BIEN500- Fall 2023

- Organization of spinal cord
- Sensory receptors / Muscle spindles
- Different types of reflexes
- Voluntary movement
- 3 major areas of the motor cortex
- Role of brain stem in motor control
- Cerebellum and Basal ganglia for motor control

Lecture 17

(Some materials incorporated from Dr. A. Chiu)

Spinal Cord Function

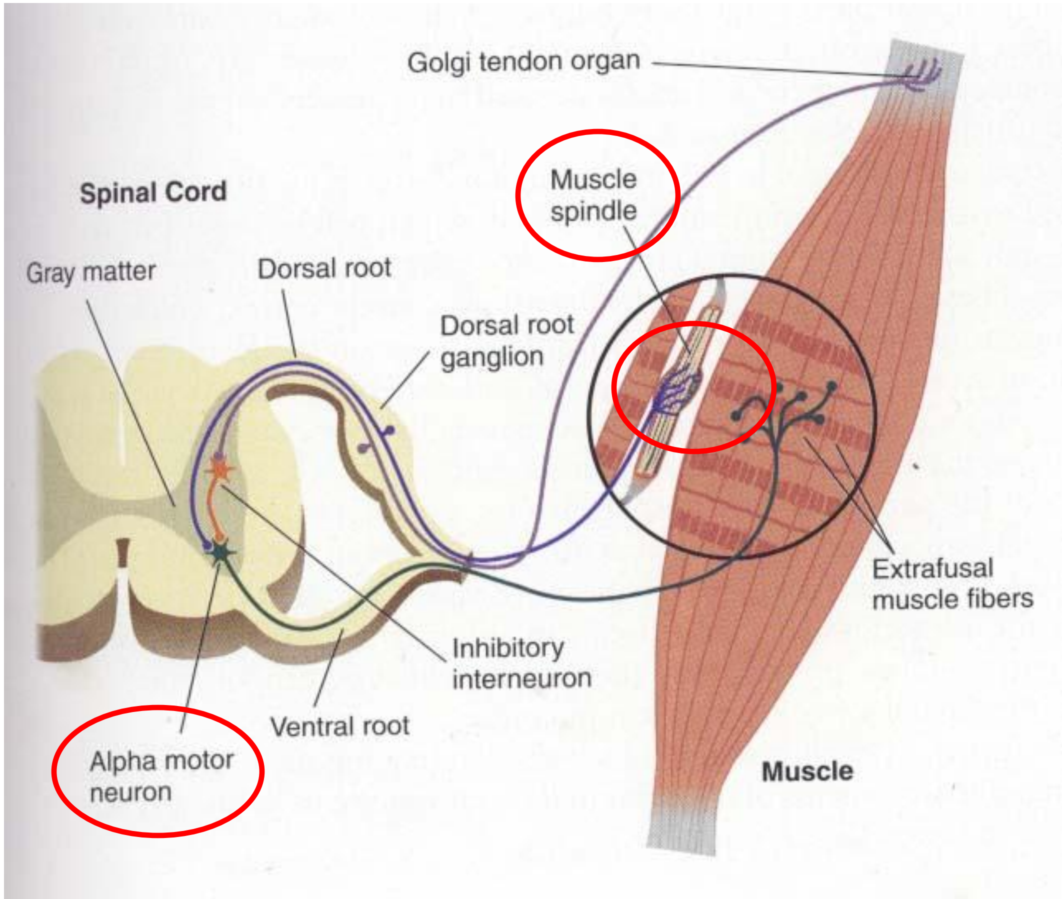
- Conduct signals between the brain and the periphery of the body.
- Some level of signal processing may be needed:
  - Reflex actions
  - More complicated actions, such as walking

Spinal Cord Function-02

Sensory Information is integrated at all levels of the nervous system and causes appropriate motor responses that begin in the spinal cord with relatively simple muscle reflexes, extend into the brain stem with more complicated responses, and finally extend to the cerebrum, where the most complicated muscle skills are controlled.

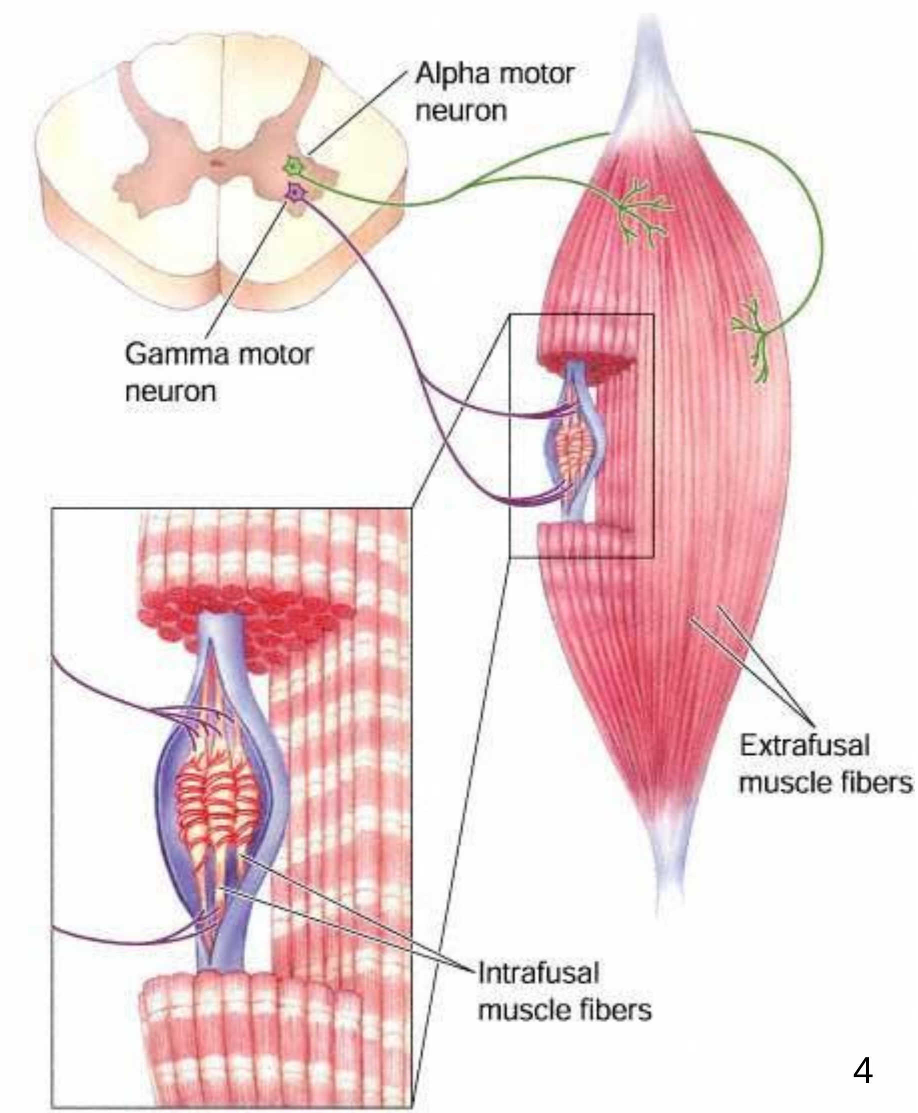
Spinal Cord Divisions

- **Anterior Motor Neurons**
  - Alpha Motor Neurons
    - Type Aα nerve fibers
    - Enervate large skeletal muscles
    - Stimulate 3 to several hundred fibers each
  - Gamma Motor Neurons
    - Type Aγ nerve fibers
    - Send signals to muscle spindles
- **Interneurons**
  - Perform Integrative functions
  - Most signals in spine are processed through these



Receptor Function of Muscle Spindle

- small group of muscle fibers walled off by a collagen sheath.
- intrafusal fibers vs extrafusal fibers
- Stimulated by stretching
- Send signals as a result of
  - muscle length
  - changes in length.



Local control by spinal cord

Need for spinal cord and benefits for potential recover mechanisms:

Example: there is no neuronal circuit anywhere in the brain that causes the specific to-and-fro movement of the legs that is required for walking. Instead, the circuits for these movements are in the cord, and the brain simply sends commands to signal the spinal cord to in motion the walking process.

Alpha and Gamma motor neurons

These give rise to large type A alpha (Aα) motor neuron fibers, with average diameter of 14 microns. These fibers branch many times after they enter the muscle and innervate the large skeletal muscle fibrils. Stimulation of a single α nerve fiber excites anywhere from 3-several hundred skeletal muscle fibers, which are collectively called the motor unit.

Gamma motor neurons transmit impulses through much samller type A gamma (Aγ) motor nerve fibers, with average diameters of 5 microns. These go to the center of the muscle spindle and help to control basic muscle “tone”.

Interneurons in the Spinal Cord

Only a few incoming sensory signals from the spinal neurons or signals from the brain terminate directly on the anterior motor neurons. Instead, almost all these signals are transmitted first through interneurons, where they are appropriately processed.

Interneurons-02

--Interneurons are present in all areas of the cord gray matter These cells are about 30 times as numerous as the anterior motor neurons.
--They are small, and highly excitable, often exhibiting spontaneous activity and capable of firing as rapidly as 1500 times per second.

The interconnections among the interneurons and anterior motor neurons are responsible for most of the integrative functions of the spinal cord.
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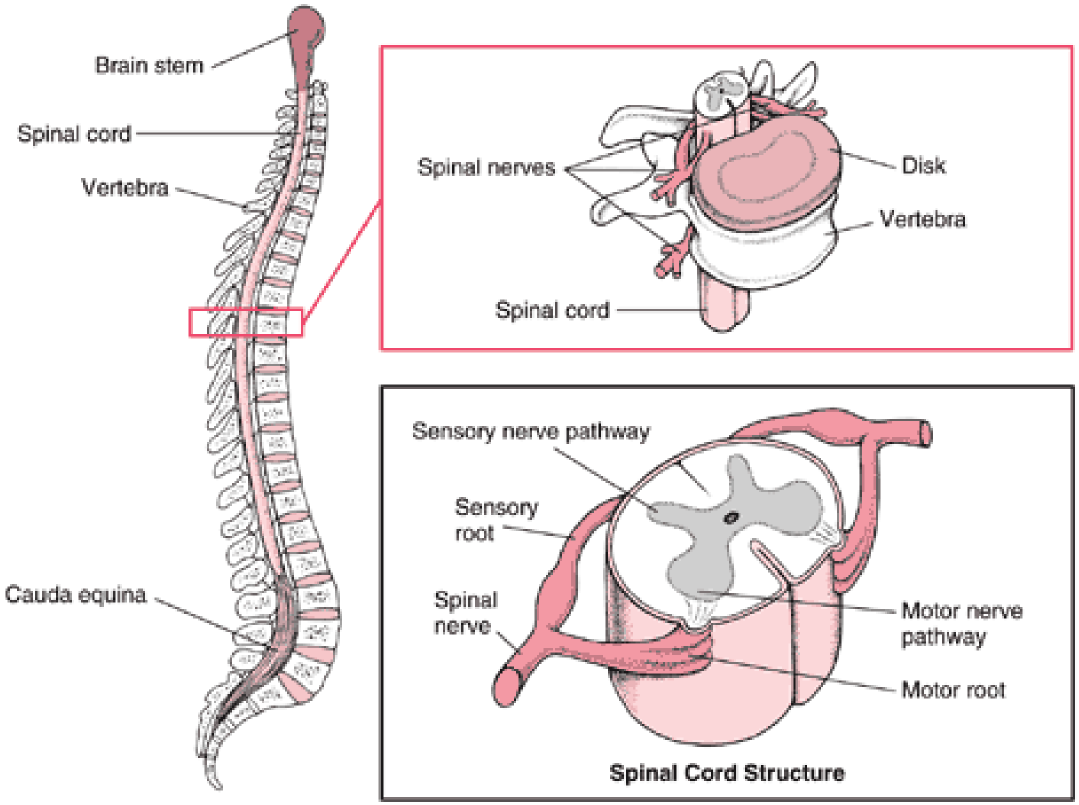
Spinal Cord & Reflexes

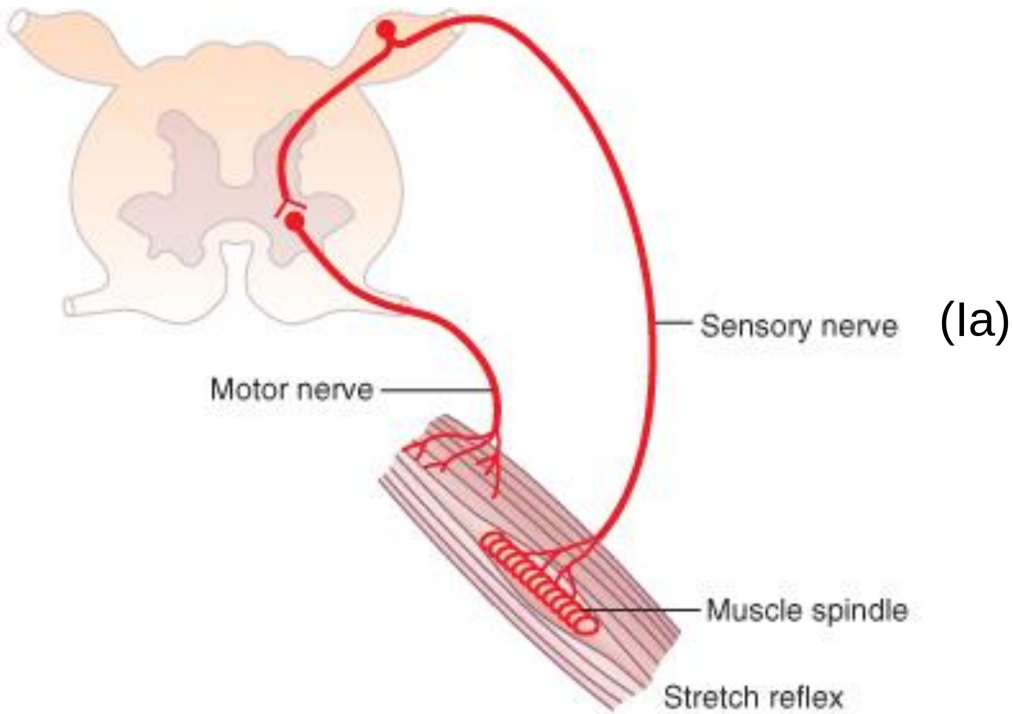
"involuntary movement": based on reflexes which involves sense organs (affectors) and effectors.



http://www.merck.com/media/mmhe2/figures/fg076_2_2.gif

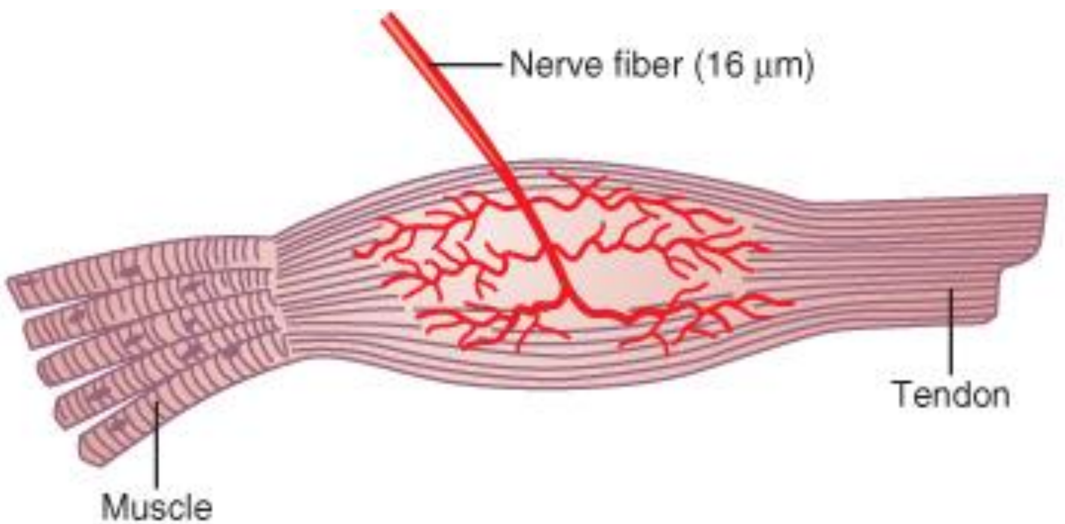
Muscle Stretch Reflex

- Muscle stretch causes contraction
  - First dynamic (short term), then static (long term)
  - Shortening of muscle will cause inhibition
  - Monosynaptic



Golgi Tendon Organ

- Encapsulated sensory receptor
- Detects tension rather than length.
- Found between tendon and muscle.
- Signals transmitted by type Ib nerve fibers.
- Negative feedback to prevent overstimulation.
- May help even out muscle load on fibers.



Muscle Sensory Receptors

- Proper control of muscle function requires not only excitation of the muscle by spinal cord anterior motor neurons but also continuous feedback of sensory information from each muscle to the spinal cord, indicating the functional status of each muscle at each instant.
- That is : what is the length of the muscle?- what is the instantaneous tension?- how rapidly is the length or tension changing?
- To provide this information the muscles and their tendons are supplied abundantly with two special types of sensory receptors: 1) muscle spindles and 2) golgi tendon organs..

Muscle Sensory Receptors-02

- 1) muscle spindles are distributed throughout the belly of the muscle and send information to the nervous system about muscle length or rate of change of length.
- 2) golgi tendon organs- are located in the muscle tendons and transmit information about tendon tension or rate of change of tension.

- The signals from these two receptors are almost entirely for the purpose of intrinsic muscle control. They operate almost completely at a subconscious level. However, they do transmit tremendous amounts of information not only to the spinal cord but also to the cerebellum and even to the cerebral cortex, helping these portions of the nervous system function to control muscle contraction ..

Different types of reflexes

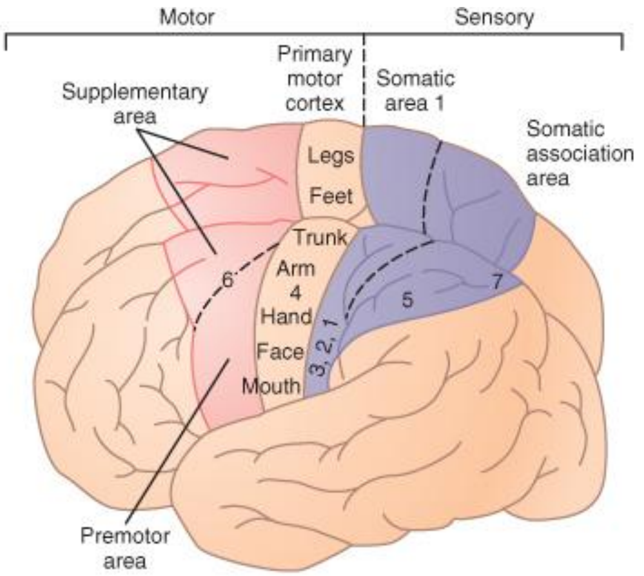
- Flexor – cutaneous sensory stimulus cause contraction
- Withdrawal – pain, through interneurons not brain
- Crossed extensor – delay after flexor, opposite limb extend, walking
- Scratch – initiate by itch or tickle
- Spinal cord – these responses occur in decerebrate animals
- Autonomic – change in skin perfusion, sweating, intestinal reflexes

For the lack of sensory input - Spinal Shock

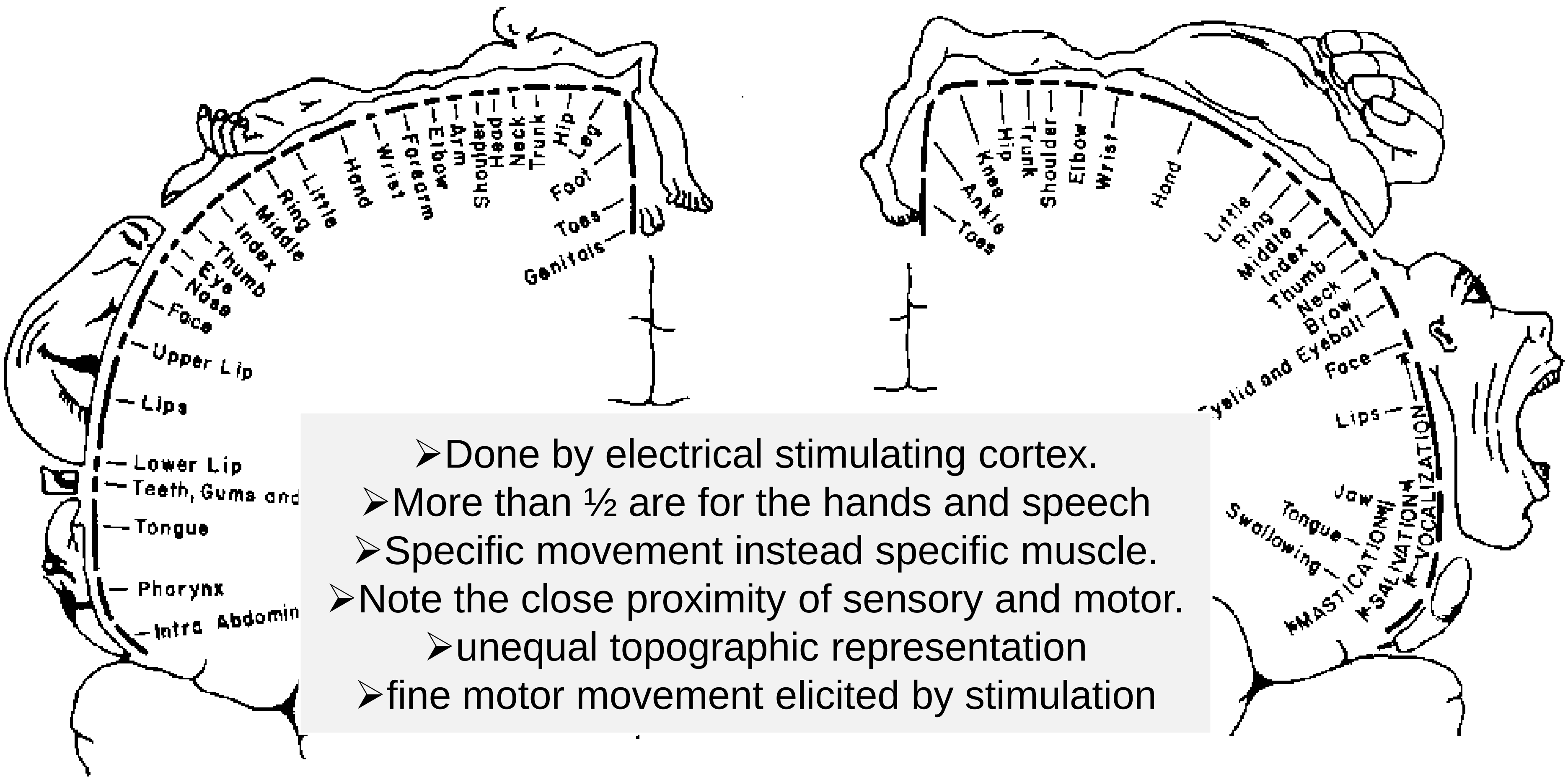
- Occurs when spinal cord is deprived of brain input.
- Spine recovers after days.
- Similar mechanism applies to most nerves
- Recovery may be excessive
- Affected functions:
  – Arterial blood pressure
  – Skeletal muscle reflexes are blocked
  – Bladder/bowel control are lost (but recoverable)

3 major areas of motor cortex

- Control complex movements. (or voluntary)
  - Primary motor cortex
  - Premotor area
  - Supplementary area



Primary motor cortex



- ➢Done by electrical stimulating cortex.
- ➢More than ½ are for the hands and speech
- ➢Specific movement instead specific muscle.
- ➢Note the close proximity of sensory and motor.
- ➢unequal topographic representation
- ➢fine motor movement elicited by stimulation

Penfield and Rasmussen: The cerebral cortex of man: A clinical study of localization of function, 1968.

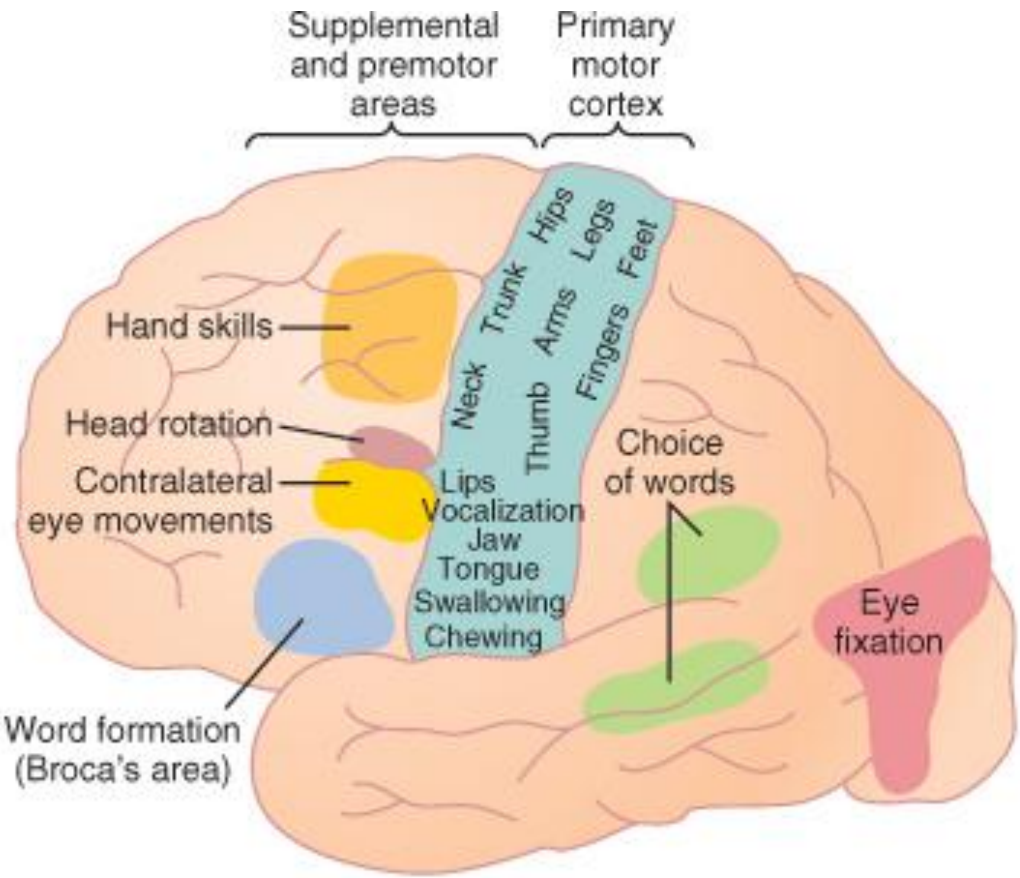
Supplementary motor area

- Topographically organized
- Functions in concert with premotor area to provide attitudinal, fixation or positional movement for the body
- Provides the background for fine motor control of the arms and hands by premotor and primary motor cortex
- Simulation often elicits bilateral movements.

What is the significant of being bilateral?

- Grasping with both hands
- Climbing
- Walking
- Body-wide coordination
- Positional movements of head and eyes

More specialized area



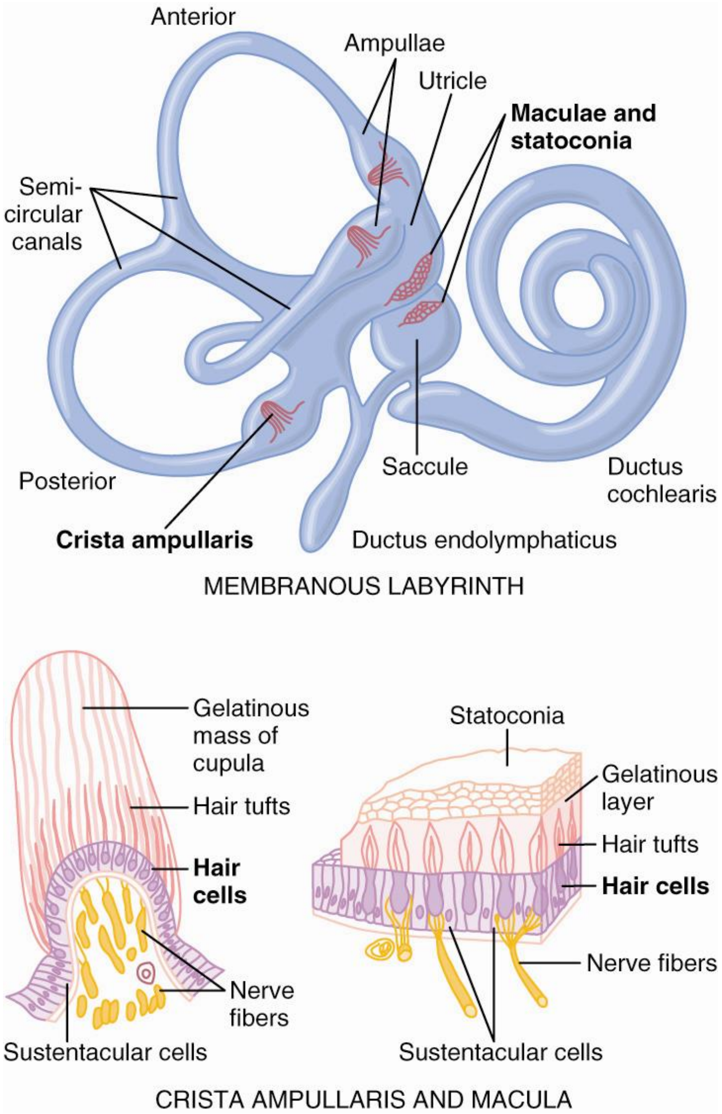


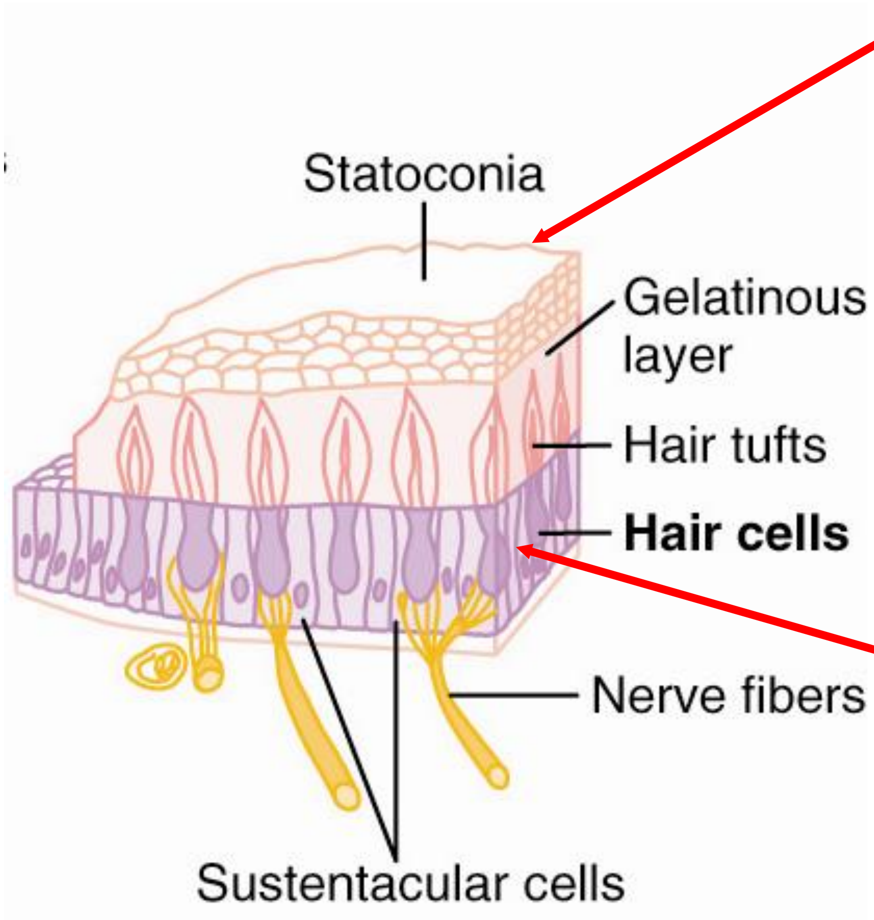
Figure 55-9; Guyton and Hall

The Vestibular Apparatus

System of bony tubes and chambers in the temporal bone:

- semicircular ducts
- utricle
- saccule

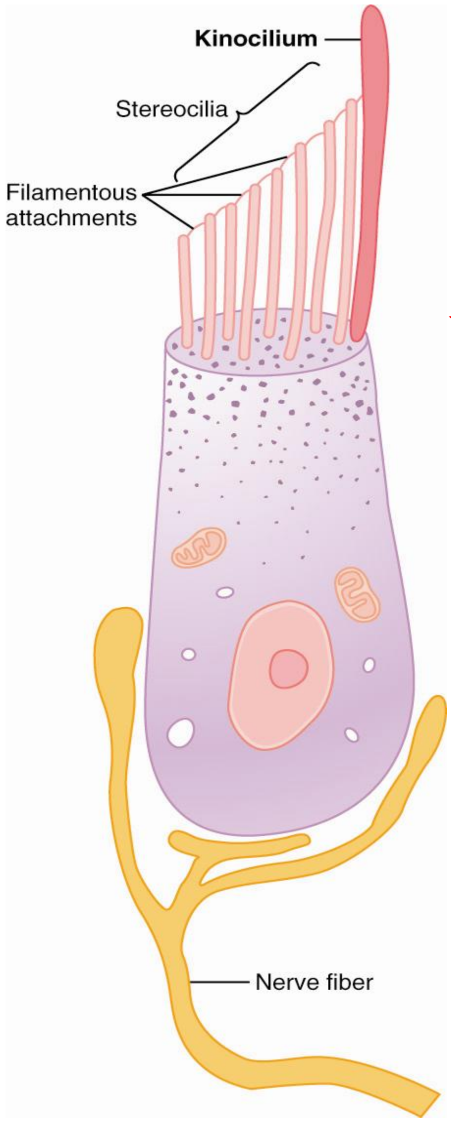
Within the utricule and the saccule are sensory organs for detecting the orientation of the head with respect to gravity called the *macula.*



The statoconia make the structure *top heavy* so that it is capable of responding to changes in head position.

Gravity sensitive receptor consists of gravity sensitive hair cells.

Figure 55-9;
Guyton and Hall



Have a series of protrusions called *stereocilia* and one large protrusion called the *kinocilium.* These structures are directionally sensitive.

Bending in one direction causes depolarization, bending in the opposite direction cause hyperpolarization.

Figure 55-10;
Guyton and Hall

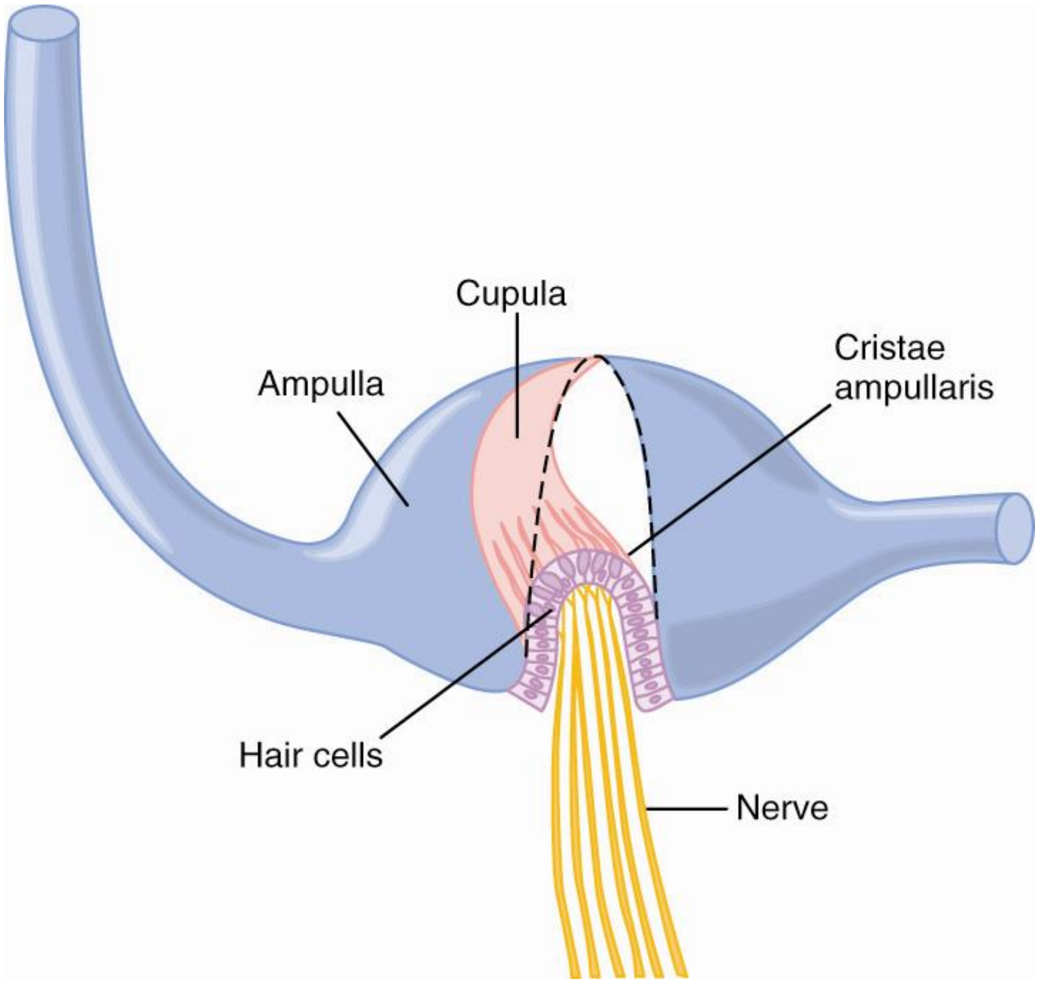


Figure 55-11; Guyton and Hall

- All located at 90^0 to each other representing all 3 planes in space.

- Each duct has an enlargement at the end called an *ampulla.*

- Within the ampulla is a sensory structure called the *crista ampullaris*.

- Bending the crista ampullaris in a particular direction excites the hair cells

Maintaining Equilibrium

- Information from the hair cells in the maculae of the utricles and saccules is transmitted to the brain via the vestibular nerve.
- When the body is accelerated forward the hair cells of the maculae bend in the opposite direction, this causes one to feel as if they are falling backward.
- Reflexes cause the body to lean forward.

The Cerebellum, the Basal Ganglia, and Overall Motor Control

- Cerebral cortex deals with actual control of movement.

- How about planning?
- How about complex coordination?
- How about intensity?
- How about direction?

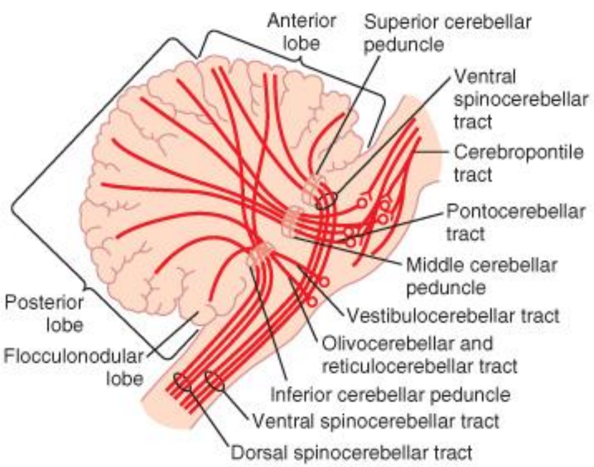
Cerebellum & Basal Ganglia

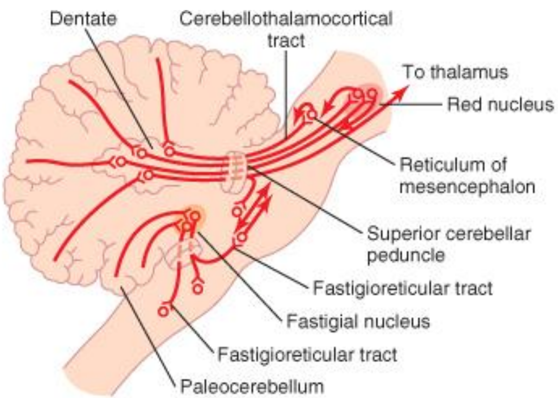
- responsible for coordinating muscle activity
- sequences the motor activities
- monitors and makes corrective adjustments in the activities initiated by other parts of the brain
- compares the actual motor movements with the intended movements and makes corrective changes
- A feedback system

Neuronal Circuit of Cerebellum

- Afferent – inputs
- From brain
- From periphery

- Efferent – outputs
- To brain
- To periphery

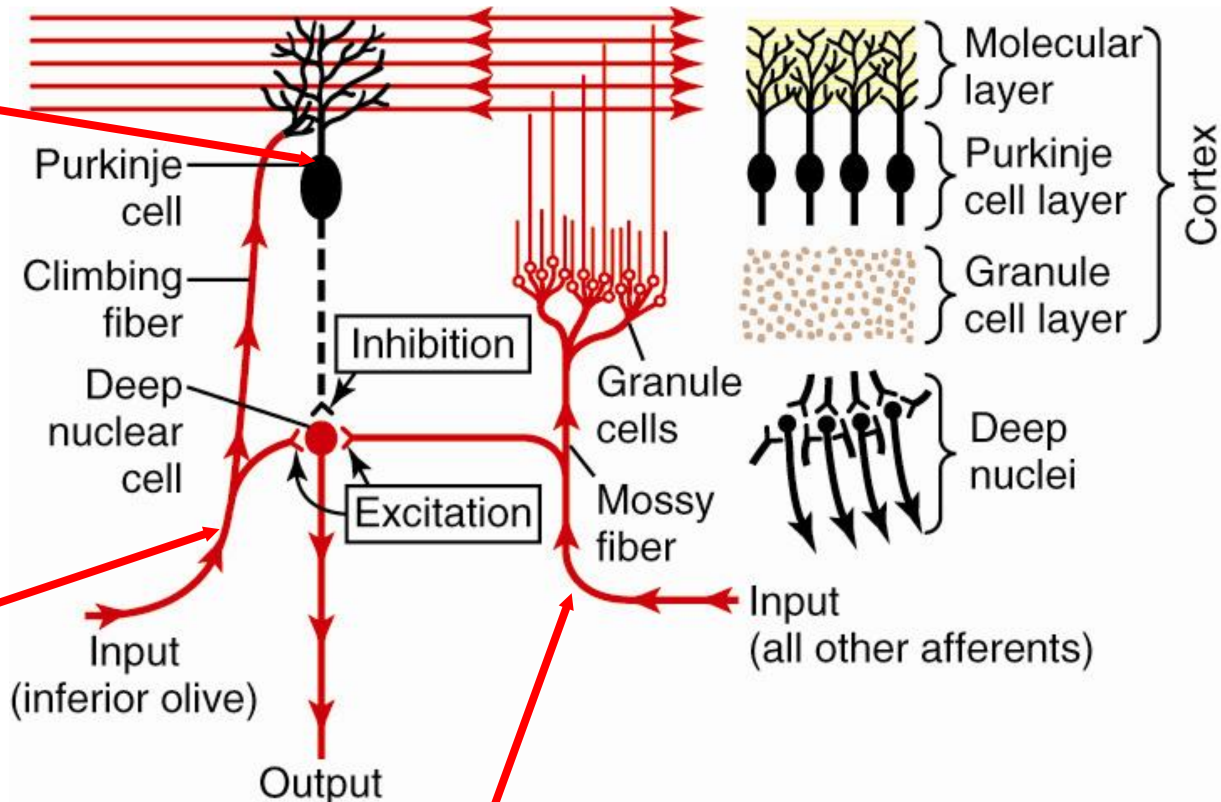




Neuronal Circuit of the Cerebellum

Deep nuclear cells receive excitatory and inhibitory inputs

Inhibitory from Purkinje cells



Excitatory afferent inputs from climbing fibers and mossy fibers

Figure 56-7; Guyton & Hall

Neuronal Circuit of the Cerebellum

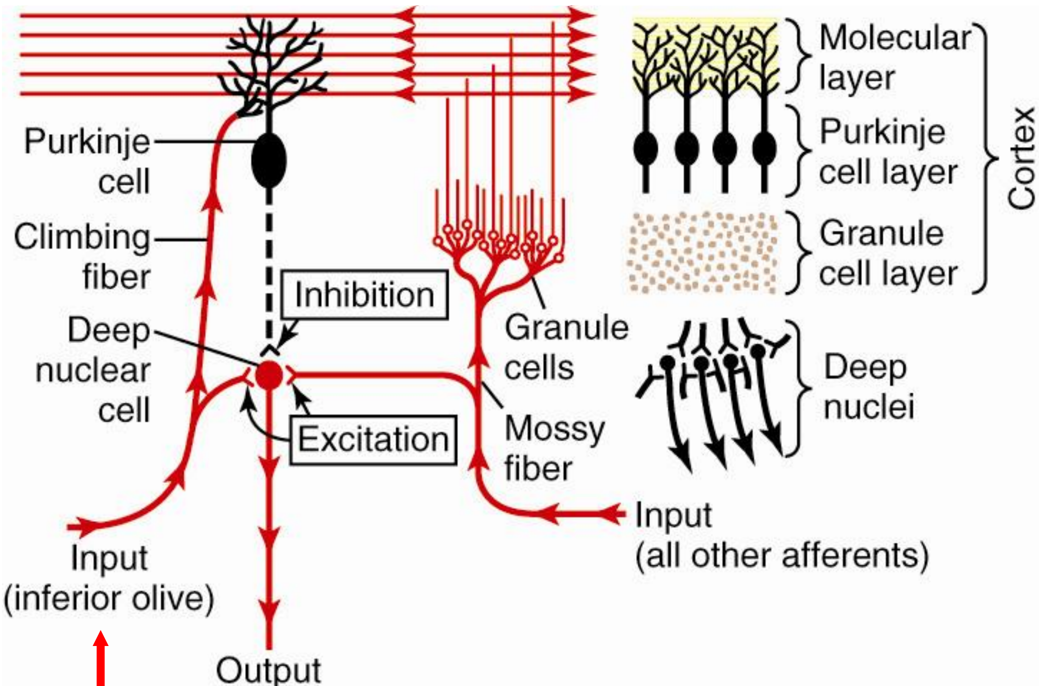
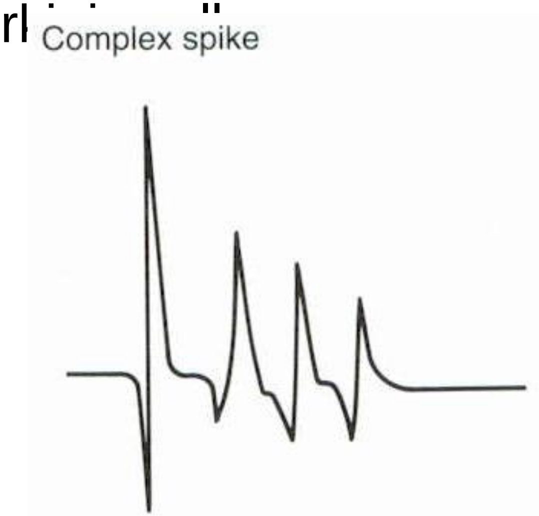


Figure 56-7; Guyton & Hall

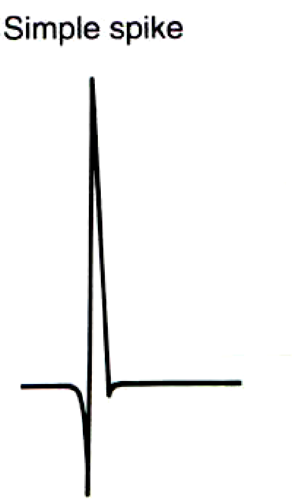
climbing fibers send branches to the deep nuclear cells before they make extensive connections with the dendrites of the Purkinje cell. Causes **complex spike** output from Purk



all **climbing fibers** originate from the inferior olive

Neuronal Circuit of the Cerebellum

mossy fibers relay all other afferent input into the cerebellum, also send branches to the deep nuclear cell



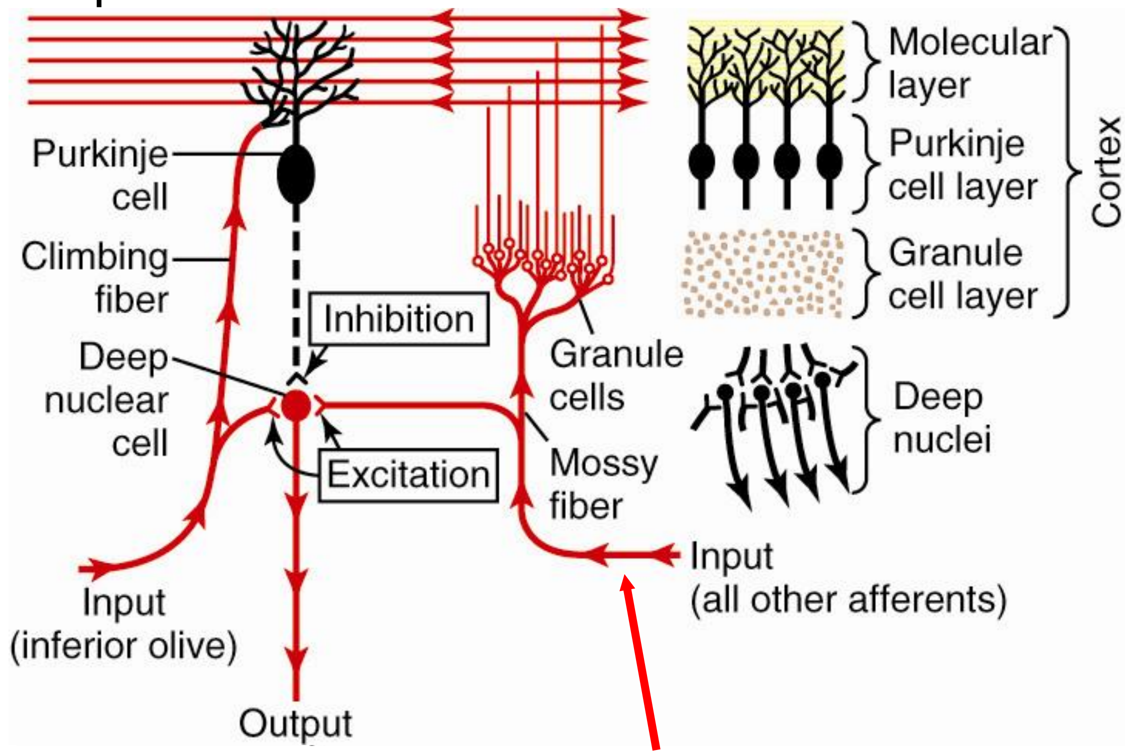


Figure 56-7; Guyton & Hall

mossy fiber stimulation causes a simple spike output

mossy fibers terminate in the granular cell layer.

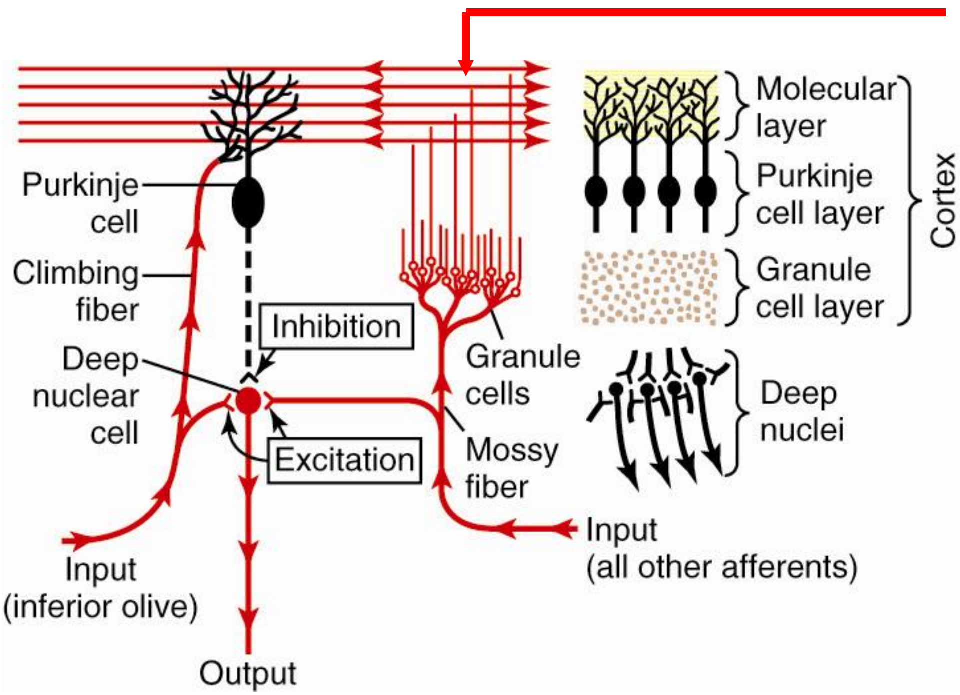
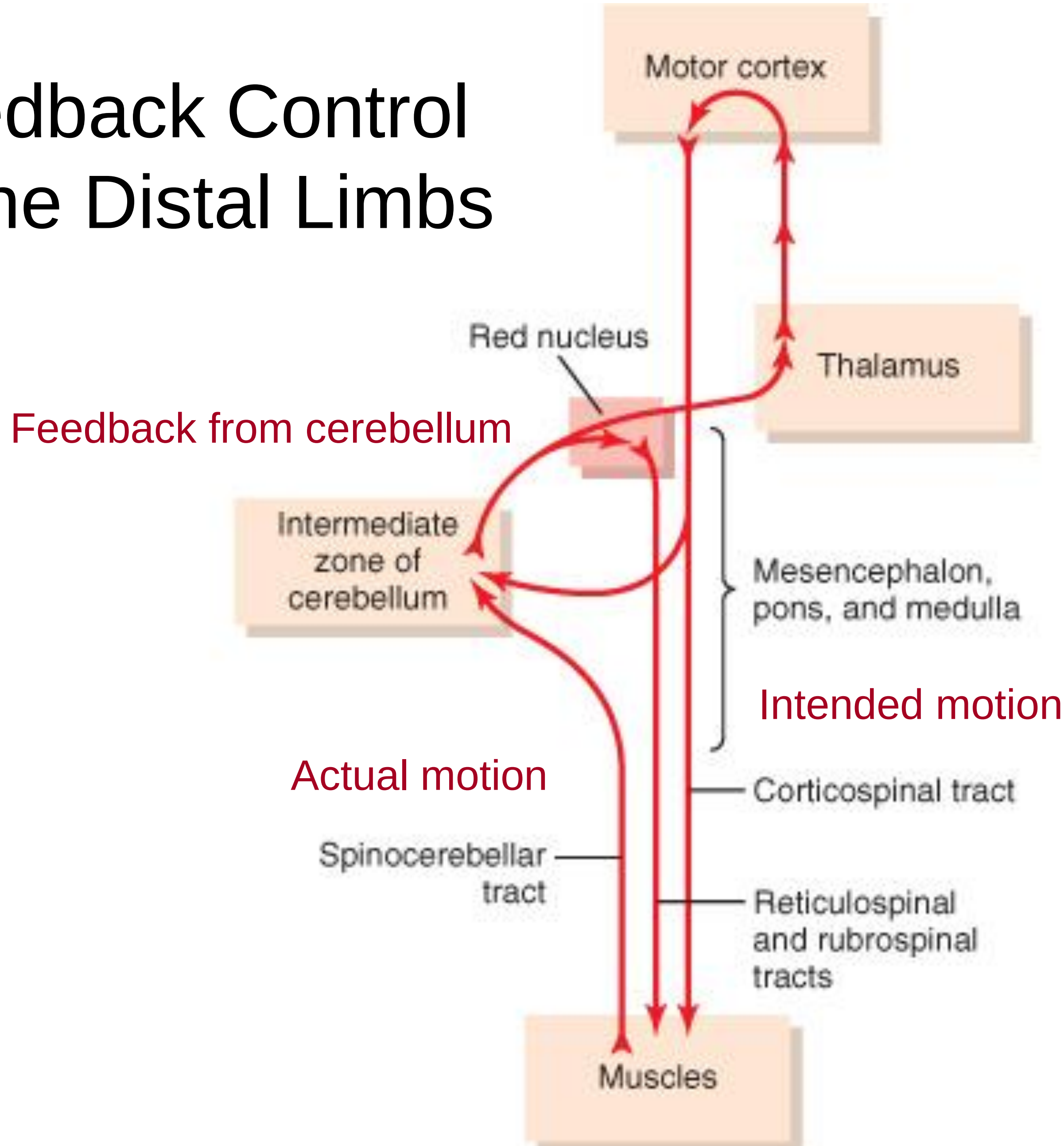


Figure 56-7; Guyton & Hall

granular cells send axons to the molecular cell layer where they divide and go a few mm in opposite directions to become parallel fibers in the molecular layer

500 - 1000 granule cells for every Purkinje cell, anywhere from 80,000 to 200,000 parallel fibers synapse with each Purkinje cell

Feedback Control of the Distal Limbs



Non-Motor Functions of the Cerebellum

- Estimation of speed.
- Prediction of timing.
- Interpreting spatiotemporal relations.

Abnormalities of the Cerebellum

- Dysmetria and Ataxia (uncoordinated movements via over-compensation)
- Past pointing (moves beyond the point of intention)
- Overshoot of motion (oscillation, intention tremor)
- Dysdiadochokinesia (cannot locate body parts in fast movement)
- Dysarthria (cannot coordinate speech)
- Cerebellar nystagmus (tremor of the eyeballs)
- Hypotonia (loss of muscle tone)

Basal Ganglia

- Control *complex* motor activity
  - E.g. writing letters of the alphabet
  - Cutting paper with scissors
  - Shooting a basketball
  - Hammering nails
  - Throwing a football/baseball