

Clinical Physiology of the Balance System



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Maintenance of Balance

CNS collects information about static / dynamic position of the body in relation to the ground and the surroundings from certain sensors in different parts of the body



Information from different sensors integrated in the brain and compared with previously stored experiences



A very precise, coordinated and accurately timed motor output generated *reflexly* which contracts some specified muscles and restores balance.



3 'must know' of physiology

What constitutes the balance system:
the convoluted ANATOMY of the vestibular system



Balance function in normals:
the complex PHYSIOLOGY



Aberrations in the functioning of the balance system:
when the balance system is screwed up



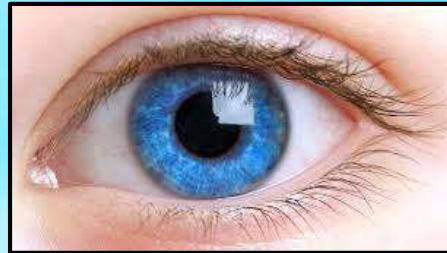
Physiology of Balance

Afferent **SENSORY** system
(inputs to the brain from)

Vestibular labyrinths



Eyes



Proprioceptors

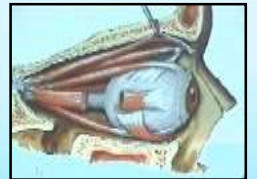


• Efferent **MOTOR** system
(output generated by the brain to)

Muscles of LIMBS / TRUNK / NECK through
VESTIBULOSPINAL reflex system.



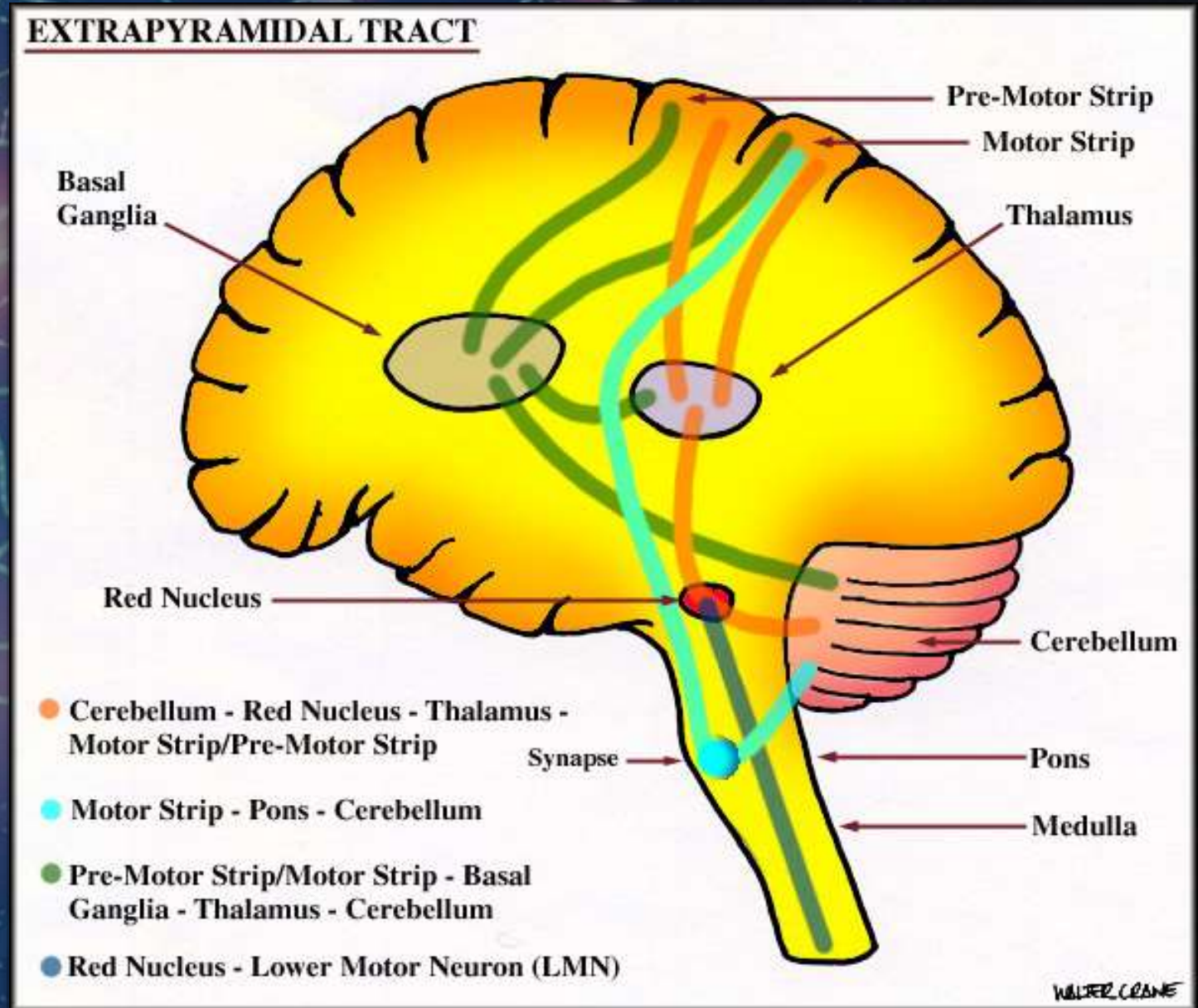
Muscles of the EYES through
VESTIBULO-OCULAR reflex system.



- *Cerebellum fine tunes the motor output*
- *Cognitive system determines the nature of the response*
- *Higher centers in the brain modulate the motor response*

Parts of the CNS majorly involved in modulating the motor output

- Pyramidal & Extra-pyramidal systems
- Basal ganglia
- Reticular formation
- Thalamus
- Cerebellum
- Ascending / descending tracts in spinal cord



The Reflex Pathway

Afferent sensory organ



vest. labyrinth/ eyes/ proprioceptors

Afferent neural pathway

*vestibular nerve/ optic nerve/
ascending column in spinal cord*

Center of the reflex

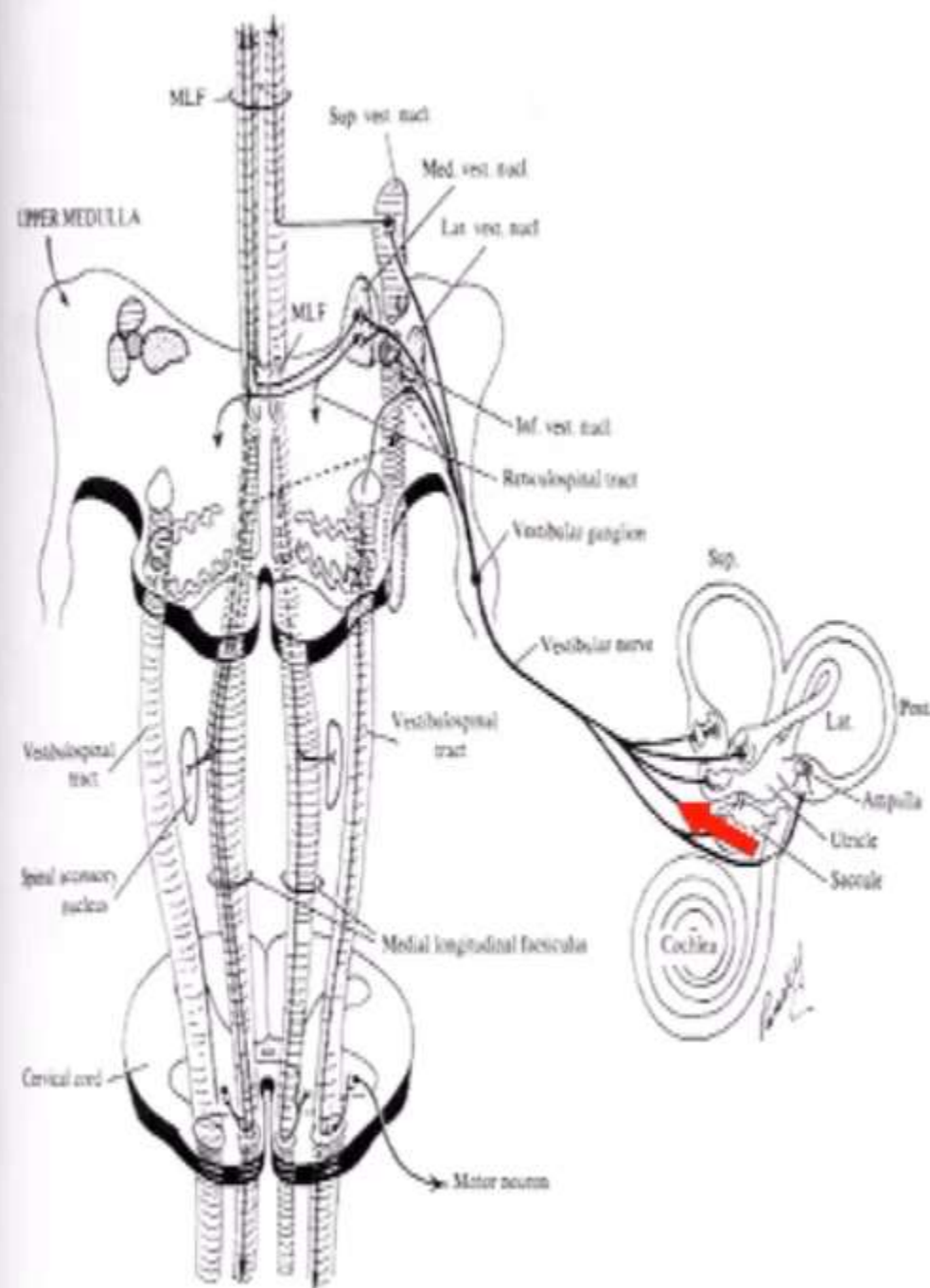
Vestibular nucleus

Efferent motor pathway

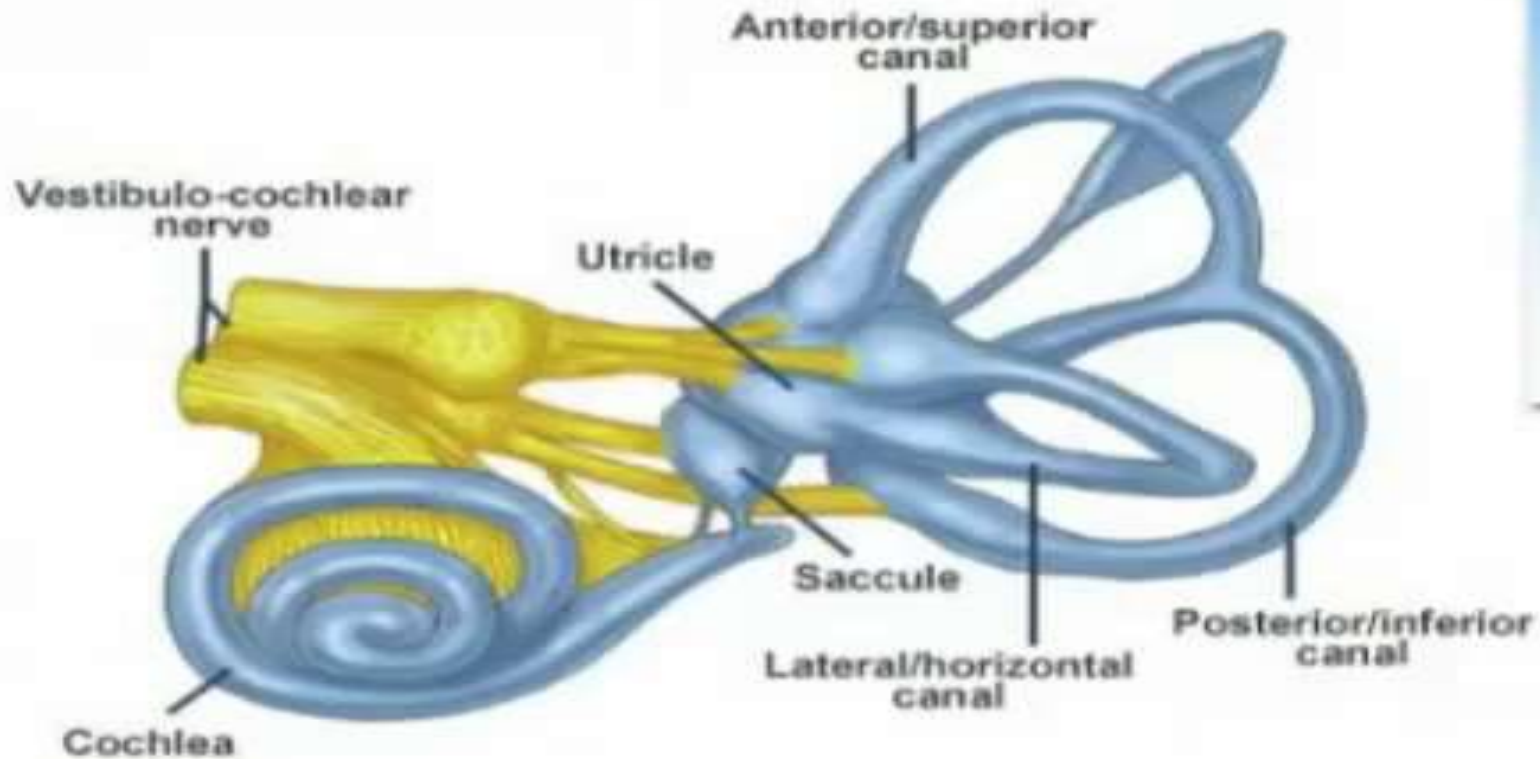
*MLF to oculomotor nuclei 3/4/6h cr nv
Descending vestibulo-spinal tract
Ant. horn cells – peripheral*

Effector motor organ

Extra-ocular / skeletal muscles



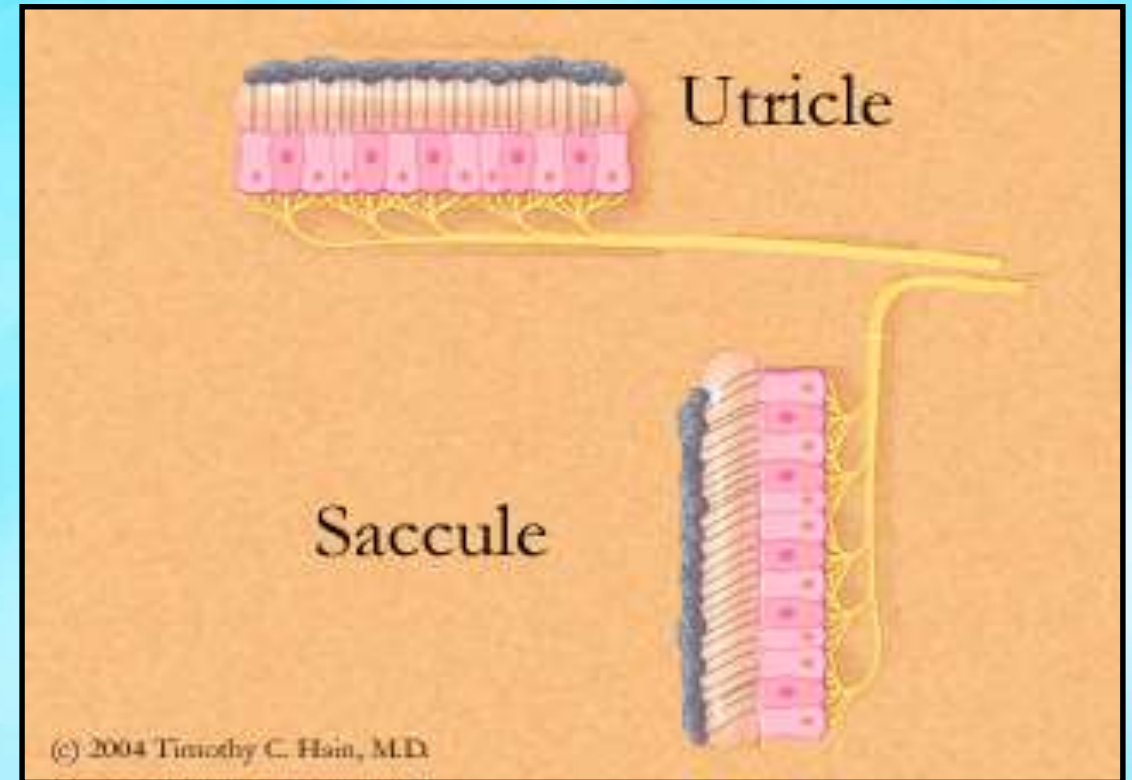
Parts of the vestibular labyrinth and its different functions -



VESTIBULAR LABYRINTH

ROLE of the OTOLITH organs in maintenance of balance

- **semicircular canals** transduce angular & rotational accelerations.
- **otolithic organs** transduce
 - linear acceleration, esp. horizontal (utricle) and vertical (sacculle) displacements.
 - the force of gravity acting on the body and any movement away from gravity (graviception)...*in otolithic dysfunction, this information does not reach the brain*
 - *Provides perception of verticality*



In practice

*Most VFTs evaluate semicircular canal function; otolith function, although very important in our daily activities for maintaining balance, are rarely evaluated...the **Subjective Visual Vertical test** evaluates the perception of the horizontal and vertical which is an otolithic function, **cervical VEMP** evaluates saccular function and **ocular VEMP** evaluates utricular function*

VESTIBULAR FUNCTION in real life



The utricle, saccule and semicircular canals in action...

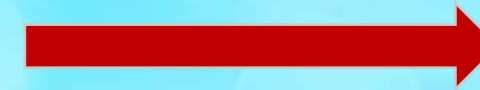
VESTIBULAR PHYSIOLOGY IN HEALTH AND DISEASE

RIGHT



...NORMAL...

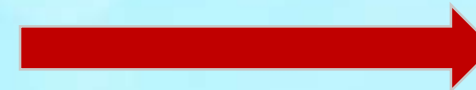
LEFT



Sensation of VERTIGO is caused when there is a disparity in the electrical discharge from the 2 vestibular labyrinths. Hence severe vertigo is felt if one vestibular labyrinth is damaged



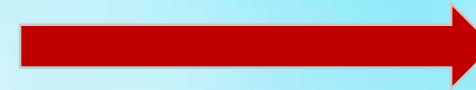
...VERTIGO...



If both vestibular labyrinths are damaged, INSTABILITY and not vertigo is the primary symptom. This happens because the vestibular system becomes insensitive to any destabilizing force

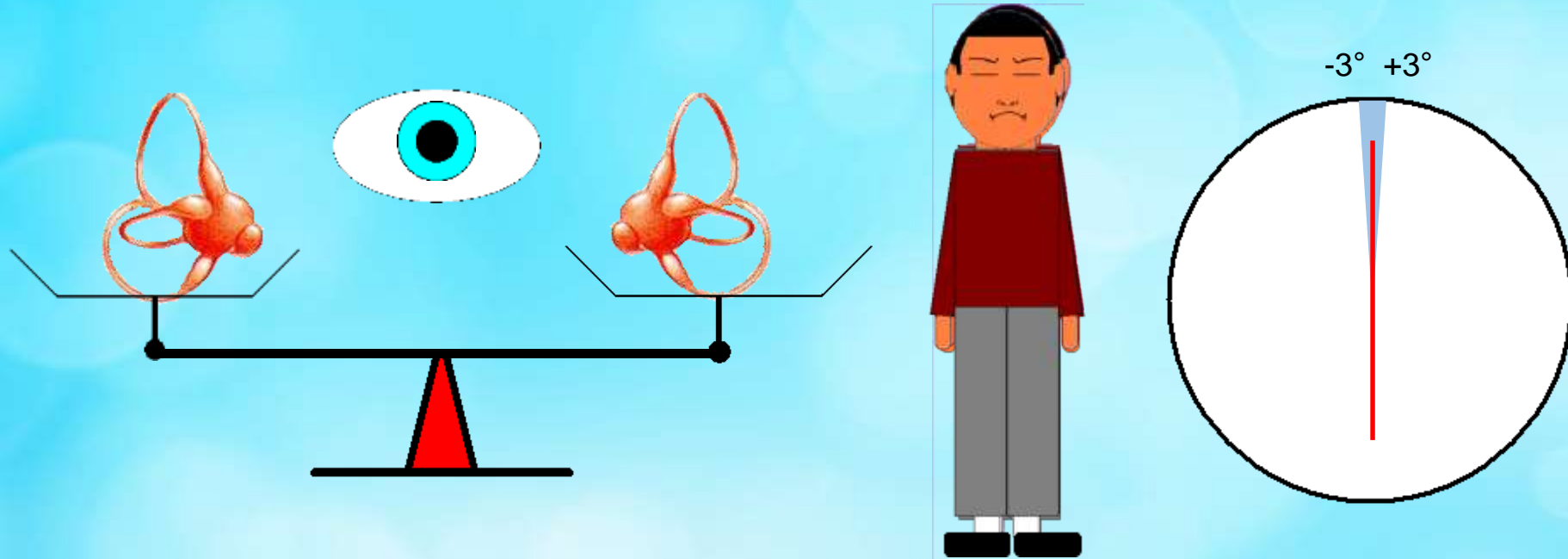


...INSTABILITY...



In a Vestibular damage of the left side

- in case of sudden & uncompensated left vestibulopathy, the healthy right labyrinth takes the upperhand; *there is a RIGHT beating nystagmus, patient falls towards the LEFT, sense of verticality tilts toward this affected i.e., LEFT side..*



-in case of a compensated vestibular deficit and in slowly progressive vestibular deficit, *the nystagmus disappears or is absent, the patient gradually becomes steady & does not fall towards the affected side and sense of verticality returns*

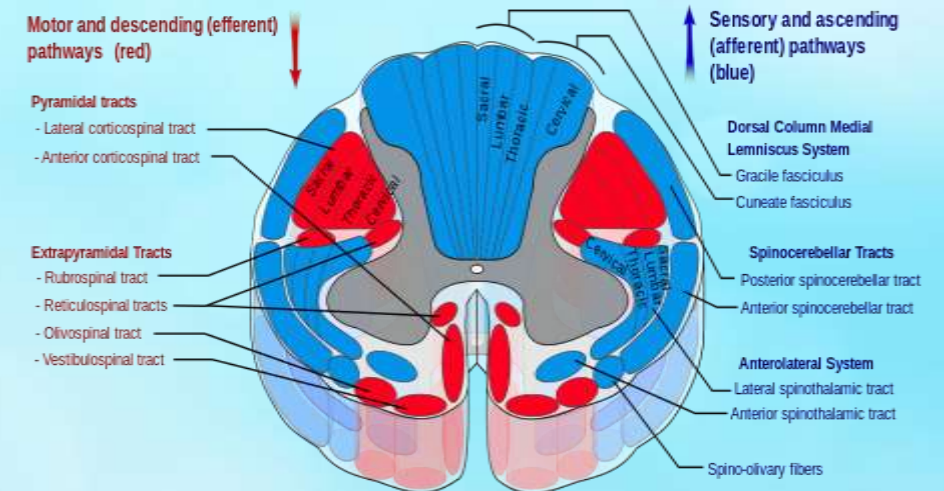
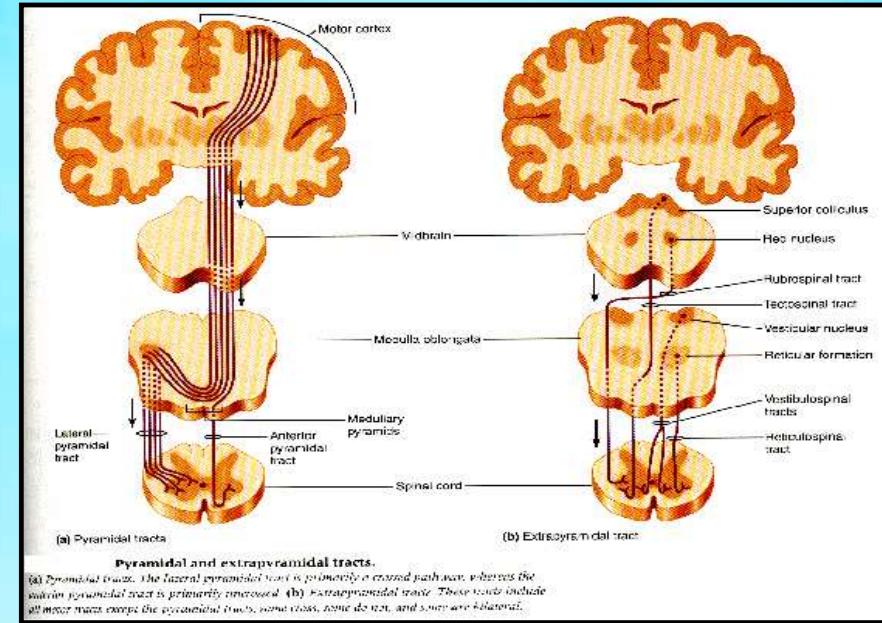
SOME HARD FACTS

- The vestibular labyrinths are **NOT** the only system that control balance
- **Visual** system, **CNS** esp. the **oculomotor** system and the **cerebellum**, peripheral NS, musculo-skeletal system, somatosensory system, **cognitive system** & the **psychic system** have significant influence on the functioning of the balance system
- In the vestibular labyrinth too, the **otolith** organs and the ant. & posterior semicircular canals have a very major role to play which is no less important than the lateral semicircular canals



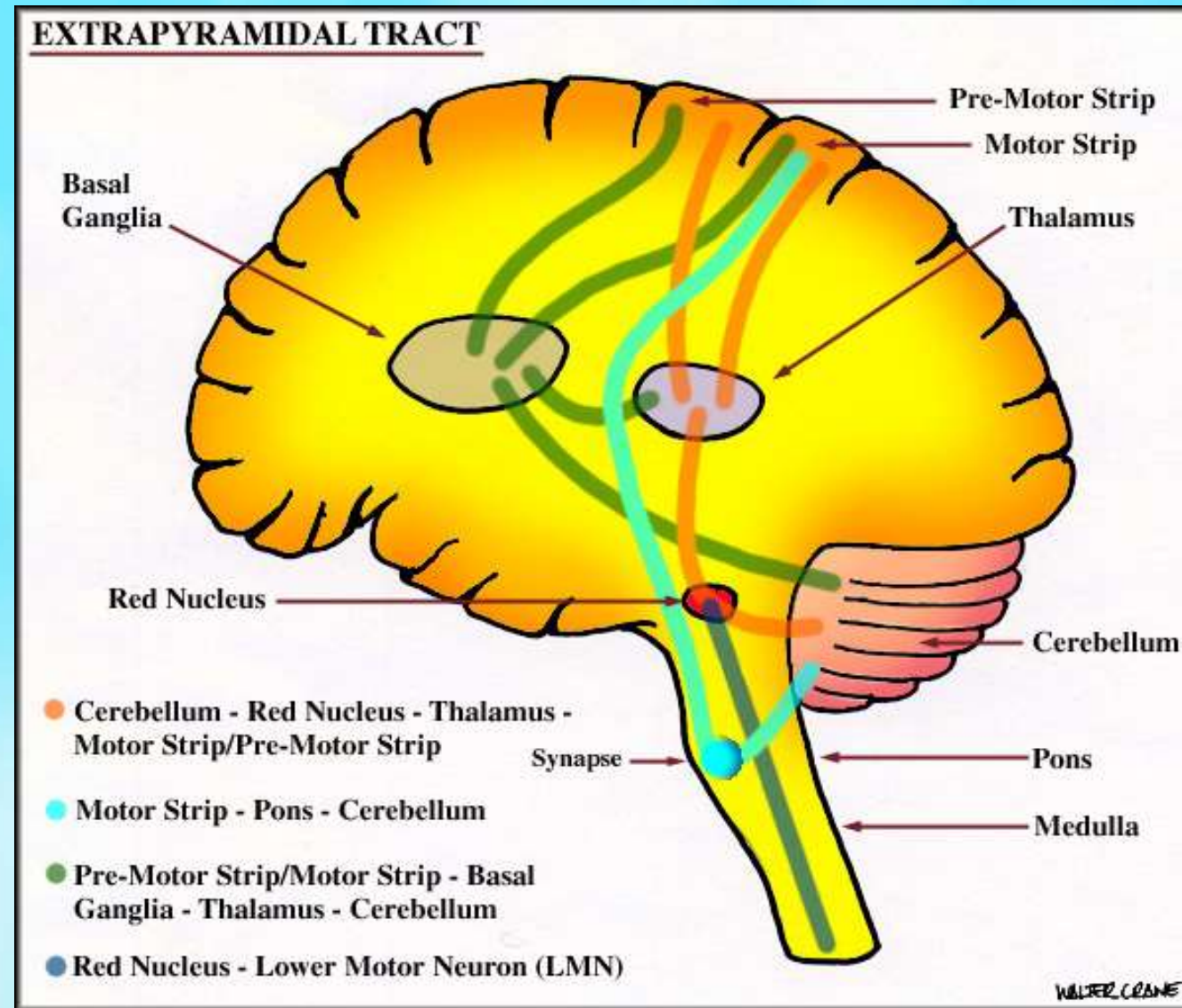
SOME HARD FACTS

- Motor output is controlled by:
 - cerebral cortex / subcortical centers
 - cerebellum
 - Brainstem
- Acts through:
 - pyramidal / extrapyramidal pathways
 - oculomotor system
 - descending columns in spinal cord



Role of the Central Nervous System in maintaining balance

- Pyramidal & Extra-pyramidal systems
 - cortical influence of lower motor centers
- Basal ganglia
- Reticular formation
 - somatic motor control through reticulospinal tracts to maintain muscle tone, posture, balance, motor movement
- Thalamus
 - acts as a relay station in the neural pathway between the cerebrum/cerebellum before they enter the spinal cord
- Cerebellum
- Ascending / descending tracts in spinal cord



Extra Pyramidal Disorders

- **Parkinsonism**

- rigidity, bradykinesia, tremor, postural deficit

- **Dystonia**

- torsion spasms of limbs, trunk and neck

- **Tardive dyskinesia**

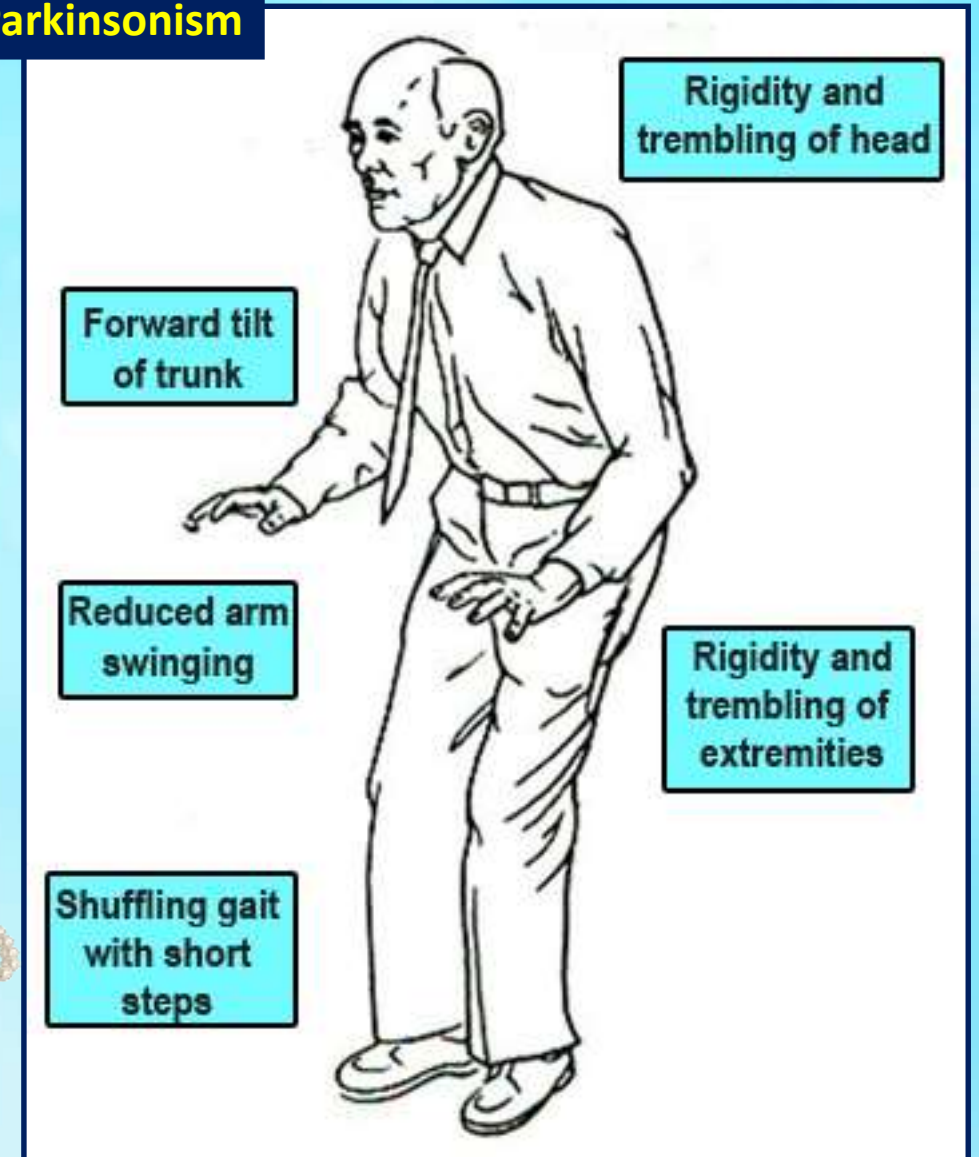
- **Chorea**

- **Athetosis**

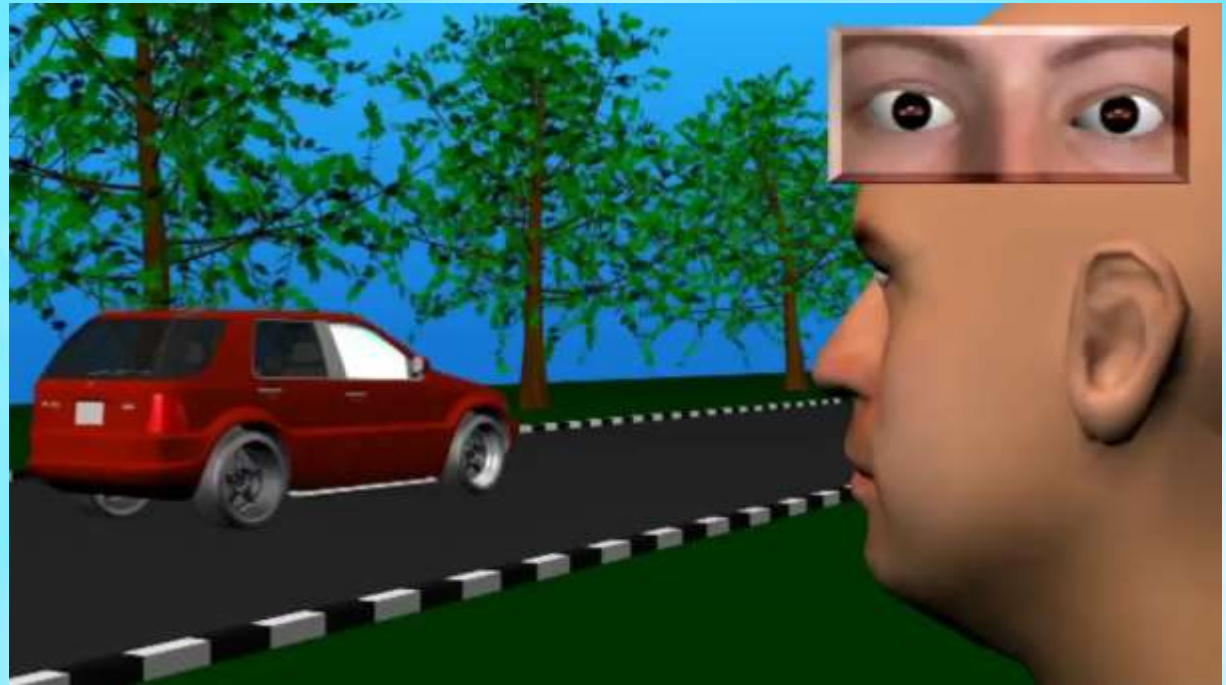
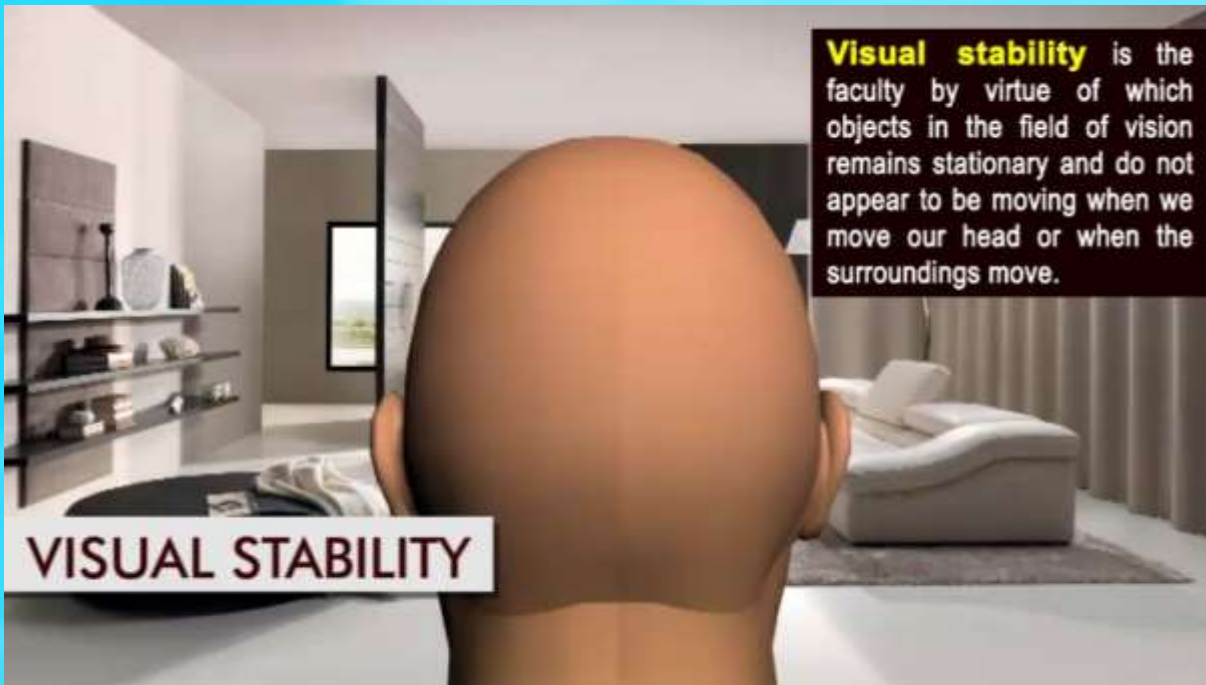
Clinical Pearl

In the initial stages, all of these present with imbalance only, as motor activities are affected; anti-vertigo drugs like prochlorperazine and cinnarizine only aggravate the disorder

Parkinsonism



Functions of the Balance System (1 of 3): Gaze stabilization



Goal: maintenance of a stable & clear image of the visual surroundings when:-

(1) head is moving but visual target is stable (2) head is stable but visual surroundings / target is stable , (3) both head & visual surroundings/target are moving

- Operates through **VESTIBULO-OCULAR REFLEX system (VOR)**
- **Very complex mechanism involving vestibular & oculomotor systems**
- **Can be evaluated by clinical tests and investigations like e.g., VHIT, Saccade test, OPK test, SPS test, gaze test**

OCULOMOTOR SYSTEM

- the motor system to move the eyes in different ways so as to **FIXATE / STABILISE** images of surrounding objects in the fovea under all circumstances.

Purpose-

1. **Provide GAZE STABILISATION**
2. **Provide good visual acuity / spatial orientation**
3. **Prevent oscillopsia when subject moves the head or surrounding objects move in 3D space.**

Very complex process & involves many mechanisms any of which if jeopardised, leads to **CENTRAL VERTIGO**; hence thorough evaluation of oculomotor system is mandatory in all patients presenting with balance disorders

VOR, SPS, OPK, SC GAZE holding system all control the contraction of the extra-ocular muscles

