Cerebellum

Cerebellar Signs

Key Cerebellar Functions

- Comparison of intent and action (ie., errors) and generates corrective signals
- Motor learning and adaptation
- Motor cognition and general cognition (new evidence; controversial)
- Plays a role in automating and optimizing behavior
Lecture Plan:

- Structural and functional overview
- Principal pathways into and out of the cerebellum
- Experimental approaches to reveal:
  - Anticipatory control
  - Motor learning
  - Mental processes underlying movement control

Motor Hierarchy

Exerts influence at all levels

Cerebellar Functional Anatomy
Cerebellar Cortex

Deep Cerebellar Nuclei:
Dentate
Interposed
Fastigial
Input-output Organization

Cerebellar cortex: Deep Cerebellar Nuclei, Fastigial Nuclei, Interposed Nuclei, Vestibular Nuclei

Extrinsic inputs: mossy fiber, climbing fiber

Cerebellar Divisions

Spinocerebellum (Vermis + Intermed. Hem)
- Control of limbs and trunk
- Cerebrocerebellum (Lateral hemisphere)
- Planning of movement
- Vestibulo-cerebellum (Floculo-nodular lobe)
- Control of eye & head movements
- Balance


Vestibulo-cerebellum: Floculo-nodular lobe

Nissl-stained section through cerebellar cortex
Cerebellar Cortex

Inputs
- Climbing fibers
- Mossy fibers

Output
- Purkinje neurons

Interneurons
- Granule neurons
- Stellate neurons
- Basket neurons
- Golgi neurons

Purkinje neuron

Apical dendrites

Cell body

Cerebellar Cortex

Inputs
- Climbing fibers
- Mossy fibers

Output
- Purkinje neurons

Interneurons
- Granule neurons +
- Stellate neurons -
- Basket neurons -
- Golgi neurons -
Cerebellar Cortex: activation by mossy fibers

Inputs
- Climbing fibers
- Mossy fibers

Output
- Purkinje neurons

Interneurons
- Granule neurons
- Stellate neurons
- Basket neurons
- Golgi neurons

to Deep Cerebellar Nuclei

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Cerebellar Cortex: activation by climbing fibers

Inputs
- Climbing fibers
- Mossy fibers

Output
- Purkinje neurons

Interneurons
- Granule neurons
- Stellate neurons
- Basket neurons
- Golgi neurons

to Deep Cerebellar Nuclei

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Inferior olivary nucleus: source of all climbing fibers

to cerebellum, via inferior peduncle

Mossy fibers from all other sources
Cerebellar Cortex: Inhibitory interneurons

**Inputs**
- Climbing fibers
- Mossy fibers

**Output**
- Purkinje neurons

**Interneurons**
- Granule neurons
- Stellate neurons
- Basket neurons
- Golgi neurons

Functional divisions

To lateral systems
- Spinocerebellum
- Vestibulo-cerebellum

To medial systems
- Spinocerebellum

To frontal motor areas
- Vestibulo-cerebellum

Eye movement & balance
- Vestibulo-cerebellum

Motor planning
- Vestibulo-cerebellum

Motor execution
- Vestibulo-cerebellum

Motor planning & execution
- Vestibulo-cerebellum
Medial & lateral systems

- Fastigial
- Vestibulocerebellum via vestibular nuclei

Intermediate and Lateral Hemispheres

- Planning and limb control
- Thalamus and Cortical motor areas
- Brain stem nuclei
- Cerebellar cortex & Deep nuclei
- Ipsilateral

Vermis & Vestibulocerebellum

- Thalamus and Cortical motor areas
- Cerebellar cortex & Deep nuclei
- Brain stem nuclei
- Axial control
- Bilateral
Functions of the Cerebellum

- Feed forward or predictive motor control (nuts & bolts of skilful movements)
- Motor learning/adaptation
- Non motor functions:
  - Active tactile exploration
  - Higher brain functions (cerebellar cognitive-affective syndrome)

Anticipatory control

- Anticipating the motor consequences of an event
  - See stop light and brake
  - Predict baseball location during batting
  - Anticipating duck location in an video game
- Cerebellum’s role:
  - Fairly low level routines
  - Correlations & associations
- Implemented via lateral and medial pathways

Feed-Forward or Predictive Control

Normal:
- Perturbation extends arm, stretching biceps
- Muscle action flexes arm and tends to restore arm position
- Anticipatory contraction of triceps (extensor) prevents flexion overshoot
  - Occurs during triceps shortening; not stretch reflex
- BRAKE
- Result: arm position stabilized at start position
Feed-Forward or Predictive Control

Block cerebellar function (cool):

- Perturbation extends arm, stretching biceps
- Biceps contraction prolonged
- Muscle action flexes arm but well beyond initial arm position 
  OVERSHOOT
- Delayed triceps contraction
  - Reverts to simple stretch reflex
  - LOSS of brake (antic. control)
- Result: cycle of flexion-extension (similar to cerebellar tremor)

Feed-Forward or Predictive Control

Delayed triceps (antagonist) produces oscillations

Motor Learning
Non-motor Function

Passive stimulation  
Discriminate roughness

Manipulate only  
Manipulate + discriminate

Cerebellar Motor Functions

- Implemented via lateral and medial pathways, especially the corticospinal tract
- Incorporated into motor programs via frontal motor areas (SMA, premotor cortex...)
- Becomes part of motor strategy via prefrontal cortex

All work together during a motor task:
- Anticipatory control during motor learning
- Using sensory information to guide movement
Cerebellar Cognitive Affective Disorder

- Lesions of the posterior lobe and vermis
- Impairment of executive functions
  - Planning, verbal fluency, abstract reasoning
- Difficulties with spatial cognition
  - Visuo-spatial organization, visual memory
- Personality changes
  - Blunting of affect, inappropriate behaviors
- Language disorders
  - Agrammatism

Conclusions

- Cerebellar lesions produce
  - Incoordination & errors not weakness
  - Lose ability to anticipate errors
  - Lose ability to correct
- Motor learning
- Not just motor