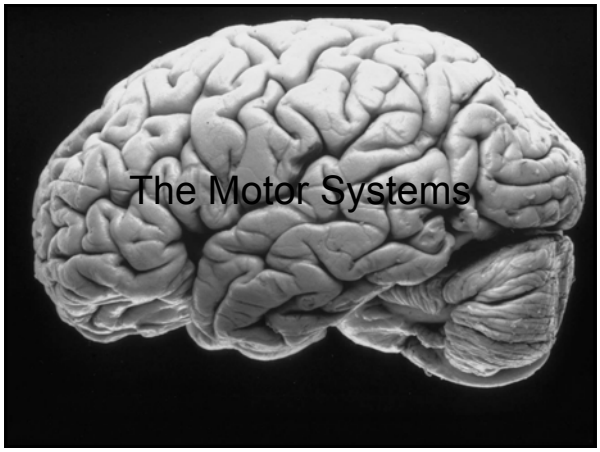


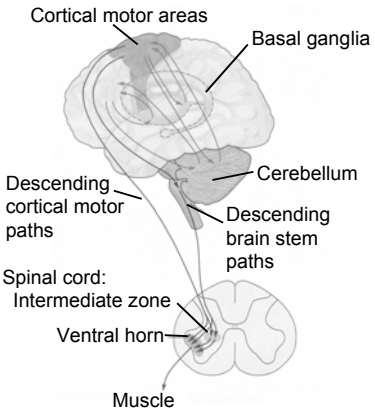
What's the motor system?

- Parts of CNS and PNS specialized for control of limb, trunk, and eye movements
- Also holds us together
- From simple reflexes (knee jerk) to voluntary movements (96mph fast ball)
- Remarkable: Muscles only contract

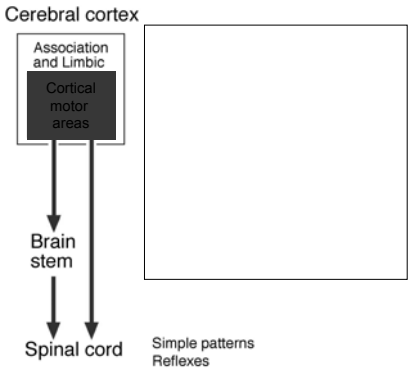
Plan

- Components of the motor systems
  - Focus on spinal control of limbs and trunk
  - Same principles apply to to head control via brain stem
- Basic principles of movement control
  - What is helpful for understanding basic motor system organization
- Motor programs for voluntary movement
- Descending motor pathways
- Note about motor system's bad rep…

Motor Systems



Functional Hierarchy of Motor Paths



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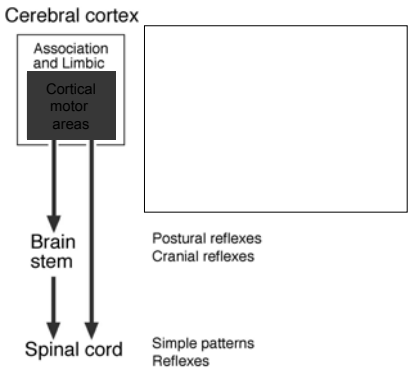
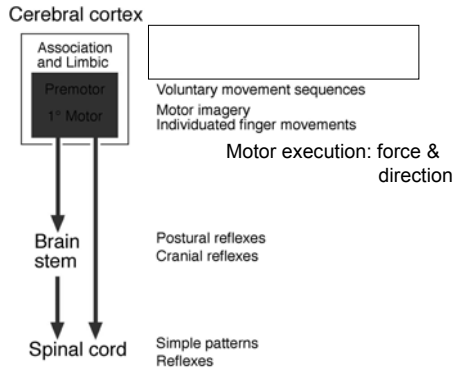
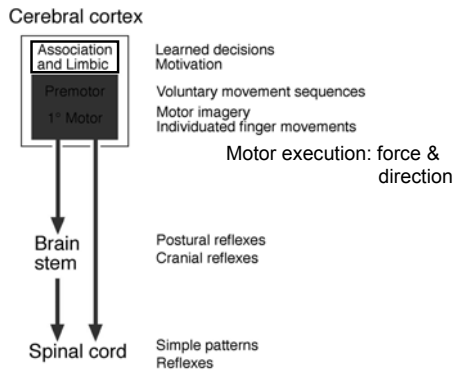


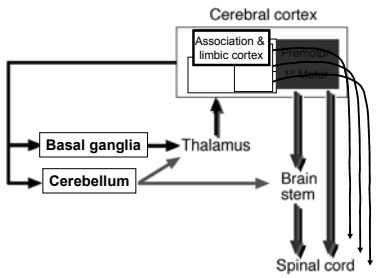
Functional Hierarchy of Motor Paths

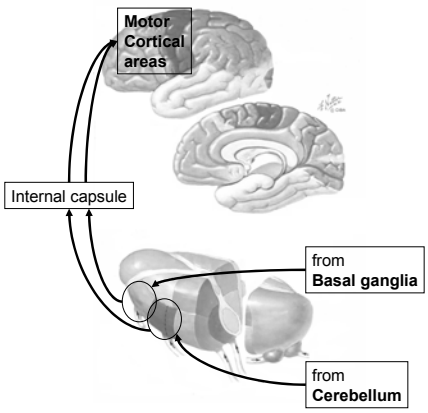


Functional Hierarchy of Motor Paths



Parallel Organization





Hierarchical & Parallel Organization of the motor systems

- Top down organization of the motor pathways--opposite that of sensory paths
- Subcortical motor centers--cerebellum & basal ganglia--access cortical motor areas via the **thalamus** (not just sensory)
- Organization of multiple subcortical and cortical motor circuits-reminiscent of parallel sensory pathways

Organization of Movements

- Hierarchical: 3 major types
  - Reflexes
  - Postural adjustments
  - Voluntary movements
    - …from simple to complex
- Diverse & adaptive
  - Purposeful

Organization of Movements

- Hierarchical: 3 major types
  - Reflexes — Spinal cord circuits
  - Postural adjustments — Spinal & Brain stem
  - Voluntary movements — Spinal cord, Brain stem, & cortex

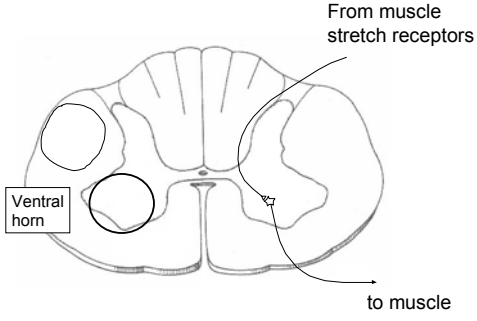
Postural adjustments & voluntary movements depend more on cerebellar and basal ganglia function than reflexes

Dual purpose: 1) upcoming lectures; 2) context for motor pathways

Reflexes

- Stimulus-evoked involuntary muscle contraction
- Monosynaptic (+) reflex
  - Knee jerk
  - Jaw jerk
- Simple neural representation (circuit)

Knee Jerk



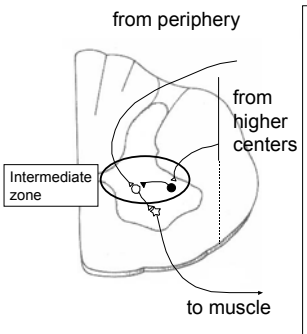
Reflexes

- Stimulus-evoked involuntary motor muscle contraction
- Monosynaptic (+) reflex
  - Knee jerk
  - Jaw jerk
- Disynaptic reflex (+)
  - withdrawal

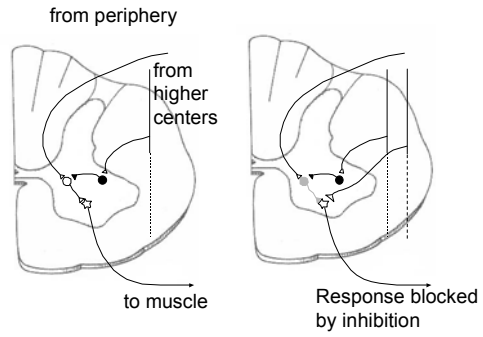
Why Disynaptic?

- Greater control (neural gate)
  - Very simple context
- More complex response

Greater control:



Greater control:



Motor I/O

S — R Knee-jerk

Motor I/O

S — R Knee-jerk

S_1 — R_1

S_n — R_n

Automatic postural adjustments

- Balance
- Limb support

- Flexible than reflexes (greater #; each w/control)
- Constrained than voluntary

Postural adjustments

- Context important
  - Can reorganize depending on context
- Feedback control – reactive
  - Error correction
  - Response **lags** stimulus; sometimes too late; sometimes vicious circle
- Feed forward control – predictive
  - Response **anticipates** stimulus
  - More timely, but depends on **practice**
- Depends on **cerebellum, brain stem pathways** & **spinal cord**
- More complex neural representation

Voluntary movements

- Organized around purposeful acts
- Flexible input – output relationships
  - Limitless
  - Price to pay: whole brain

Voluntary movements

- Organized around purposeful acts
- Flexible input – output relationships
  - Limitless
  - Price to pay: whole brain
- Recruits all motor systems components & much of the association cortex

Discuss:

- Goal representation
- Motor programs

The goal of voluntary movements is represented… somewhere

- Motor equivalence
  - Individual motor actions share important characteristics even when performed in different ways
- Abstract representation; effector independent
  - Hand writing
  - Soccer
- Goal representation
- ??Association & **Premotor cortex**

Voluntary movements are organized by motor programs

- Translate goal into action
  - Formation of a **movement representation**, or motor program
- ??**Premotor cortex** --> **Primary motor cortex**
- Program
  - To produce the desired goal, **which muscles** should contract and **when**
- 2 Key movement characteristics that are **programmed**
  - Spatial (hand path; joint angles) **Kinematic program**
  - Force **Dynamic program**

Kinematic & Dynamic Programs in Reaching

- Reach to target--(Sensation to Action)
  - Visual cortex-->Association cortex-->Premotor-->1° motor
- Distinct **kinematic** and **dynamic** programs
  - Reach up
    - Against gravity
    - More force to achieve goal
  - Reach down
    - Gravity assists
    - Less force to achieve goal
  - Flexible control

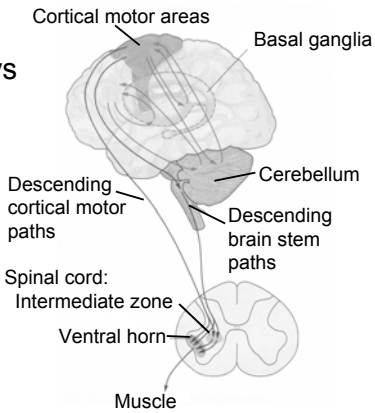
Summary

- Motor behavior hierarchy
  - Reflexes
  - Postural adjustments
  - Voluntary movements
- Internal/neural representations
  - Reflexes
  - Postural adjustments
  - Voluntary movements

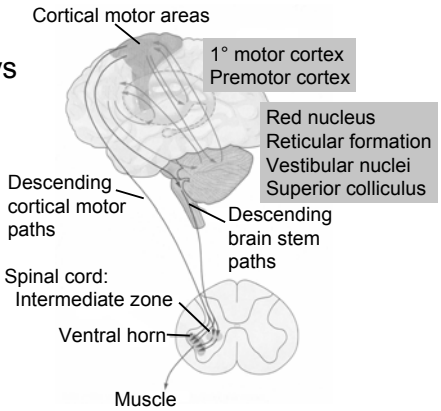
simple; invariant
↓
complex; flexible

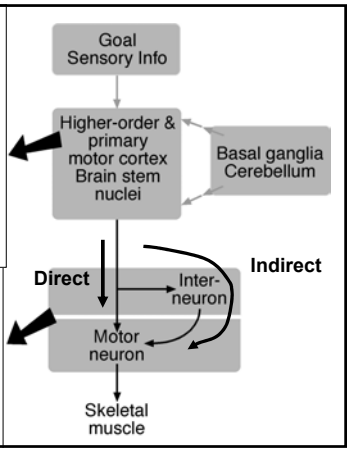
- Voluntary movements
  - Goal representation
  - Kinematic and dynamic programs
  - No wonder why voluntary movement recruit entire motor system

Motor Pathways



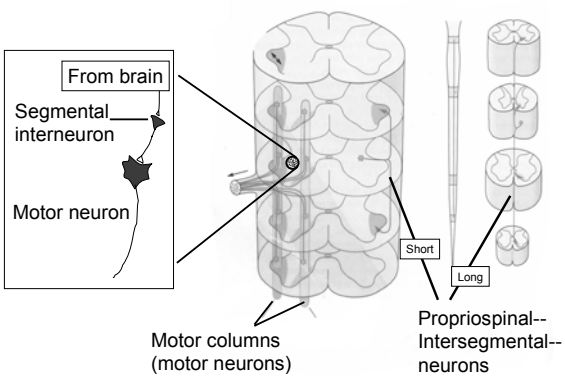
Motor Pathways

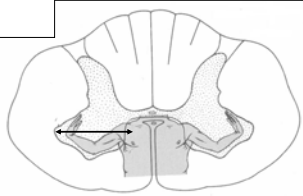




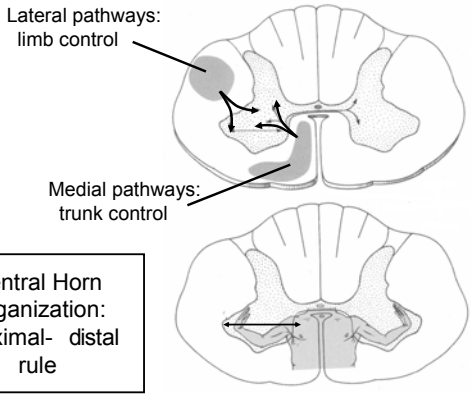
Motor pathways organized around the motor nuclei

Spinal Motor Columns



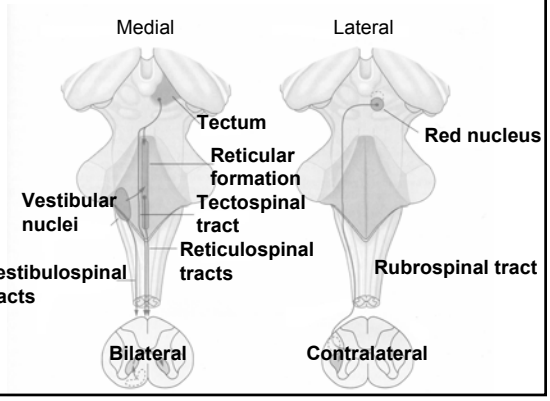


Ventral Horn Organization: Proximal- distal rule



Ventral Horn Organization: Proximal- distal rule

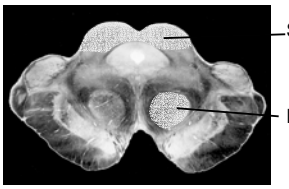
Brain Stem Motor Paths



Brain Stem Pathways

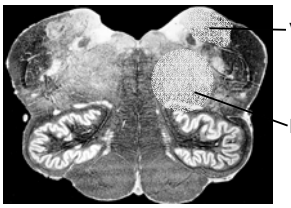
- Lateral
  - Rubrospinal tract: distal limb control; crude
- Medial
  - Tectospinal tract: eye-head coordination
  - Reticulospinal tract: automatic postural adjustments and movements (hip; shoulder)
  - Vestibulospinal tract: balance (axial muscles); automatic postural adjustments

Brain stem nuclei



Superior colliculus
Tectospinal tract

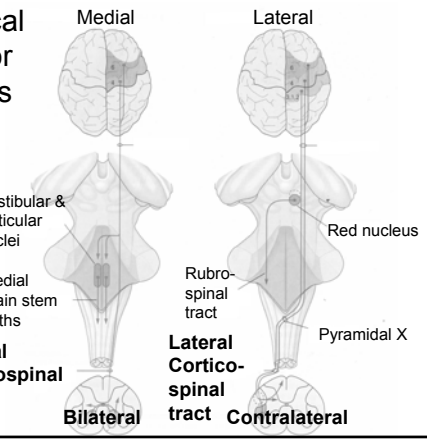
Red nucleus
Rubrospinal tract



Vestibular nuclei
Vestibulospinal tracts

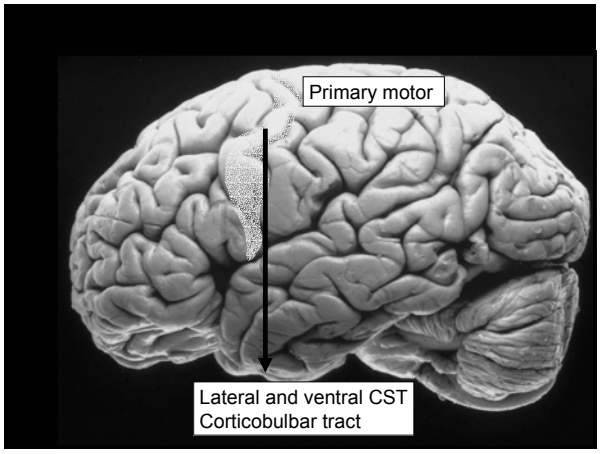
Reticular formation
Reticulospinal tracts

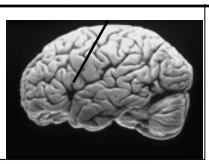
Cortical Motor Paths

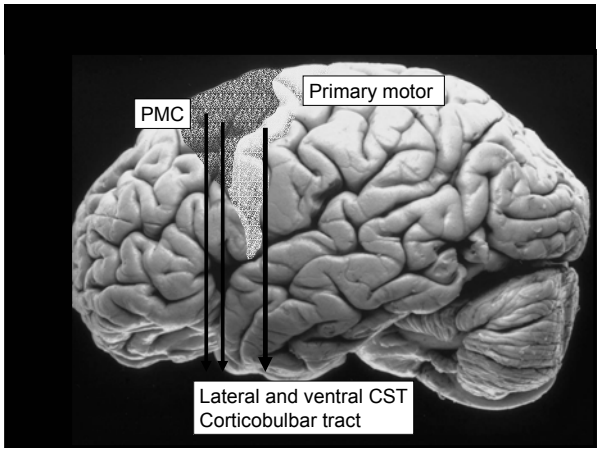


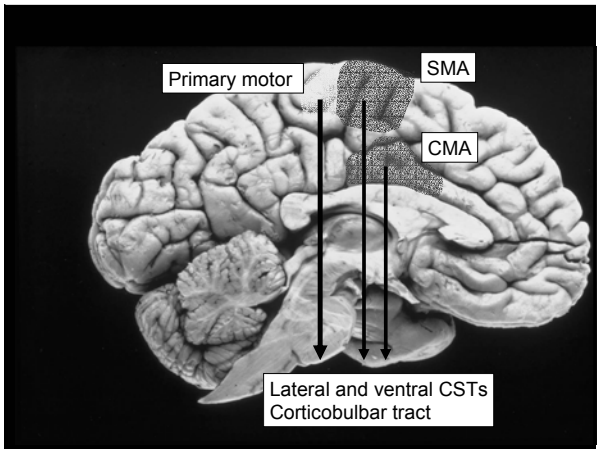
Cortical motor paths

- Lateral corticospinal tract
  - Limb control mostly
- Ventral corticospinal tract
  - Proximal muscle control; mostly upper body
- For cranial muscle control: Corticobulbar tract
  - with medial and lateral components









Why bother study the motor pathways?

- Anatomical substrates: How it works
- Multiple parallel paths & diversity of spinal connections
  - Damage to 1° motor cortex and **pre-motor cortex** projections recover some lost functions
  - Damage to cortex and **brain stem paths** recover some lost functions
  - With spinal cord injury. loss of monosynaptic connections and alternate paths via **segmental** and **intersegmental interneurons** can recover some lost functions