

BMD ENG 301
Quantitative Systems Physiology
(Nervous System)

Final Review Questions from Students

Professor Malcolm MacIver

Final Exam: Friday Dec 9 9am, Split between LR3 and Pancoe (you will get notified which room next week). Extended time room: TBA.

Office hours during Finals week:

Emily Schafer

Tuesday 2:30pm Tech M345

First 30-45 minutes will be review; second half will be normal office hours style. The review will be recorded for students unable to make it.

Thursday 2pm-3:30pm on zoom, at channel

<https://northwestern.zoom.us/j/6162956576>

Weihong Yeo:

Thursday 10-11am Tech E311

Malcolm MacIver

Wednesday 3pm-5pm. Willens Wing Atrium. If you don't find me in Willens Wing Atrium, please knock on my office door in the Willens Wing, B292.

14. What effect(s) on action potentials might you expect to see if the external potassium concentration was reduced? [6 points]

Reducing the external potassium concentration will make E_K and thus the resting potential more negative. Hence, the action potential threshold will be effectively increased; i.e., more depolarization is needed to reach threshold [2 points]. Opening of the potassium channels will limit the membrane potential of the peak of the action potential [2 points]. The undershoot on the declining phase of the action potential will reach a lower membrane potential [2 points].

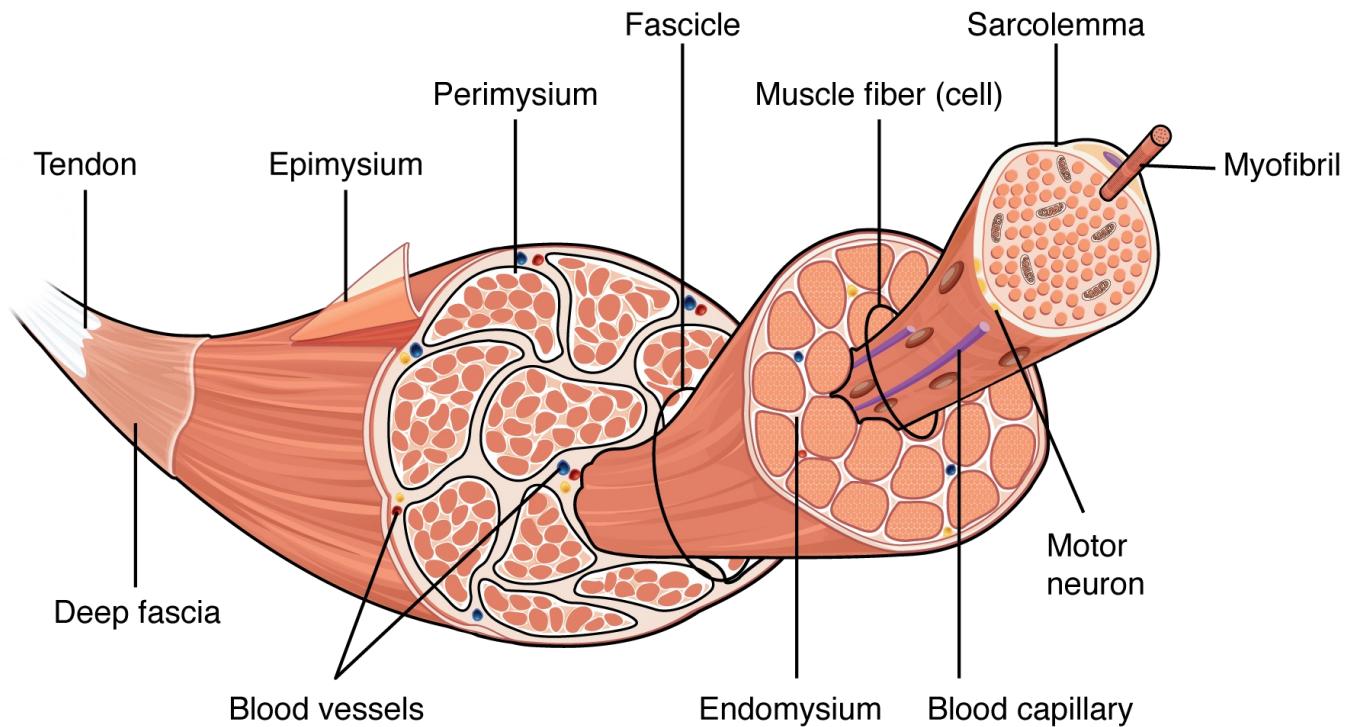
Q: Can we go over the structure of the muscle again (content from the muscle lecture- is the myofibril the smallest unit or is it made up of sarcomeres which are then the smallest unit

Q: Please review stretch reflex circuitry (figure 16.10)

Q: Gamma neurons and modulation of set point of intrafusal fibers

Q: Are soleus muscles extrafusal and tibius anterior muscles intrafusal?

Muscle Structure and the Neuromuscular Junction



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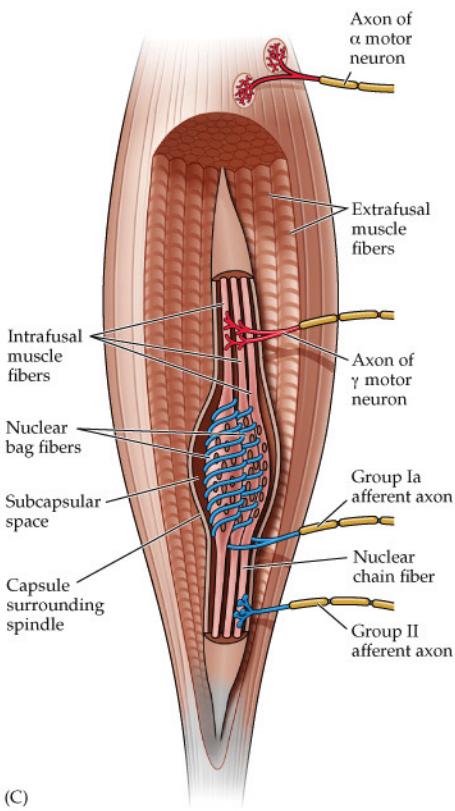
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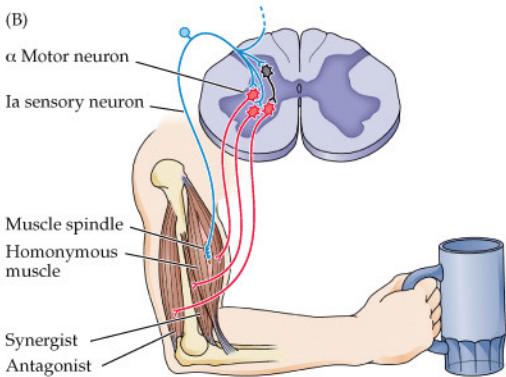
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Stretch reflex circuitry

(A) Muscle spindle



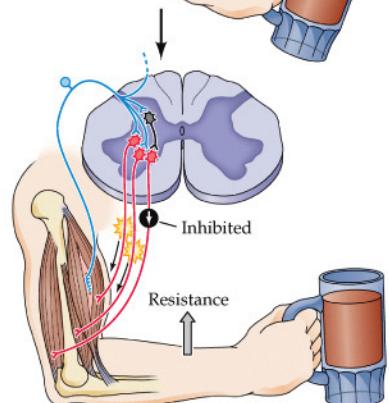
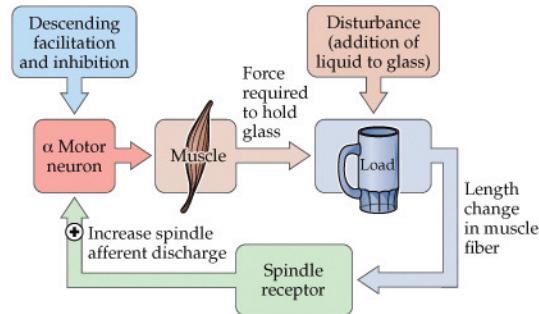
(B)



P. 368:

Group Ia afferents tend to respond phasically to small stretches. This is because Ia afferent activity is dominated by signals transduced by the *dynamic* subtype of nuclear bag fiber whose biomechanical properties are sensitive to the *velocity* of fiber stretch. Group II afferents, which innervate *static* nuclear bag fibers and the nuclear chain fibers, signal the level of *sustained* fiber stretch by firing tonically at a frequency proportional to the degree of stretch, with little dynamic sensitivity. The centrally projecting branch of the

(C)



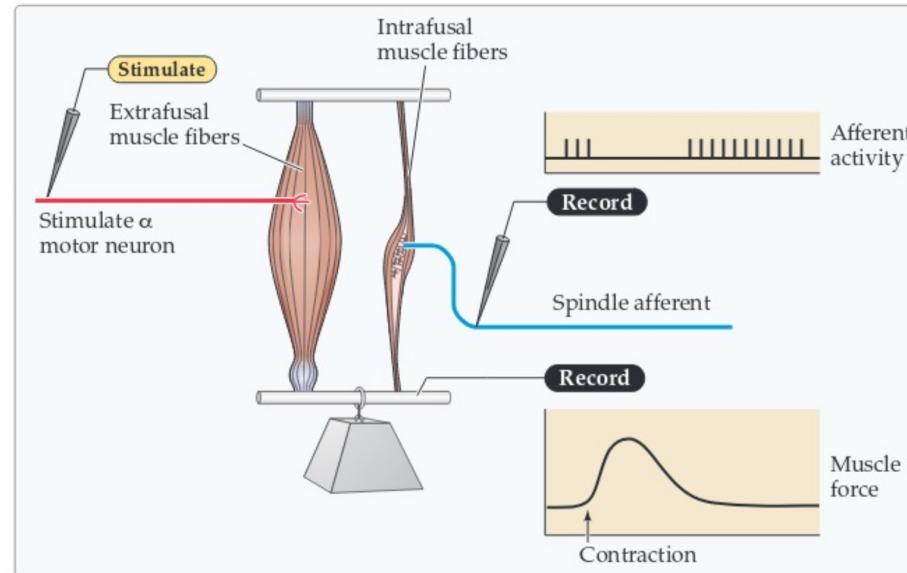
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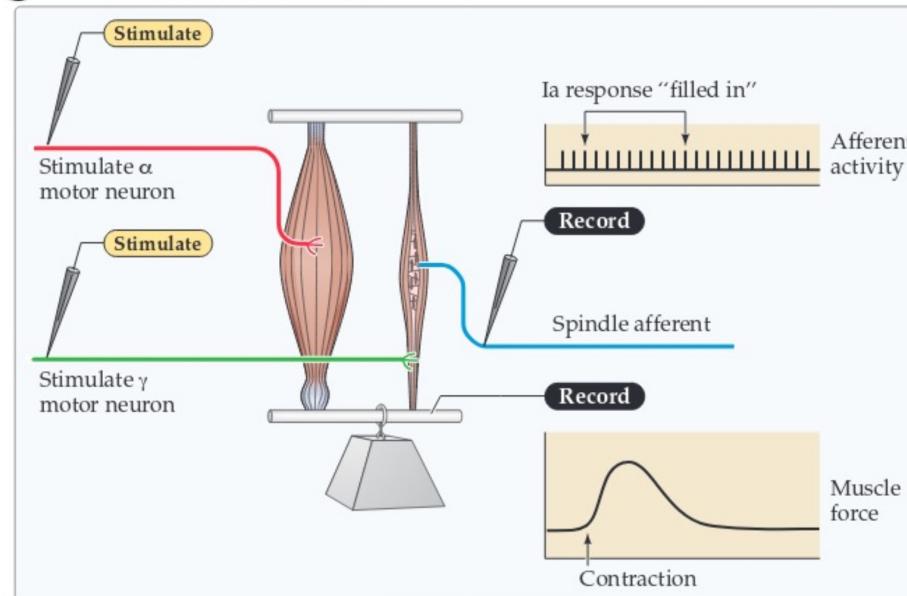
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(A) α Motor neuron activation without γ



↶ (B) α Motor neuron activation with γ



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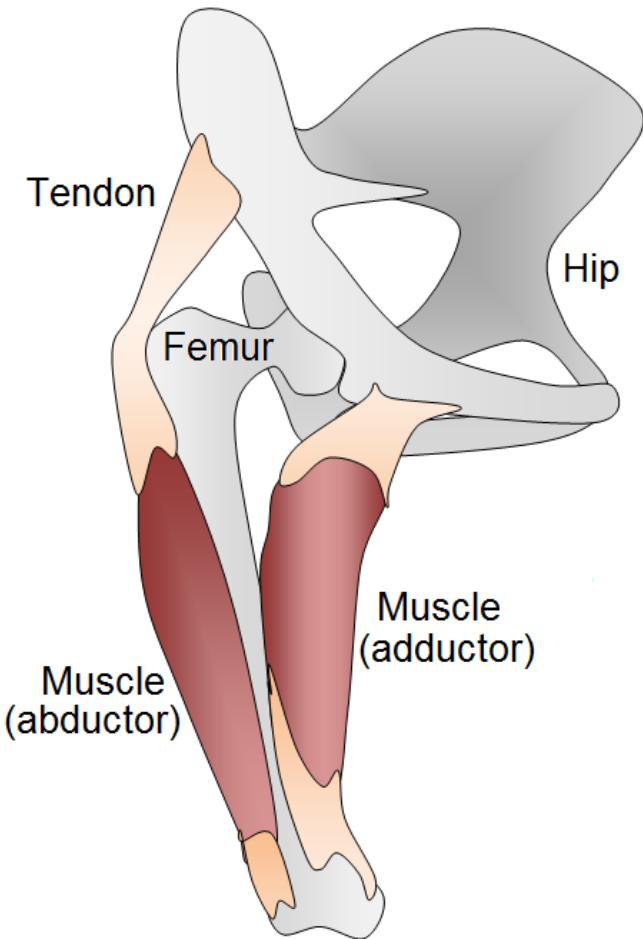
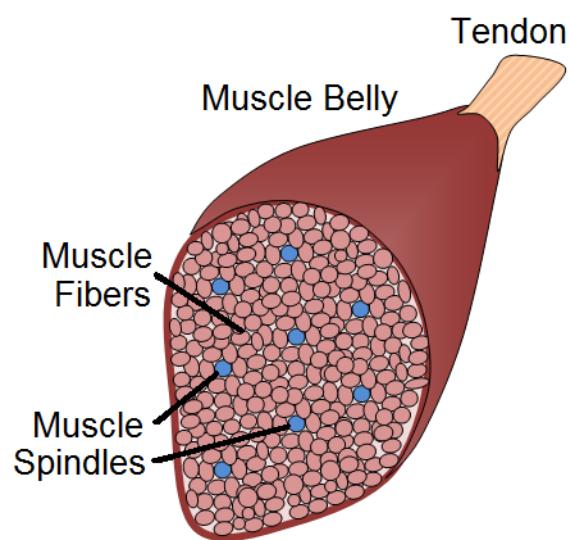
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Placement of Spindles

- ★ Found in almost all muscles
- ★ From 10 to over a 1000 spindles in each muscle
- ★ Number of spindles roughly proportional to size of muscle
- ★ Do not run the length of the muscle
 - ★ except for short muscles



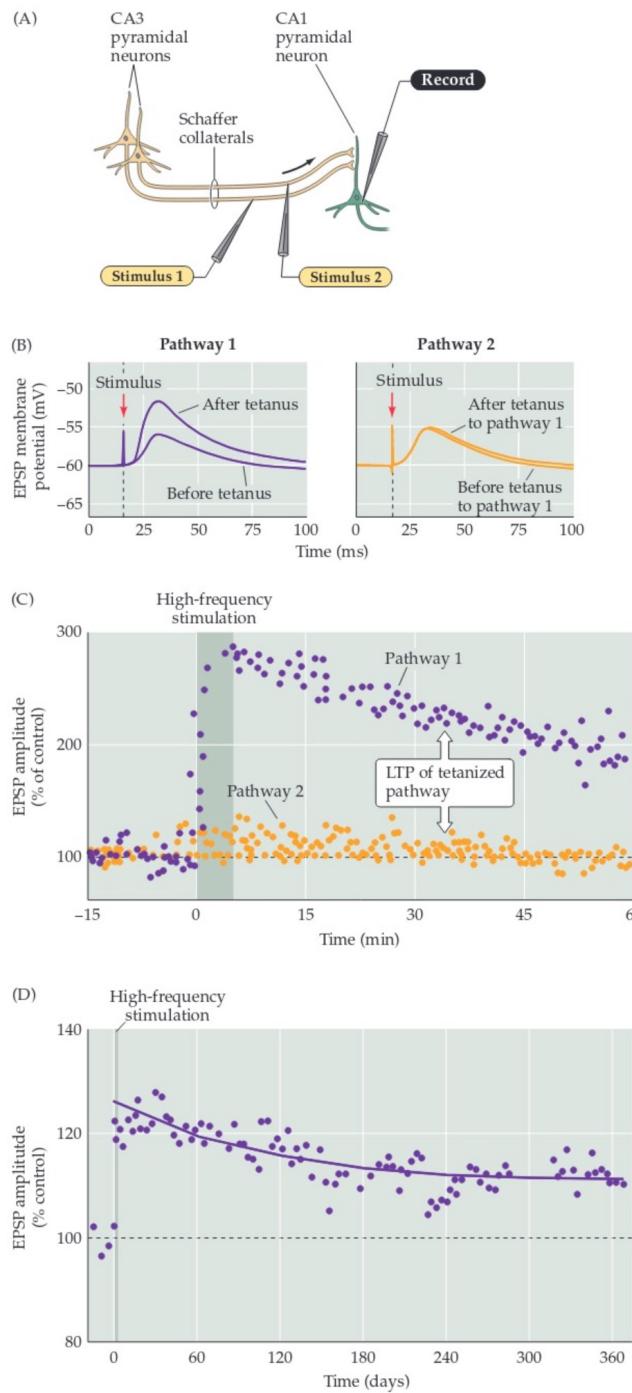
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Q: LTP as it relates to silent synapses

Long-Term Potentiation at a Hippocampal Synapse

Long-term synaptic plasticity has also been identified in the mammalian brain. Here, some patterns of synaptic activity produce a long-lasting increase in synaptic strength known as **long-term potentiation (LTP)**, whereas other patterns of activity produce a long-lasting decrease in synaptic strength, known as **long-term depression (LTD)**. LTP and LTD are broad terms that describe only the direction of change in synaptic efficacy; in fact, different cellular and molecular mechanisms can be involved in producing LTP or LTD at different synapses throughout the brain. In general, LTP and LTD are produced by different histories of activity and are mediated by different complements of intracellular signal transduction pathways in the nerve cells involved.

Fig 8.7



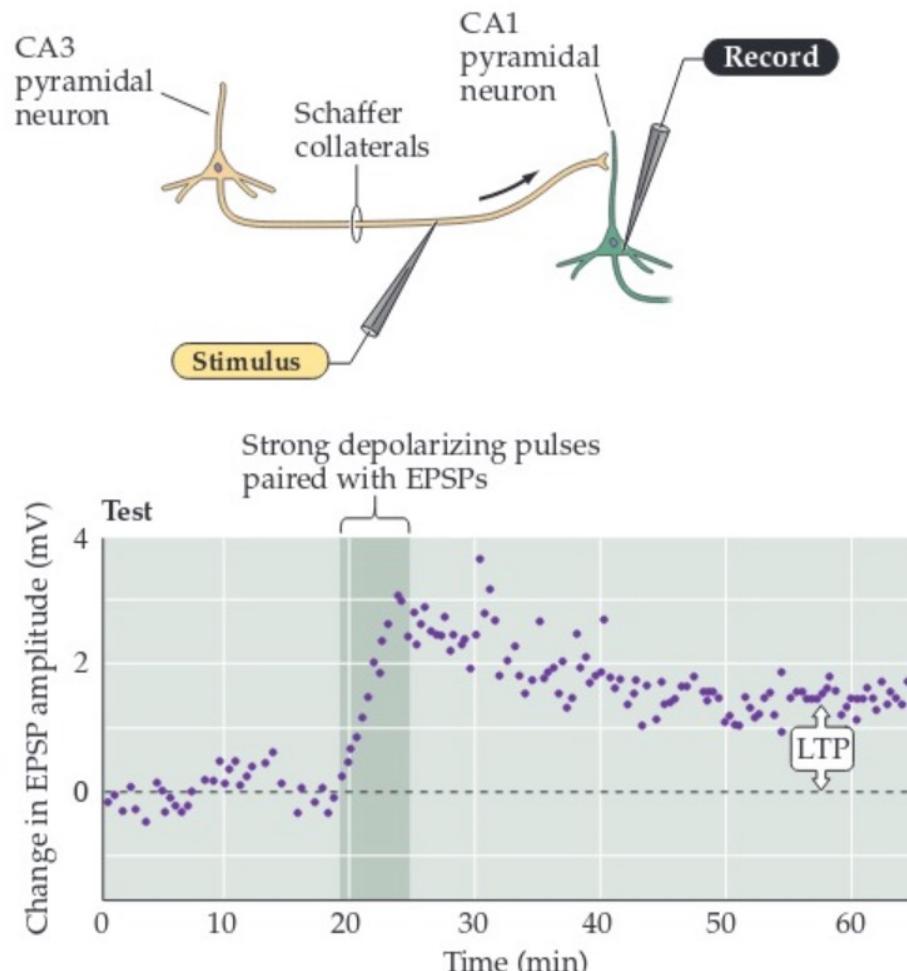
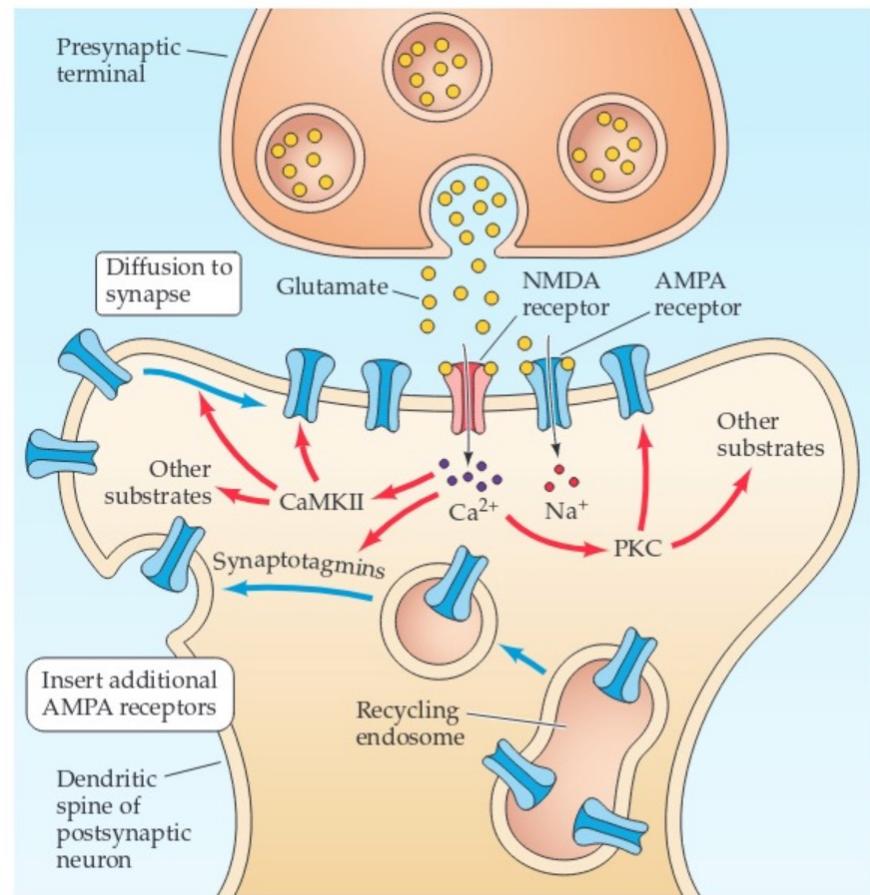


FIGURE 8.8 Pairing presynaptic and postsynaptic activity causes LTP. Single stimuli applied to a Schaffer collateral synaptic input evoke EPSPs in the postsynaptic CA1 neuron. These stimuli alone do not elicit any change in synaptic strength. However, brief polarization of the CA1 neuron's membrane potential (by applying current pulses through the recording electrode), in conjunction with the Schaffer collateral stimuli, results in a persistent increase in the EPSPs. (After Gustafsson et al., 1987.)

FIGURE 8.13 Signaling mechanisms underlying LTP.

During glutamate release, the NMDA receptor channel opens only if the postsynaptic cell is sufficiently depolarized. The Ca^{2+} ions that enter the cell through the channel activate postsynaptic protein kinases, such as CaMKII and PKC, that trigger a series of phosphorylation reactions. These reactions regulate trafficking of postsynaptic AMPA receptors through recycling endosomes, leading to insertion of new AMPA receptors into the postsynaptic spine. Subsequent diffusion of AMPA receptors to the subsynaptic region yields an increase in the spine's sensitivity to glutamate, which causes LTP.



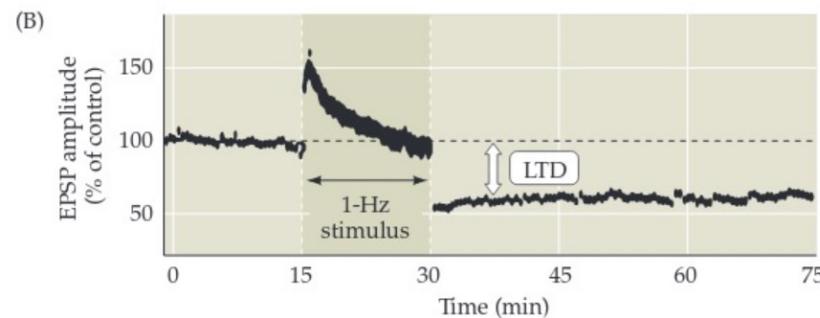
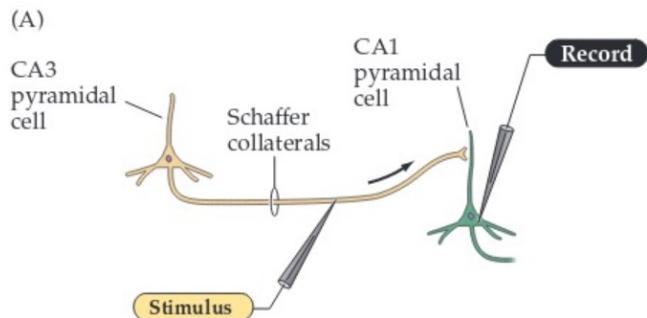
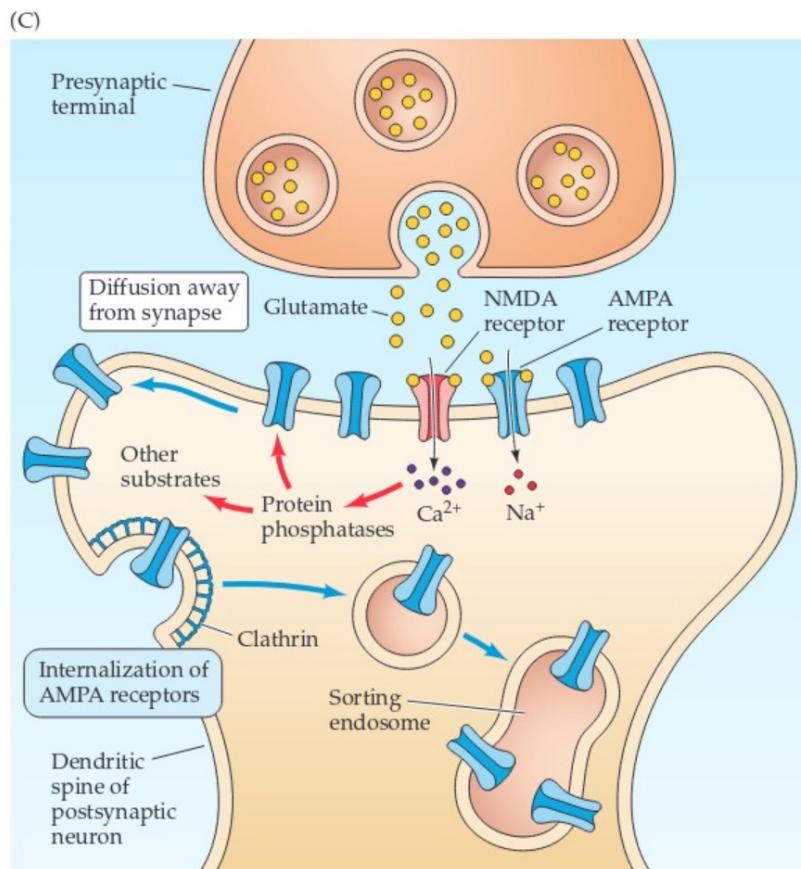


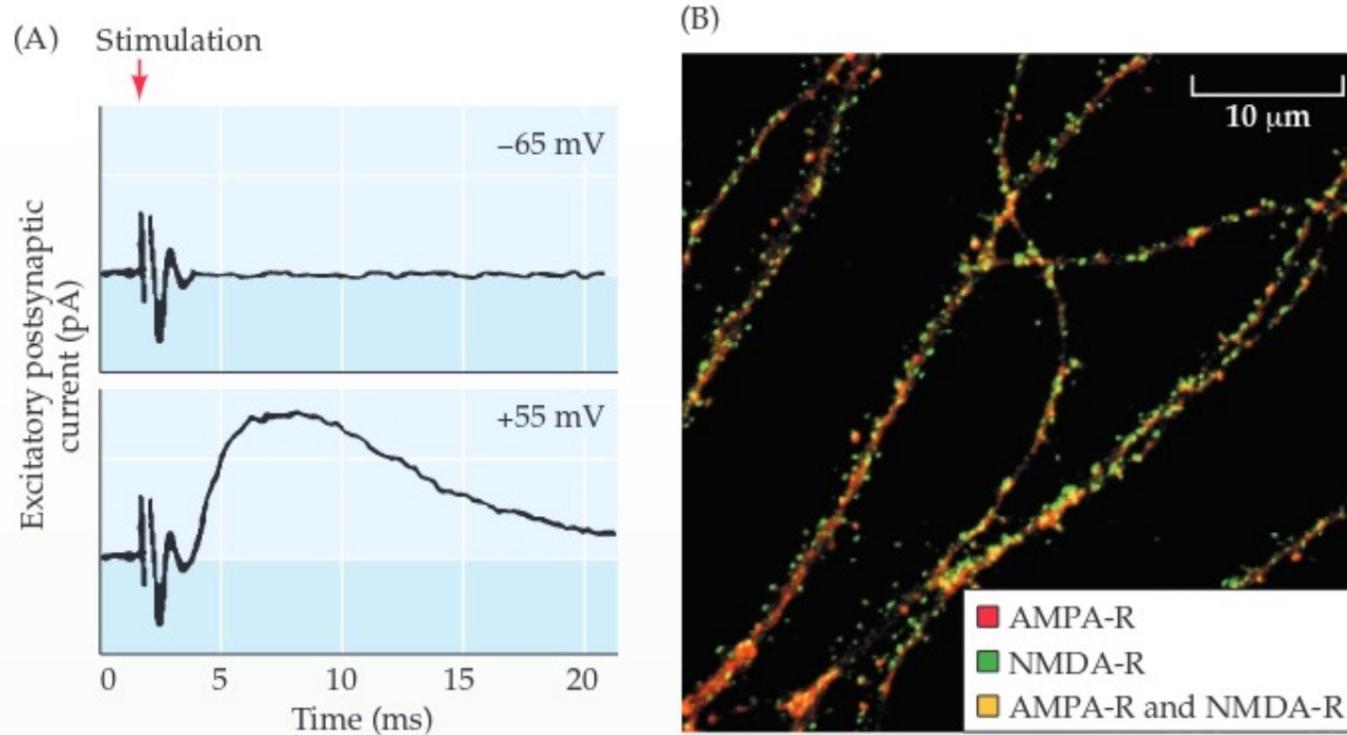
FIGURE 8.16 Long-term synaptic depression in the hippocampus. (A) Electrophysiological procedures used to monitor transmission at the Schaffer collateral synapses on CA1 pyramidal neurons. (B) Low-frequency stimulation (one per second) of the Schaffer collateral axons causes a long-lasting depression of synaptic transmission. (C) Mechanisms underlying LTD. A low-amplitude rise in Ca^{2+} concentration in the postsynaptic CA1 neuron activates postsynaptic protein phosphatases, which cause internalization of postsynaptic AMPA receptors, thereby decreasing the sensitivity to glutamate released from the Schaffer collateral terminals. (B after Mulkey et al., 1993.)



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Q: LTP as it relates to silent synapses

BOX 8B ■ Silent Synapses



(A) Electrophysiological evidence for silent synapses. Stimulation of some axons fails to activate synapses when the postsynaptic cell is held at a negative potential (-65 mV, upper trace). However, when the postsynaptic cell is depolarized (+55 mV, lower trace), stimulation produces a robust response. (B) Immunofluorescent localization of NMDA receptors (green) and AMPA receptors (red) in a cultured hippocampal neuron. Many dendritic spines are positive for NMDA receptors but not AMPA receptors, indicating NMDA receptor-only synapses. (A after Liao et al., 1995; B courtesy of M. Ehlers.)

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Q: LTP as it relates to silent synapses

Q: Review pattern generators

Q: Review MLR and CPG locomotion network

Q: basal ganglia: what is the role of medium spiny neurons?

Q: overarching view of how motion is initiated - do signals originate in motor cortex or do proprioceptive afferents go to cortex first?

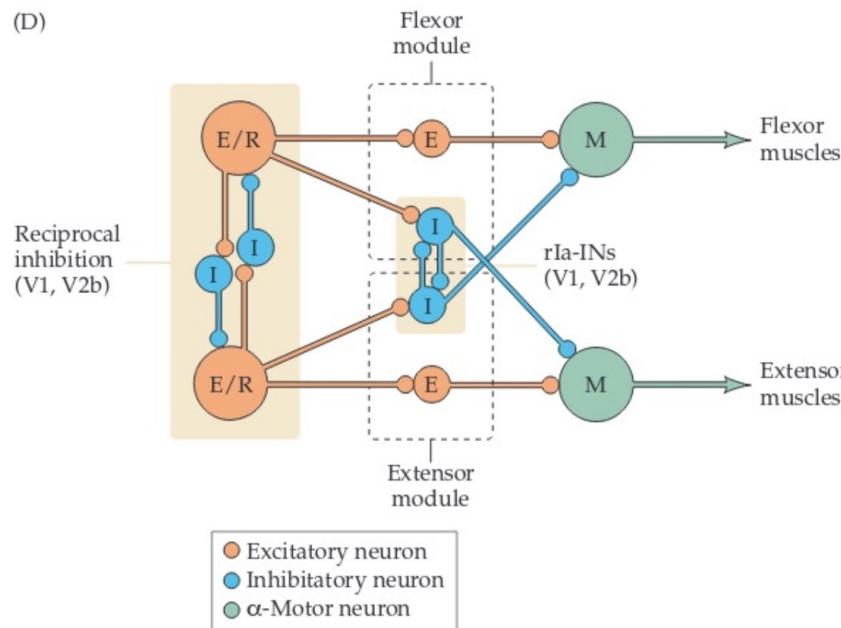
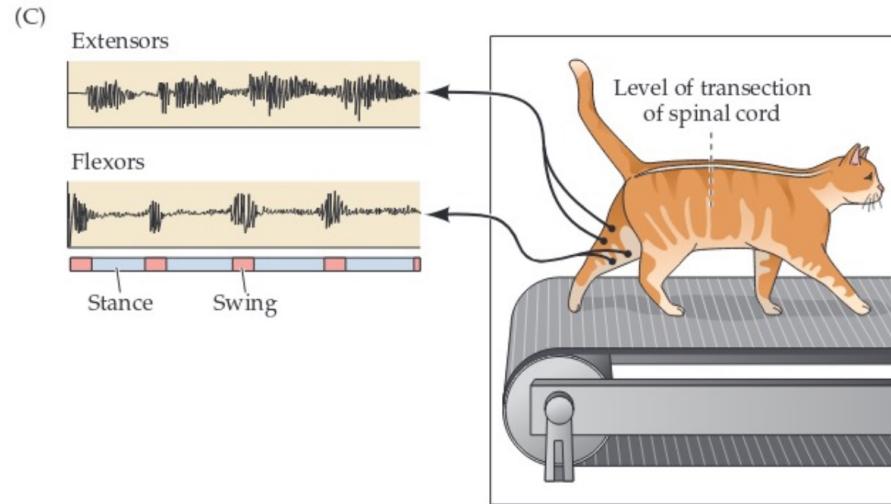
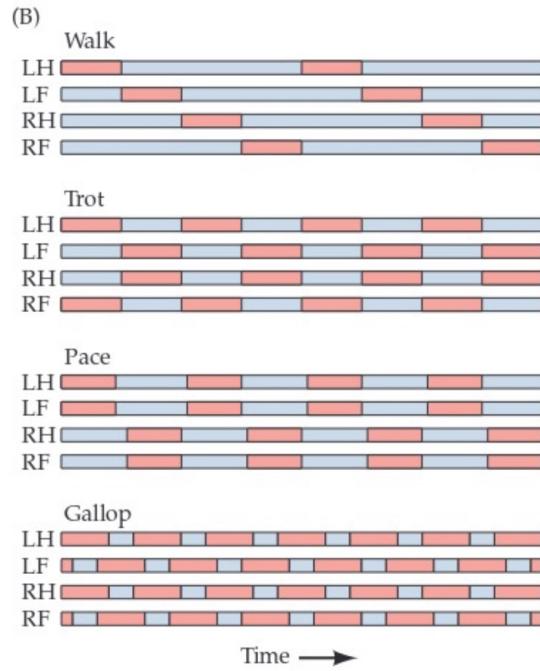


FIGURE 16.15 The mammalian cycle of locomotion is organized by central pattern generators in the spinal cord. The locomotion cycle is shown here for a cat. (A) Diagram and electromyographic recordings of the step cycle, showing leg flexion (F) and extension (E) and their relation to the swing and stance phases of locomotion. (B) Comparison of the stepping movements for different gaits. Pink bars, foot lifted (swing phase); blue bars, foot planted (stance phase). (C) Transection of the spinal cord at the thoracic level isolates the hindlimb segments of the cord. After recovering from surgery, the hindlimbs are still able to walk on a treadmill, and reciprocal bursts of electrical activity can be recorded from flexors during the swing phase and from extensors during the stance phase of walking. (D) Schematic illustrating a circuit for central pattern generation of locomotion. Neuronal modules for flexion and extension antagonism (dashed boxes) comprise excitatory neurons and reciprocally connected Ia inhibitory interneurons (rIa-INs). These modules receive input from excitatory rhythm-generating interneurons (E/R), which are reciprocally inhibited by interneurons belonging to the V1 and V2b classes of spinal cord interneurons (expressing distinct transcription factors and derived from distinct embryonic lineages); rIa-INs also belong to the V1 and V2b neuronal classes. (A-C after Pearson, 1976; D after Kiehn, 2016.)

~~Q: Review pattern generators~~

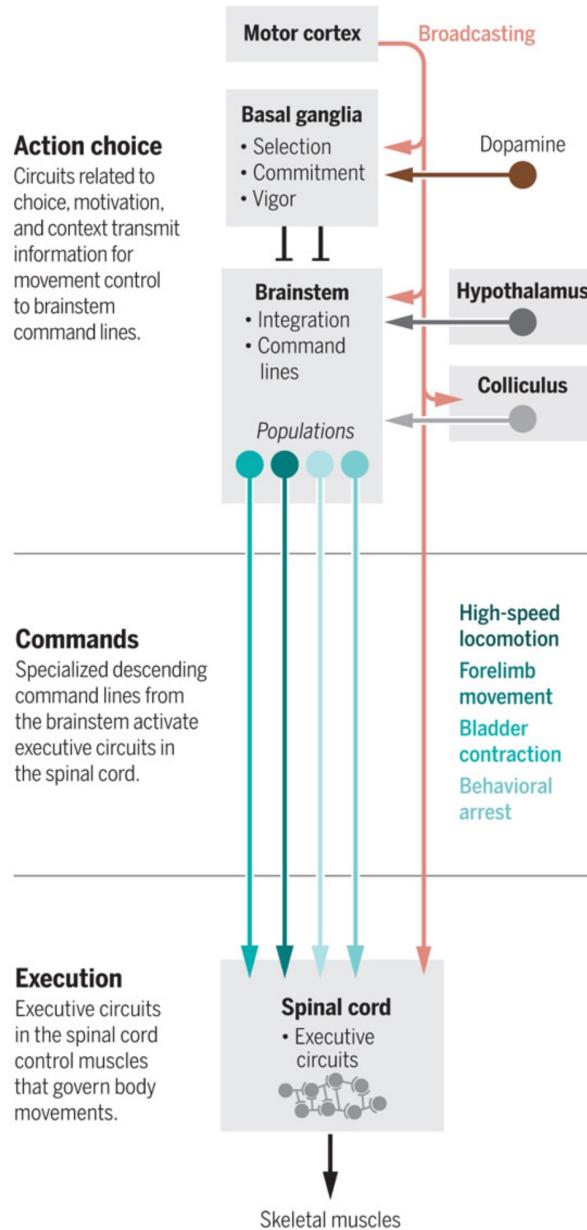
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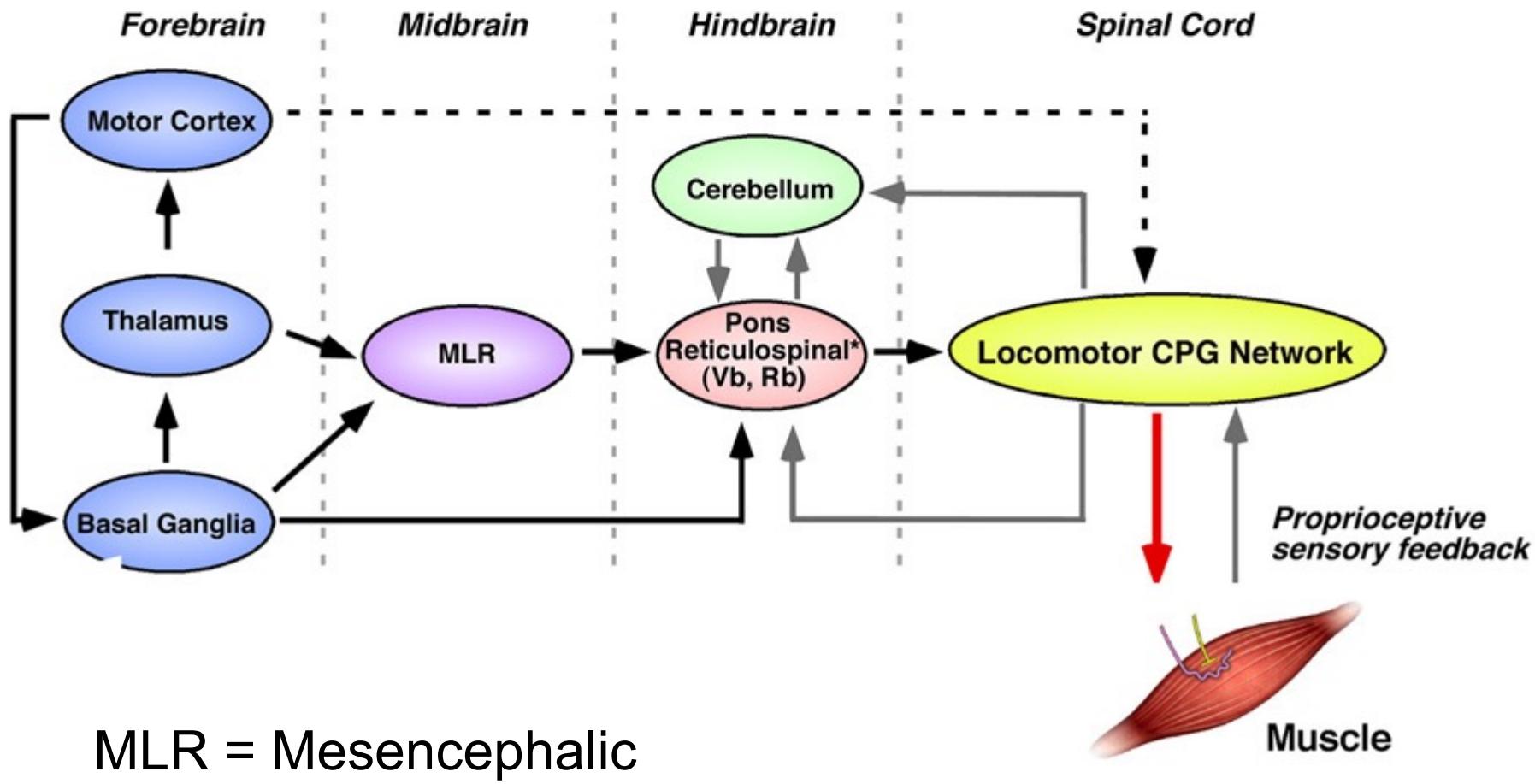
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Circuits for body movements

Movement requires the coordinated activation of many different neuronal populations across multiple brain regions.



The Interacting Parts



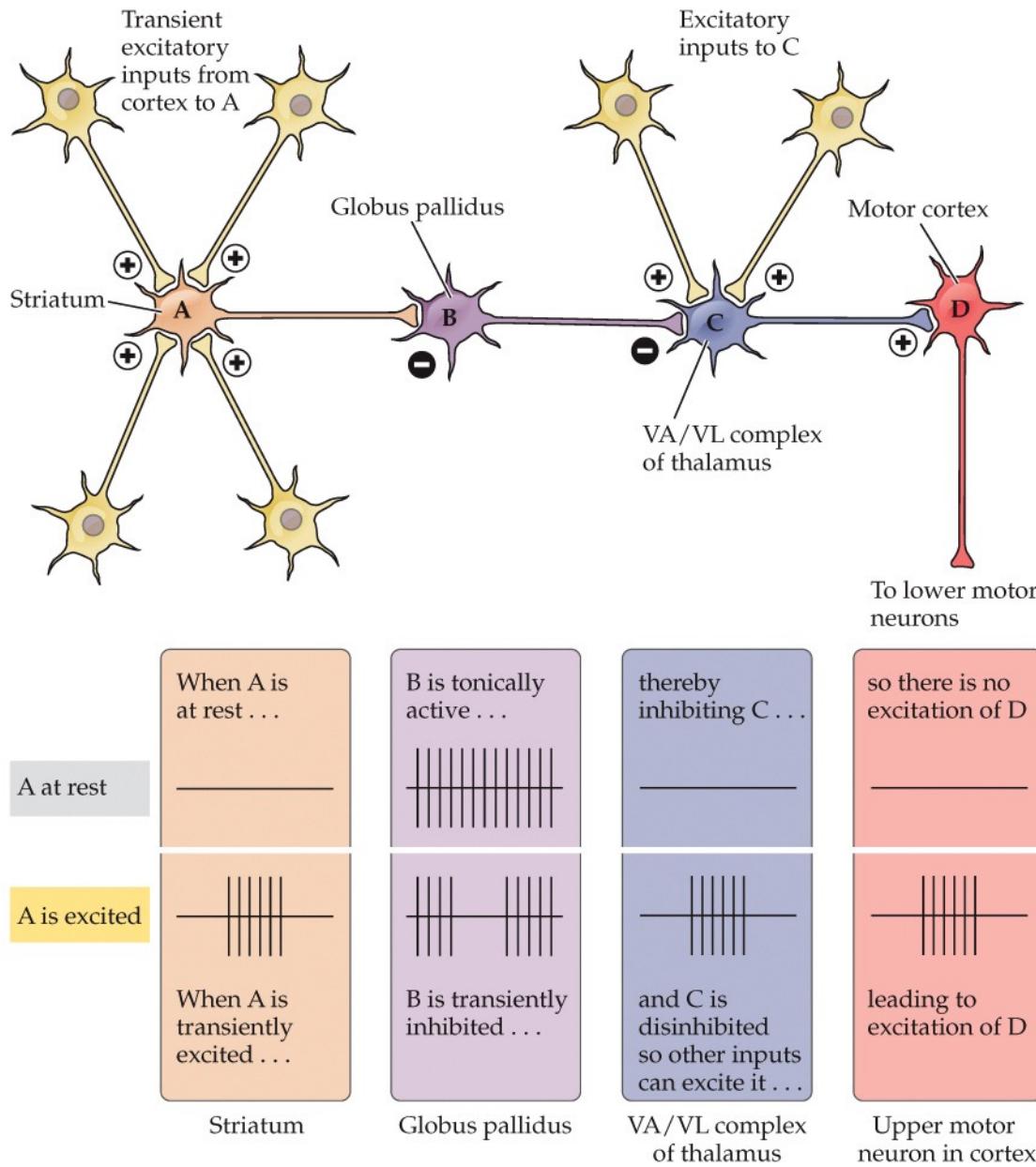
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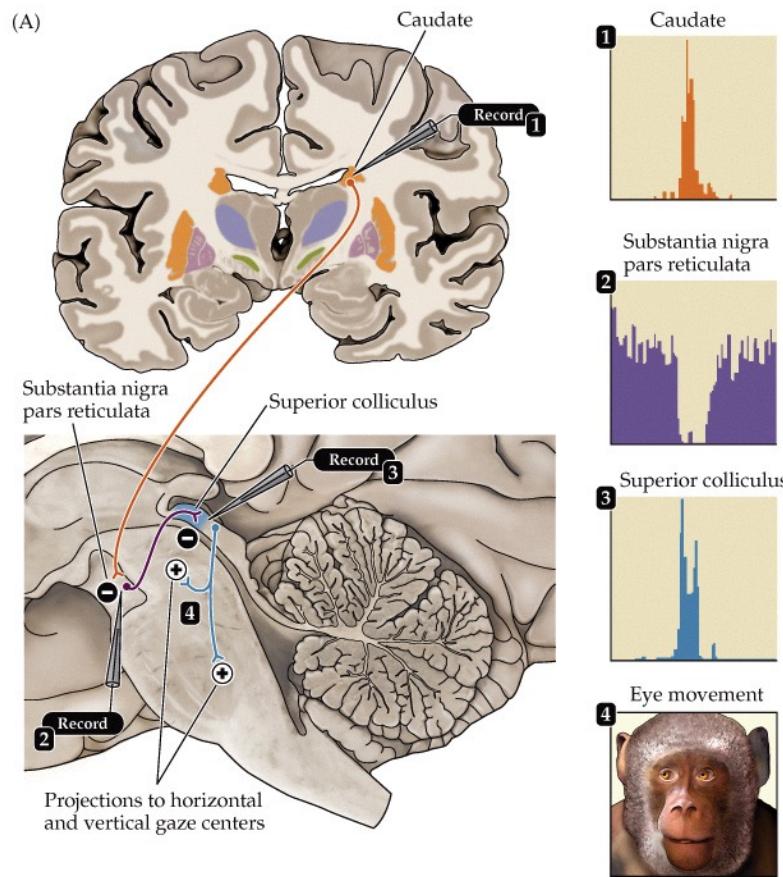
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A chain of nerve cells arranged in a disinhibitory circuit



The role of basal ganglia disinhibition in the generation of saccadic eye movements



Graph 1 after Hikosaka and Wurtz (1986) *Exp. Brain Res.* 63: 659–662; Graphs 2–3 after Hikosaka and Wurtz (1983) *J. Neurophysiol.* 49: 1285–1301.

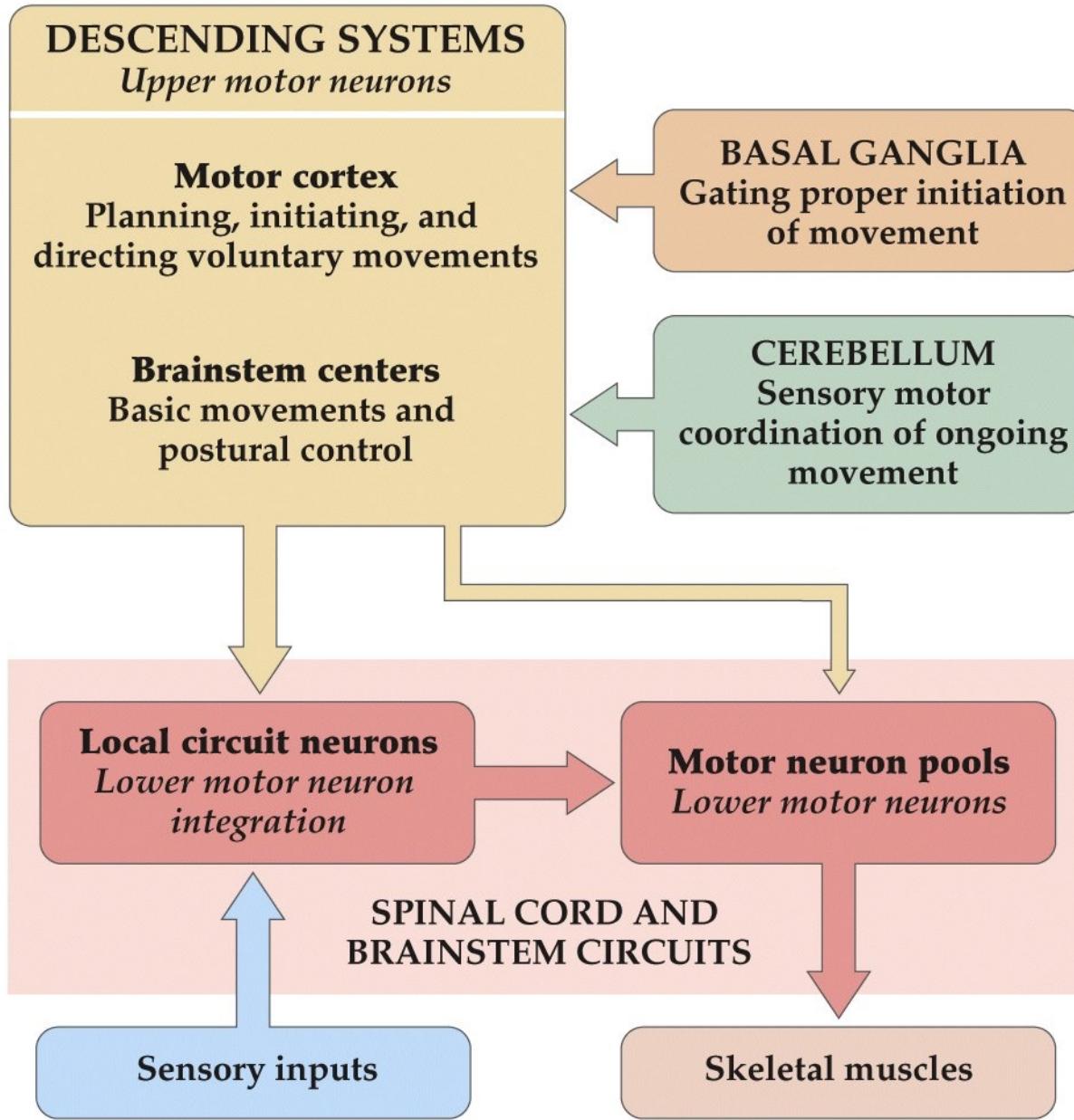
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Organization of neural structures involved in the control of movement



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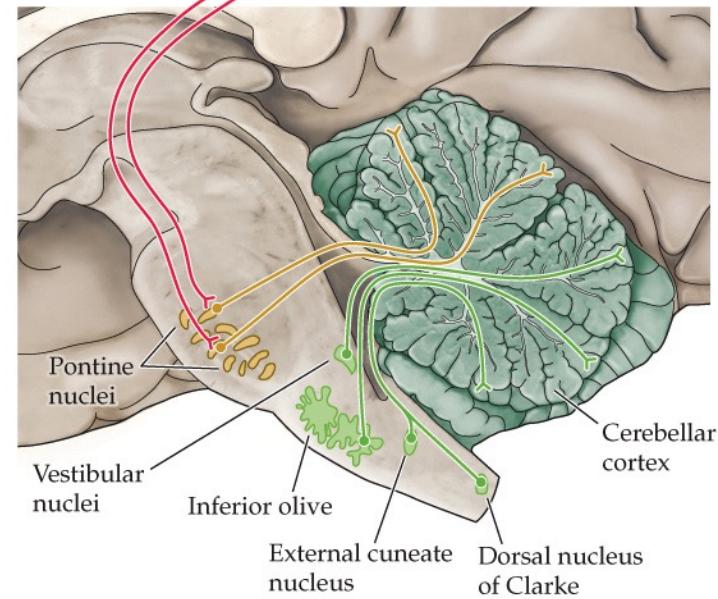
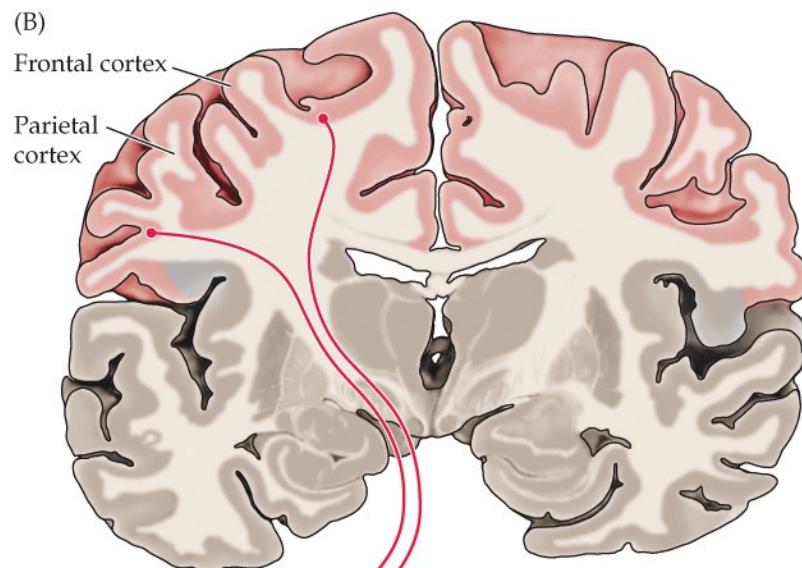
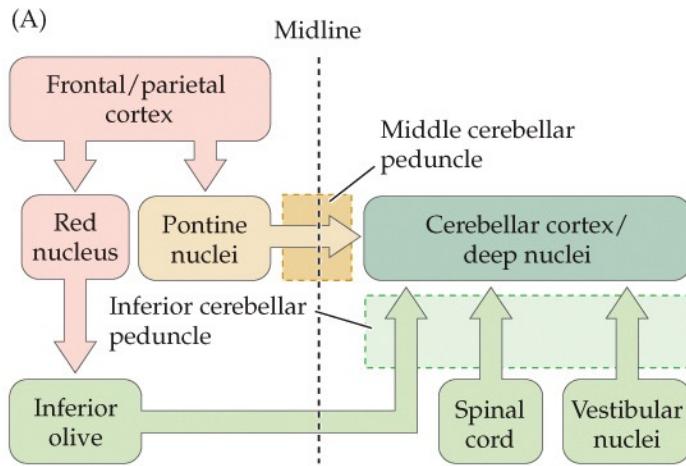
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Q: cerebellum pathways

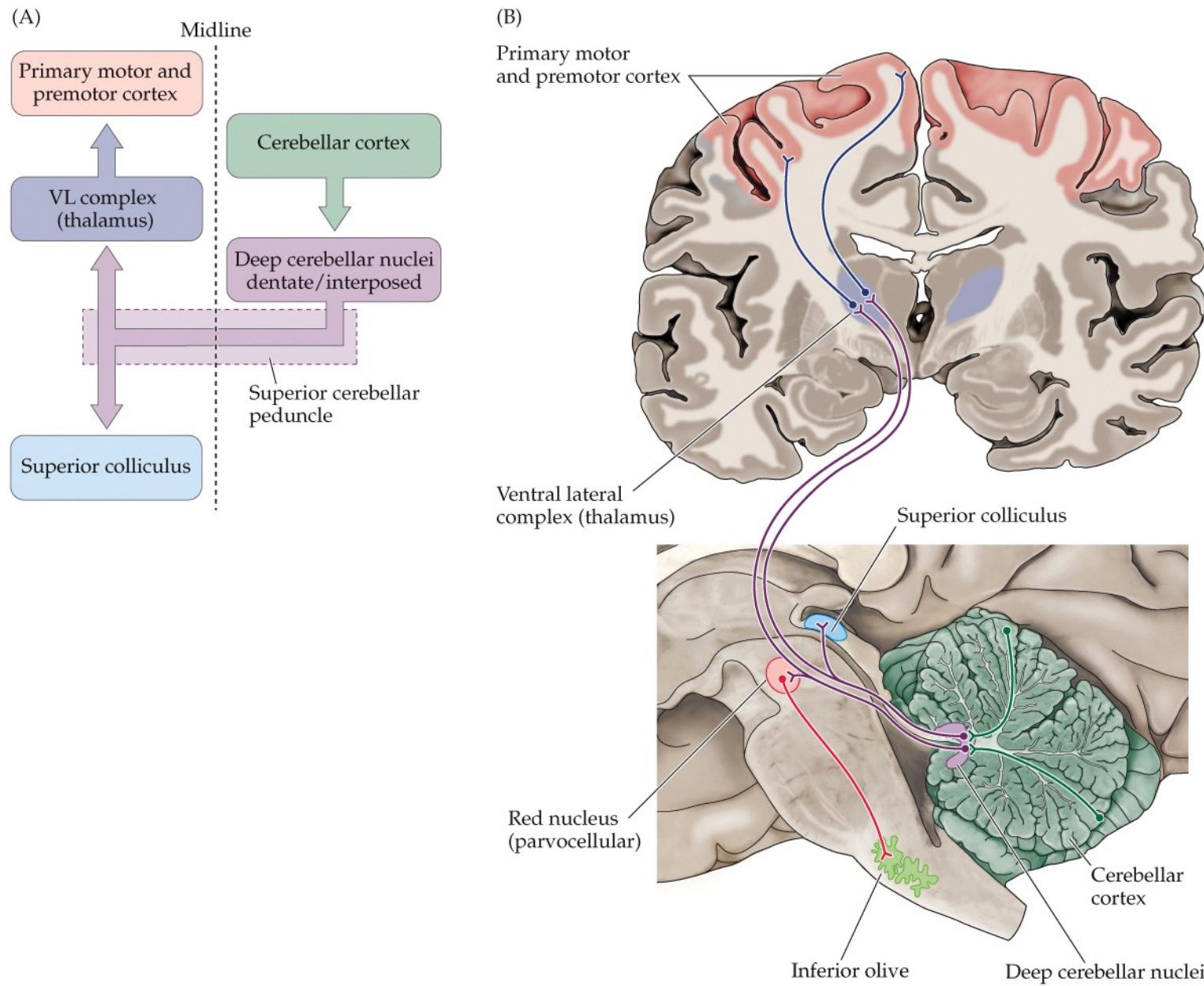
Q: contralateral vs ipsilateral

Q: key functions and processes in cerebellum

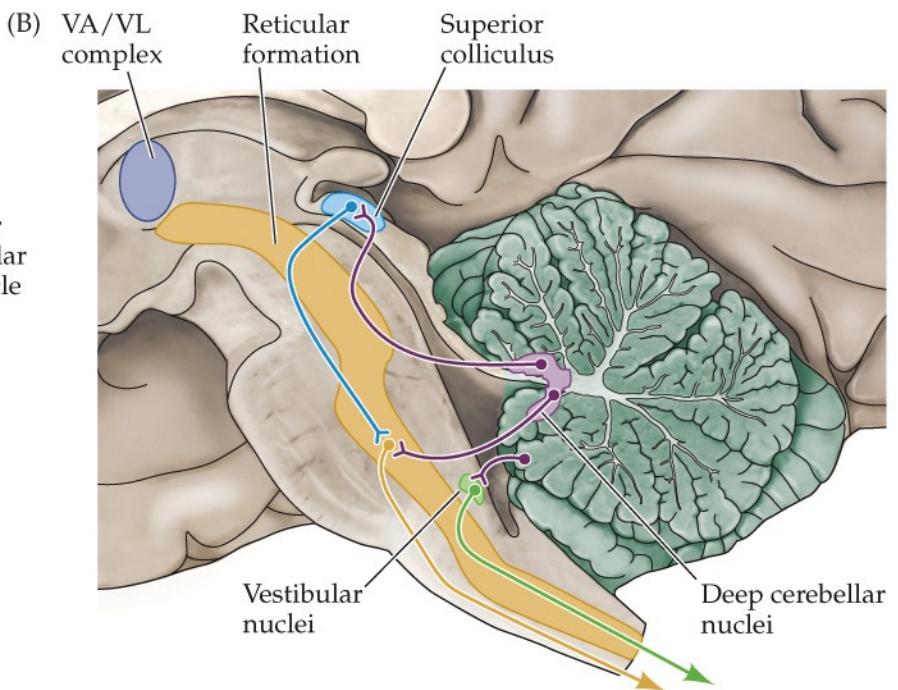
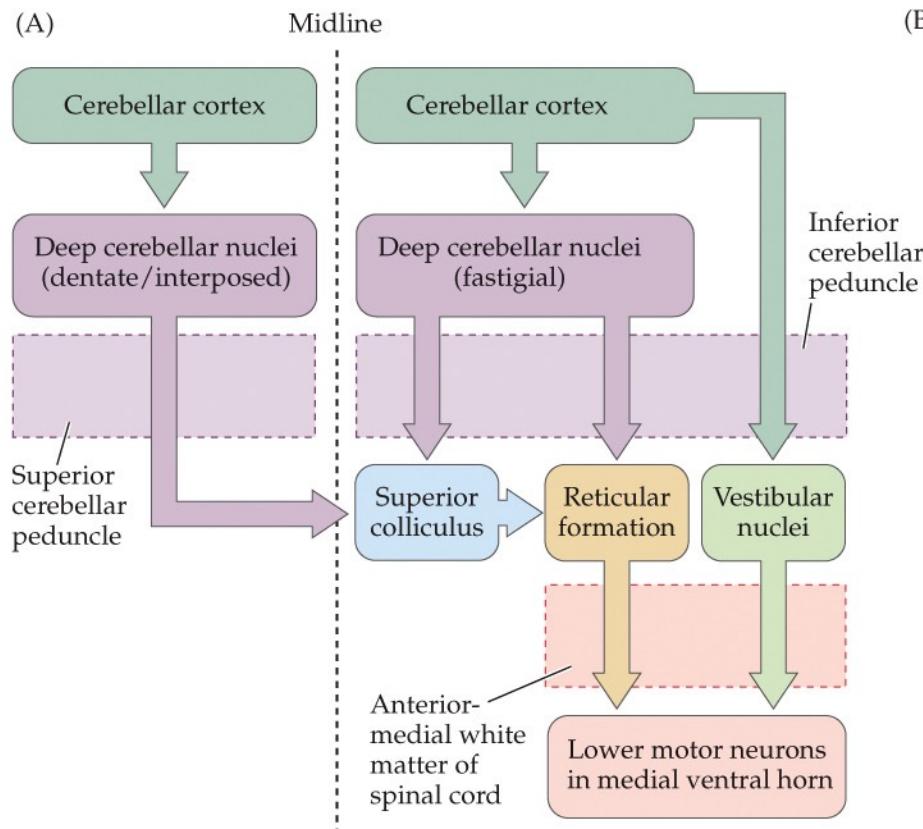
Functional organization of the inputs to the cerebellum



Functional organization of the major outputs from the cerebellum to cortical motor systems



Functional organization of the major outputs from the cerebellum to brainstem motor systems



NEUROSCIENCE 6e, Figure 19.7
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~~Q: cerebellum pathways~~

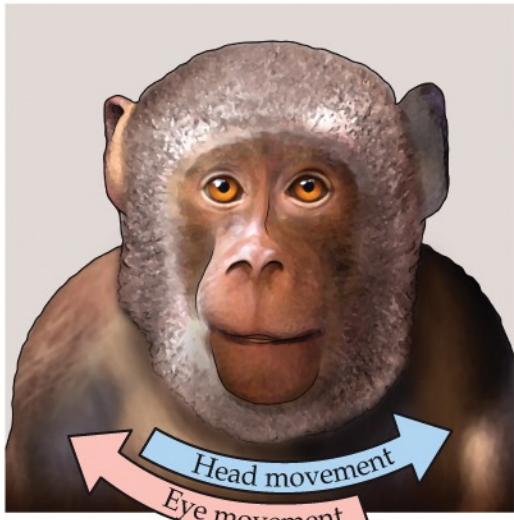
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Q: key functions and processes in cerebellum

- **Cerebrocerebellum** – regulation of highly skilled movements, especially the planning and execution of complex spatial and temporal sequences of movement (including speech)
- **Vestibulocerebellum** – regulation of movements underlying posture and equilibrium
- **Spinocerebellum** – movements of the distal muscles, such as movements of the limbs in walking, movements of proximal muscles and regulation of eye movements in response to vestibular inputs

Learned changes in the vestibulo-ocular reflex in monkeys

Normal vestibulo-ocular reflex (VOR)

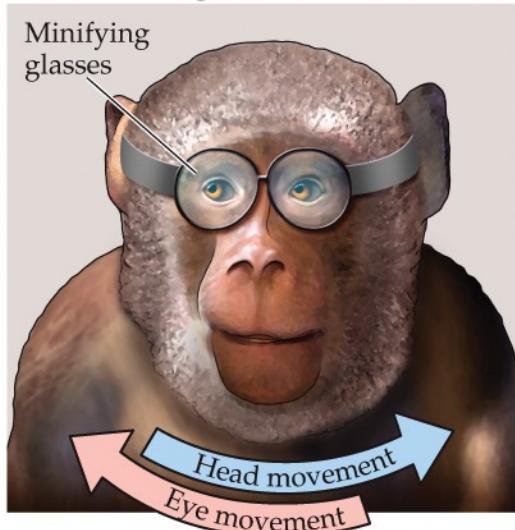


Head and eyes move in a coordinated manner to keep image on retina.

NEUROSCIENCE 6e, Figure 19.14

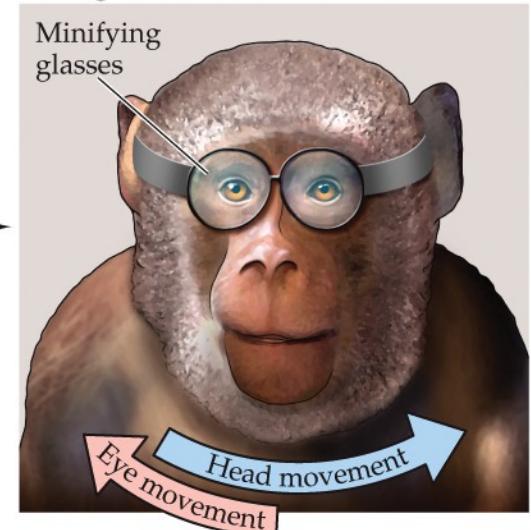
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VOR out of register



Eyes move too far in relation to image movement on the retina when the head moves.

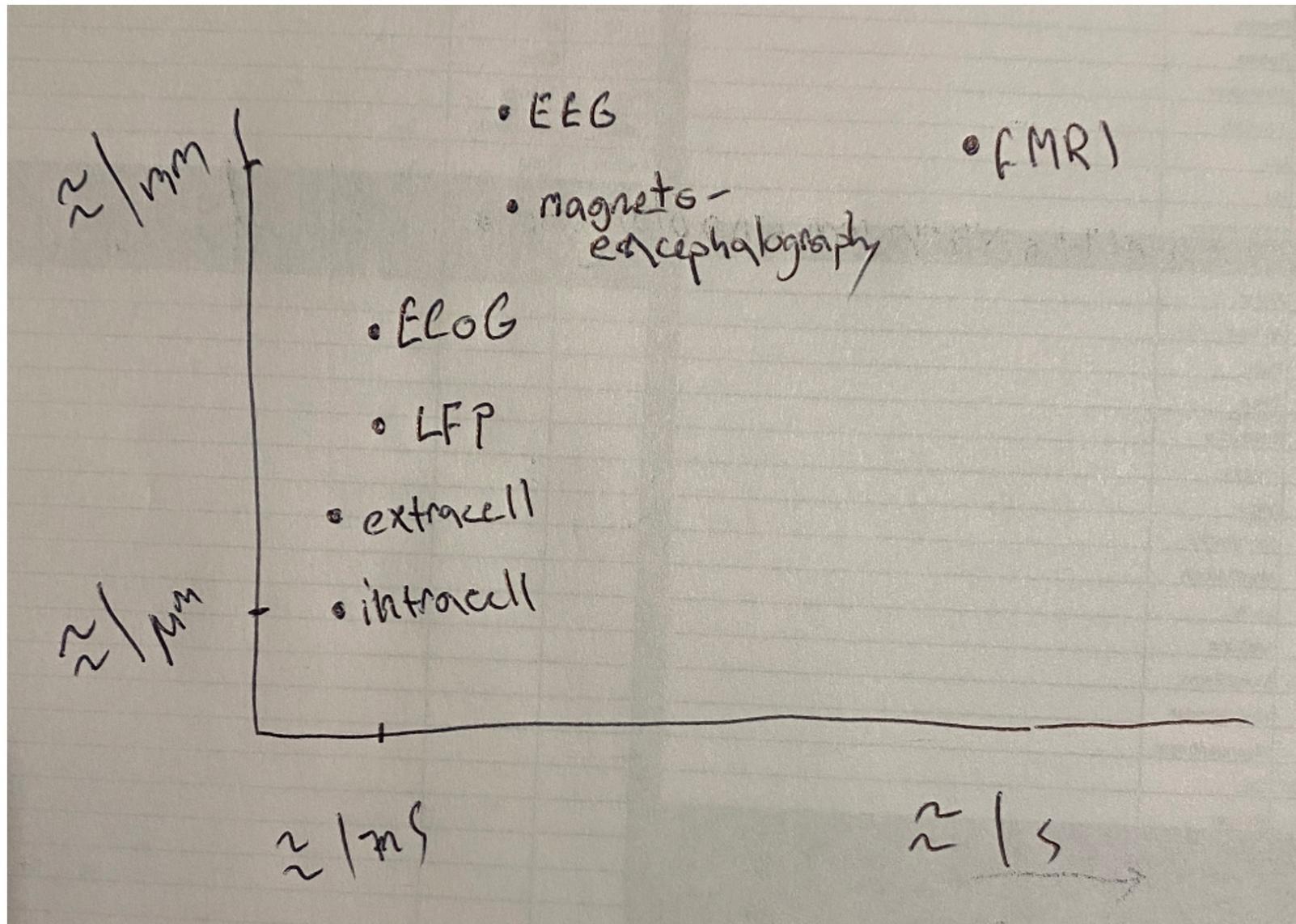
VOR gain reset



Eyes move smaller distances in relation to head movement to compensate.

Q: list of techniques for monitoring neural signals

Q: Spatial & temporal resolution for functional brain imaging techniques



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~~Q: Spatial & temporal resolution for functional brain imaging techniques~~