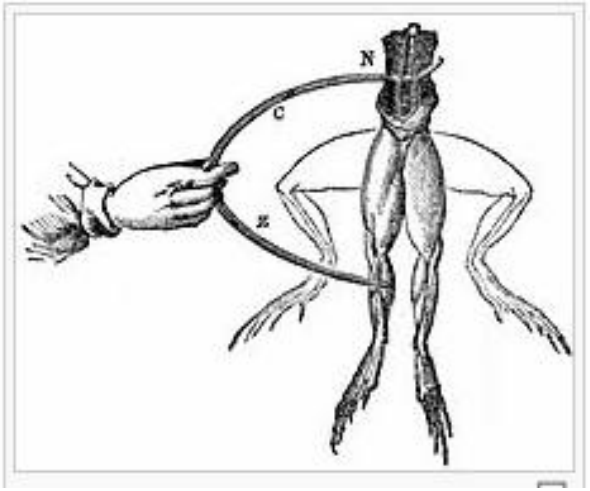
-Each motor neuron innervates 100-1000 muscle fibers

-A ***motor unit*** consists of a motor neuron and all muscle fibers it innervates



The beginning of electromyography…

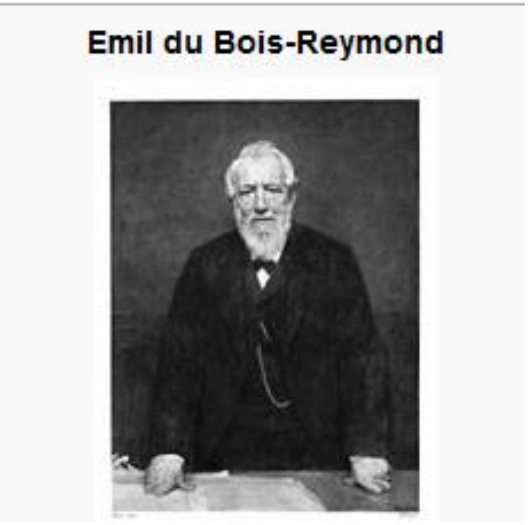




Frog Hindlimbs

In 1792, **Luigi Galvani** demonstrated that electricity could generate muscle contractions

"Bioelectricity"

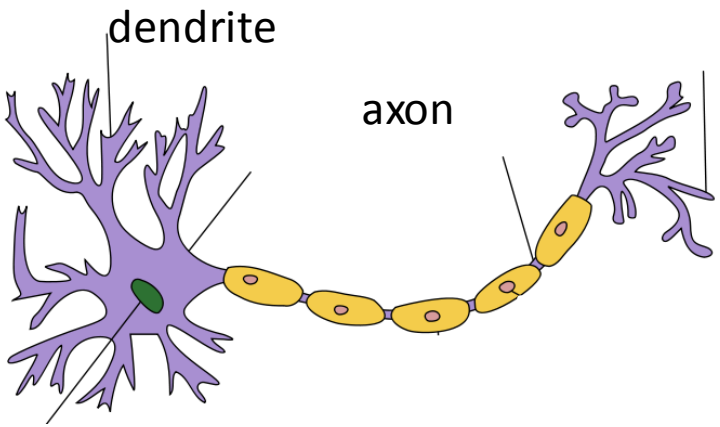


In 1849, **Emil du Bois-Reymond** found that electric potential also be recorded

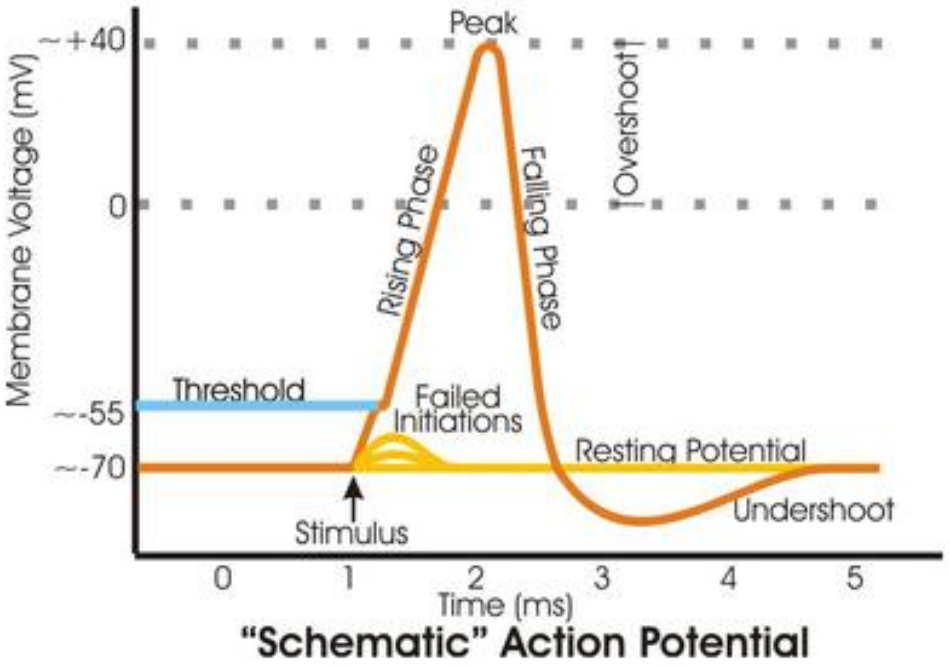
First actual EMG recording occurred in 1890 **by Étienne-Jules Marey**.

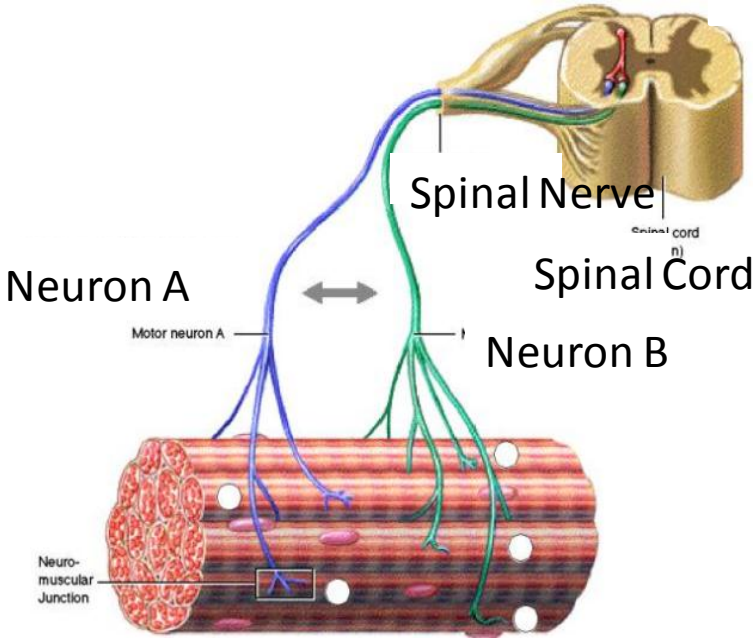
Muscle Activation

Neuron



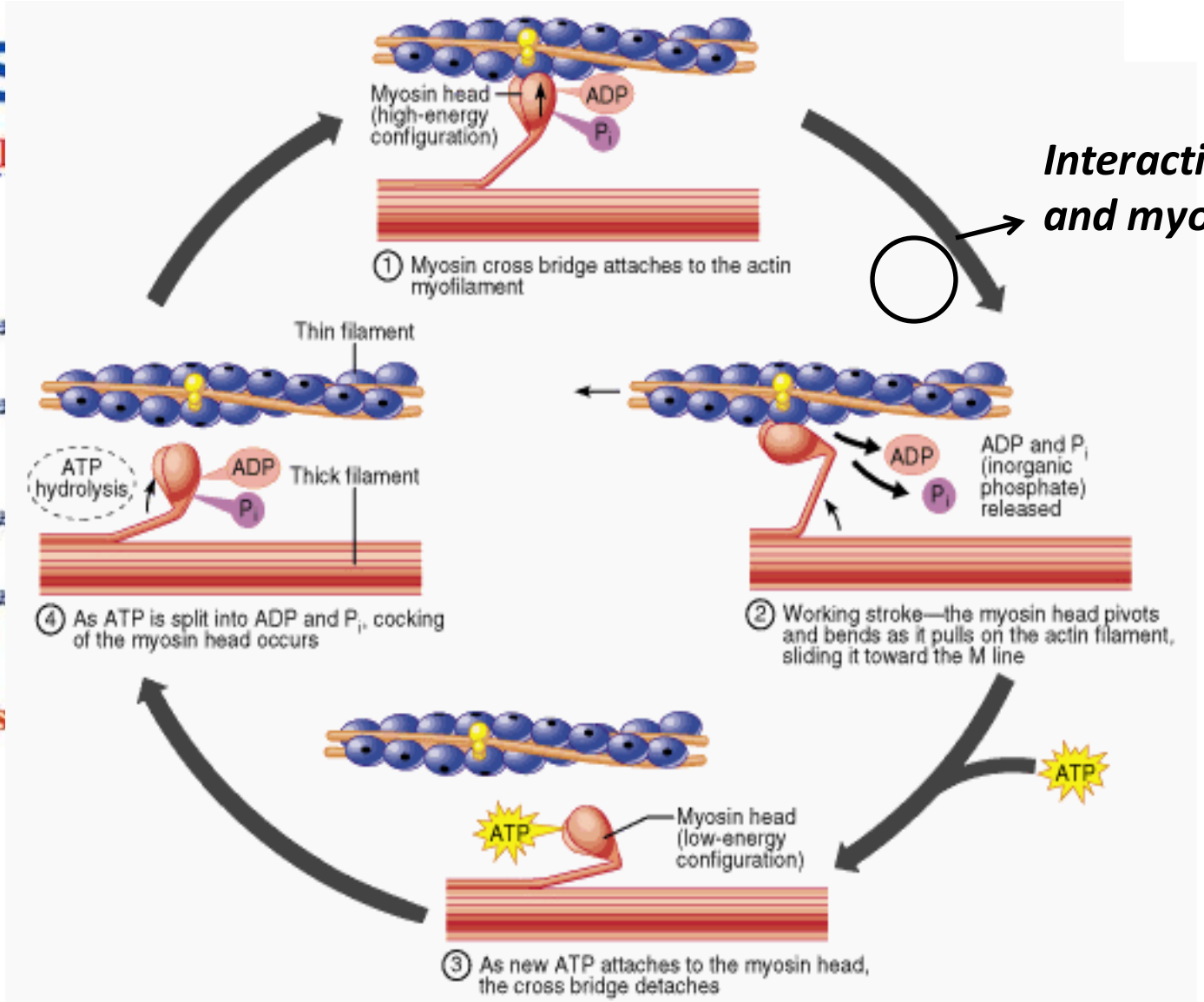
Action potentials *are the main form of communication by the nervous system*





Neuromuscular Junction

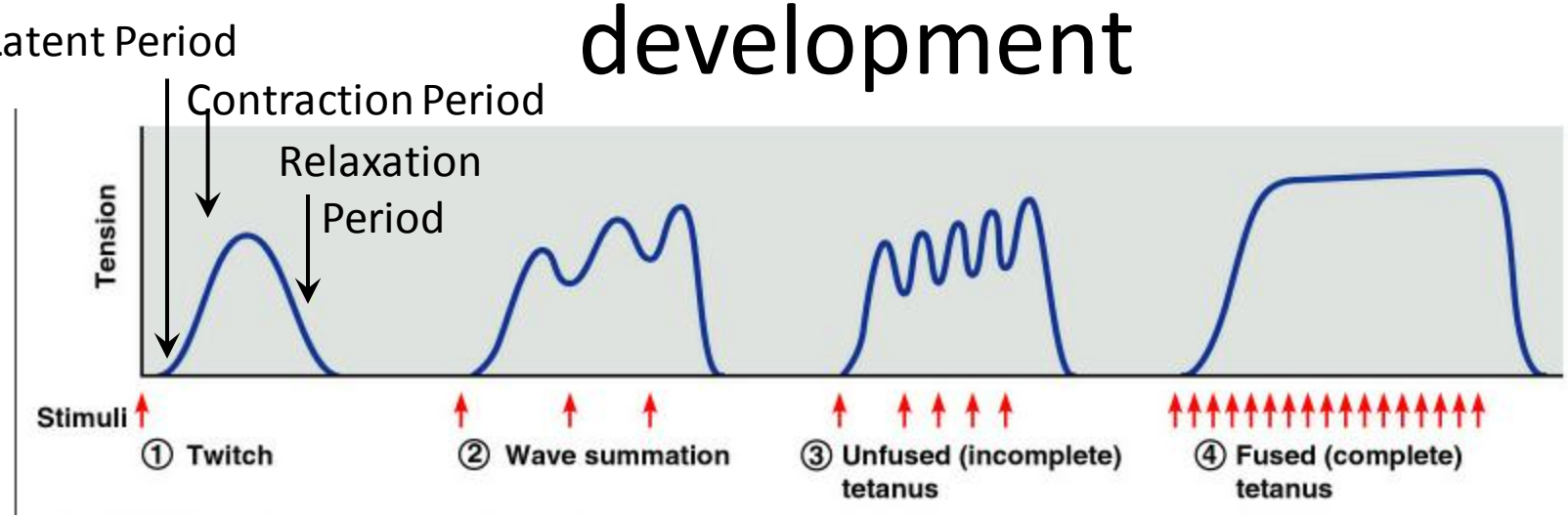
Contractile Unit in Muscle



Interaction of actin and myosin heads

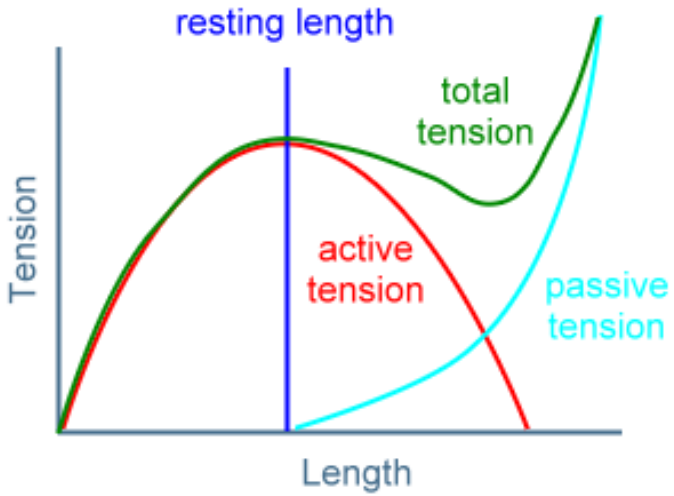
The process of attachment, rotation and detachment therefore continues as long as Ca^{2+} and ATP are present in the cell in sufficient amounts.

Action potential and force development

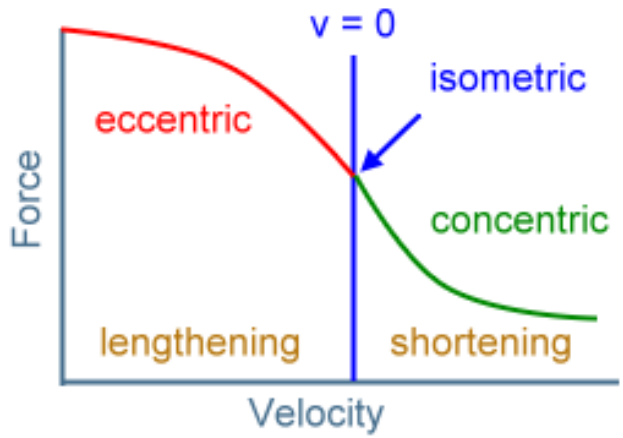


- Latent period lasts about 2 msec (milliseconds) and is the time between stimulation of muscle cells and force generation.
- Contraction period lasts about 10 –100 msec and is the period during which force is increasing.
- Relaxation period, which lasts 10 –100 msec, is the period when force is decreasing.

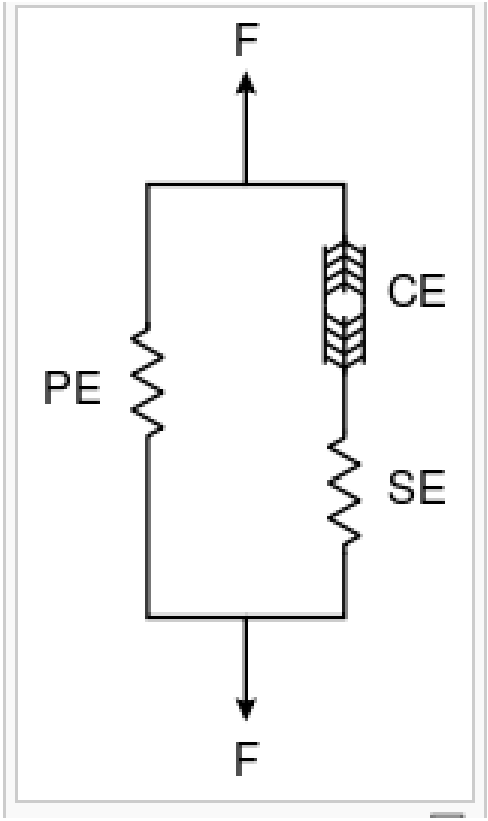
Hill Muscle Model



Length-Tension Curve of a Muscle



Force-Velocity Curve of a Muscle



Hill, A.V. *Proc. Lond. B,* (1938)

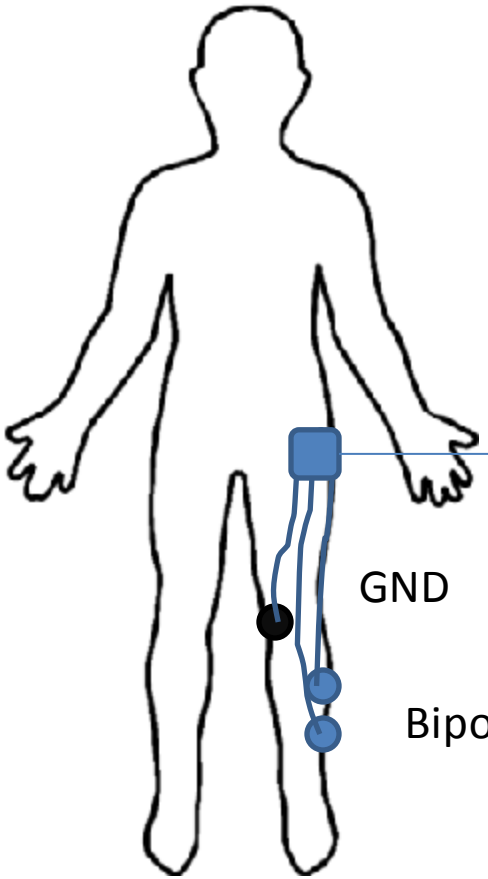
Tension developed in muscle not only depends on activation level, but also on muscle length, velocity and history.

Human Electromyography

Surface Electrodes:
Non-invasive method to measure from large superficial musculature

Use EMG as a measure of neural activation during locomotion

Experimental Setup

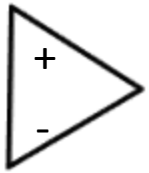


GND

Bipolar Electrodes

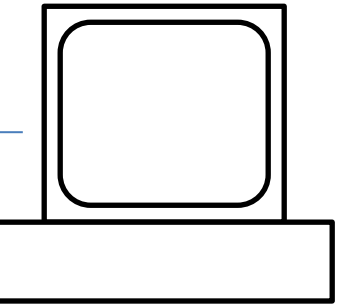
EMG Signal

Amplifier Circuit
x1000



DAQ Board

Computer



High Pass Filter between 2- 10 Hz to remove movement artifact

Part	Quantity	Cost	Notes
Battery (9V)	2	$3.00	
Instrumentation Amplifier (INA 128)	1	$3.00	
Surface Electrodes	50	$16.00	
Connector Cables	1 set	$45.00	
USB Cord (15’)	1	$15.00	
DAQ Board (NI DAQ- USB 6009)	1	$279	**optional, data can be recorded using computer sound card
Miscellaneous (Jumper cables, bread board, solder, etc.)	1	$20	
Computer	1		
Total		$381.00	Note: if we use sound card then price could be as low as $100.00

Speed affects muscle activity amplitude and timing

A. R. den Otter, A.C. H. Geurts, T. Mulder, J. Duysens. **Speed related changes in muscle activity from normal to very slow walking speeds.** *Gait and Posture.* (2003)

"The main role of the muscles in the regulation of walking speed is to control the accelerating and decelerating forces of individual body segments to establish safe forward progression . As a result, the amplitude of muscle activity increases with walking speed because of the need for larger muscular force output."

M. P. Murray, L. A. Mollinger, G. M. Gardner, S. B. Sepic. **Kinematic and EMG patterns during slow, free, and fast walking.** *J of Orthopedic Research.* (1984)

A. L. hof, H. Elzinga, W. Grimmius, J. P. K. Halbertsma**. Speed dependence of averaged EMG profiles in walking**. *Gait and Posture.* (2002)

G. Cappellini, Y. P. Ivanenko, R. E. Poppele, F. Lacquaniti. **Motor Patterns in Human Walking and Running**

Detection of muscle fatigue using EMG

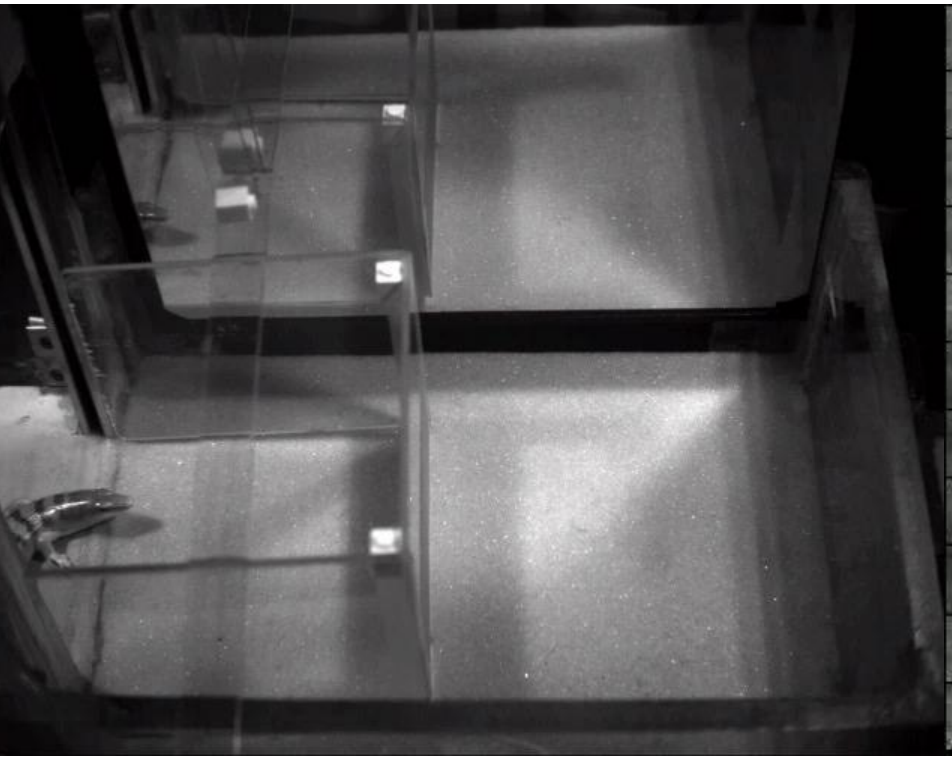
P. V. Komi and P. Tesch. **EMG frequency spectrum, muscle structure, and gatigue during dynamics contraction in man.** *Euro. J. of Applied Physiol.* (1979).

M. Cifrek, V. Medved, S. Tonkovic, S. Ostoiic**. Surface EMG based muscle fatigue evaluation in biomechanics**. *Clinical Biomechanics.* (2009)

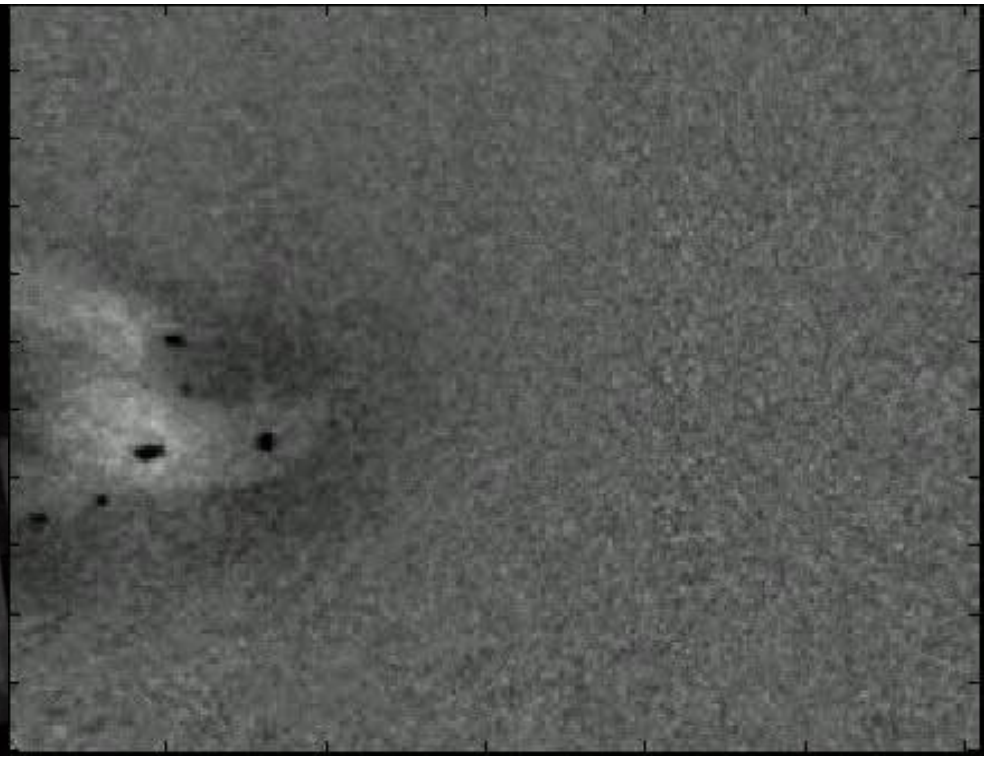
"Almost a century ago Piper, a professor of physiology at the Royal Friedrich-Wilhelms-University in Berlin, noticed a certain "slowing" of surface myoelectric signals during static contraction (Piper, 1912). In addition to this phenomenon Cobb and Forbes (1923) also noted an increase in the signal amplitude as one of the manifestations of fatigue during the static contraction. Unfortunately, due to imperfect instrumentation, these have remained only laboratory efforts of a kind. The development of electronics in the second half

Sandfish Burial

Slowed x10



1 cm



1 cm

High Speed Above Surface Video

Black Opaque Spots: Lead Markers

X-Ray Imaging

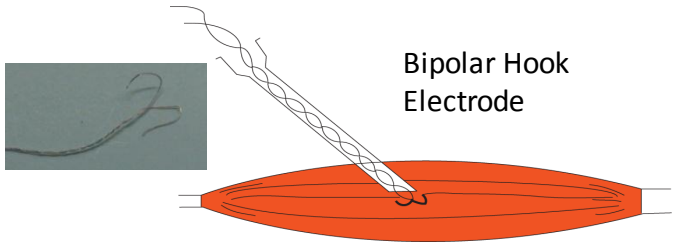
Sandfish does not actively use limbs to locomote sub-surface

Maladen, et.al., *Science*, (2009) 325, 314-318

Electromyography

Method of recording electric potentials in muscle cells caused during neurological activation

A single action potential in motor neuron can activate hundreds of muscle fibers in synchrony and resulting currents sum to generate an electrical signal that is readily detectable outside the muscle itself. Barrage of action potentials results in a complex pattern of electrical potentials (on order of 100µV in amplitude) that can be recorded as an elctromyogram (EMG).



Implantation Sites