9.01 Introduction to Neuroscience
Fall 2007

Movement II

Sebastian Seung

Supraspinal motor areas

- Brainstem
- Cortex
- Basal ganglia
- Cerebellum

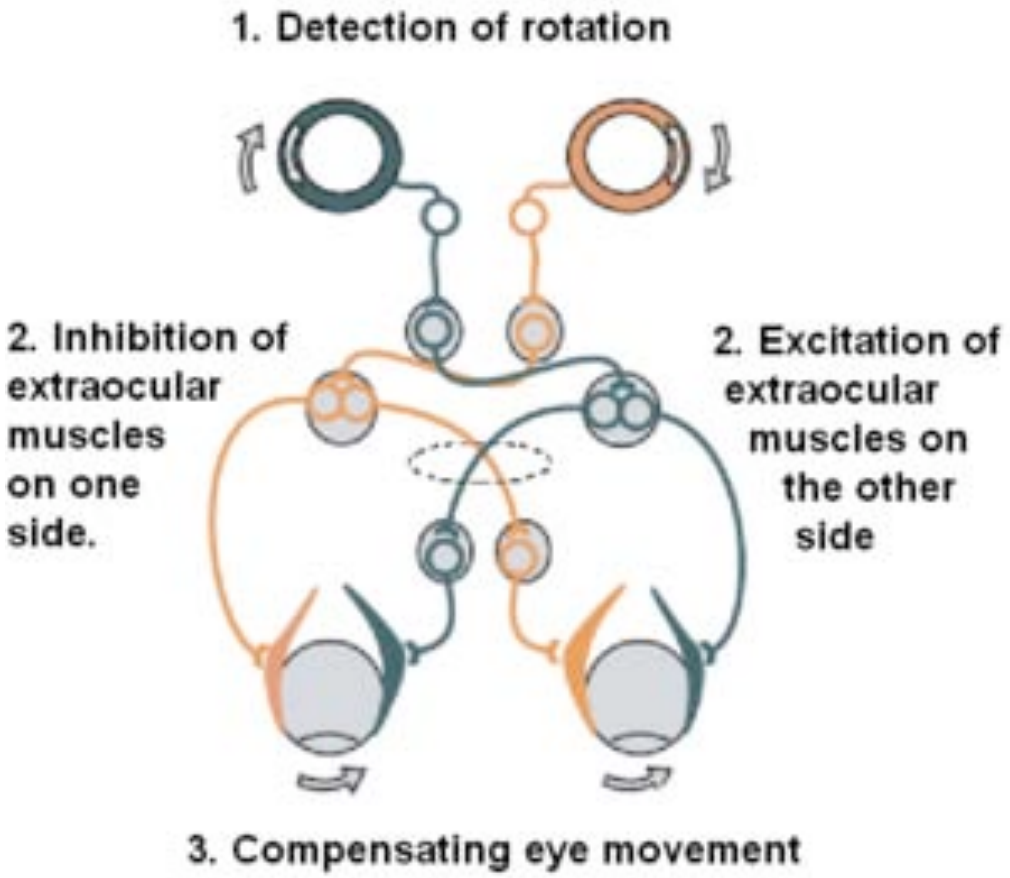
Eye movements are controlled by six extraocular muscles

- One pair of muscles for each:
  - Horizontal
  - Vertical
  - Torsional
- Extraocular motor neurons are in the brainstem

Eye movements are gaze-shifting or gaze-stabilizing

- Gaze-shifting (foveating)
  - saccades (involve superior colliculus)
  - smooth pursuit
- Gaze-stabilizing
  - optokinetic reflex
  - vestibulo-ocular reflex

Vestibulo-ocular reflex



Courtesy of Tutis Vilis. Used with permission.

Vestibular organs

- The semicircular canals sense angular velocity of the head
- The otolith organs sense head tilt
- Both contain hair cells.

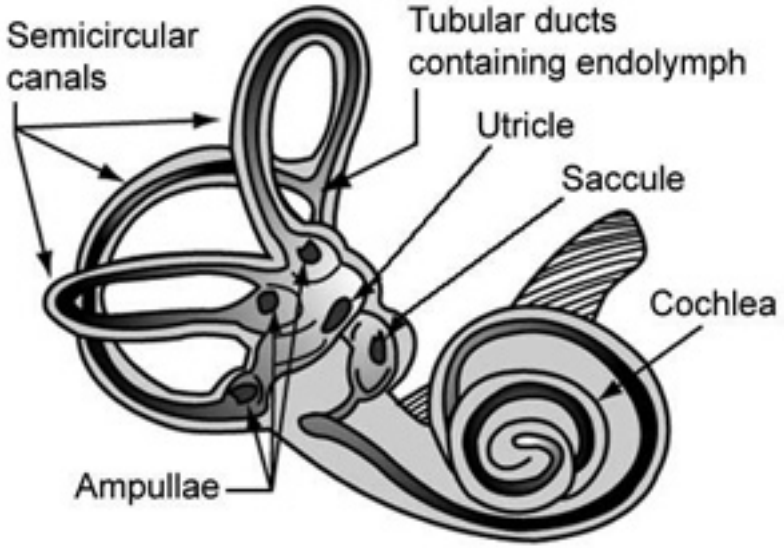
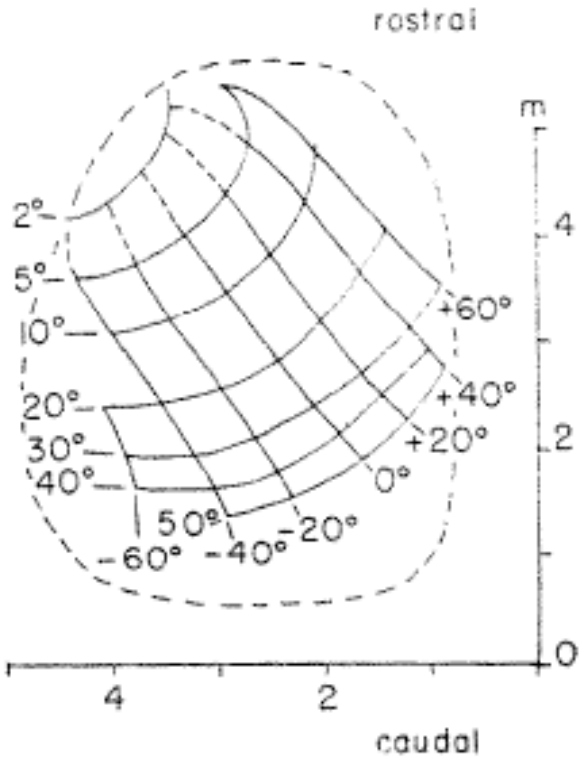


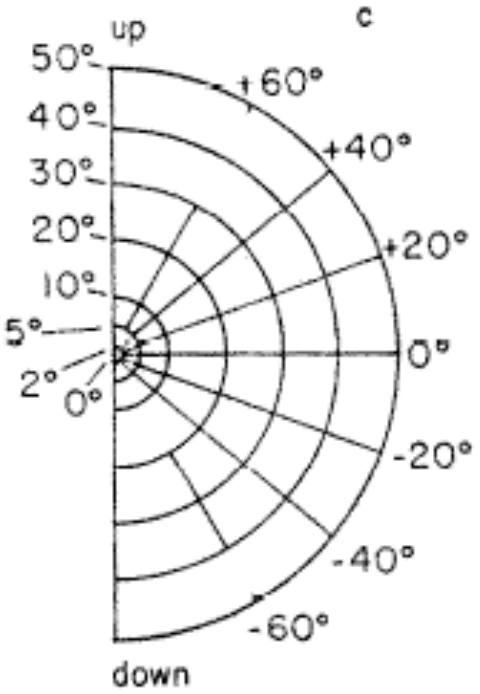
Figure 2: The Vestibular System - semicircular canals and otolith organs

Source: NASA
See Figure 13.4 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Map of saccade vectors on the superior colliculus

- left superior colliculus
- contralateral visual field





Robinson, 1972

Upper motor neurons

- Located in brainstem and cortex.
- Axons to spinal cord or brainstem.
- May or may not directly contact lower motor neurons.

Corticospinal pathways

- lateral column of the white matter of the spinal cord
- decussate in the brainstem
- lesion studies in monkeys
  - inability to move shoulders, elbows, wrists, fingers independently
  - posture is intact

Motor cortical areas

- Primary motor cortex (M1)
  - Area 4
  - precentral gyrus, anterior to central sulcus
- Premotor cortex
  - Area 6, anterior to Area 4
  - medial: supplementary motor area (SMA)
  - lateral: premotor area (PMA)

Motor cortical areas

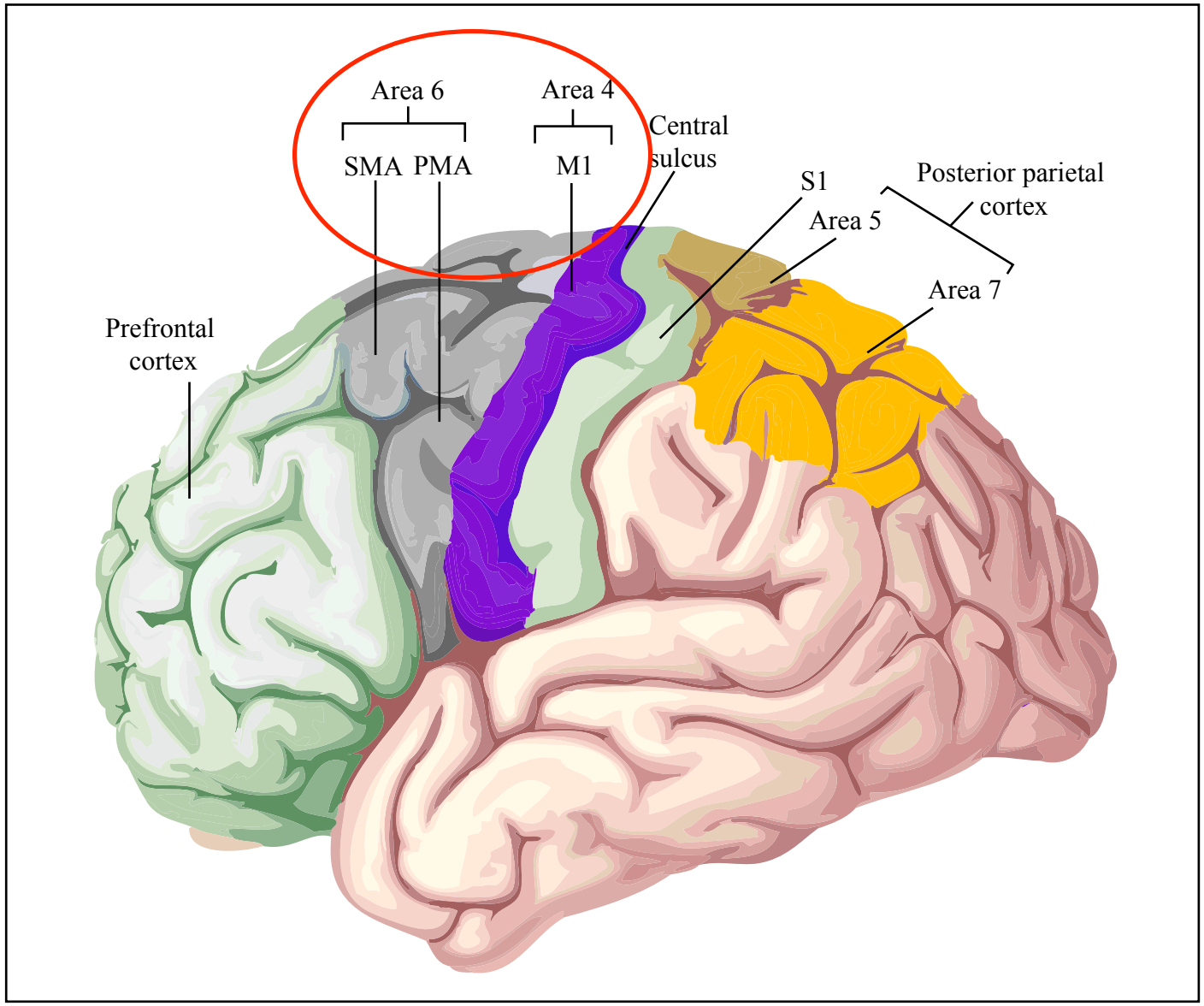


Figure by MIT OpenCourseWare. After Figure 14.7 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Center-out reaching task

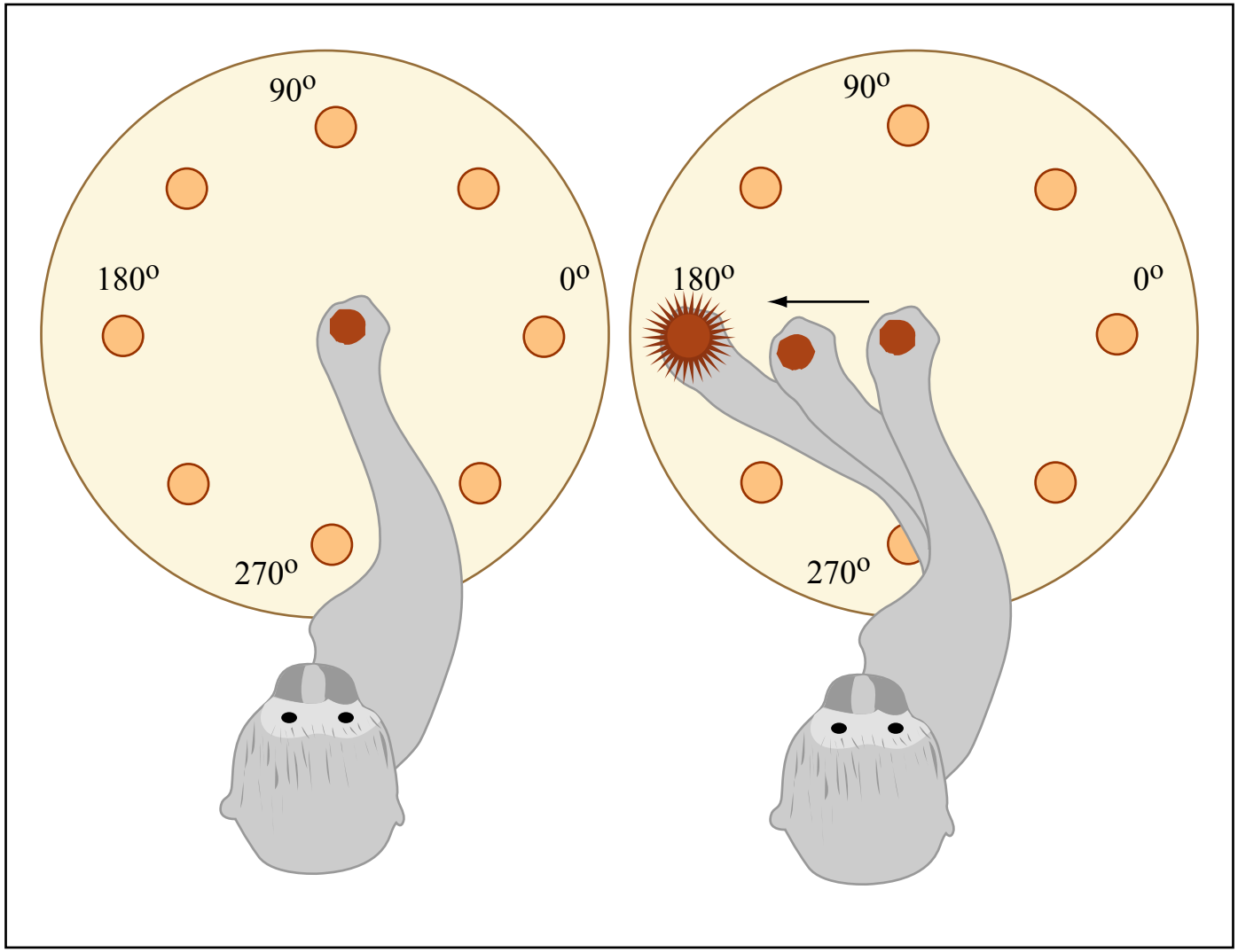
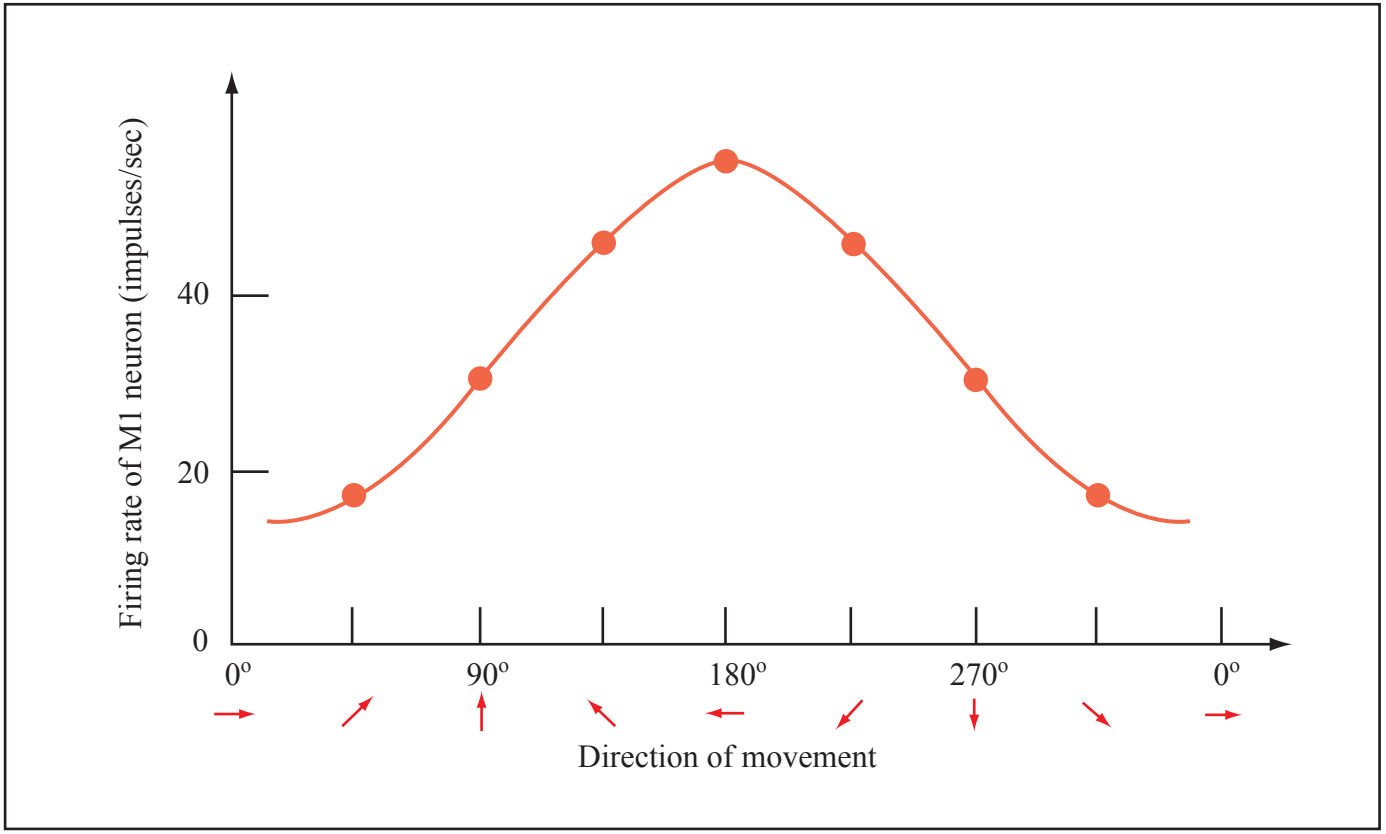


Figure by MIT OpenCourseWare. After Figure 14.13a in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

M1 cells are broadly tuned to reaching direction



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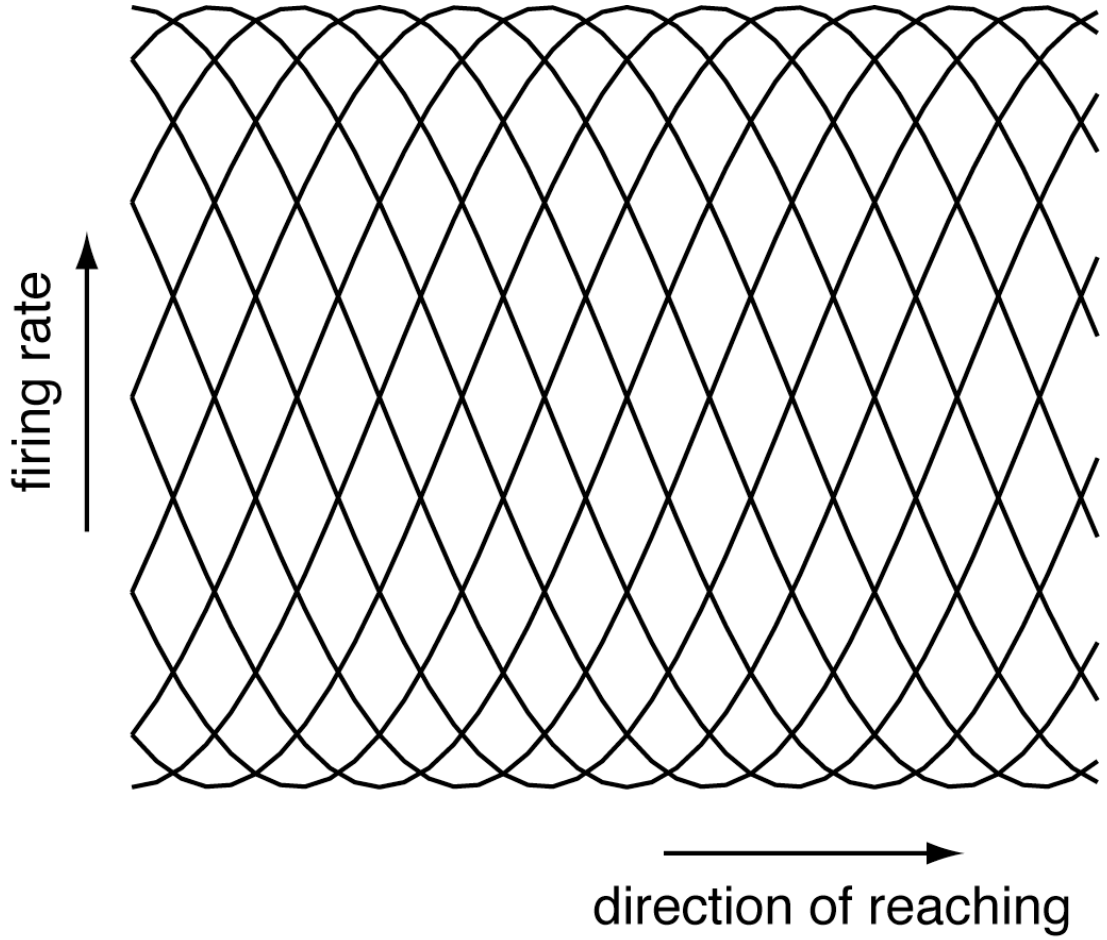
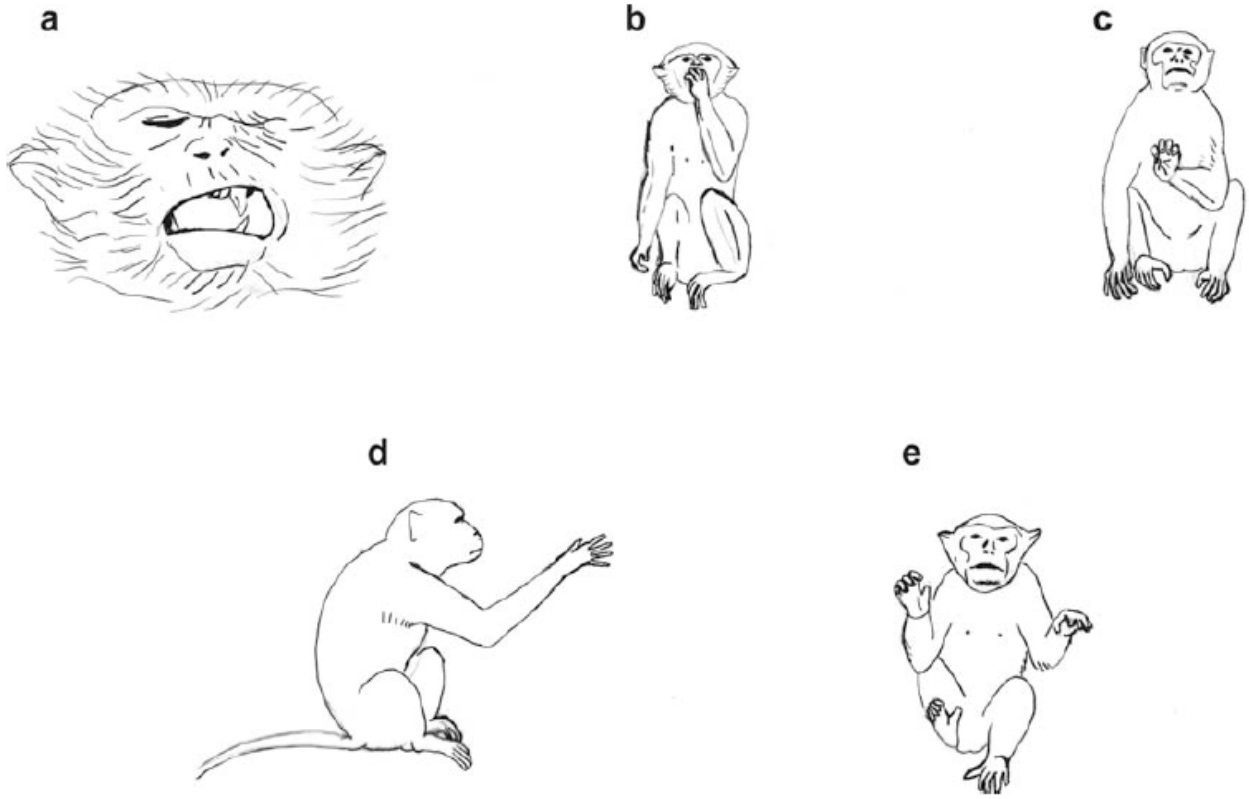
An idealized population of tuning curves



Functions of motor cortical areas?

- classical view
  - M1: somatotopic map of muscles
  - premotor cortex: sequences, planning
- revisionist view
  - M1 and premotor areas control complex movements

Complex actions evoked by electrical stimulation



Graziano, 2006

The final common pathway

- “To move things is all that mankind can do ... for such the sole executant is muscle, whether in whispering a syllable, or in felling a forest.”
- Charles Sherrington, 1924

Basal ganglia

- striatum
  - dorsal: caudate nucleus, putamen
  - ventral: nucleus accumbens
- globus pallidus
- subthalamic nucleus
- substantia nigra

Parkinson's disease

- resting tremor disappears during movement
- slow finger movements in affected hand

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Photo of person sitting in a chair with palms resting on their thighs.

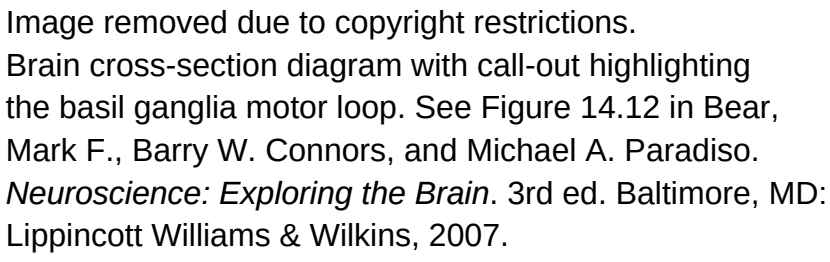
Parkinson's disease is characterized by hypokinesia

- bradykinesia
  - slowness of movement
- akinesia
  - difficulty in initiating voluntary movement
- rigidity
- resting tremor (hands and jaw)
- cognitive deficits

Dopamine neurons are lost in Parkinson's disease

- 1 in 1000
- Neurodegenerative disorder
- Loss of neurons in substantia nigra

The striatum disinhibits the thalamus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Brain cross-section diagram with call-out highlighting the basil ganglia motor loop. See Figure 14.12 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Therapies for PD

- L-dopa
- Pallidotomy
- Deep brain stimulation

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Brain cross-section diagram with call-out highlighting the basil ganglia motor loop. See Figure 14.12 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Huntington's disease is characterized by hyperkinesia

- dyskinesias
  - abnormal movements
- dementia
- personality disorders
- degeneration of striatum

HD is an autosomal dominant genetic disease

- The chance of inheriting HD is 50%.
- A genetic test can determine whether someone will develop the disease.
- The onset is usually 40-50 years of age.

HD is a polyglutamine disease

- The end of the huntingtin (Htt) gene has a trinucleotide repeat: CAGCAGCAG...
- The normal form has less than 40 repeats.

The cerebellum contains about half the brain's neurons

- 10% of total brain volume
- "crystalline" anatomy
- loss of the cerebellum has surprisingly little effect

The cerebellum has gray and white matter divisions

- cerebellar cortex
  - convoluted sheet
- deep cerebellar nuclei
  - output

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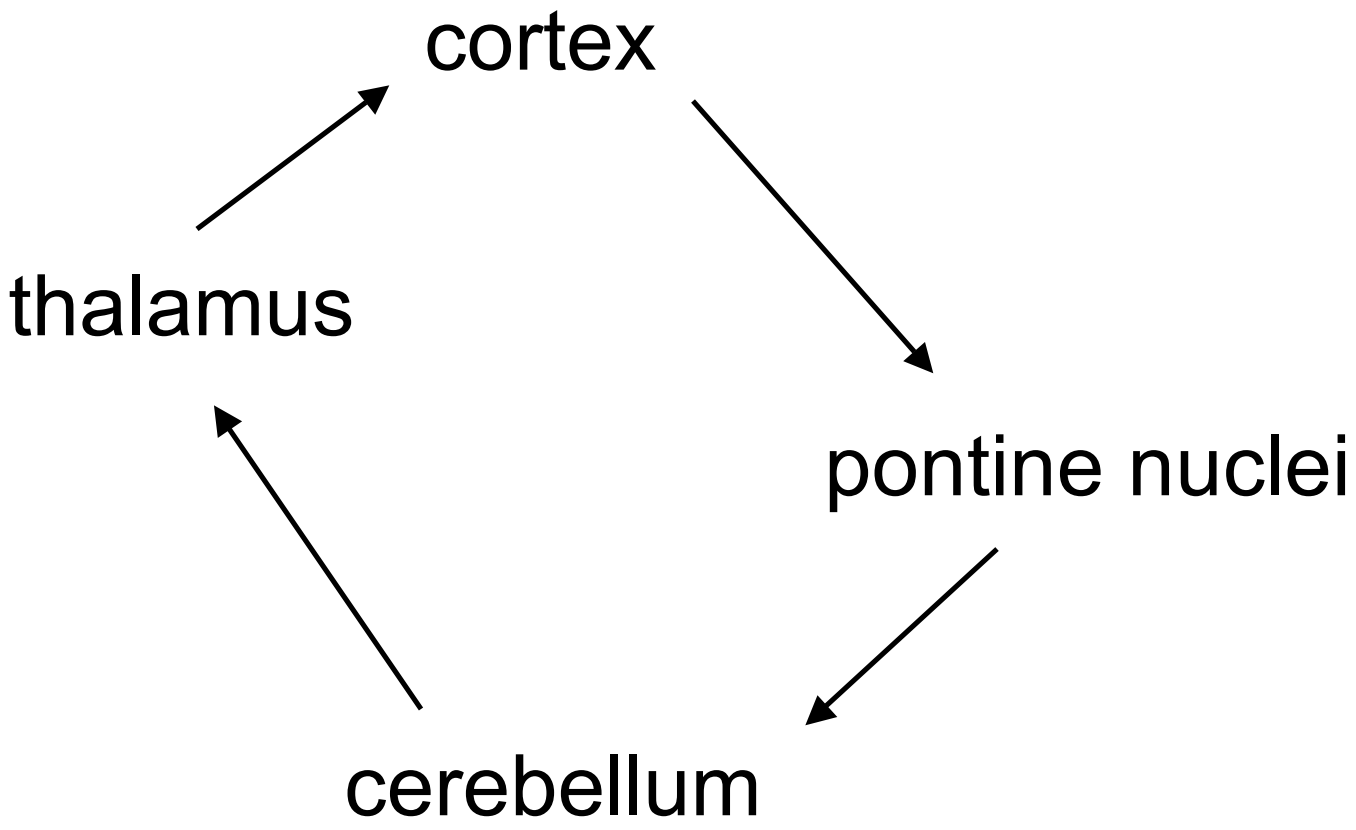
See Figure 14.17 in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007.

Cerebellar damage results in ataxia

- uncoordinated and inaccurate movements
- dysynergia
  - loss of coordinated, multijoint movement
- dysmetria
- intention tremor

There is a loop between the cortex and the cerebellum



Cerebellar function

- fine movement
- equilibrium
- posture
- motor learning