

# Organization of the Motor System

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## Outline

- Hierarchical organization of movements
- Feed-back and Feed-forward control of movements
- Hierarchical organization of motor systems

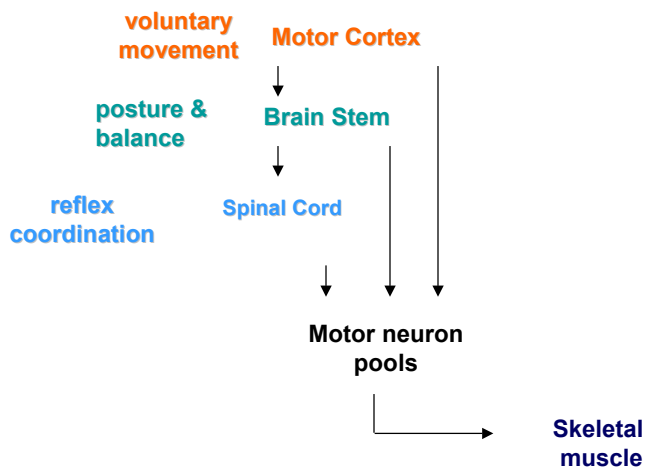
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## The Motor Systems Generate movements that are hierarchically organized

- Rapid (reflexive) response to harmful stimuli
- Maintain posture with respect to gravity
- Voluntary, purposeful movements

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## Overview - organization of motor systems



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## Reflex

- Involuntary movement, mediated by motor circuitry in the spinal cord
- Coordinated patterns of muscle contraction and relaxation
- Movement governed by the type of sensory receptors stimulated
  - Stretch receptors produce stretch reflexes
  - Cutaneous receptors produce withdrawal reflex

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## Voluntary Movement

- Initiated to accomplish a specific goal
- Triggered by external stimuli
- Improve with practice

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## Voluntary Movement

- Responds to feedback mechanisms to correct for internal and external changes
- Two types of feedback mechanisms
  - Feed forward
  - Feed back

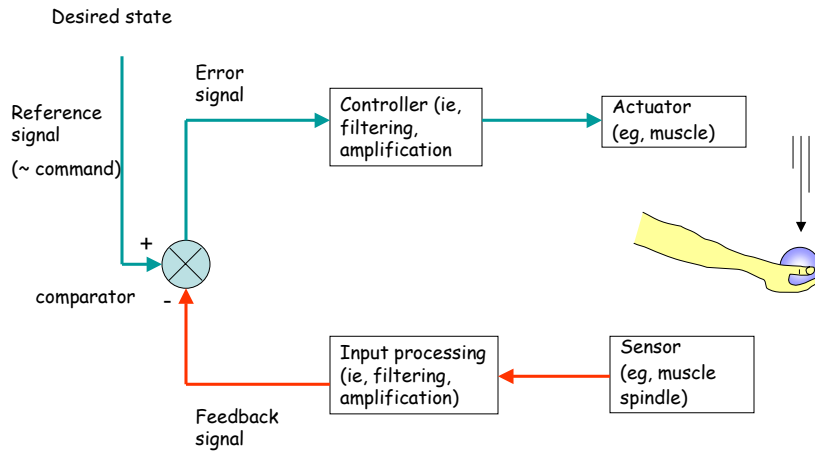
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## Feed-back Control

- Reactive
  - Responds to the current state of affairs
- Depends on sensory signals
  - To detect changes and perturbations in the state of affairs
- Characterized by gain
  - Gain is kept relatively low so as to be sensitive to changes in the state of affairs

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## Feedback control: command specifies desired state



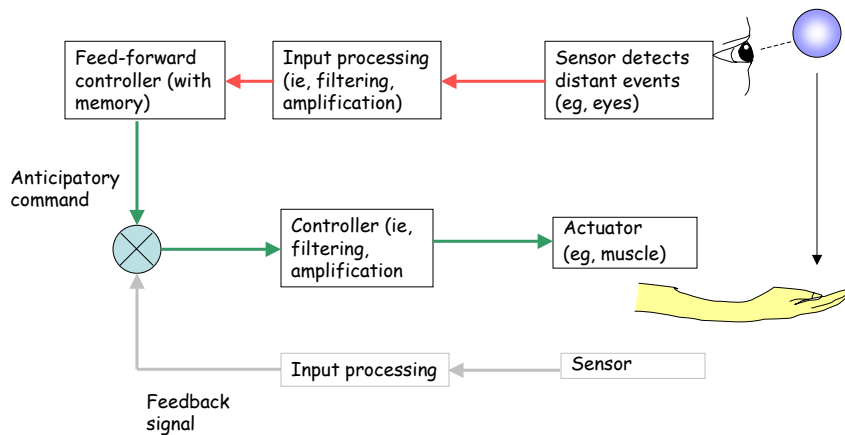
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## Feed-forward Control

- Anticipatory
- Depends on experience, senses
- Essential for rapid action
- Can modify the operation of feedback mechanisms

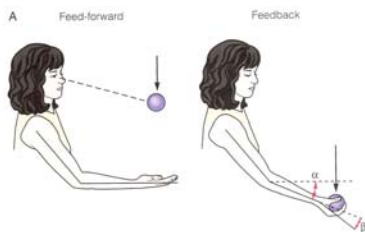
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## Feed-forward control: command specifies response



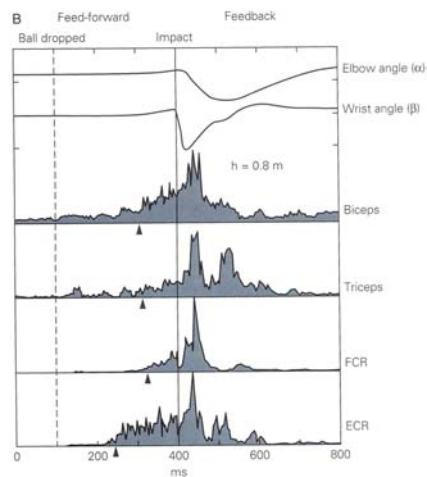
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## Catching a ball requires feed-forward and feedback controls



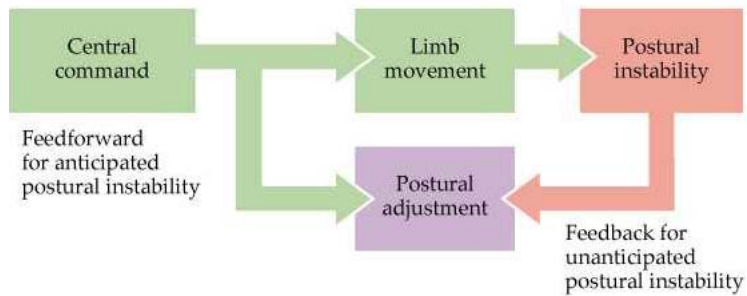
The anticipatory responses, before the impact of the ball, consist of coactivation of biceps and triceps muscles.

After impact there is a transient activation of the stretch reflex with further co-activation of flexor and extensors.



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## Feedforward and feedback mechanisms of postural control



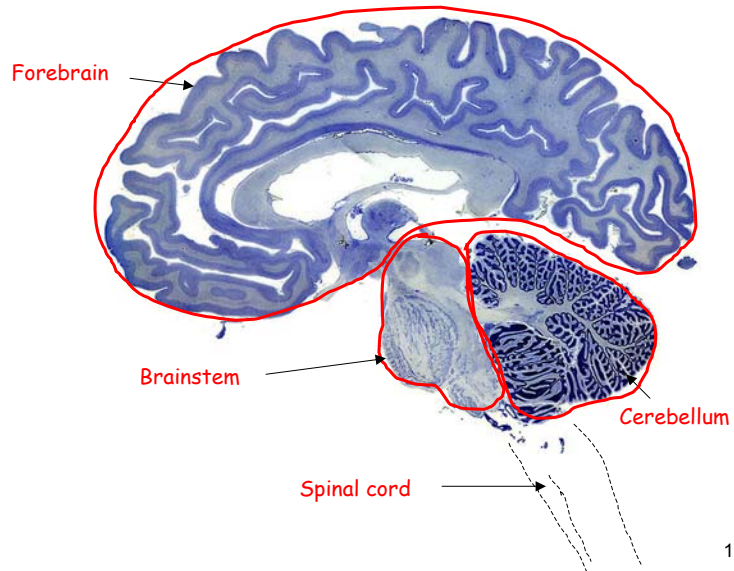
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## Hierarchical Organization of Motor Systems

- Level 1: The spinal cord
- Level 2: The brain stem
- Level 3: The cortex

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## A Little Brain Anatomy...

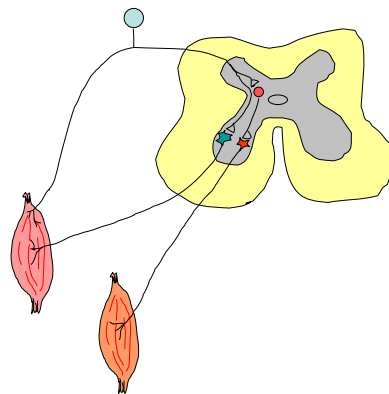


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## Hierarchical Organization of Motor Systems

### Level 1: The spinal cord

- Mediates reflexes, automatic movement
- Motor neurons and interneurons in spinal cord receive projections from higher centers that modulate these movements



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# Hierarchical Organization of Motor Systems

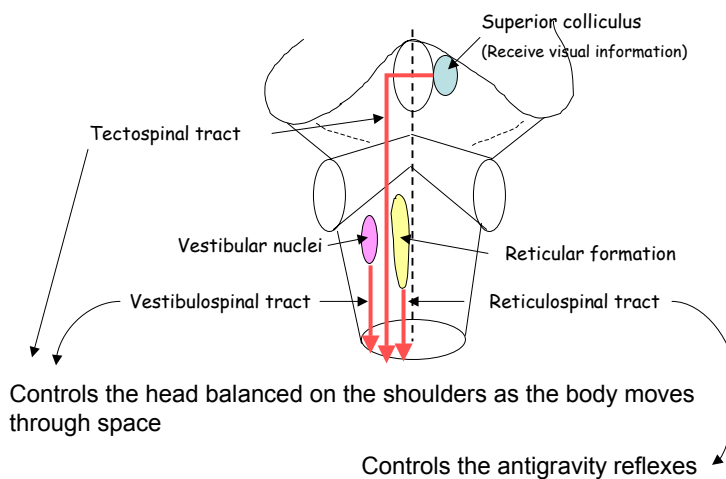
## Level 2: The Brain Stem

Two Systems:

- Medial Descending Systems
  - Integrate visual, vestibular, somatic information
  - For control of posture
- Lateral Descending System
  - Controls distal muscles (e.g., arm & hand)

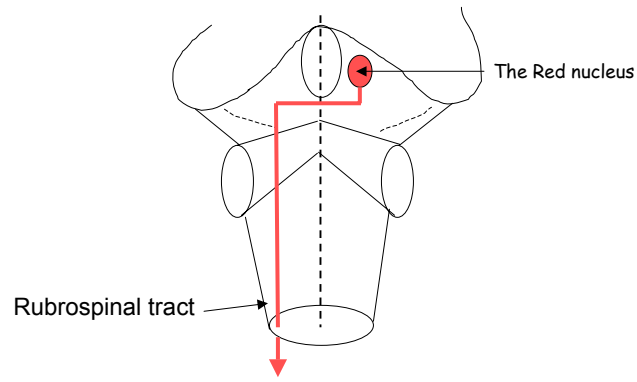
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## The Medial Descending Systems



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## The Lateral Descending Systems - from brain stem nucleus



Rubrospinal tract controls goal-directed limb movements such as reaching and manipulating.

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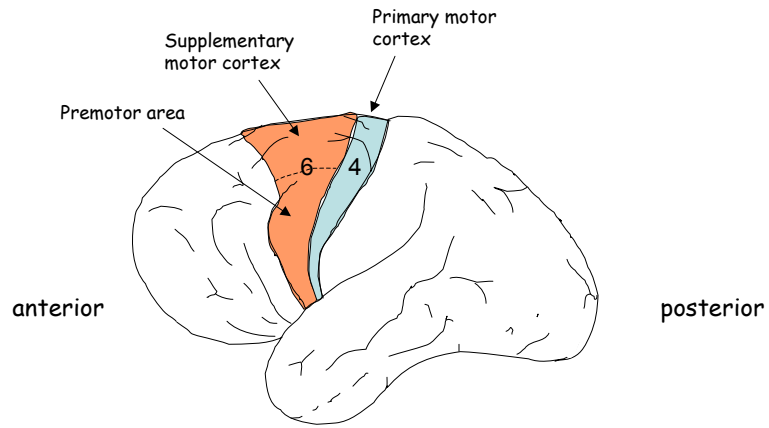
## Hierarchical Organization of Motor Systems

### Level 3: The Cortex

- Motor Cortex (primary motor cortex, premotor and supplementary motor cortex)
- Projects directly
  - to the spinal cord to regulate movement
  - Via the *Corticospinal Tract*
- Projects indirectly
  - Via the Brain stem to regulate movement

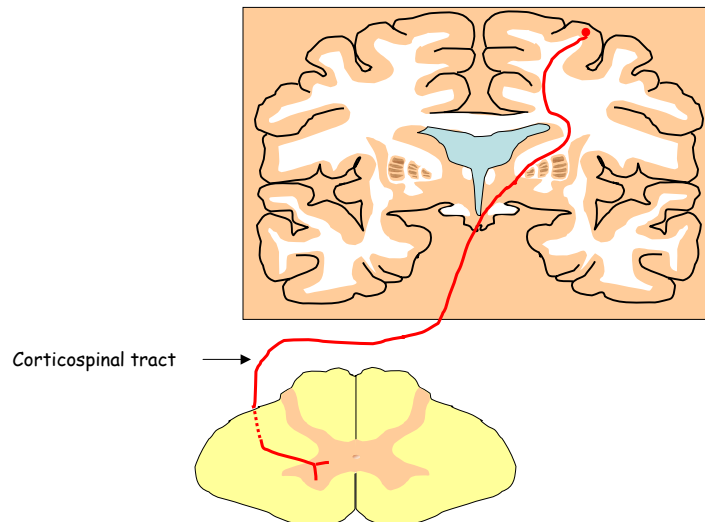
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## The Motor Cortex



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## The Lateral Descending Systems - from cortex



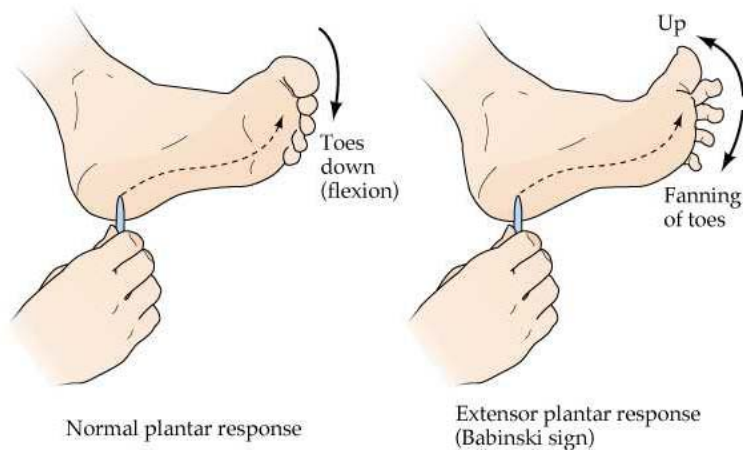
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## Effects of the lateral pathway lesions

- Late 1960s, done by Lawrence and Kuypers.
- Lesions in both corticospinal and rubrospinal tracts in monkeys.
- Unable to make fractionated movements of the arms and hands. Unable to move shoulders, elbows, wrists and fingers independently.
- Voluntary movements were slower and less accurate.
- Able to maintain normal posture.

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## Babinski reflex and corticospinal tract lesion



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