Cerebellum

Cerebellar Signs
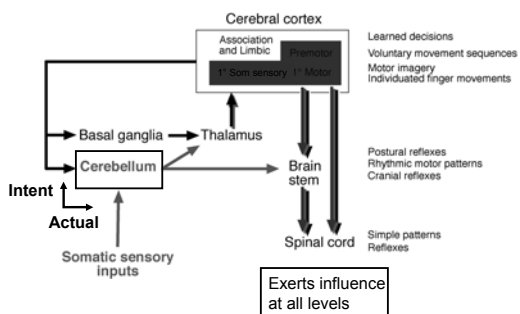

Key Cerebellar Functions

- Comparison of intent and action (ie., errors) and generates corrective signals
- Motor learning and adaptation
- Motor cognition and general cognition (new evidence; controversial)

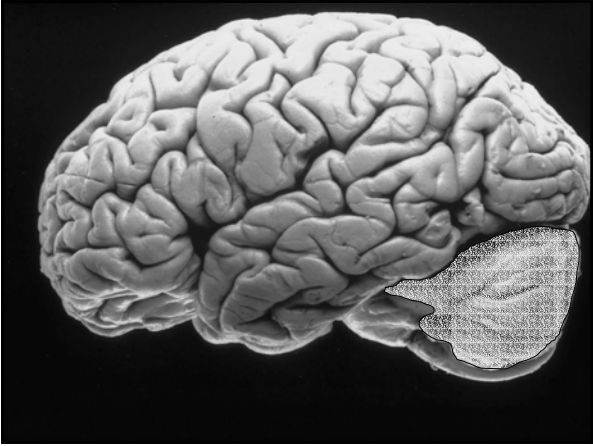- Plays a role in automating and optimizing behavior

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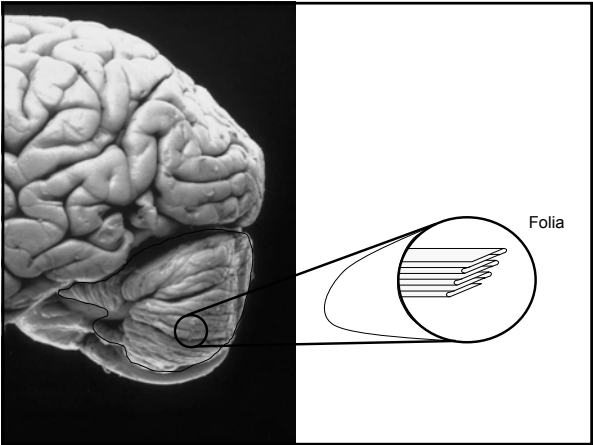
- Structural and functional overview
- Principal pathways into and out of the cerebellum
- Experimental approaches to reveal:
  – Anticipatory control
  – Motor learning
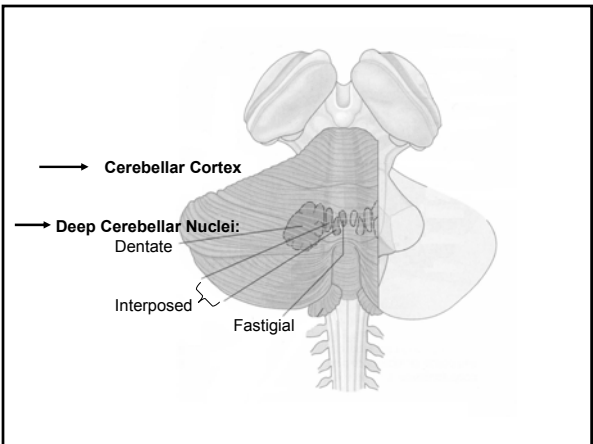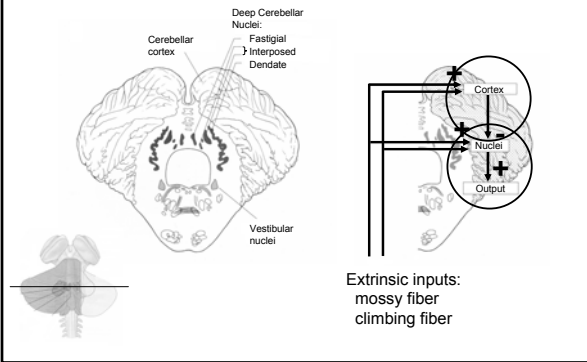 – Mental processes underlying movement control

Motor Hierarchy

Cerebral cortex

Association and Limbic
Premotor
1° Som sensory 1° Motor

Learned decisions
Voluntary movement sequences
Motor imagery
Individuated finger movements

Basal ganglia → Thalamus

Cerebellum

Intent
Actual

Somatic sensory inputs

Brain stem

Postural reflexes
Rhythmic motor patterns
Cranial reflexes

Spinal cord

Simple patterns
Reflexes

Exerts influence at all levels

Cerebellar Functional Anatomy

_____

_____

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Folia

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Cerebellar Cortex

Deep Cerebellar Nuclei:
Dentate

Interposed

Fastigial

_____

_____

_____

_____

_____

_____

_____

Input-output Organization

Deep Cerebellar Nuclei:
Fastigial
Interposed
Dendate

Cerebellar cortex

Cortex

Nuclei

Output

Vestibular nuclei

Extrinsic inputs:
mossy fiber
climbing fiber

Cerebellar Divisions
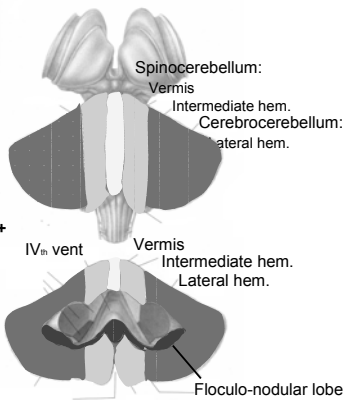
Spinocerebellum
(Vermis + Intermed. Hem)

Control of limbs and trunk

Cerebrocerebellum
(Lateral hemisphere)

Planning of movement+

Vestibulo-cerebellum
(Floculo-nodular lobe)

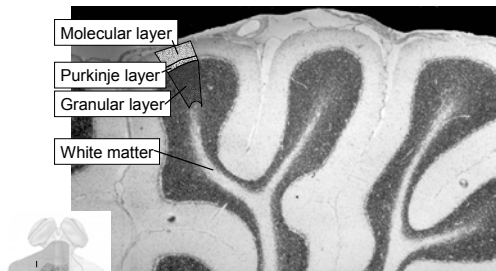**Control of eye & head movements
Balance**

Spinocerebellum:
Vermis
Intermediate hem.
Cerebrocerebellum:
Lateral hem.

IV_{th} vent

Vermis
Intermediate hem.
Lateral hem.

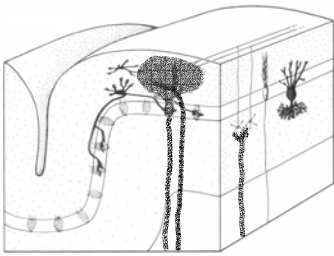Floculo-nodular lobe

Molecular layer

Purkinje layer

Granular layer

White matter

Nissl-stained section through cerebellar cortex

Cerebellar Cortex

Inputs
→ Climbing fibers
→ Mossy fibers

Output
→ Purkinje neurons

Interneurons
 Granule neurons
 Stellate neurons
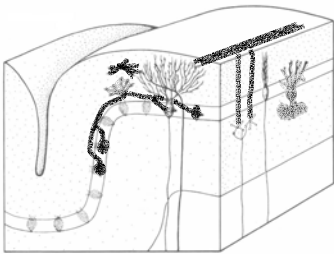 Basket neurons
 Golgi neurons

Apical dendrites

Cell body

Purkinje neuron

Cerebellar Cortex

Inputs
 Climbing fibers
 Mossy fibers

Output
 Purkinje neurons

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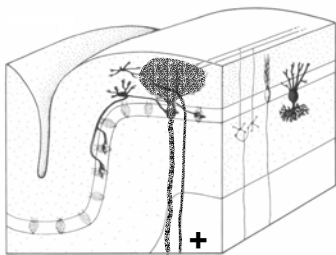→ Basket neurons **-**
→ Golgi neurons **-**

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
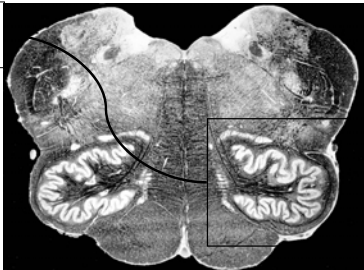

Cerebellar Cortex: activation by climbing fibers

Inputs
→ Climbing fibers
Mossy fibers

Output
→ Purkinje neurons

Interneurons
Granule neurons
Stellate neurons
Basket neurons
Golgi neurons
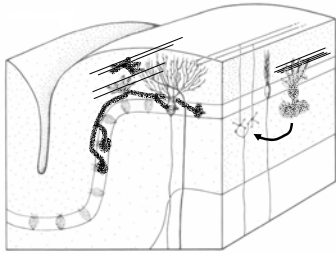
+
-
to Deep Cerebellar Nuclei

Inferior olivary nucleus: source of all climbing fibers

to cerebellum, via inferior peduncle

Mossy fibers from all other sources
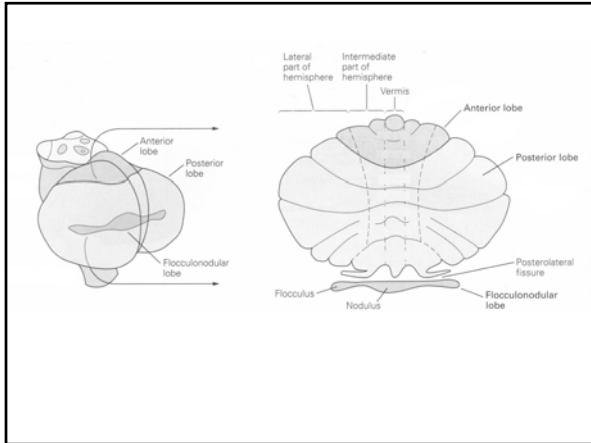
Cerebellar Cortex: Inhibitory interneurons

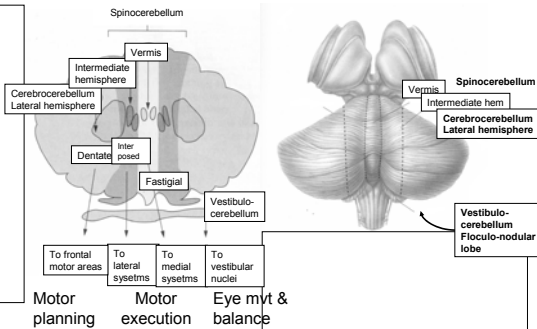**Inputs**
Climbing fibers
Mossy fibers
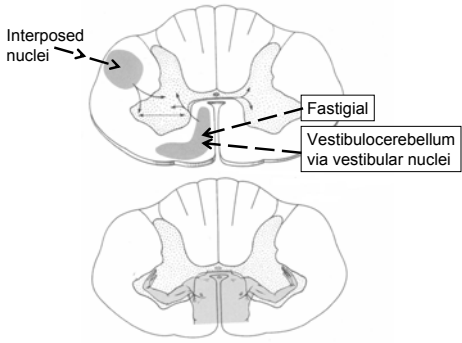
Output
Purkinje neurons

Interneurons
Granule neurons
→ Stellate neurons
→ Basket neurons
→ Golgi neurons

Lateral part of hemisphere
Intermediate part of hemisphere
Vermis
Anterior lobe
Posterior lobe
Anterior lobe
Posterior lobe
Flocculonodular lobe
Posterolateral fissure
Flocculus
Nodulus
Flocculonodular lobe

Functional divisions

Spinocerebellum
Vermis
Intermediate hemisphere
Cerebrocerebellum Lateral hemisphere
Dentate
Inter posed
Fastigial
Vestibulo-cerebellum
To frontal motor areas
To lateral sysetms
To medial sysetms
To vestibular nuclei

Vermis **Spinocerebellum**
Intermediate hem
Cerebrocerebellum Lateral hemisphere
Vestibulo-cerebellum Floculo-nodular lobe

Motor planning   Motor execution   Eye mvt & balance

Medial & lateral systems

Interposed nuclei

Fastigial

Vestibulocerebellum via vestibular nuclei

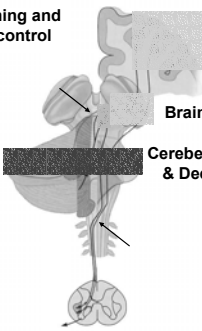Intermediate and Lateral Hemispheres

Planning and limb control

Thalamus and Cortical motor areas

Brain stem nuclei

Cerebellar cortex & Deep nuclei

Ipsilateral
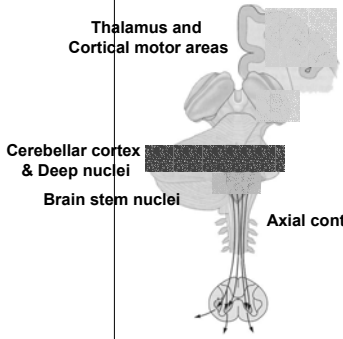

Vermis & Vestibulocerebellum

Thalamus and Cortical motor areas

Cerebellar cortex & Deep nuclei

Brain stem nuclei
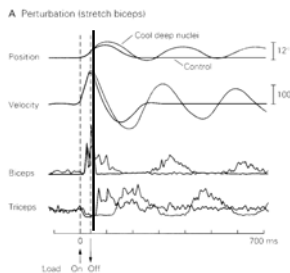
Axial control

Bilateral

Functions of the Cerebellum

- Feed forward or predictive motor control (nuts & bolts of skillful 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
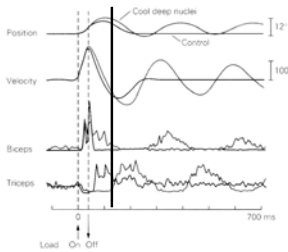- Implemented via lateral and medial pathways

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**
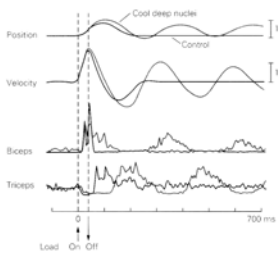
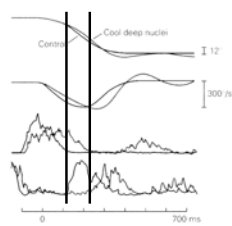## Feed-Forward or Predictive Control

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)**
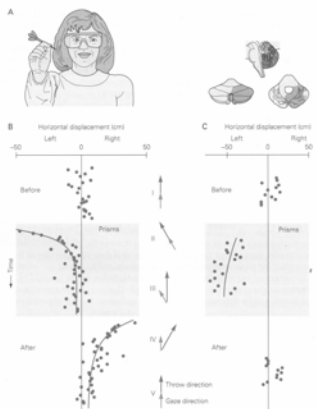
Feed-Forward or Predictive Control

Delayed triceps (antagonist) produces oscillations

Motor Learning

Non-motor Function

Passive stimulation   Task   Discriminate roughness

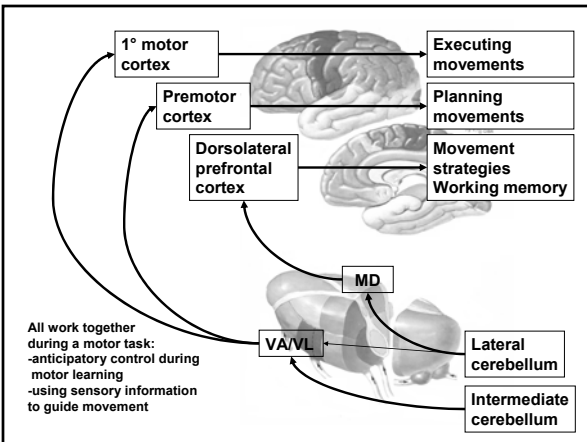No movement

Movement

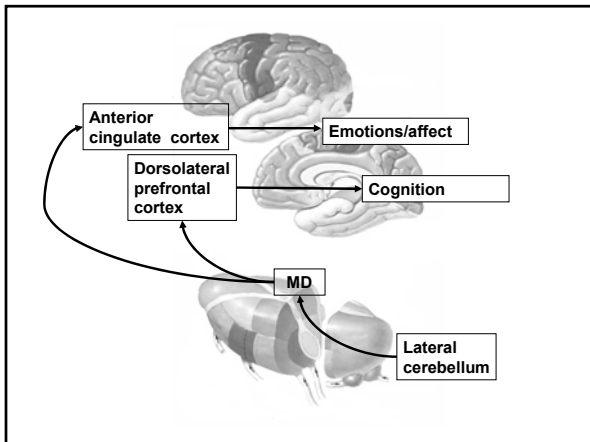Manipulate only   Manipulate + discriminate

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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

1° motor cortex → **Executing movements**

Premotor cortex → **Planning movements**

Dorsolateral prefrontal cortex → **Movement strategies Working memory**

MD

VA/VL ← **Lateral cerebellum**

Intermediate cerebellum

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

Anterior cingulate cortex → Emotions/affect

Dorsolateral prefrontal cortex → Cognition

MD

Lateral cerebellum

Conclusions

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