Chapter 55:

Cortical and Brainstem Control of Motor Function

Motor Cortex

- Divided into 3 sub areas
  - primary motor cortex
    - unequal topographic representation
    - fine motor movement elicited by stimulation
  - premotor area
    - topographical organization similar to primary motor cortex
    - stimulation results in movement of muscle groups to perform a specific task
    - works in concert with other motor areas

Motor Cortex (Cont.)

- supplemental motor area
  - topographically organized
  - simulation often elicits bilateral movements.
  - functions in concert with premotor area to provide attitudinal, fixation or positional movement for the body
  - it provides the background for fine motor control of the arms and hands by premotor and primary motor cortex

Motor Areas of the Cortex

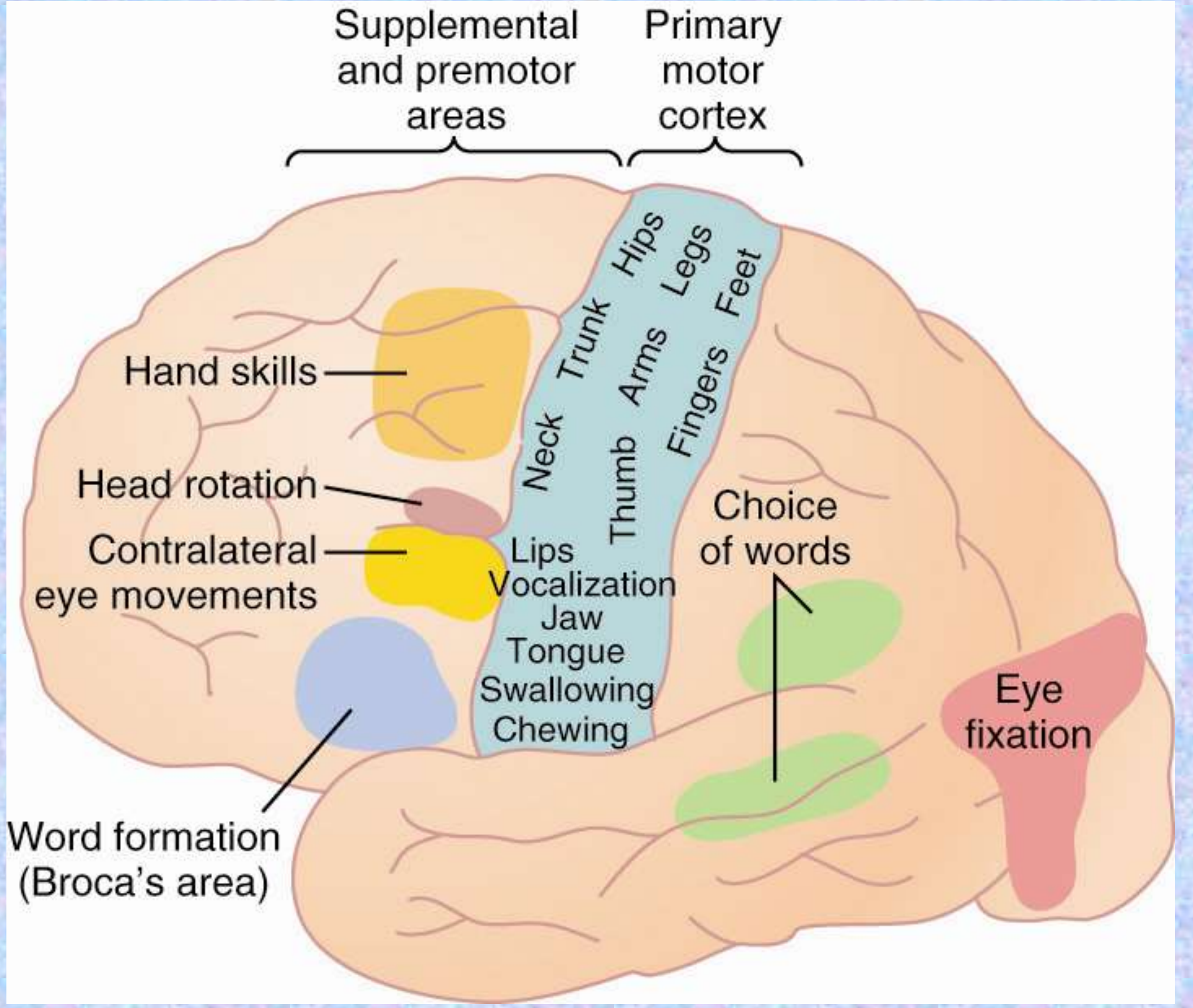


Figure 55-3

Functional Organization of the Primary Motor Cortex

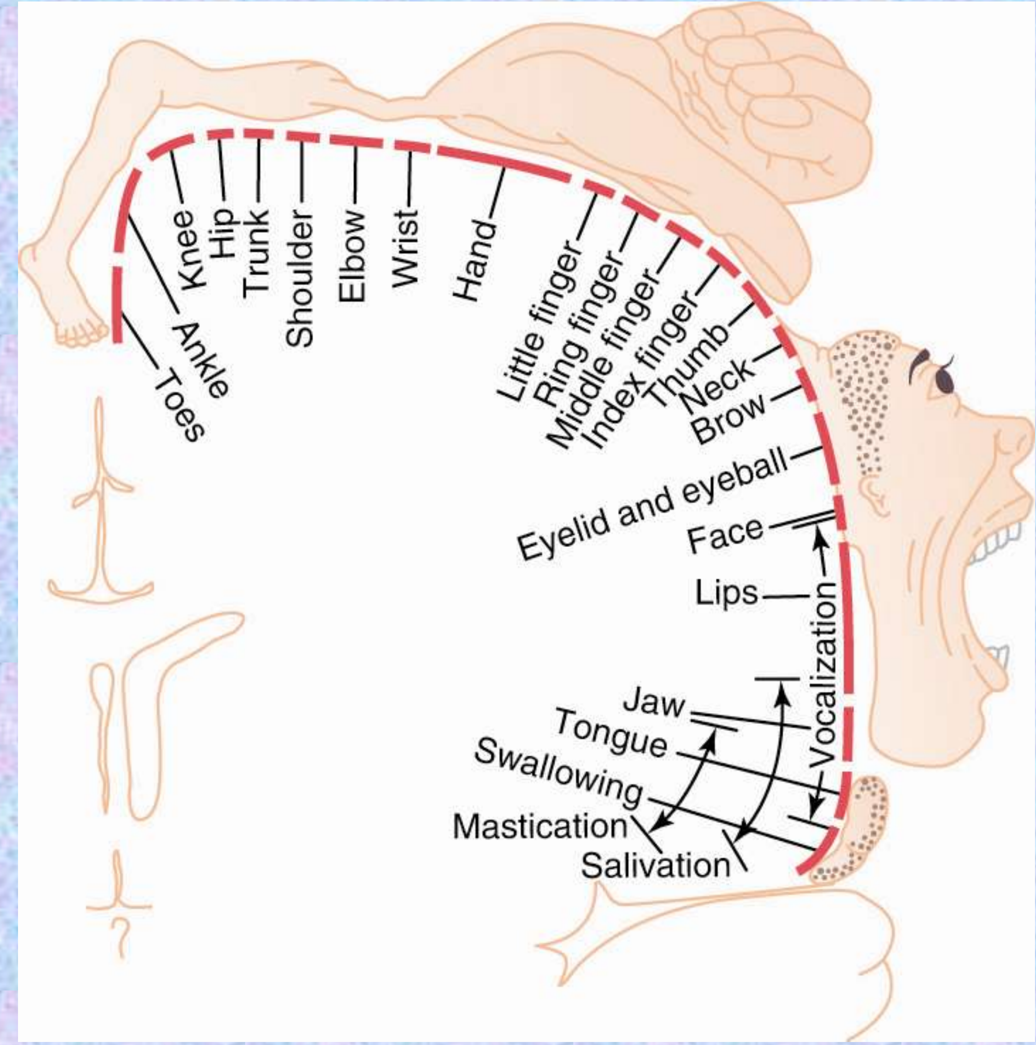


Figure 55-2

Specialized Areas of the Motor Cortex

- Broca’s area
  - damage causes decreased speech capability
  - closely associated area controls appropriate respiratory function for speech
- eye fixation and head rotation area
  - for coordinated head and eye movements
- hand skills area
  - damage causes *motor apraxia* the inability to perform fine hand movements

Transmission of Cortical Motor Signals

- Direct pathway
  - corticospinal tract
  - for discrete detailed movement
- Indirect pathway
  - signals to basal ganglia, cerebellum, and brainstem nuclei

Corticospinal Fibers

- 34,000 Betz cell fibers, make up only about 3% of the total number of fibers
- 97% of the 1 million fibers are small diameter fibers
  - conduct background tonic signals
  - feedback signals from the cortex to control intensity of the various sensory signals to the brain

Other Pathways from the Motor Cortex

- Betz collaterals back to cortex sharpen the boundaries of the excitatory signal
- Fibers to caudate nucleus and putamen
- Fibers to the red nucleus, which then sends axons to the cord in the rubrospinal tract
- Reticular substance, vestibular nuclei and pons then to the cerebellum
- Therefore the basal ganglia, brain stem and cerebellum receive a large number of signals from the cortex.

Incoming Sensory Pathways to Motor Cortex

- Subcortical fibers from adjacent areas of the cortex especially from somatic sensory areas of parietal cortex and visual and auditory cortex.
- Subcortical fibers from opposite hemisphere which pass through *corpus callosum*.
- Somatic sensory fibers from ventrobasal complex of the thalamus (i.e., cutaneous and proprioceptive fibers).

Incoming Sensory Pathways to Motor Cortex (Cont.)

- Ventrolateral and ventroanterior nuclei of thalamus for coordination of function between motor cortex, basal ganglia, and cerebellum.
- Fibers from the intralaminar nuclei of thalamus (control level of excitability of the motor cortex), some of these may be pain fibers.

Red Nucleus and the Rubrospinal Tract

- Substantial input from primary motor cortex
- Primary motor cortex fibers synapse in the lower portion of the nucleus called the magnocellular portion which contains large neurons similar to Betz cells.
- Magnocellular portion gives rise to rubrospinal tract.
- Magnocellular portion has somatotopic organization similar to primary motor cortex.

Red Nucleus and the Rubrospinal Tract

- Stimulation of red nucleus causes relatively fine motor movement, but not as discrete as primary motor cortex.
- Accessory route for transmission of discrete signals from the motor cortex.

Red Nucleus and Rubrospinal Tract

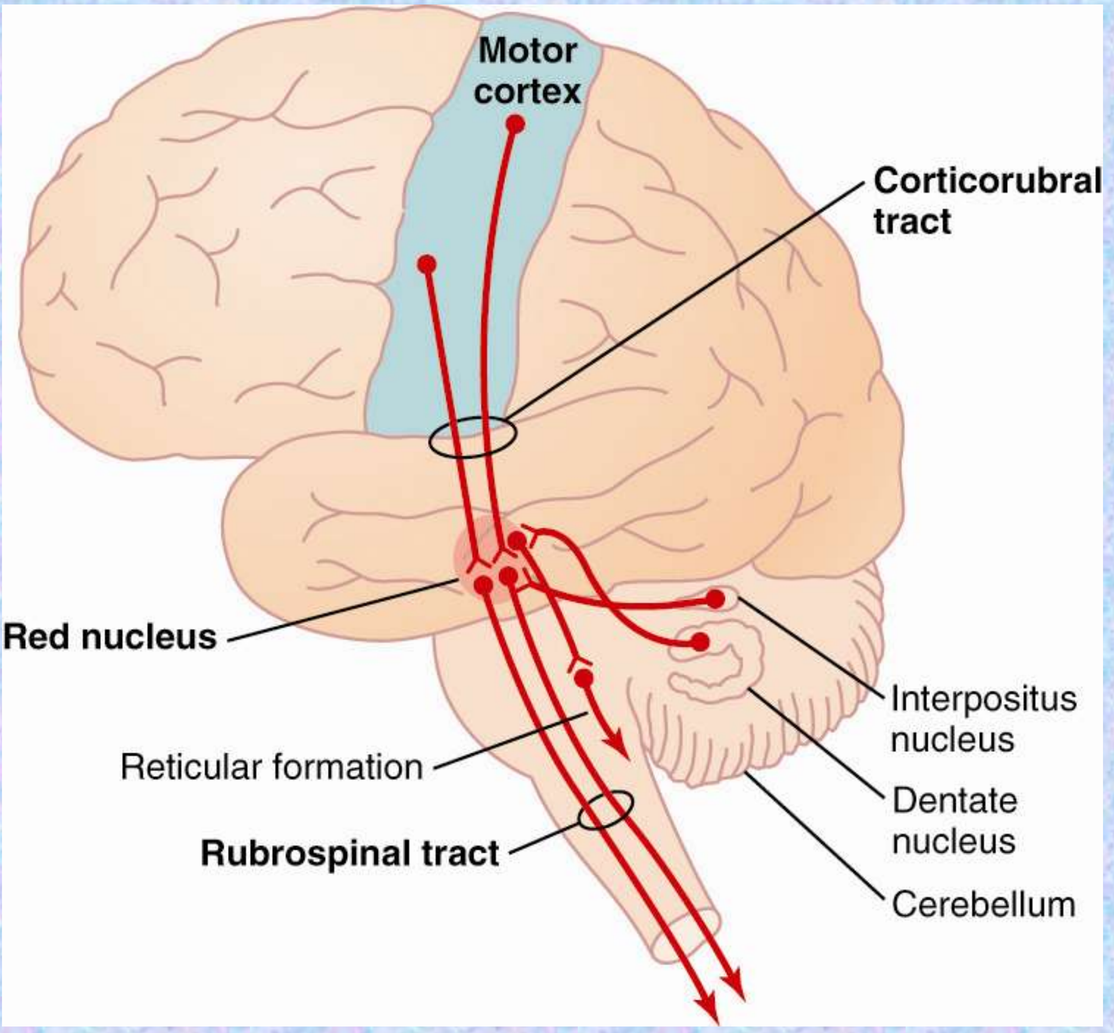


Figure 55-5

Sensory Feedback is Important for Motor Control

- Feedback from muscle spindle, tactile receptors, and proprioceptors fine tunes muscle movement.
- Length mismatch in spindle causes auto correction.
- Compression of skin provides sensory feedback to motor cortex on degree of effectiveness of intended action.

Excitation of Spinal Motor Neurons

- Motor neurons in cortex reside in layer V.
- Excitation of 50-100 giant pyramidal cells is needed to cause muscle contraction.
- Most corticospinal fibers synapse with interneurons.
- Some corticospinal and rubrospinal neurons synapse directly with alpha motor neurons in the spinal cord especially in the cervical enlargement.
- These motor neurons innervate muscles of the fingers and hand.

Lesions of the Motor Cortex

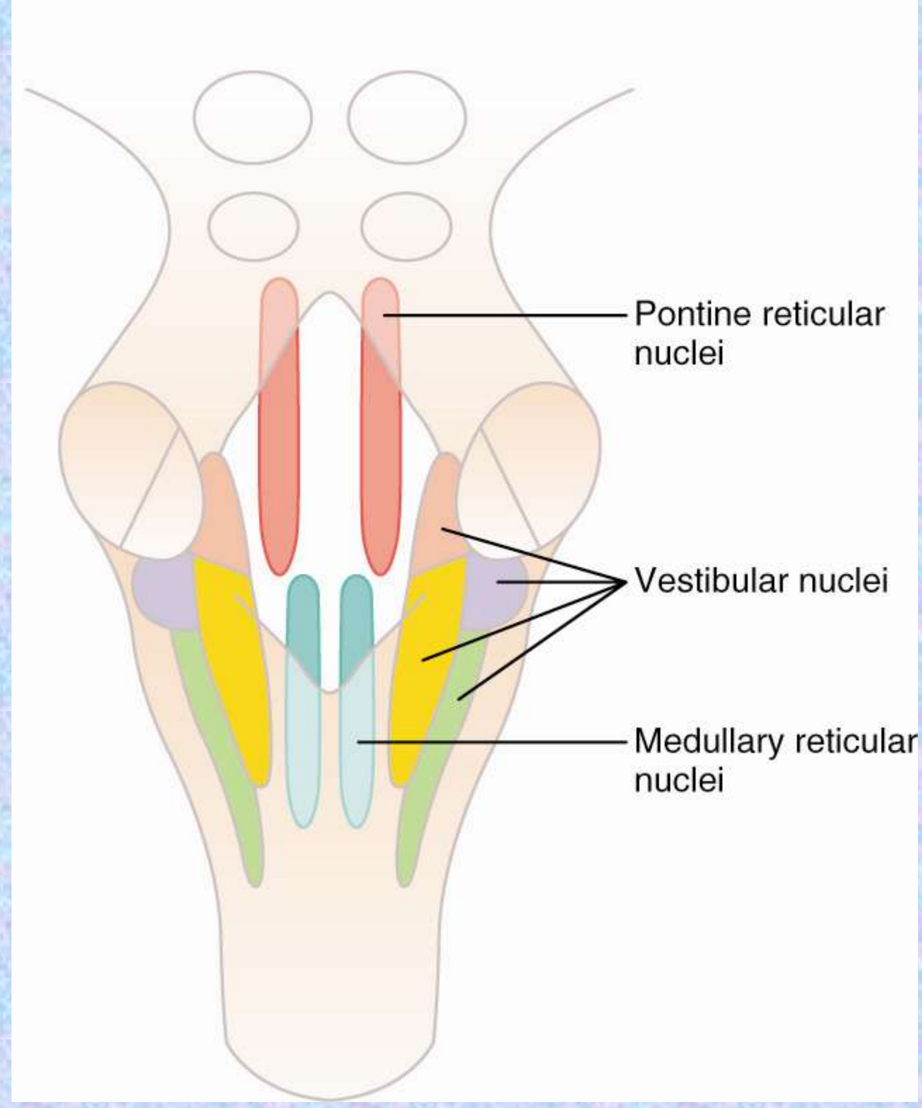
- Primary motor cortex - loss of voluntary control of discrete movement of the distal segments of the limbs.
- Basal ganglia - muscle spasticity from loss of inhibitory input from accessory areas of the cortex that inhibit excitatory brainstem motor nuclei.

Control of Motor Function by the Brainstem

- Brainstem as an extension of the spinal cord.
  - performs motor and sensory functions for the face and head (i.e., cranial nerves).
  - similar to spinal cord for functions from the head down.
- Contains centers for stereotypic movement and equilibrium.

Support of the Body Against Gravity

- The muscles of the spinal column and the extensor muscles of the legs support the body against gravity.
- These muscles are under the influence of brainstem nuclei.
- The pontine reticular nuclei excite the antigravity muscles.
- The medullary reticular nuclei inhibit the antigravity muscles.



Orientation of the Pontine and Medullary Reticular Nuclei

Figure 55-7

Pontine Reticular Nuclei

- Transmit excitatory signals through *pontine reticulospinal tract.*
- Pontine reticular nuclei have a high degree of natural excitability.
- When unopposed they cause powerful excitation of the antigravity muscles.

Medullary Reticular Nuclei

- Transmit inhibitory signals to the antigravity muscles through the *medullary reticulospinal tract.*
- These nuclei receive collateral input from the corticospinal tract, rubrospinal tract, and other motor pathways.
- These systems can activate the inhibitory action of the medullary reticular nuclei and counterbalance the signals from the pons.

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 Vestibular Apparatus

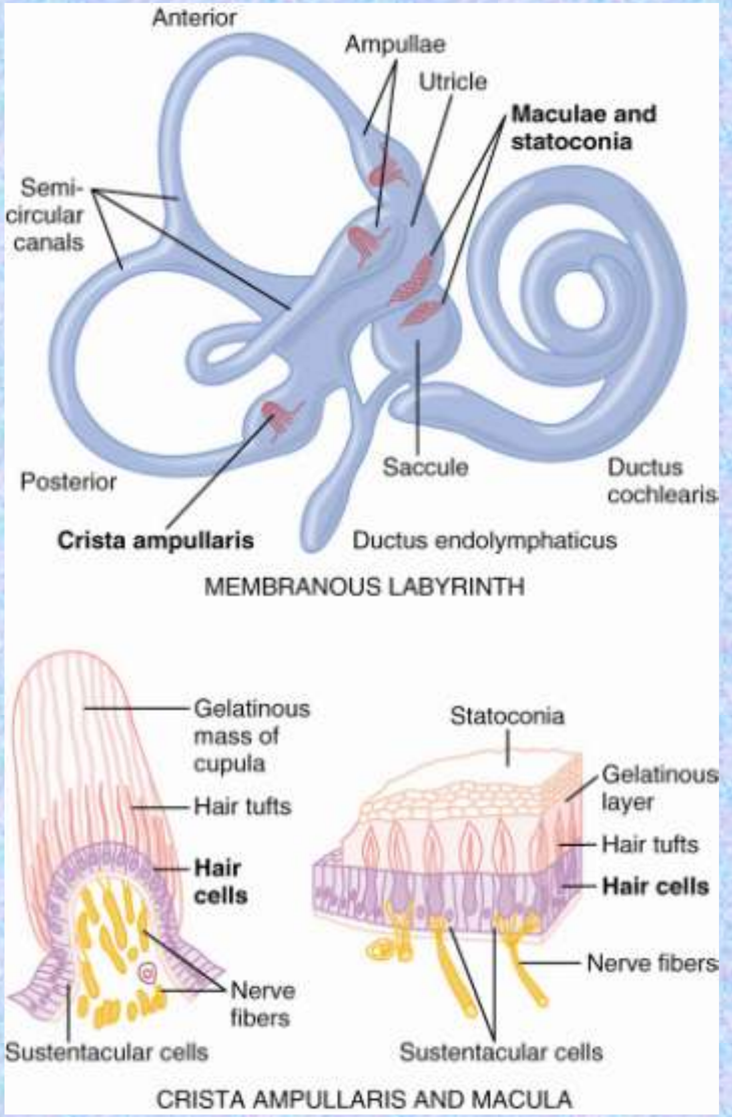


Figure 55-9

The Macula

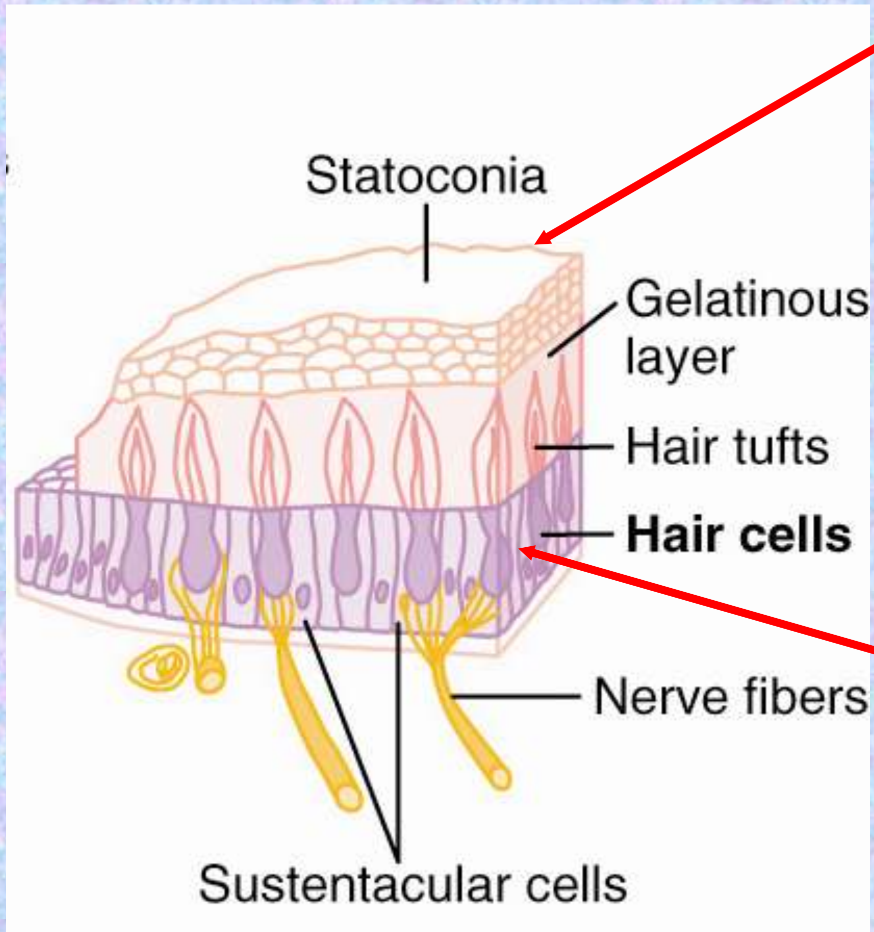
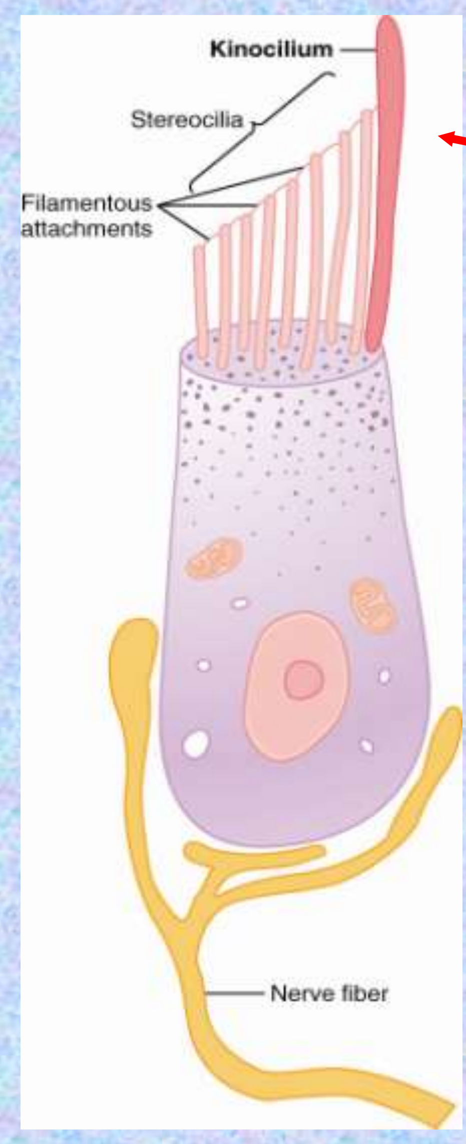


Figure 55-9

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.

Hair Cells



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

Detection of Head Orientation

- In each macula different hair cells are oriented in different directions.
- Some are stimulated when the head bends forward, some when the head bends backward, some when the head bends to the side.
- The pattern of excitation of the hair cells apprises the brain of the orientation of the head with respect to gravity.

Semicircular Canals

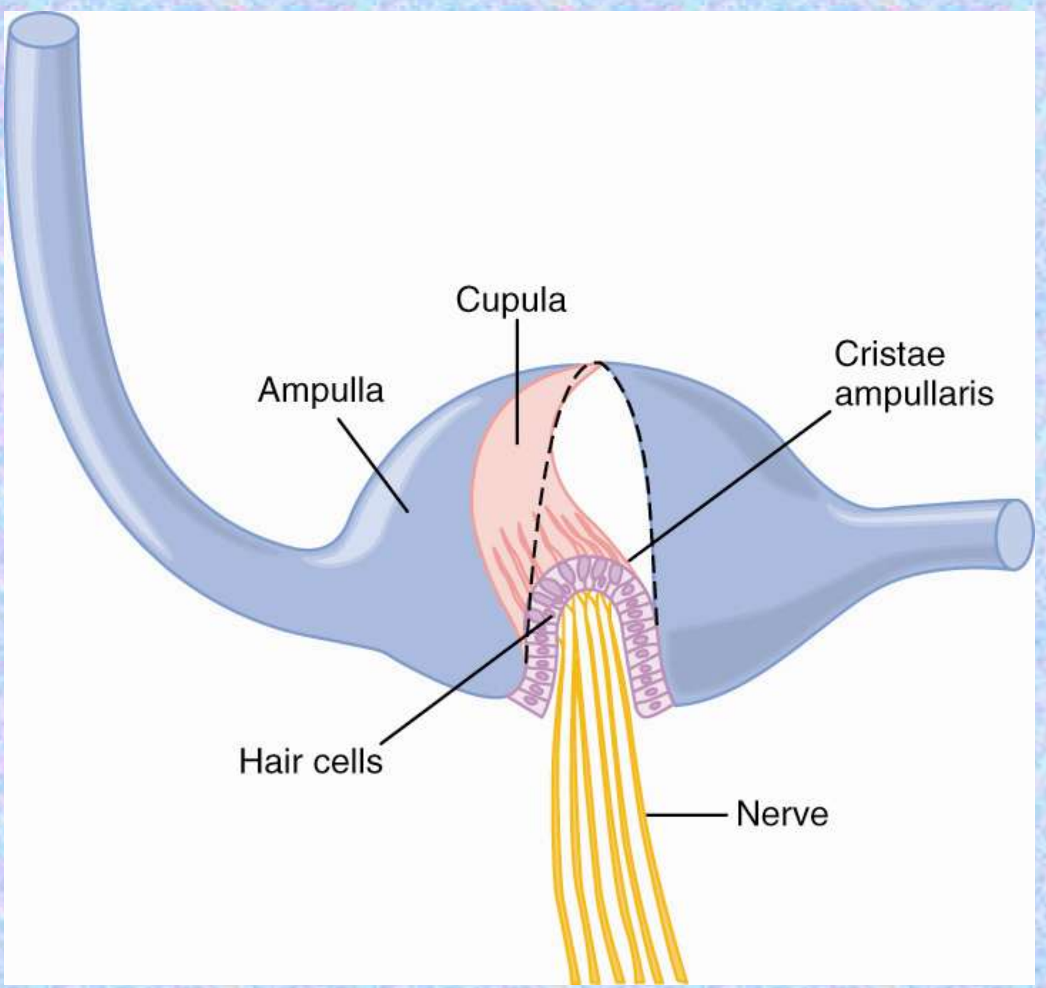


Figure 55-11

- 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.

Semicircular Ducts Detect Angular Acceleration

- Rotation of the duct detects rotational movements of the head.
- Endolymph tends to remain stationary in the duct because of inertia.
- Rotation of the duct in one direction causes relative movement of endolymph in the opposite direction activating the receptors in the crista ampullaris.
- Stop the rotation, the opposite happens.

Response of a Hair Cell When a Semicircular Canal is Stimulated

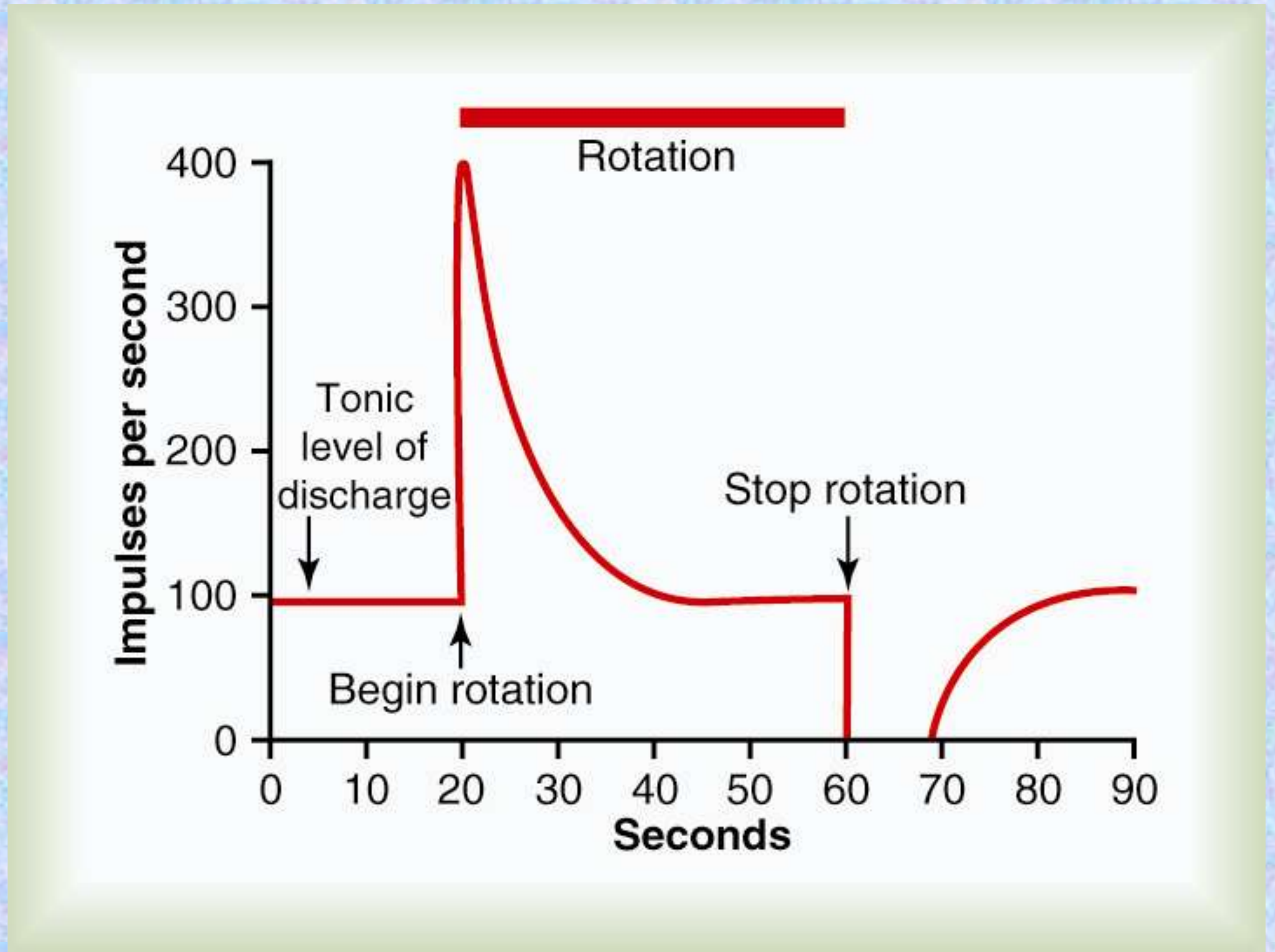


Figure 55-12

Predictive Function of the Semicircular Ducts

- Semicircular ducts predict situations in which equilibrium will be affected and this information is sent to the brain.
- Corrective measures are initiated before the equilibrium is affected.
- Neck proprioceptors and visual input also contribute to the maintenance of equilibrium.

Neuronal Connections of the Vestibular Apparatus

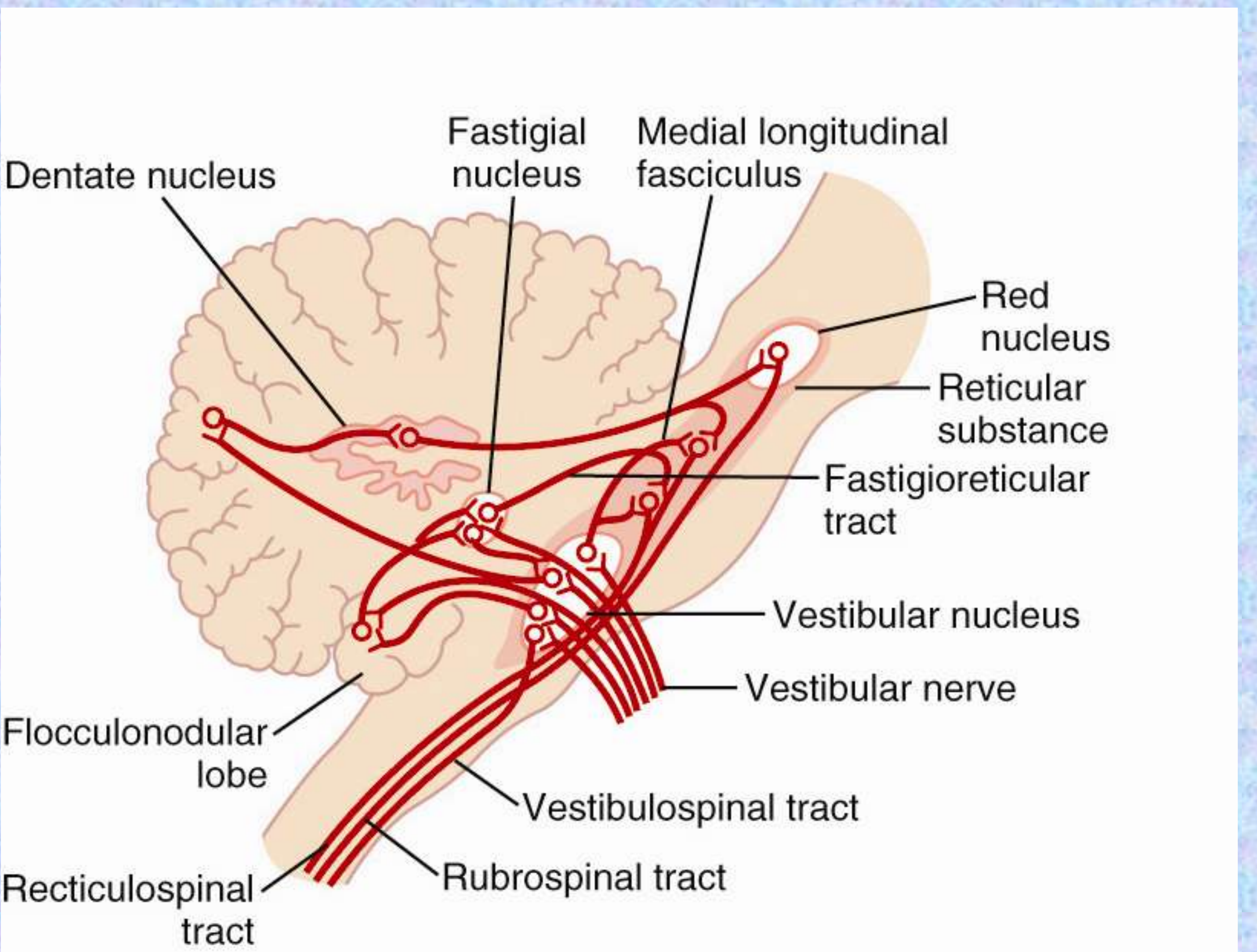


Figure 55-13