EYE MOVEMENT :-

- Eye movts evolved to hold the image of external world
- Three cranial Nerve nuclei supply the extra ocular muscles
  1. Oculomotor nucleus :- Ipsilateral medial and inferior re
     Ipsilateral ~~su~~ inferior oblique
     Contralateral superior rectus
  2. Trochlear nucleus ~~nerve~~ :- Contralateral superior oblique
  Abducens nucleus :- Ipsilateral lateral rectus.

- These motor neurons for eye movts form some of the smallest motor units [1:10 nerve to muscle ratio].
- Abducens nuclei have interneurons which project via the medial longitudinal fasciculus to medial rectus motor neurons in the contralateral oculomotor nucleus.

⇒ **Vestibulo ocular reflex :-**

- Visual acuity degrades rapidly when there is eye movt in relation to external world ie there is retinal slip [slipping of visual scene across the retina].
- One of the main causes of retinal slip is the movt of head.
- VOR is one of the mechanisms to maintain stability of the visual scene on the retina.
- VOR produces eye movts that are equal & opp to ~~movts of head~~

occurs in both light and dark as the stimulus is head acceleration.

- VOR is an open loop system → immediate behaviour of the reflex is not regulated by feedback about the success or failure of its output.

- There are both translational & rotational VOR's as well as separate subsystems for handling movts about different direction

- <u>Neural circuitry of VOR</u> :- VOR counters head motion by causing rotation of eyes in opp direction.

- Angular VOR are caused by more straightforward [but complex] pathways

-

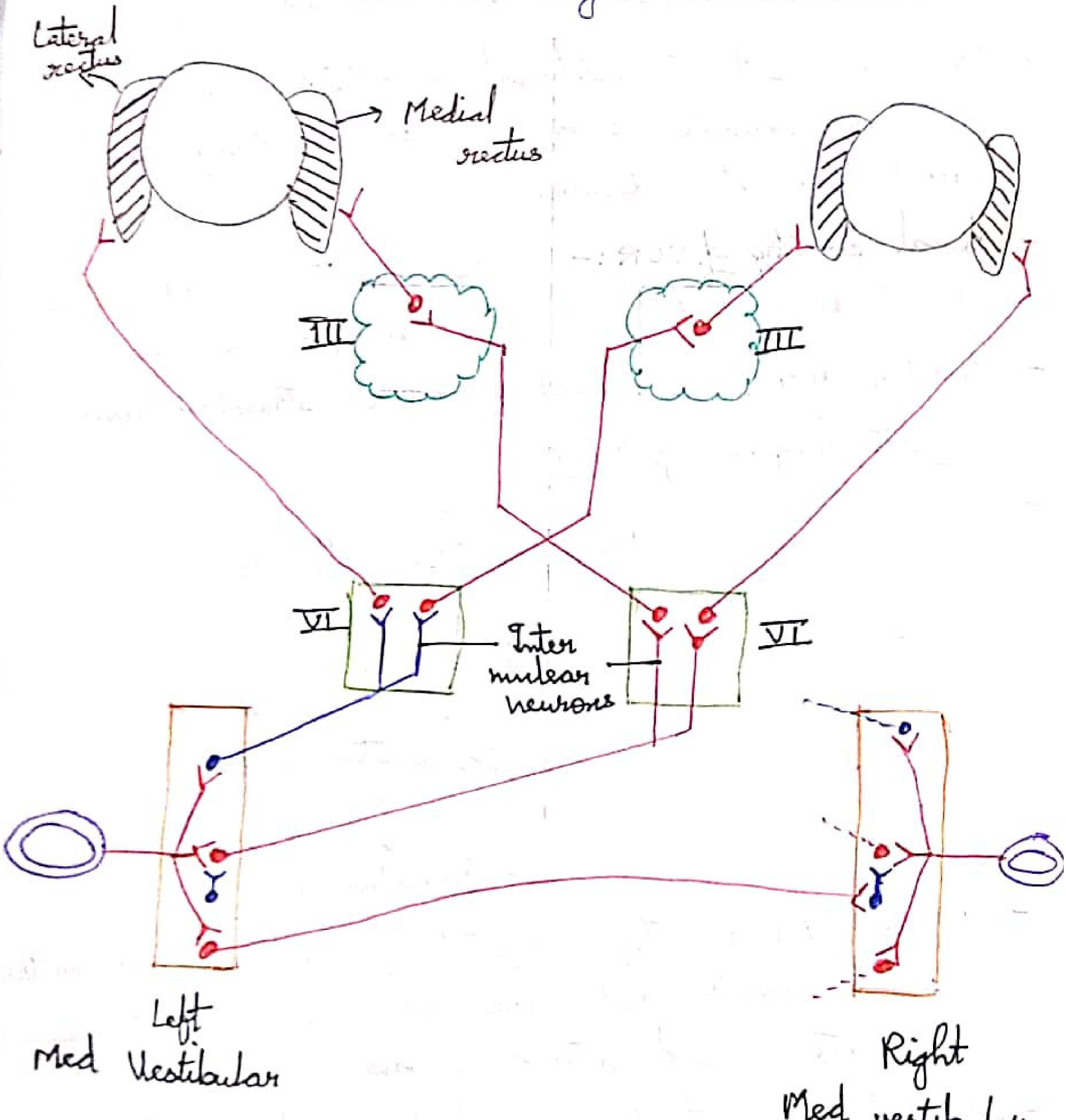
Primary Vestibular afferents
↓
Vestibular nuclei
↓
Oculomotor nuclei
↓
Extra ocular muscles

- Pathway for generating horizontal eye movt originates in the horizontal canals and those for vertical movt originate in anterior and posterior canals.

- Vestibular afferent fibres involved in horizontal VOR pathway synapse primarily in the medial vestibular nucleus which projects to the abducens nucleus bilaterally

... project ipsilaterally and excitatory ones project contralaterally

- Double decussation of this pathway results in aligning of the responses of functional synergists [eg - the left medial rectus with the right lateral rectus.



Blue — Inhibitory
Red — Excitatory

→ superior vestibular nucleus → direct bilateral projections to the oculomotor nuclei.

- Consider what happens when head is rotated to left side :-

Leftward rotation of head → causes visual image to slip towards right.

↓

↑ in the activity of left vestibular afferents

↓

Medial Vestibular nucleus

- Ipsilateral abducens → Inhibition
  - Inhibition of left lateral rectus
  - Inhibition of Rt Medial rectus
- Contralateral abducens → Excitation
  - Contraction of rt lateral rectus
  - Contraction of left medial rectus

∴ When the head rotates towards left there is movt of both eyes towards rt [by Rt lateral rectus and left medial rectus]. Rotation of both eyes is towards ~~to~~ right.

- Mirror image pathways originating from rt canal → changes in activity thru them during leftward rotation would be exactly the opposite and thus they would function synergistically with the

- Commissural fibres that connect two medial vestibular nuclei are excitatory but end on local inhibitory interneurons of the contralateral vestibular nucleus and thus inhibit the projections of that nucleus
- Commissural cells in the left vestibular nucleus are activated and ∴ cause active inhibition of rt medial vestibular nuclei projection neurons

This commissural pathway is powerful enough to modulate the activity of the contralateral vestibular nuclei even after uni~~bi~~lateral labyrinthectomy

- Parts of the Vermis and flocculonodular lobe receive primary vestibular afferent or 2° afferent fibres or both and in turn project back to the vestibular nuclei directly and via a ~~disyn~~ disynaptic pathway involving the fastigial nucleus.

⇒ Opto kinetic reflex :-

- OKR is the second mech which stabilises the visual image on the retina.
- It often works in conjunction with the VOR
- OKR is activated by movt of the visual scene whether caused by motion of the scene itself or by head motion.

[illegible] slip of the visual scene on retina detected by [illegible]sitive retinal ganglion cells.

- OKR circuits feed into the same circuits as used by the vestibular system.

- OKR is particularly important for maintaining a stable image when head movts are slow bcoz the VOR works poorly in these conditions.

- Neural circuitry of OKR :-

- The stimulus is retinal slip ⇒ photoreceptors are the start of the reflex arc.

- Key brainstem centres ⇒ Nucleus of optic tract (NOT)
  Accessory optic nuclei (AON)

- Direction selective motion sensitive retinal ganglion cells are a major afferent source carrying visual info to these nuclei.

- Additional input comes from higher visual areas of occipital & temporal lobes → This input is impt in primates.

- Cells of NOT and AON have large receptive fields and their responses are selective for the direction and speed of movt of visual scene.

- The efferent connections of these nuclei are numerous and complex.

There are polysynaptic pathways to the oculomotor and abducens nuclei and monosynaptic input to vestibular nuclei which allow interaction with VOR

- There are projections to precerebellar nuclei including inf olivary nucleus and basal pontine nucleus ⟶ flocculus ⟶ vestibular nuclei

⇒ **Saccades :-**

- Very rapid discrete movts that bring a particular region of the visual world onto the fovea are called saccades.
- Saccades may also be used to rapidly scan the envt.
- Saccades – extremely rapid eye movts
  ↳ In humans eye vel during saccade = 800 degrees per sec
  During VOR = 10 degrees/sec
  OKR = upto 120 degrees/sec
- Saccades – voluntary / reflex
- They can also be made towards auditory or other sensory cues in the dark or towards memorised targets.
- Visual processing is suppressed just before and during saccades – Saccadic suppression.
  Function :- to prevent sensations of rapid, sudden movt of the visual world that would result during a saccade in the absence of such suppression.
  Mechanism :- not fully known.

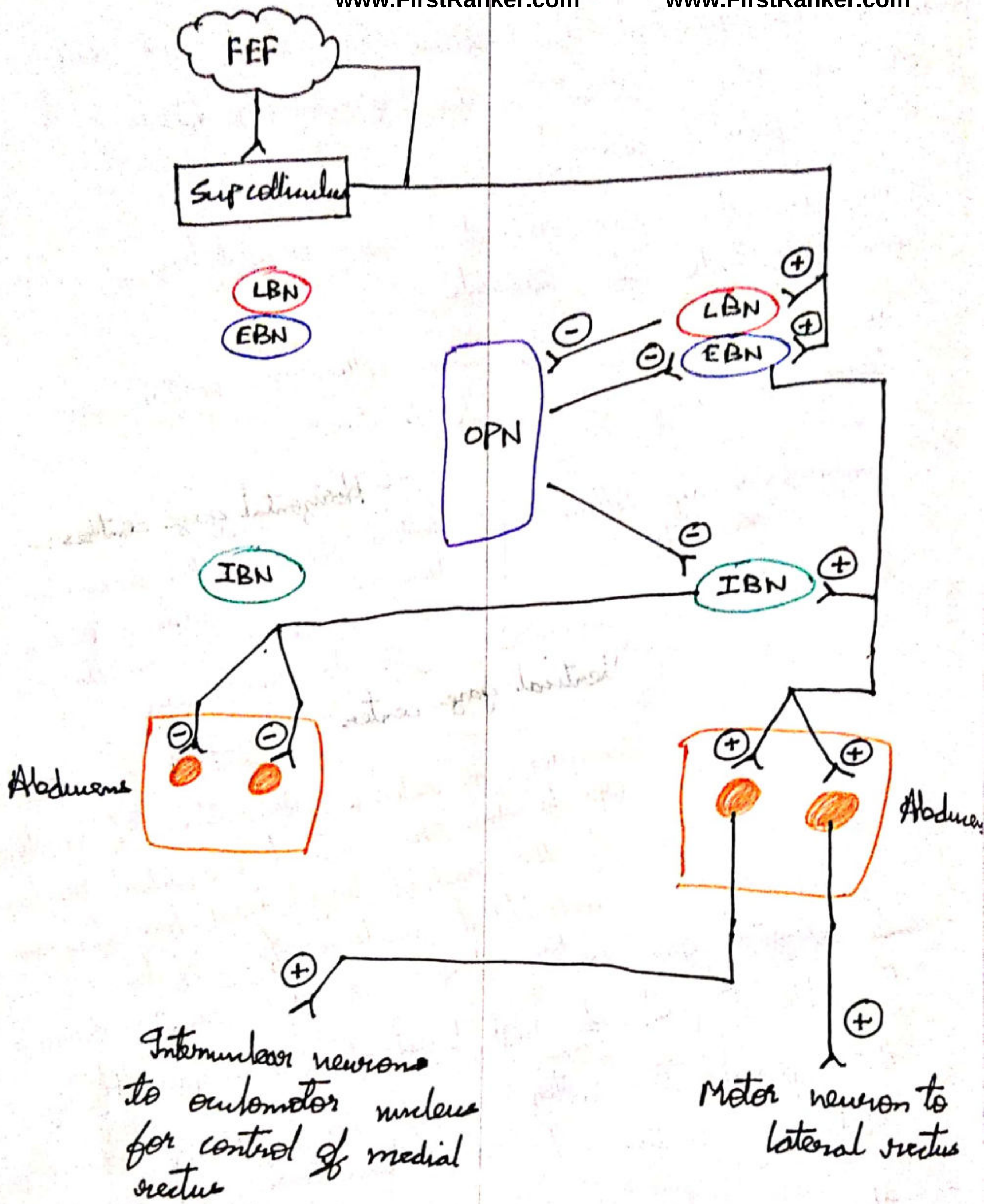
...ral circuitry of saccade :-

- Saccades are generated in response to activity in sup colliculus and cerebral cortex [frontal eye fields and posterior parietal areas].
- Activity in the sup colliculus → computation of direction and amplitude of saccade.
- The deep layers of the sup colliculus contain a topographic map of saccade locations.
- Info from Sup colliculus goes to

  → Horizontal gaze centres :- control of horizontal saccades
  Neurons in paramedian pontine reticular formation in the vicinity of abducens nuclei

  → Vertical gaze center → control of vertical saccades — reticular formation of midbrain specifically the rostral interstitial nucleus of the medial longitudinal fasciculus & interstitial nucleus of Cajal.

- Each horizontal gaze center has saccatory burst neurons [capable of prod of high burst of spikes (1000 Hz)] that project to motor neurons in the ipsilateral abducens nucleus and to internuclear neurons
- It has inhibitory burst neurons as well that inhibit contralateral abducens.
- Gaze center has neurons showing tonic activity and burst tonic activity
- Omnipause neurons [OPN] in median Raphe inhibits



LBN – long head burst neurons
FEF – frontal eye field
IBN – Inhibitory burst neurons
EBN – Excitatory " "
OPN – Omnipause neuron.

Activity of FF & Sup colliculus

↓

Inhibition of OPN

↓

Excitation of Burst neurons on contralateral side

EBN
- Motor neurons to lateral rectus
- Motor neurons to medial rectus

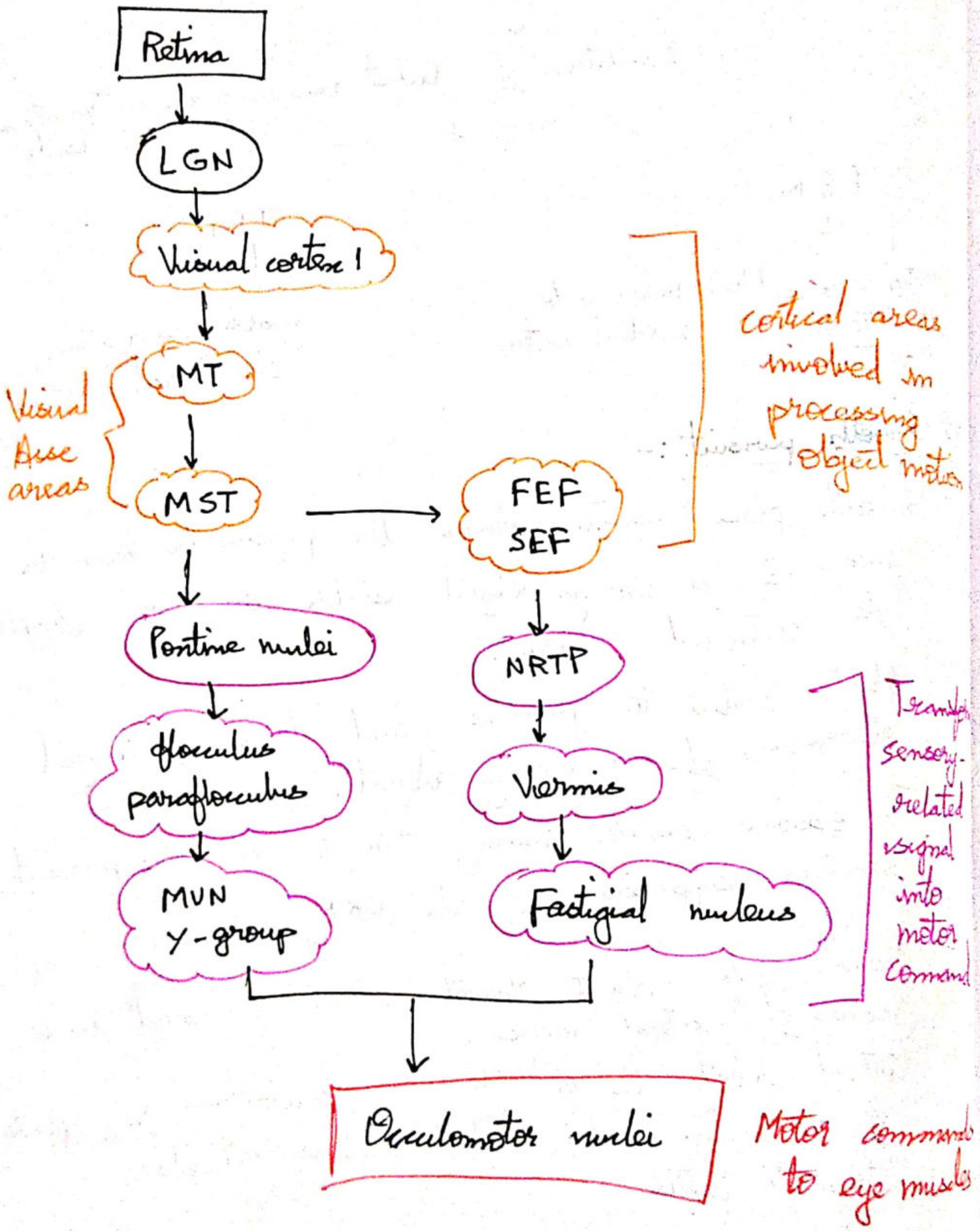
IBN
- Enable relaxation of Burst neurons.

⇒ **Smooth pursuit :-**

- Smooth pursuit system allows the person to keep the image of a moving object stable on fovea despite its continued motion.
- Ability limited to primates and allows prolonged observation of a moving object.
- To observe small moving targets smooth pursuit requires suppression of the OKR
- Visual info about target vel is processed in a series of cortical areas.
- Cortical activity is fed to the cerebellum via parts of the pontine nuclei and Nucleus reticularis tegmenti pontis.
- Posterior lobe vermis, flocculus & paraflocculus recieve

... they in turn project to the vestibular nuclei.

- From this vestibular nuclei activity can be forwarded to oculomotor, abducens and trochlear nuclei.



pink - Brainstem > cerebellar areas

⇒ Conjugate eye movts > Vergence :-

Movt of both eyes in same direction and in an equal amount

Movt of the eyes in opp direction when object is at <30 m distance

- Both these movts are used to maintain a target on both the foveae - necessary for binocular vision
- stimulus for vergence - diplopia > blurry image
- Neural circuits underlying vergence are not well known.
- Cerebellar lesions impair vergence movts
- Lesions of medial longitudinal fasciculus - no affect