PHYSIOLOGY

SHEET NO. 13

WRITER : Doctor 018

CORRECTOR : Rawan Fratekh

DOCTOR : Faisal Mohammad

❖ Control of Motor Function by the Brainstem:

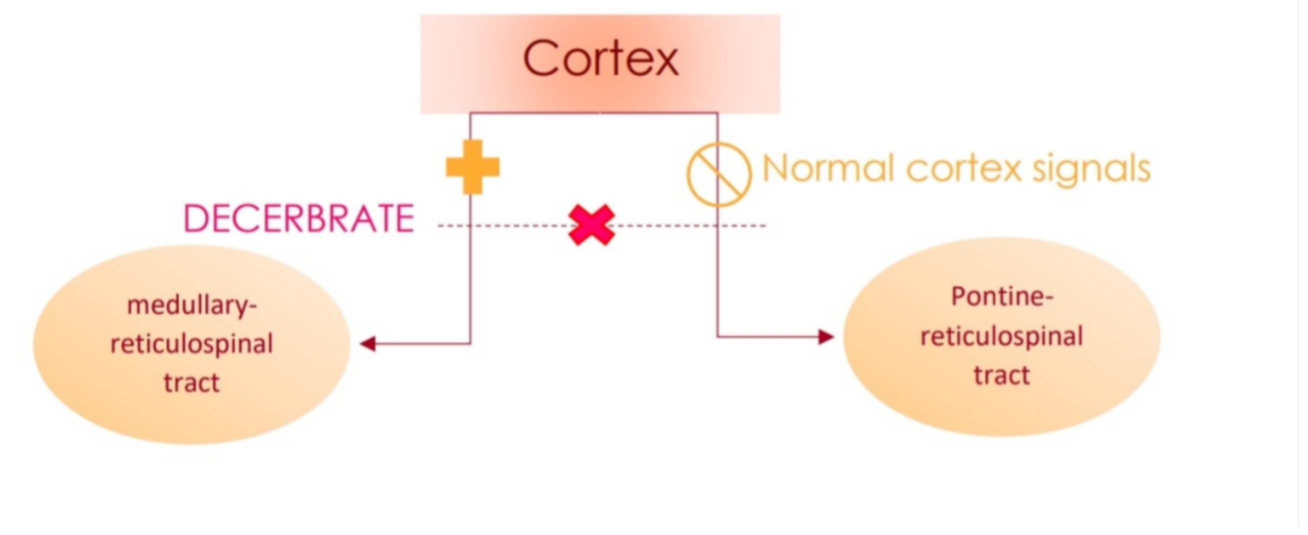
- Brainstem as an extension of the spinal cord.
  - performs motor and sensory functions for the face and head (i.e., cranial nerves).
  - similar to spinal cord for functions from the head down.
- Contains centers for stereotypic movement and equilibrium.

❖ Support of the Body Against Gravity:

- The muscles of the spinal column and the extensor muscles of the legs oppose the effect of gravity to maintain balance and posture and thus are called "antigravity muscles". These muscles are under the influence of brainstem nuclei. As we proceed, you'll notice that many tracts influence the activity of these muscles. But for now, let's just focus on these two antagonistic tracts
  1. The pontine reticular nuclei excite the antigravity muscles.
  2. The medullary reticular nuclei inhibit the antigravity muscles.

Pontine Reticular Nuclei	Medullary Reticular Nuclei
○ Transmit excitatory signals through **pontine (medial) reticulospinal tract**. ○ **intrinsically active:** Pontine reticular nuclei have a high degree of natural excitability. ○ When unopposed they cause powerful excitation of the antigravity muscles.	○ Transmit inhibitory signals to the antigravity muscles through the **medullary (lateral) reticulospinal tract**. ○ **Not** intrinsically active: These nuclei receive collateral input from the corticospinal tract, rubrospinal tract, and other motor pathways. Cortico-medullary input excites this tract. ○ These systems can activate the inhibitory action of the medullary reticular nuclei and **counterbalance** the signals from the pontine reticulospinal. ○ Part of the lateral system because it inhibits the extensors and excite the flexors

- Coordinated body movement depends on an appropriate balance between excitatory and inhibitory inputs. If an inhibitory system is disrupted, muscles become hyperactive because of the unopposed activity in excitatory inputs to motor neurons. This condition, characterized by increased muscle tone is known as “spastic paralysis”.
  - **Decerebrate rigidity:** removal of the cortical control over the medullary reticulospinal keeps the pontine reticulospinal unchecked which results in hyperactivity of anti-gravity muscles.

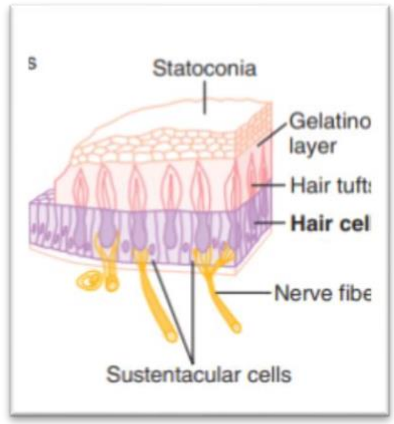


Vestibular Apparatus:

- In addition to its role in hearing, the inner ear has another specialized component, the vestibular apparatus, which provides essential information for the sense of equilibrium and for coordinating head movements with eye and postural movements. The vestibular apparatus consists of the semicircular canals and the otolith organs (utricle and saccule).
  - As in the cochlea, all components of the vestibular apparatus contain endolymph and are surrounded by perilymph. Also, similar to organ of Corti, each component contains hair cells that respond to mechanical deformation (mechanoreceptors) triggered by the movements of the endolymph. And like the auditory hair cells, the vestibular receptors may be either depolarized or hyperpolarized, depending on the direction of the fluid movement.

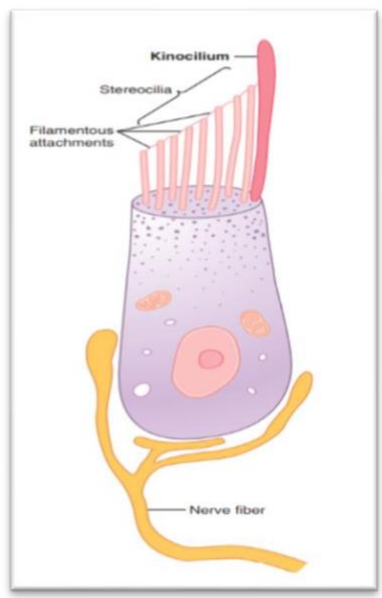
❖ Otolith organs:

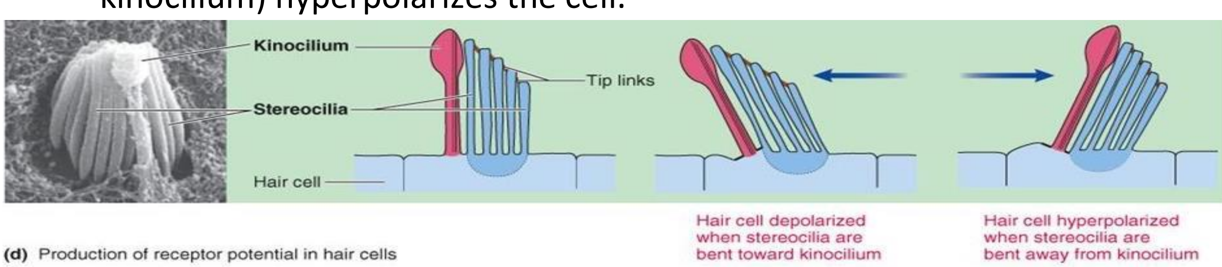
- The utricle and saccule provide information about the position of the head relative to gravity (static head tilt) and also detect changes in the rate of **linear motion or linear acceleration** (moving in a straight line regardless of the direction).
- The **Macula** is the sensory area of both the utricle and saccule. Each macula is covered by a gelatinous layer whose movement displaces the hairs and result in changes in hair cells potential. Many tiny crystals of calcium carbonate, the statoconia ("ear stones"), are suspended within the gelatinous layer, making it heavier. The macula contains thousands of hair cells, these hair cells project their cilia up into the gelatinous layer. The weight of the statoconia bends the cilia in the direction of gravitational pull.



❖ Signal transduction:

- The hairs of one hair cell consist of one ling cilium, the **Kinocilium**, along with multiple small cilia called the stereocilia arranged in rows of decreasing height from the taller kinocilium.
- When the stereocilia are deflected by endolymph movement, the resultant tension affects mechanical gated ion channels in the hair cell.
- Depending on whether the ions channels are mechanically opened or closed by hair movement, the hair cell either depolarizes or hyperpolarizes.
- Each hair cell is oriented so that it depolarizes when its stereocilia are bent toward the kinocilium, bending in the opposite direction (away from the kinocilium) hyperpolarizes the cell.

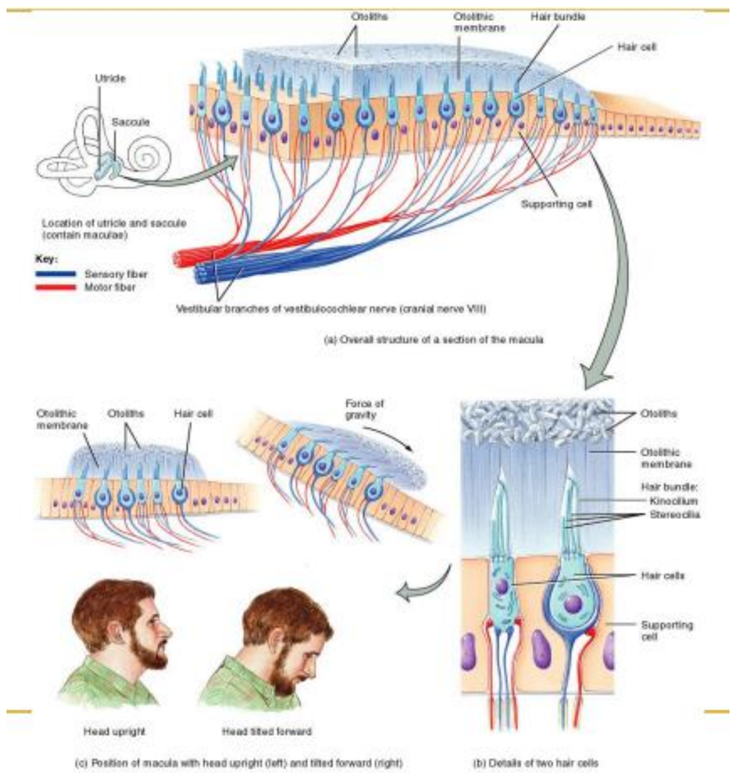




(d) Production of receptor potential in hair cells

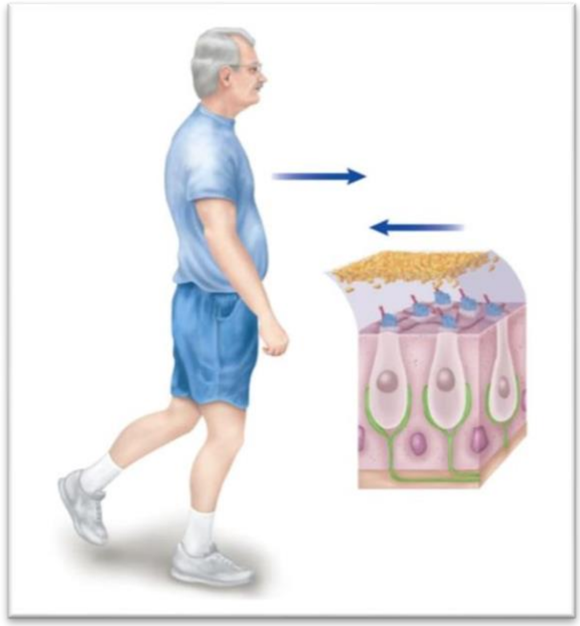
- Hair cells form a chemical synapse with afferents neurons whose axons form the vestibular nerve which unites with the auditory nerve to form the vestibulocochlear nerve. Depolarization increases the release of neurotransmitter from the hair cells, thereby increasing the rate of firing in the afferent fibers. Conversely, hyperpolarization reduces neurotransmitter from the hair cells, in turn decreasing the frequency of action potentials in the afferent fibers.

The hair cells of the maculae are embedded in the otolithic membrane which has on top of it crystals of calcium carbonate. These hair cells have two kinds of fibers: motor and sensory. The motor fibers are corticofugal fibers responsible for the negative feedback that increases the sensitivity of these cells.
When you bend your head, as in the figure, the gelatinous fluid doesn't move at the same speed as the head, but slower, and this bends the hair cells backwards causing depolarization.



❖ Let's put things into motion:

- ➲ As you start to walk forward, the top heavy statoconia lag behind at first because of its great inertia (because of inertia, a resting object remains at rest, and a moving object continues to move in the same direction unless the object is acted on by external force that induces change). The hairs are pulled toward the statoconia, they are bent in the opposite direction of the forward movement of your head, this causes you to feel as if you are falling backward. (can be corrected by leaning forward). If you maintain your walking pace, the gelatinous layer soon catches up and moves at the same rate of your head so that the hairs are no longer bent. When you stop walking, the statoconial sheet continues to move forward briefly as your head slows and stops, bending the hairs toward the front, which is opposite to the way they were bent during acceleration. This causes you to feel as if you are falling forward. (can be corrected by leaning backward).



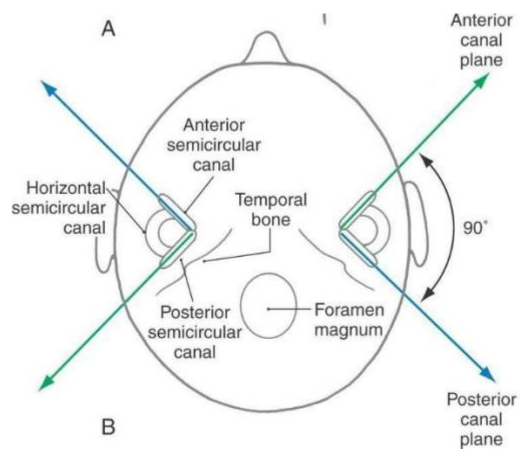
- ➲ Hair cells of the maculae detect linear acceleration and deceleration, but they do NOT provide information about movement in a straight line at a constant speed.

- ➲ How does our brain know that our head is bending forward, backward and at which degree? Again, it's all about different probabilities, different "patterns of stimulation". Hair cells are

directionally sensitive, that is in each macula, each of the hair cells is oriented in a different direction so that some of the hair cells are stimulated when the head bends forward, some are stimulated when it bends backward, others are stimulated when it bends to one side, and so forth. Therefore**, a different "pattern" of excitation occurs in the macular nerve fibers for each orientation of the head in the gravitationalfield**. This pattern of excitation of hair cells apprises the brain of the
head's orientation in space with respect to gravity.

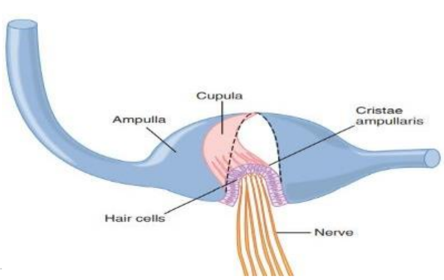
Semicircular Canals:

- The semicircular canals detect **rotational or angular acceleration** or deceleration of the head, such as when starting or stopping spinning, or turning your head. Each ear contains three semicircular canals arranged three-dimensionally in planes that lie at right angles to each other. Three semicircular canals are found in each ear:
    1. Lateral (Horizontal)
    2. Anterior
       vertical
    3. Posterior



- The lateral canals of both ears lie on the same plane. The two vertical canals in each ear are positioned perpendicular to each other, whereas the anterior canal on one side of the head is on the same plane of the contralateral posterior canal.

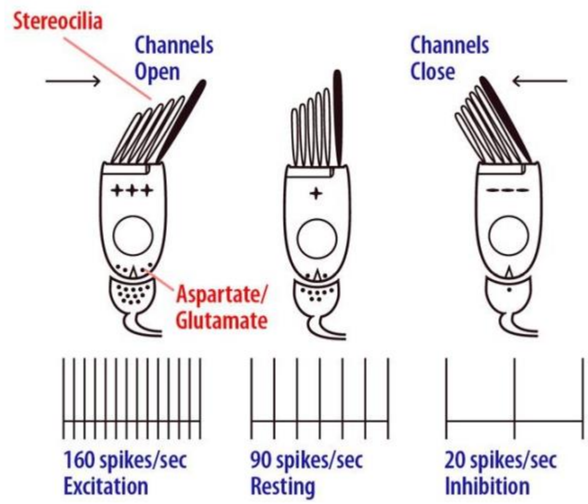
- Each semicircular duct has an enlargement at one of its ends called the **ampulla** that is filled with endolymph. The receptor hair cells of each semicircular canal are embedded in an overlying, gelatinous layer (**the cupula**), and we call them Crista Ampullaris. The copula swings in the direction of fluid movement much like seaweed movement.

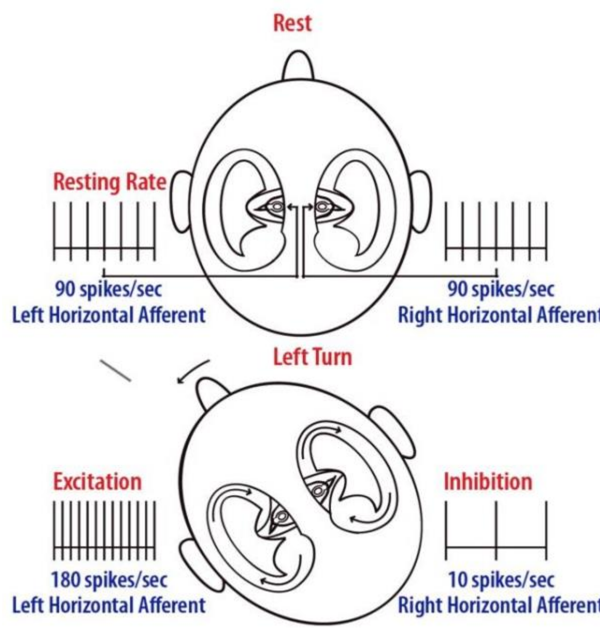


- Acceleration or deceleration during rotation of the head in any direction causes endolymph movement in at least one of the semicircular canals (because of their three-dimensional, arrangement they can detect rotations in any plane).
- As you start to move your head, the bony canal and the copula should move with your head. However, initially, the fluid within the canal which is not attached to the bony skull does not move in the direction of the rotation but lags behind because of its inertia.
- When the endolymph is left behind as you start to rotate your head, the fluid is shifted in the opposite direction of the movement (similar to your body titling to the right side when the car you are riding suddenly turns to the left). This fluid movement causes the copula to lean in the opposite direction from the head movement, bending the sensory hairs embedded in it.
- If your head movement continues at the same rate in the same direction, the endolymph catches up and moves in union with your head so that the hairs return to their unbent sate.
- When your head slows down and stops, the reverse situation occurs. The endolymph briefly continues to move in the direction of rotation while your head decelerates to stop. As a result, the copula and its hairs are transiently bent in the direction of the previous spin, which is opposite to the way they were bent during acceleration.
- Reflexes cause the body to lean forward.

- Semicircular canals detect changes in the rate of rotational movement (rotational acceleration or deceleration) of your head. They do NOT respond when your head is motionless or when its moving in a circle at a constant speed.

➲ These cells have a basal rate of discharge; in other words, they continuously release neurotransmitters and generate action potentials. This ongoing activity makes it possible to either increase or decrease the firing rate. Were it not for basal tone, it would be impossible to reduce the rate of signals during hyperpolarization, only varying degrees of increased discharge during depolarization would be possible. Consequently, your brain wouldn't be able to recognize the direction at which your head is rotating.

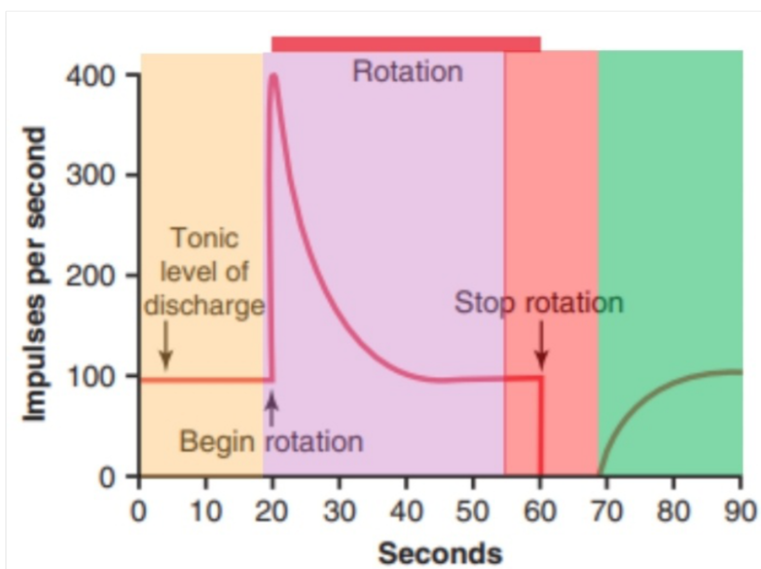




❖ <u>Response of a hair cell when semicircular canal is stimulated</u> (book's explanation):

Response is rate limited, higher rate of change results in more firing and this is important in the prediction.

Even when the cupula is in its resting position, the hair cell emits a tonic discharge of about 100 impulses per second.



At the beginning of rotation, the hairs bend toone side and the rate of discharge increases greatly, after a while with continued rotation, the excess discharge of the hair cell gradually subsides back to the resting level during the next few seconds (adaptation occurs because the copula returns to its normal position).

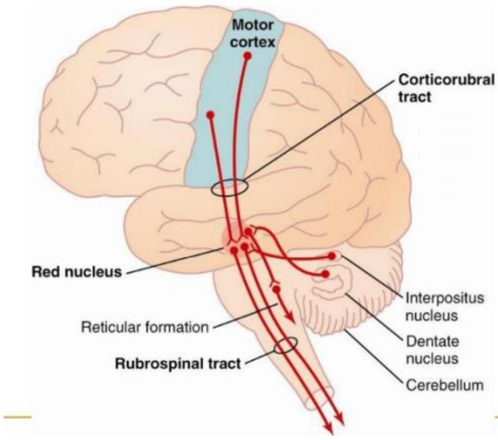
1. When the rotation suddenly stops, exactly opposite effects take place: The endolymph continues to rotate while the semicircular duct stops. This time, the cupula bends in the opposite direction, causing the hair cell to stop discharging entirely.

2. After another few seconds, the endolymph stops moving and the cupula gradually returns to its resting position, thus allowing hair cell discharge to return to its normal tonic level.

- Predictive Function of the Semicircular Ducts:
  - The semicircular ducts predict that equilibrium is going to be disrupted ahead of time. Consequently, they urge equilibrium centers to initiate appropriate corrective adjustments, which help the person maintain balance before losing it.
  - Neuronal Connections of the Vestibular Apparatus will be discussed in details in the following lectures.
- Vestibular Nuclear system:
  - Signals arising from the various components of the vestibular apparatus [utricle, saccule and semicircular canals] are carried through the **vestibulocochlear** nerve to the vestibular nuclei (a cluster of neuronal cell bodies in the brainstem) and to the cerebellum. Here the vestibular information is integratedwith input from eyes, joints, and muscles. For:
    1. Maintaining balance and desired posture (through the lateral and medial vestibulospinal tracts which excite anti-gravity muscles).
    2. Controlling the external eye muscles so that the eyes remain fixed on the same point, despite movement of the head. This is possible because the vestibular nuclei are connected to the motor nuclei of **oculomotor** nerves. That's why certain lesions in the vestibular nuclei result in "**Nystagmus**" (a condition of involuntary eye movement, also called "dancing eyes").

- Refer to the slides for further illustration of the pathways. (I haven't found them necessary).

Red Nucleus and the Rubrospinal Tract:



- The rubrospinal tract originates in the Magnocellular red nucleus of the midbrain, decussates (crossed pathway), and then descends in the lateral aspect of the spinal cord.
- It receives Substantial input from primary motor cortex (Cortico-rubral fibers).
- Magnocellular portion has somatotopic organization similar to primary motor cortex.
  - The primary motor cortex has different **regions** that control the movement of face, arms, and legs. The same principle of organization applies for this nucleus, that is different regions in the nucleus control the movement of particular muscles.
- Stimulation of red nucleus causes relatively fine motor movement, but not as discrete as primary motor cortex. Controls the movement of large flexors unlike corticospinal that controls the distal flexors concerned with fine precise movements.
  - While you hold a pencil to write something down, the lateral corticospinal tract excites the distal flexors of your hand to produce fine and precise movements. At the same time, the rubrospinal tract excites larger flexors (like elbow and wrist flexors) that are needed to produce a less precise but necessary movement.

Lateral motor system	Medial motor system
Excites Flexors 1. Lateral Corticospinal 2. Rubrospinal 3. medullary reticulospinal (counteracts the pontine reticulospinal).	Excites extensors 1. Pontine reticulospinal 2. lateral and medial vestibulospinal.

❖ Quiz:

1. Which of the following are co-planar (on the same plane) canals?
   a) Anterior vertical canal on one side and posterior vertical canal on same side.
   b) Anterior vertical canal on one side and posterior vertical canal on opposite side.
   c) Anterior vertical canal on one side and anterior vertical canal on opposite side.
   d) Anterior vertical canal on one side and anterior horizontal canal on same Side.
2. True about the Rubrospinal tract:
   a) originates from the pontine reticular formation.
   b) descends contralaterally.
   c) Controls the activity of axial muscles.
   d) is a component of the medial motor system

3. Which of the following is considered true at the beginning of linear acceleration?
   a) The statoconia lag behind and the person feels like falling anteriorly.
   b) The statoconia move forward, leaning forward can correct this.
   c) The statoconia lag behind because of its momentum.
   d) The statoconia lag behind, leaning forward can correct this.

4. The hair cells in the vestibular receptor organs:
   a) Are only stimulated during acceleration.
   b) Show hyper-polarization when the sterocillia deviate toward the kino-cillium.
   c) Show depolarization when the sterocillia deviate toward the kino-cillium.
   d) Show depolarization when the sterocillia deviate away from the kino-cillium.

- ANSWERS:
    1. B
    2. B
    3. D
    4. C