APA 2120

Lecture 7: Nervous System – Motor Programs
Sept 27, 2012

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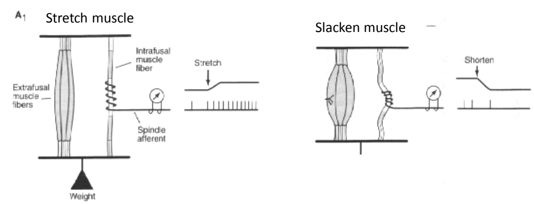
Muscle Spindles

- Basic Function
  - stretch of spindle fibers deform the sensory endings
    - increased activity of sensory neuron
  - slackening of spindle fibers
    - decreased activity of sensory neuron



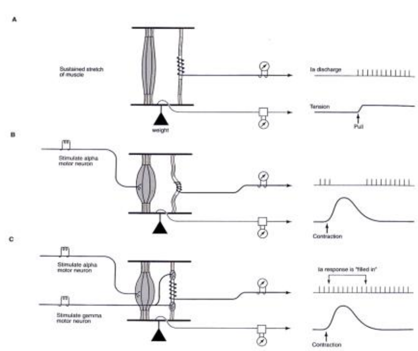
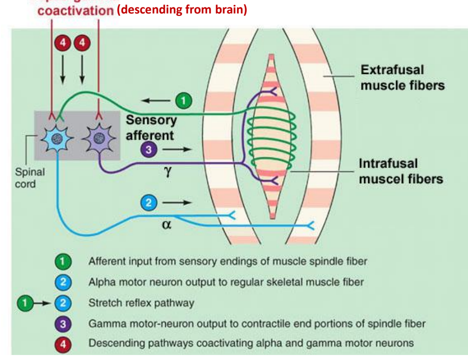
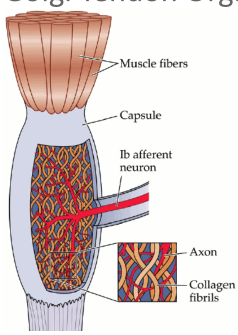


FIGURE 37–8
During active muscle contractions the ability of the spindles to sense length changes is maintained by activation of gamma motor neurons. (Adapted from Hunt and Kuffler, 1951.)
A. Sustained tension elicits steady firing of the Ia afferent.
B. A characteristic pause occurs in ongoing Ia discharge when the muscle is caused to contract by stimulation of its alpha motor neuron alone. The Ia fiber stops firing because the spindle is unloaded by the contraction.
C. If during a comparable contraction a gamma motor neuron to the spindle is also stimulated, the spindle is not unloaded during the contraction and the pause in Ia discharge is "filled in."

Alpha-gamma coactivation (descending from brain)



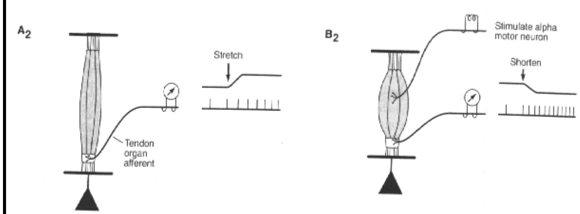
Golgi Tendon Organs (GTOs)



- Receptors found at muscle-tendon junction
- Sensitive to Active tension in muscle
- When activated, sensory neuron sends information to spinal cord to inhibit motor-neurons
  - Leads to muscle relaxation & decrease in muscle tension

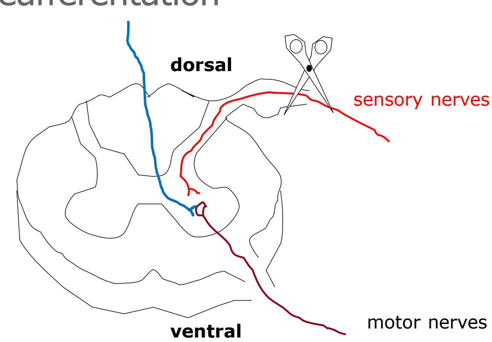
GTOs

- Basic Function
  - Active tension on the tendon organ deforms capsule and sensory nerve endings → increased activity of sensory neuron



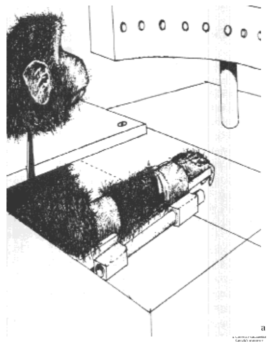
What happens if you lose proprioception?

Deafferentation



Deafferentation Studies in Monkeys

- After deafferentation, monkeys were still able to make limb positioning movements but movements were not as accurate
- Proprioceptive feedback is not essential for movement but is important for precise guidance of movement



GL – deafferented patient

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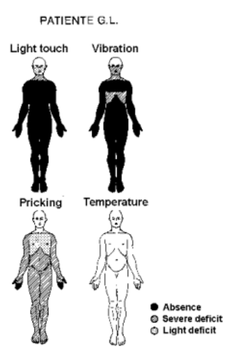

The patient GL, was 27 years old when suffering in 1975 from a first episode of acute polyneuropathy with a complete paralysis including the respiratory muscles.

A second episode of extensive sensory polyneuropathy occurred suddenly four years later (April 1979) which **selectively affected the large sensory fibers**;

A severe sensory impairment affecting her whole body below the nose has remained totally unchanged over the years.

Clinically she has a total loss of touch, vibration, pressure and kinesthetic senses and *no tendon reflexes* in the four limbs; the trunk is more moderately affected.

Jacques Paillard

Deafferentation Studies in Human

- Movements could be produced but were impaired when vision was removed

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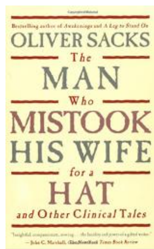
The Man who Mistook His Wife for a Hat

-Oliver Sacks

- Ch. 3 – The Disembodied Lady



Tendon Vibration

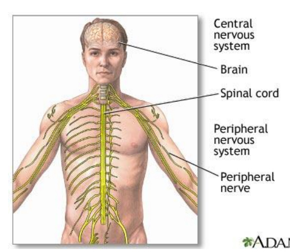
- http://www.youtube.com/watch?v=NtKWCfWzmtc

So what happens to the Sensory information?

Nervous System Organization

The human nervous system is divided into **2** major sections:

1. **Central Nervous System (CNS)**
   Includes Brain and Spinal cord
2. Peripheral Nervous System (PNS)
   - Afferent nerves = sensory nerves
     - - convey information/stimuli from body's receptors to higher level of information processing in brain and spinal cord
   - Efferent nerves = motor nerves
     - - convey information from brain and spinal cord to effectors such as muscles and glands



The Nervous System

- Peripheral Nervous System (PNS)
  - Afferent (sensory)
  - Efferent (motor)
    - Somatic (controlled)
    - Autonomic (involuntary)
      - Sympathetic (excite)
      - Parasympathetic (inhibit)
- Central Nervous System (CNS)
  - Brain
  - Spinal Cord

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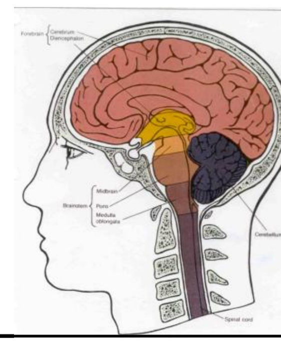
Central Nervous System (CNS) – Brain

3 major sections

1. Brainstem – lower level of control
   - contains medulla oblongata, pons, midbrain & reticular formation
2. Cerebellum = “little brain”
3. Forebrain – higher level of control
   - contains cerebrum & diencephalon



Nervous System Overview

The Nervous System

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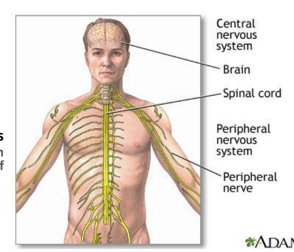

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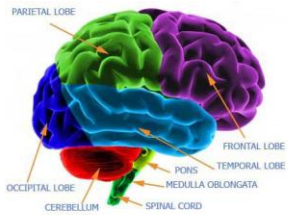
Cortex

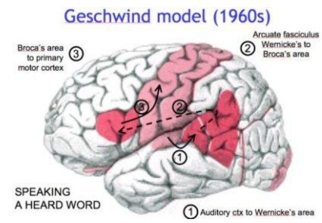
- On the outside ~2mm of the cerebrum is the "grey matter" = cerebral cortex
- Folded surface that increases the surface area of the brain

- Temporal lobe - Sensory area for Auditory & Olfactory input
    - Primary Auditory Cortex
- Occipital Lobe – Sensory area for Visual Input
    - Primary Visual Cortex
- Parietal lobe - Somatosensory information involving temperature, pressure, touch, pain
    - Primary Somatosensory cortex



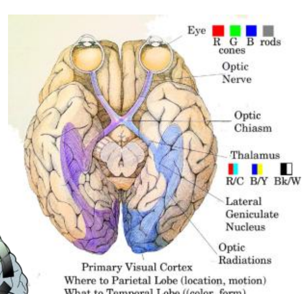
Primary Auditory Cortex

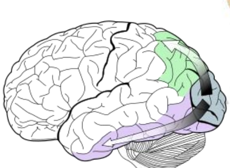
- Temporal lobe - Sensory area for Auditory & Olfactory input
    - Primary Auditory Cortex



Primary Visual Cortex

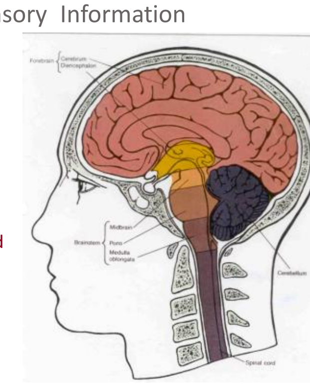
- Occipital lobe - sensory area for <u>visual input</u>
    - Primary Visual Cortex





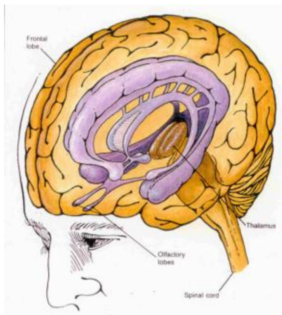
Ascending Somatosensory Information

- Input from afferent sources travels via afferent (sensory) neurons in to dorsal horns of spinal cord
    - Travels up ascending pathways of spinal cord
    - Travels through brainstem to the thalamus



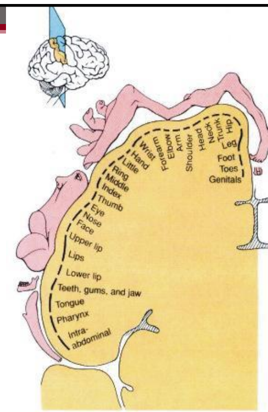
Ascending Somatosensory Information

- The thalamus is in the diencephalon area of the forebrain
  - It is "Grand Central Station" ; the sensory relay center that directs afferent information to the appropriate lobe of the cerebrum



Primary Somatosensory cortex

- Sensory cortex - area where sensory information is received
- Somatotopically Organized



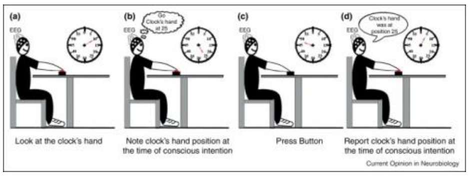
(a) Somatosensory cortex in right cerebral hemisphere

Sensory Homunculus

Response intention

- Frontal lobe of cerebrum forms ***intention to act***
  - Systems involved in learning, memory, and emotional behaviour (moods, pleasure, pain), etc., can all affect actions
- Where does this intention come from? (philosophically speaking)

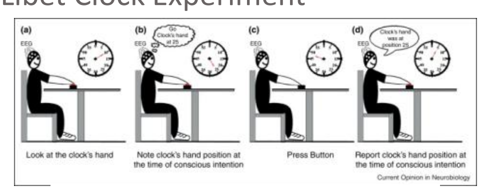
Libet Clock Experiment

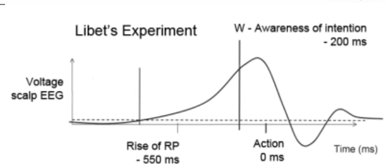


Libet Clock Experiment

- http://www.youtube.com/watch?v=IQ4nwTTmcgs

Libet Clock Experiment





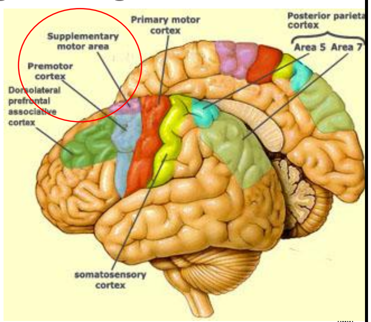
Response Programming / Execution

- Motor functions are initially organized in pre-motor areas and then the primary motor cortex
- Other areas (Basal ganglia and Cerebellum) add movement parameters to specify movement
  - i.e. amount of total force, time, muscles used, etc.

Response Programming

Premotor Areas
"staging" area where motor functions are organized

Premotor Cortex
Cingulate Motor Area
Supplementary Motor Area



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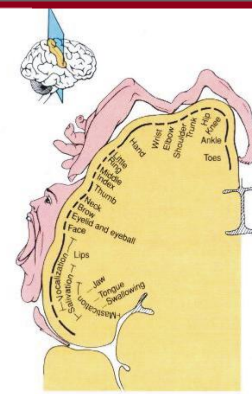
Cerebral Cortex Motor Areas

- Primary motor cortex
  - Final Organization and execution of skilled actions
  - Somatotopically organized



(b) Motor cortex in right cerebral hemisphere

Sensory Homunculus

Motor Homunculus

Response Programming / Execution

- Motor functions are initially organized in pre-motor areas and then the primary motor cortex
- Other areas (Basal ganglia and Cerebellum) add movement parameters to specify movement
  - i.e. amount of total force, time, muscles used, etc.
- Program of commands sent out as a "package"?
  - Sent down descending tracts through brainstem & spinal cord
    - Cortico-spinal / pyramidal tracts for voluntary actions

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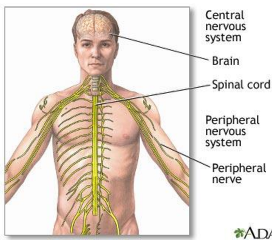
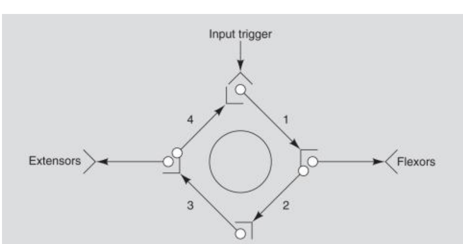
Output

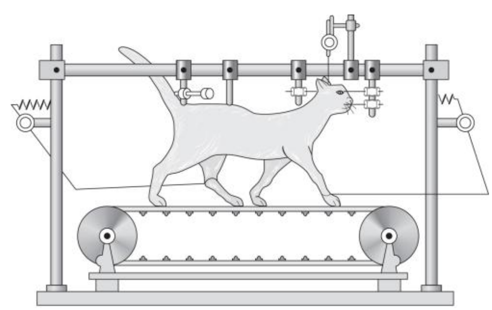
- Travels via efferent (motor) neurons in muscles to produce movement/action
  - Via descending corticospinal tracts



Open Loop Control / Motor Programs

Low level control: Central Pattern Generator





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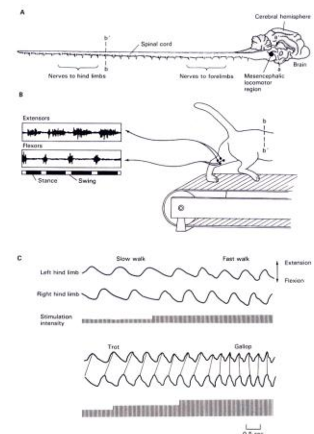
Central Pattern Generators

- Examination of gait patterns in cats has found evidence of central pattern generators
  - If the spinal cord is severed below the brain, it can still send rhythmic signals to the efferent nerves, without feedback from the limbs
  - Rhythms are sent alternately to limb flexors & extensors to produce locomotion
  - These circuits in the spinal cord that are capable of producing oscillations are called central pattern generators



Human CPG?

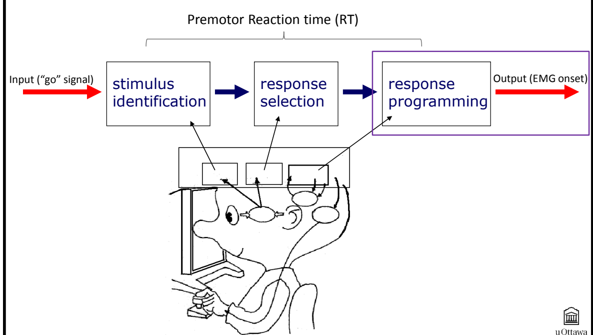
- Although this research is done on animals, it is expected that we have central pattern generators as well

http://www.youtube.com/watch?v=zdBH_JBECP0

Other Human Skills

- Although this research is done on animals, it is expected that we have central pattern generators as well
  - These are hard wired "programs" to perform a particular skill – but what about learned skills?
- One line of thinking is that we can control actions via **motor programs** that are created and executed by our central nervous system

3-stage model



Baseball Video

- http://www.youtube.com/watch?v=FrZVRuK77EE#t=3m44s

Central (as opposed to peripheral) Control

- What is a Motor Program?
  - a *pre-structured* set of neural commands, *organized in advance*, that allow the entire movement sequence to be carried out.
    - (Keele, 1968)
  - Produces movement with a minimal role for sensory information
  - Movement is carried out essentially *open-loop* until enough time has passed to allow feedback processes to operate

Do Motor Programs Exist?

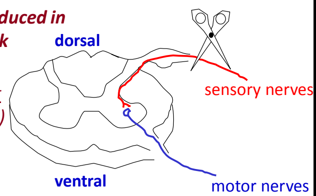
- What is the rationale for a motor program?
- Or what observations support the concept of a motor program and its features?
- **IRA#3:** Current Status of the Motor Program

Do Motor Programs Exist?

Support for existence of Motor Programs:

1. ***Movements can be produced in the absence of feedback***

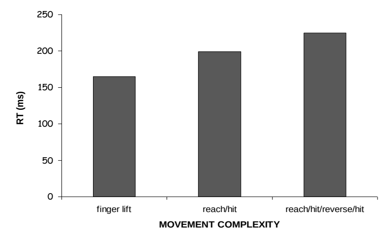
e.g. Deafferentation or Fast Movements (Boxing jab)



Do Motor Programs Exist?

Support for Motor Programs:

2. ***Reaction time increases with the complexity of movements***



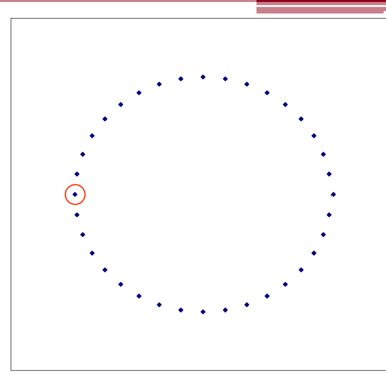
Henry & Rogers, 1960

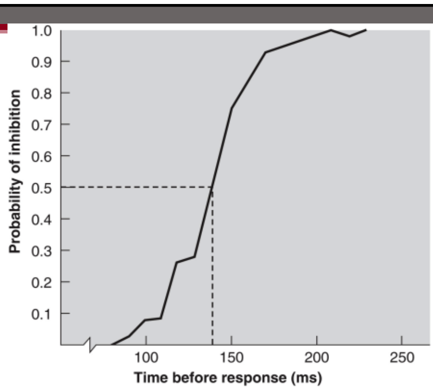
Do Motor Programs Exist?

Support for existence of Motor Programs:

3. **Stopping a response requires <u>sufficient time</u> prior to response initiation**

- Difficult to stop the initiation of a response once it has been preplanned and initiated internally and the point of no return has passed – suggests "release" of motor program
- e.g., Slater-Hammel (1960) Experiment





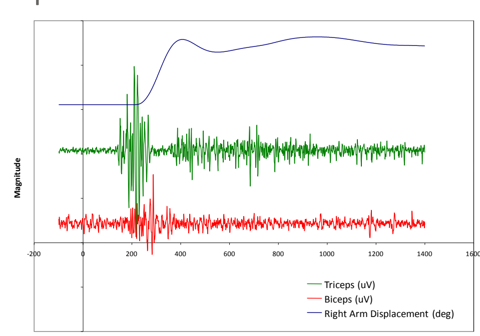
Do Motor Programs Exist?

Support for the existence of Motor Programs:

4. **Muscle activation patterns indicate that responses are executed as a unit**
   - Movement "blocking" study by Wadman (1979)
     - Performed rapid arm extension movement in "blocked" and "unblocked" condition
     - Examined tri-phasic EMG activity of triceps (agonist) & biceps (antagonist)

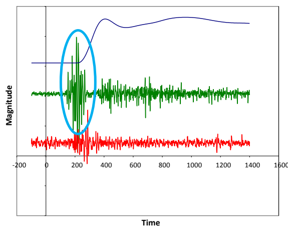
"Extend your arm quickly"

tri-phasic EMG - normal



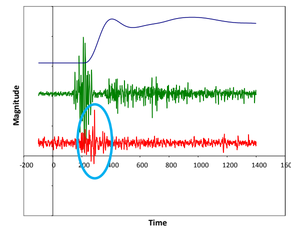
Muscle Activation Patterns

- tri-phasic muscle activation pattern
  - first agonist burst (AG1)
    - Accelerates limb



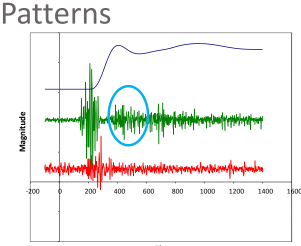
Muscle Activation Patterns

- tri-phasic muscle activation pattern
  - antagonist burst (ANT)
    - burst amplitude and timing influenced by movement extent and velocity
    - represents 'braking'



Muscle Activation Patterns

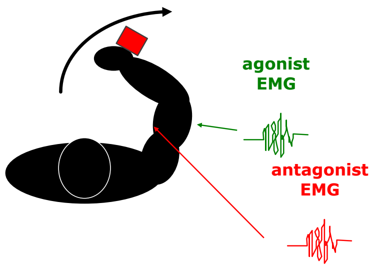
- tri-phasic muscle activation pattern
  - second agonist burst (AG2)
    - helps to "clamp" limb at target position



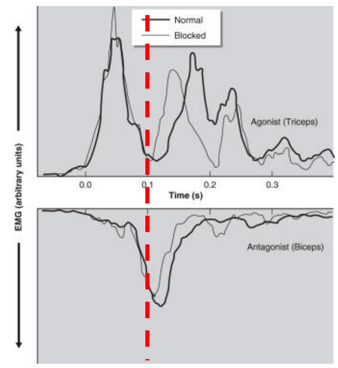
Triphasic EMG pattern

1. 1st Agonist burst
   Central origin
2. Antagonist burst
   Comes from mixed central and peripheral contributions
   can be present without feedback
   can also be influenced by feedback
3. 2nd Agonist burst
   Comes from central and peripheral contributions

Wadman et al. (1979)
Movement "Blocking"



Wadman et al.'s Data



Wadman et al. (1979)

- Motor program is sent to the muscles via an <u>open loop</u> operation
  - Commands for movement organized in advance and executed as a unit
  - Carried out open-loop until enough time for feedback processing has passed
  - Similar EMG for normal and blocked movements for first 100 msec, even though limb does not move if blocked