

THE OCULAR MOTOR SYSTEM: BASIC CONCEPTS AND ORGANIZATION

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Types of Eye Movements

Type of Eye Movement	Function	Stimulus	Clinical Tests
Vestibular	Maintain steady fixation during head rotation	Head rotation	Fixate on object while moving head; Calorics
Saccades	Rapid refixation to eccentric stimuli	Eccentric retinal image	Voluntary movement between two objects; Fast phases of OKN or of vestibular nystagmus
Smooth Pursuit	Keep moving object on fovea	Retinal image slip	Voluntarily follow a moving target; OKN Slow phases
Vergence	Disconjugate, slow movement to maintain binocular vision	Binasal or Bitemporal disparity; Retinal blur	Fusional amplitudes; Near point of convergence

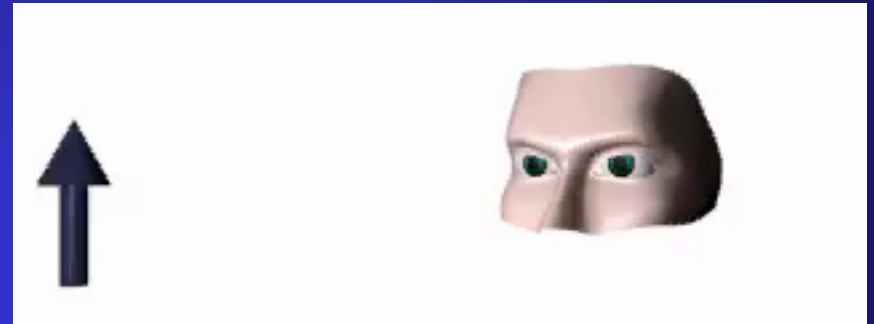
OKN = optokinetic nystagmus



SACCADES



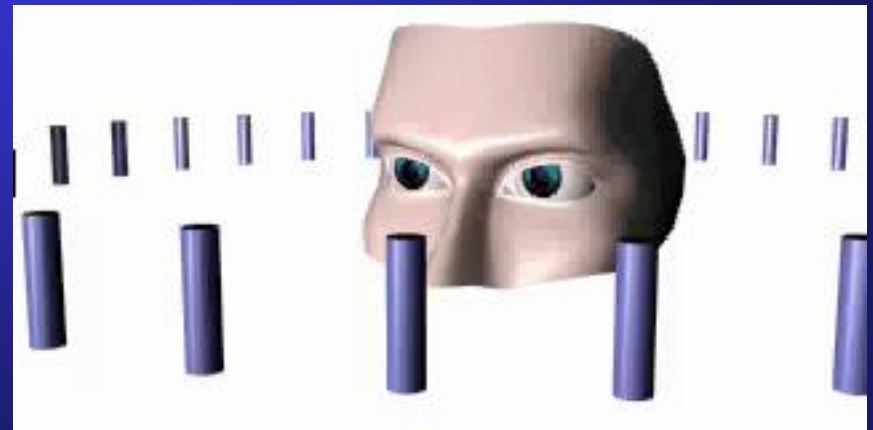
PURSUIT



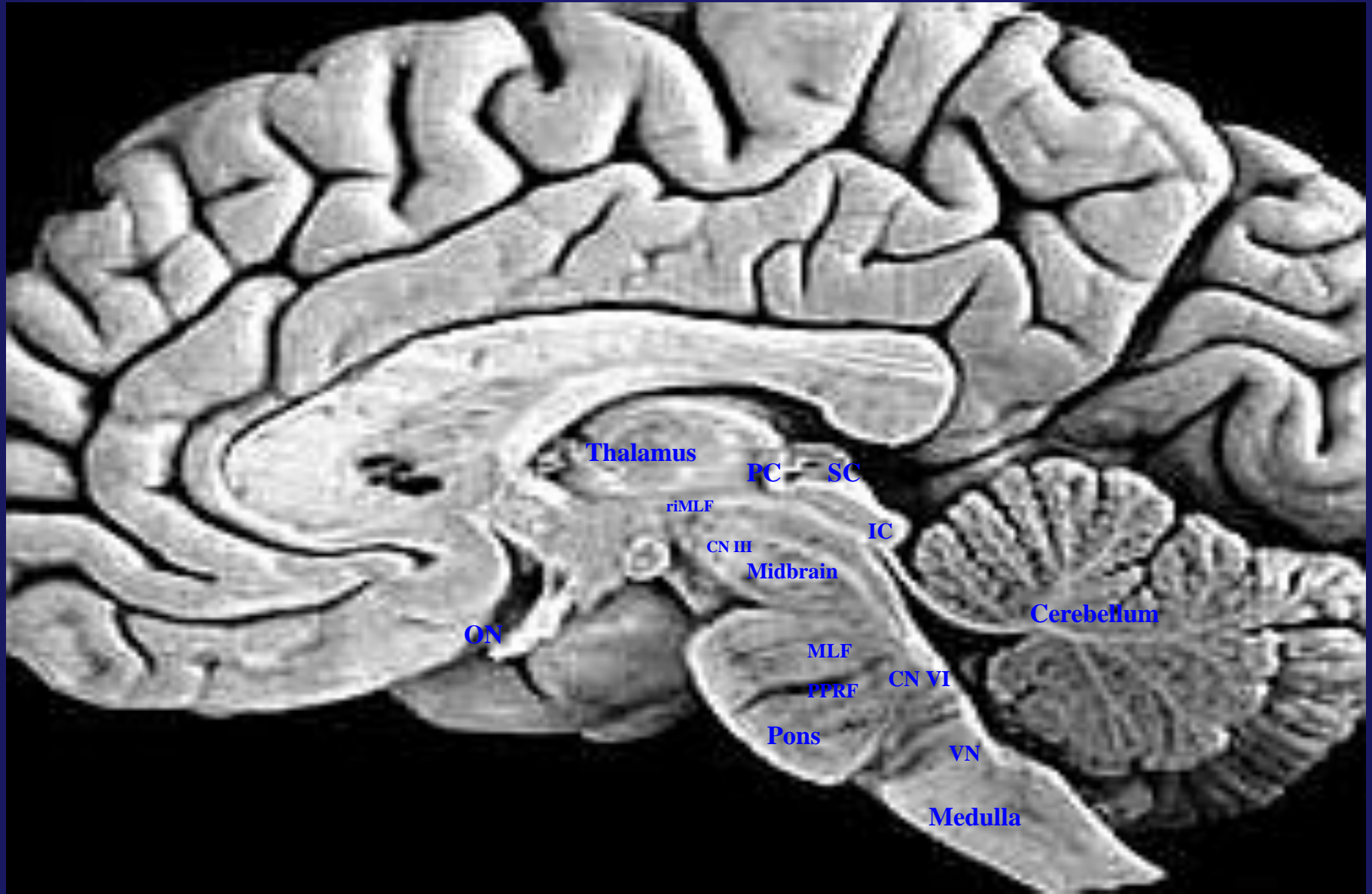
VERGENCE



VOR



OKN



Thalamus

PC

SC

riMLF

CN III

Midbrain

IC

Cerebellum

ON

MLF

PPRF

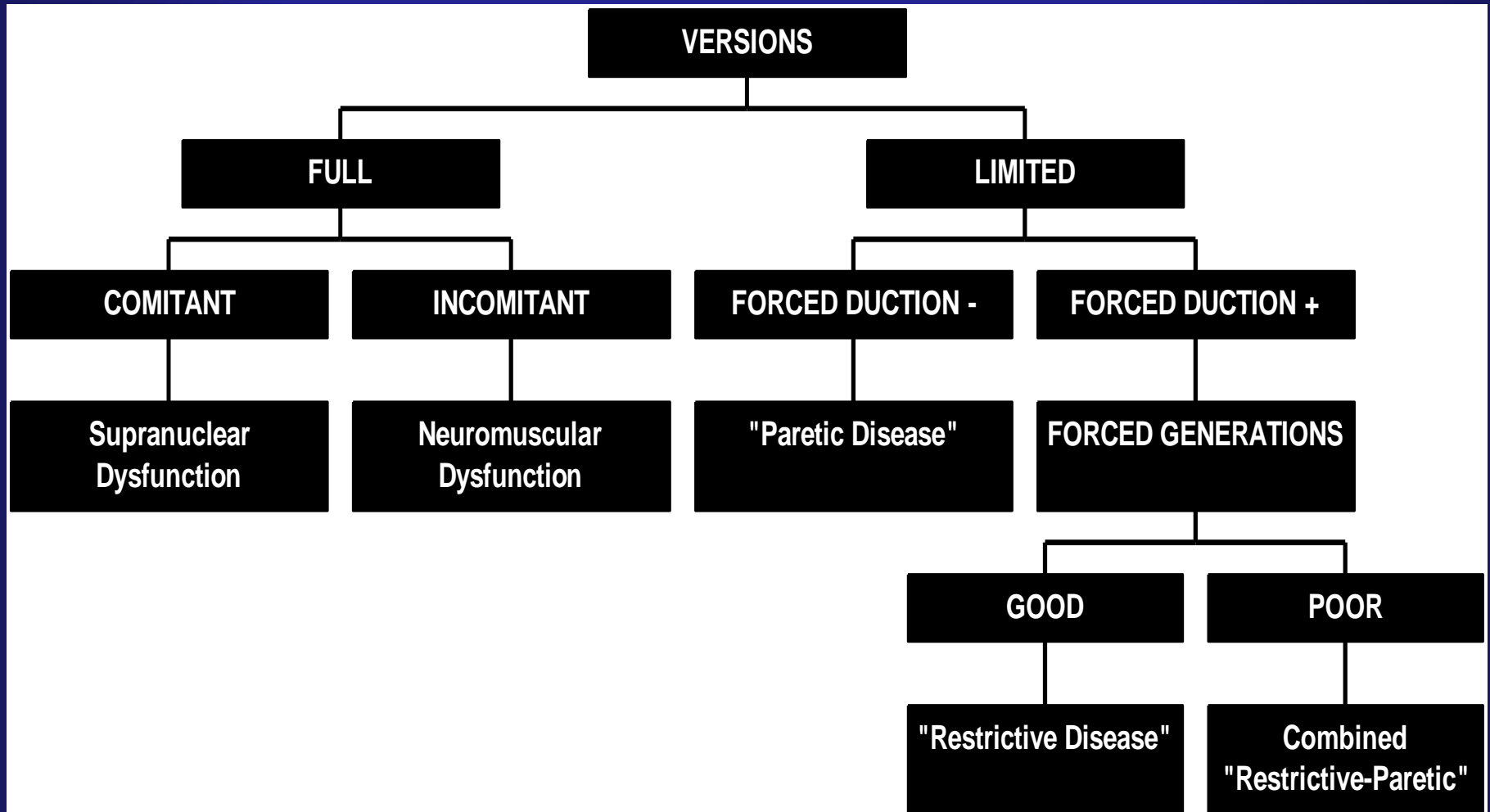
CN VI

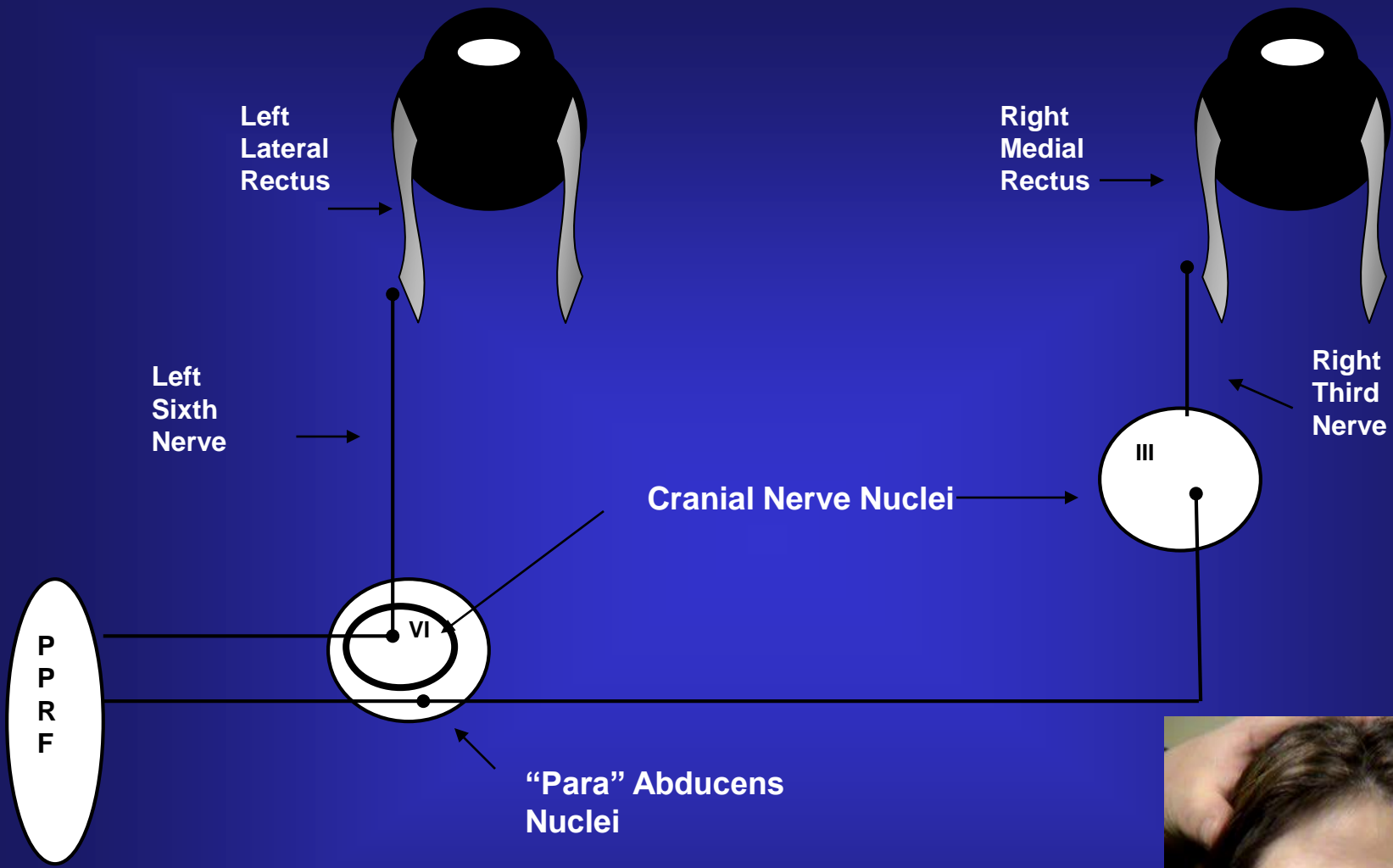
Pons

VN

Medulla

Figure 4 Clinical Evaluation of Range of Eye Movements



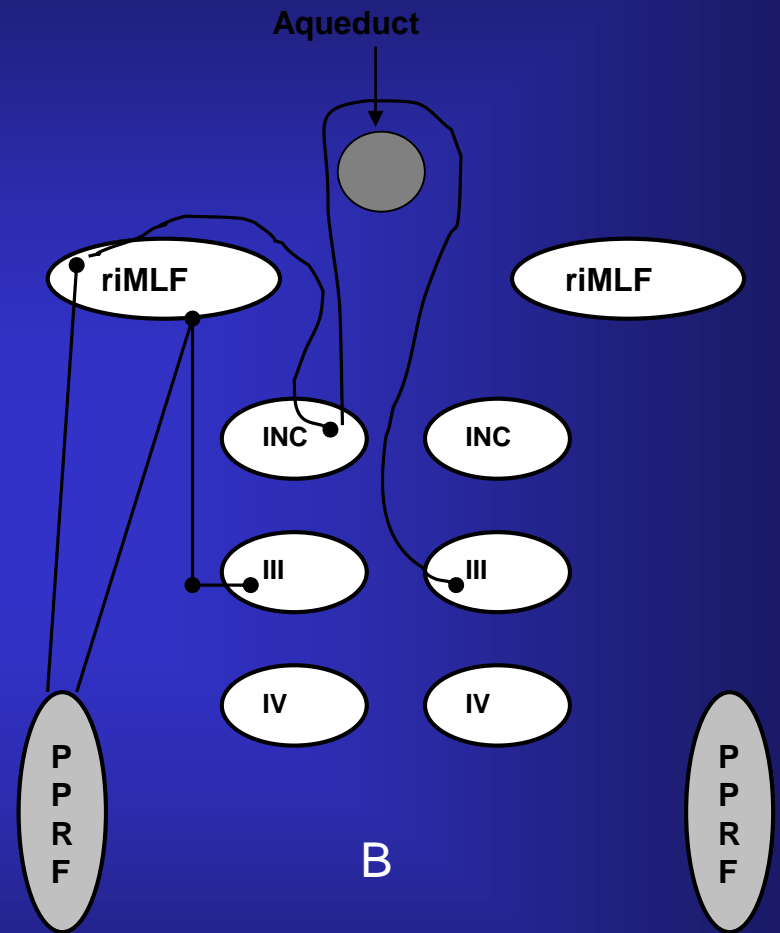
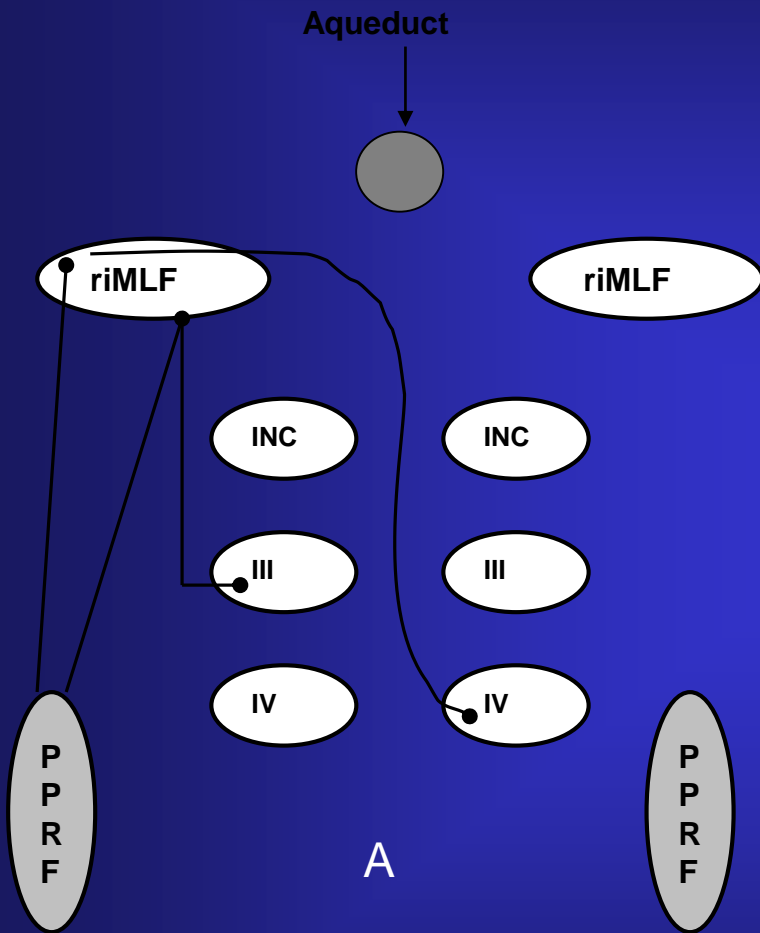


Brainstem Pathway For Horizontal Saccades



Posterior Commissure

Posterior Commissure



Brainstem Pathways For Downward (A) and Upward (B) Saccades





Testing the ability of the extra-ocular muscles to perform smooth eye movements forms an important part of the eye examination routine.

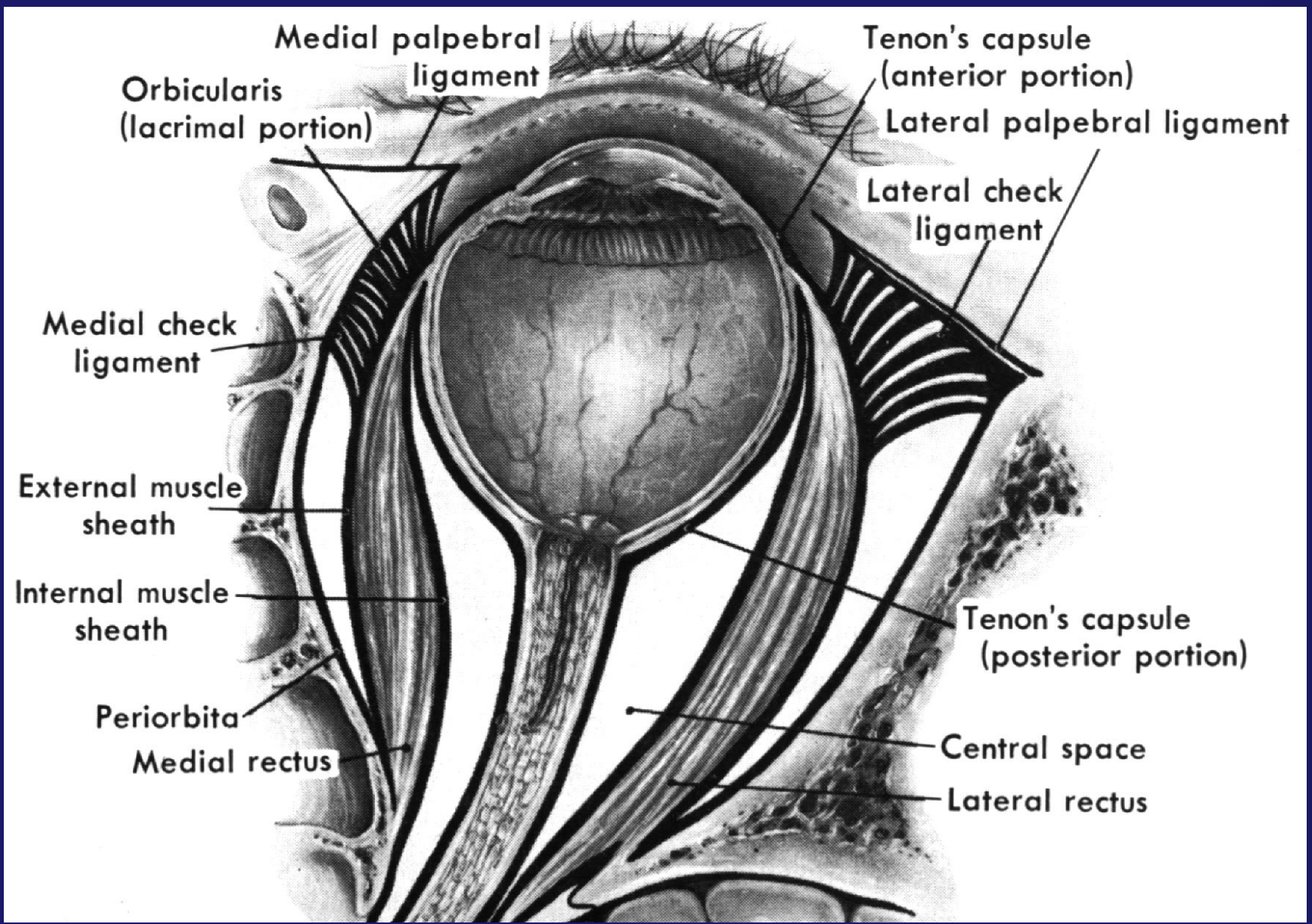
Testing Ocular Motility enables the practitioner to differentiate between

COMITANT vs INCOMITANT

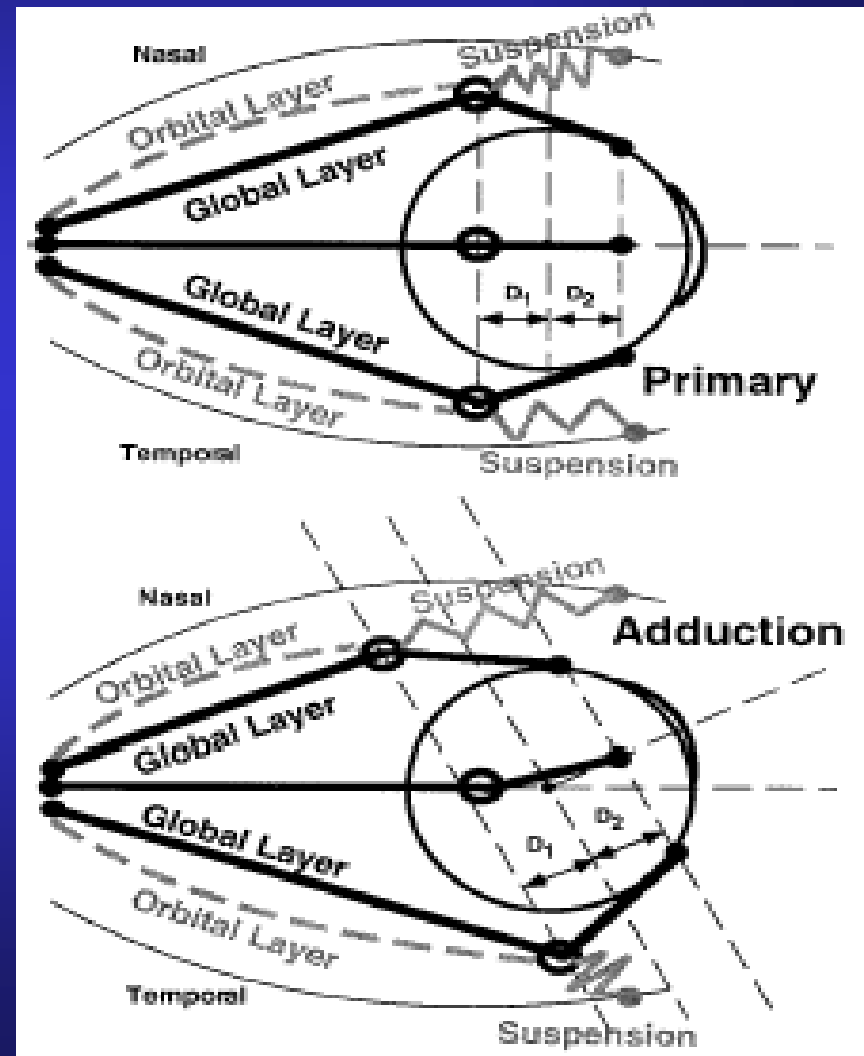
Incomitant - varies in size with the direction of gaze.

Comitant - remains constant with gaze direction





MRI Evidence-EOM Pulleys

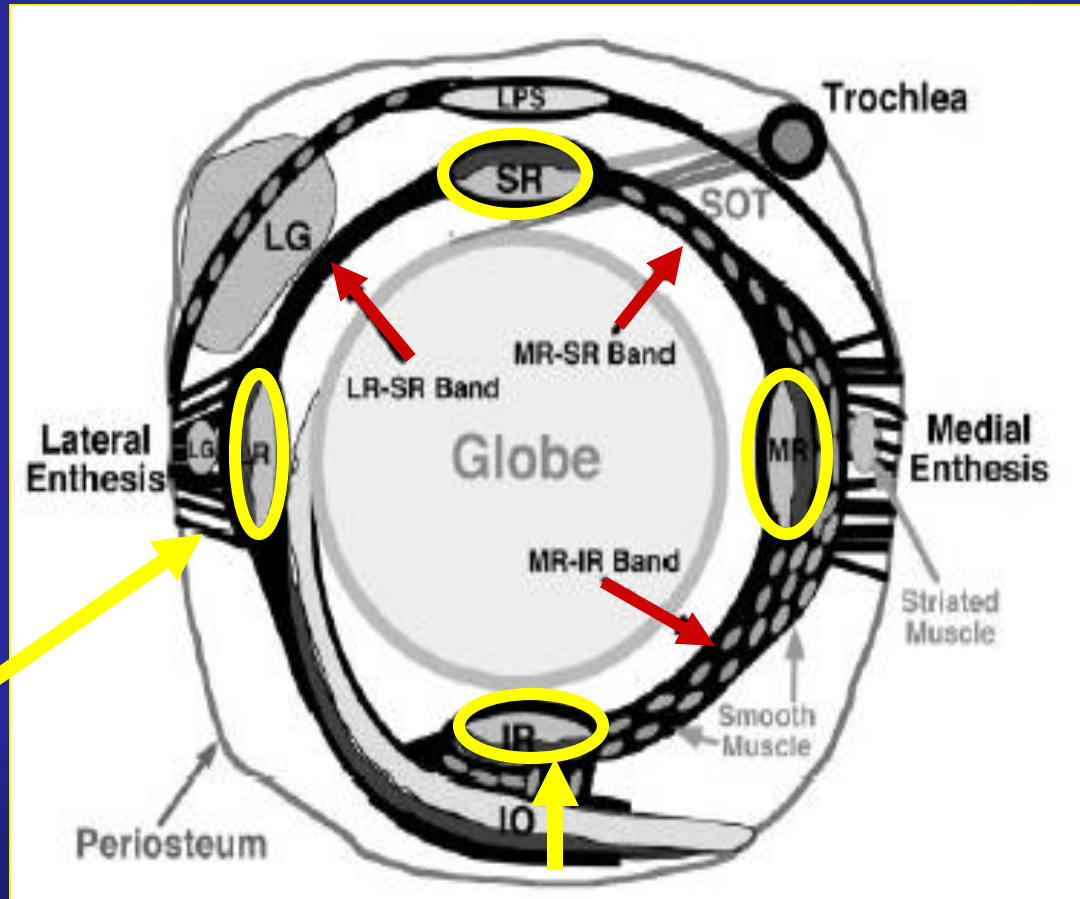


Demer JL, Miller JM, Poukens V, Vinters HV, Glasgow BJ (1995) Evidence for bromuscular pulleys of the recti extraocular muscles. Invest Ophthalmol Vis Sci 36:1125-1136

Demer JL, Oh SY, Poukens V (2000) Evidence for active control of rectus extraocular muscle pulleys. Invest Ophthalmol Vis Sci 41:1280-1290

Pulley System

Connecting Bands between the muscle pulleys forming a circle around the globe



Complete Ring encircling the EOM

Mechanics of Movement

- **Two components to neurological generation of muscle movement**
 - **Phasic Pulse**
 - **Momentary force needed to overcome the relaxation of an antagonistic muscle**
 - **Tonic Step**
 - **The long-term force needed to oppose the lesser elastic load where position is maintained**
- **Global Layer demonstrates both kinds of neurological input**
- **Orbital Layer only demonstrates tonic step**

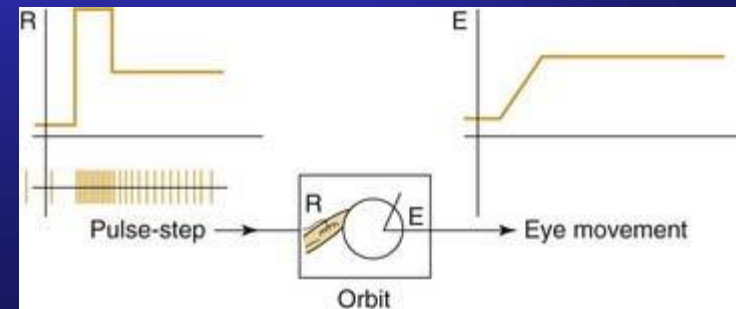
Histological Correlation

- **Orbital Layer**

- High metabolism, fatigue resistance, and luxurious blood supply of the orbital “red” fibers are tailored to their continuous elastic loading by the pulley suspensions.

- **Global Layer**

- With two kinds of forces needed, the global layer has more of a mixture of muscle fiber types
 - **Red fibers are controlled by tonic step innervation (similar to the orbital layer).**
 - **The intermediate and white fibers are supplied with phasic pulse innervation with less metabolic demands and less fatigue resistance.**



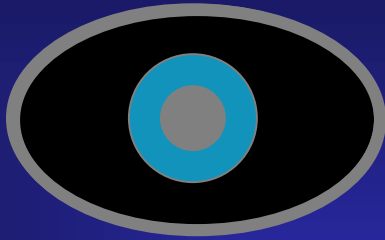
Definitions

Ductions: monocular eye movements into/from cardinal position.

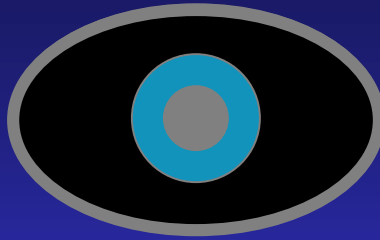
Versions: conjugate binocular eye movements that allow visual axes to move in parallel.

Vergences: binocular eye movements which allow visual axes to cross.

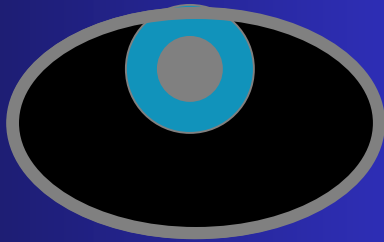
R



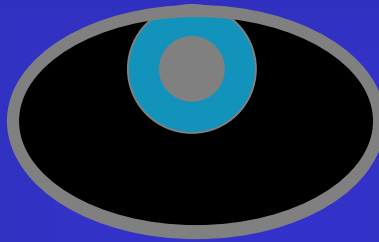
L



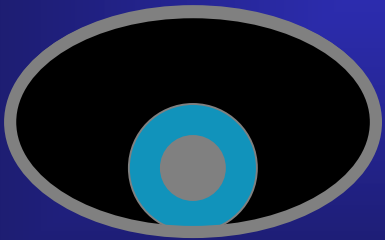
Primary Position



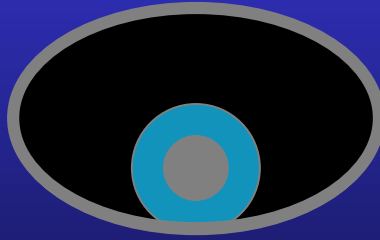
supraduction



Elevation



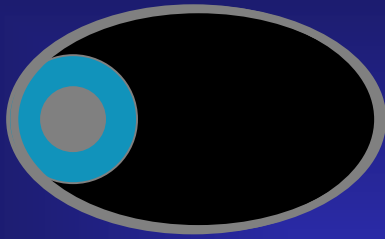
infraduction



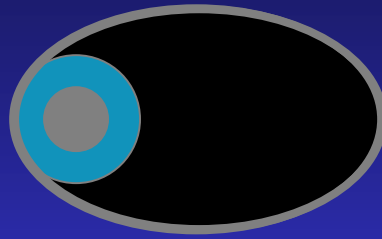
Depression

R

L

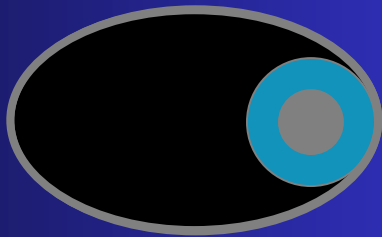


abduction

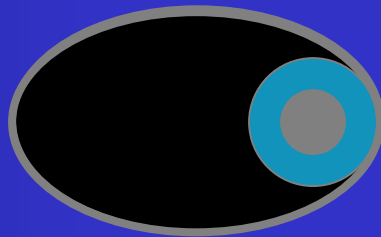


adduction

Dextro-version

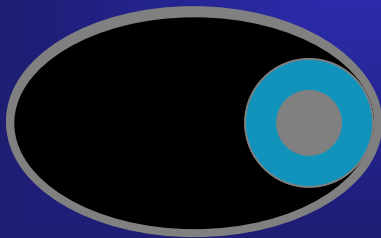


adduction

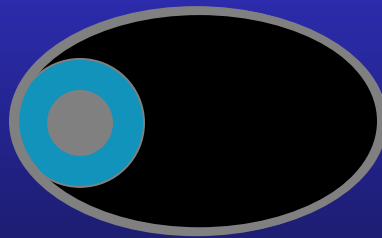


abduction

Levo-version



adduction



adduction

Convergence

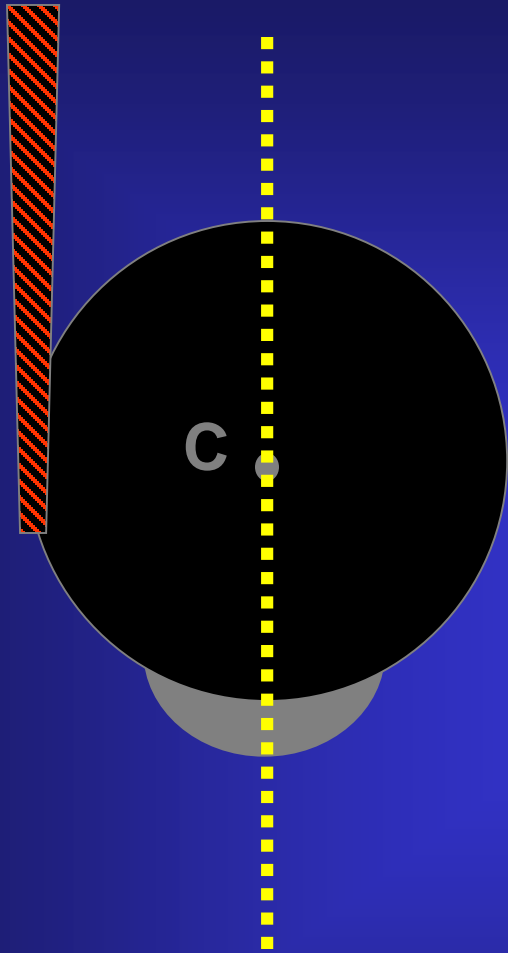
The Isolated Agonist Model



Lateral Rectus

Main Action: abduction

Innervation: Abducens



Temporal

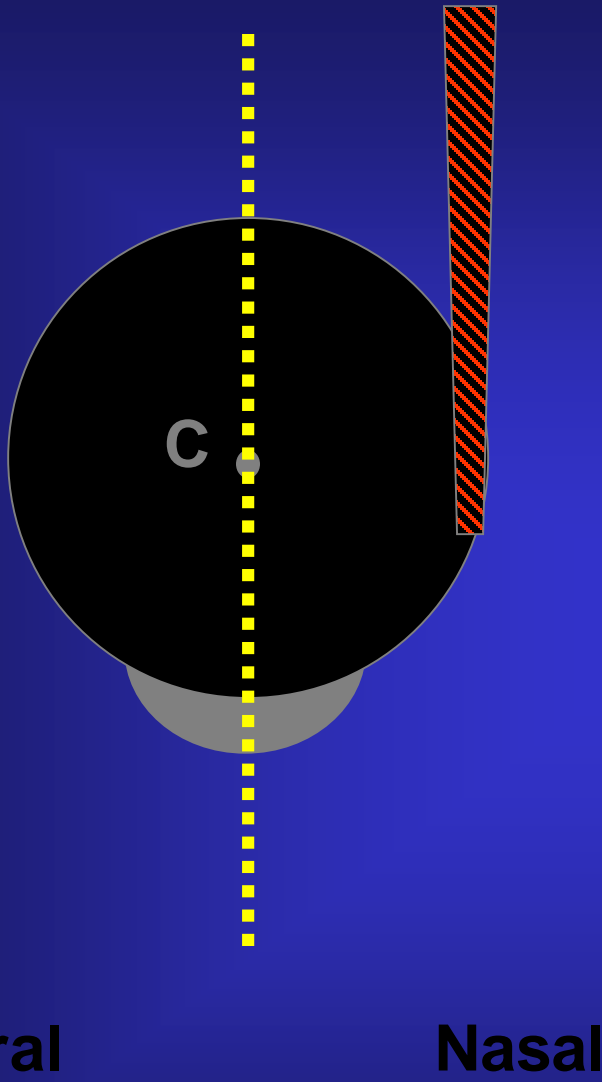
Nasal

Medial Rectus

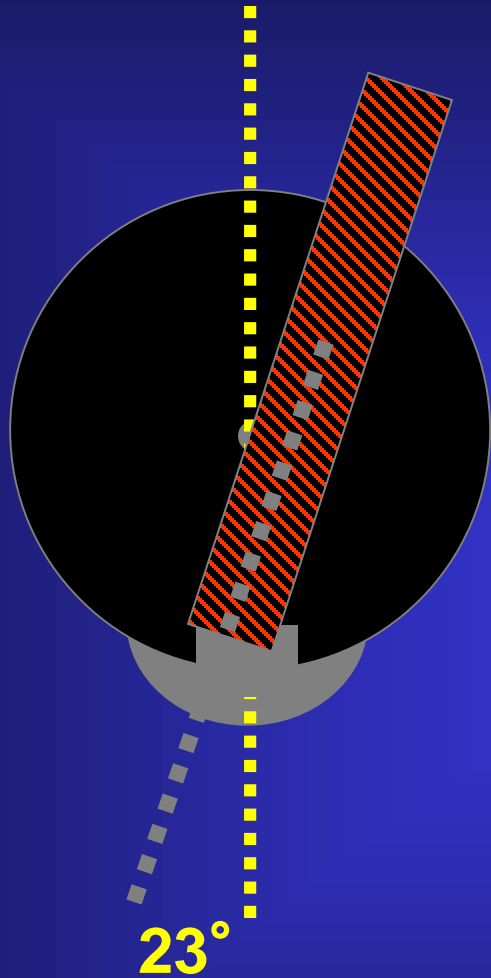
Main Action: adduction

Innervation:

Inf. Div of Oculomotor Nerve



Superior Rectus



Temporal

Nasal

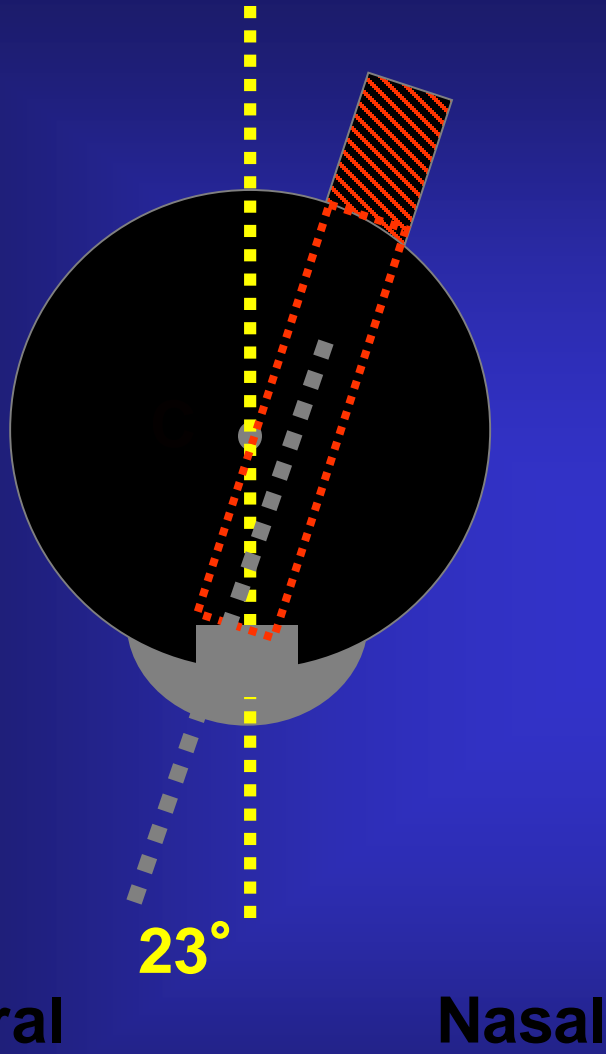
Main Action: supraduction

**Secondary: incycloduction
adduction**

Innervation:

**Sup. Div of Oculomotor Nerve
(i.e. III Cranial Nerve)**

Inferior Rectus



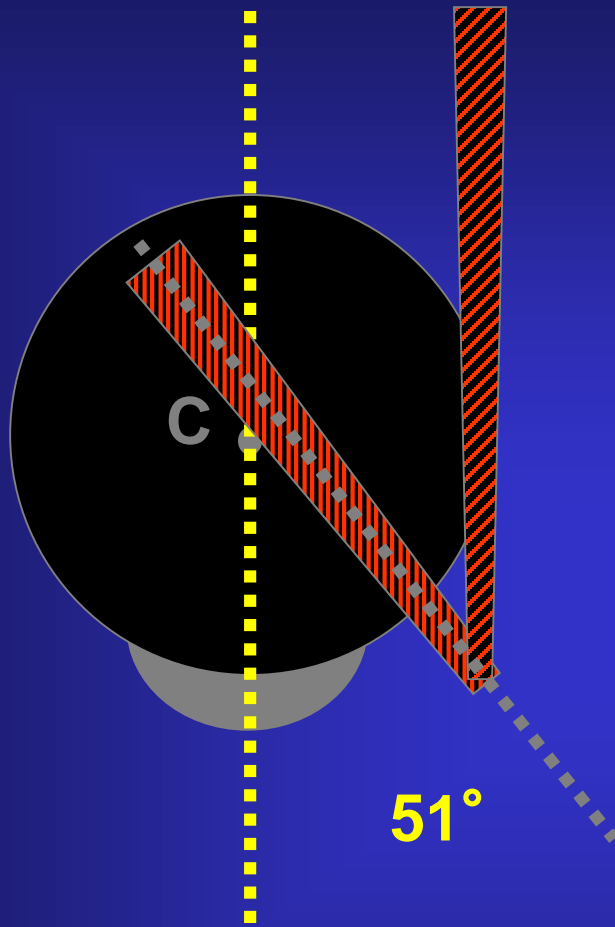
Main Action: infraduction

**Secondary: excycloduction
adduction**

Innervation:

Inf. Div of Oculomotor Nerve

Superior Oblique



Main Action: incycloduction

Secondary: depression
abduction

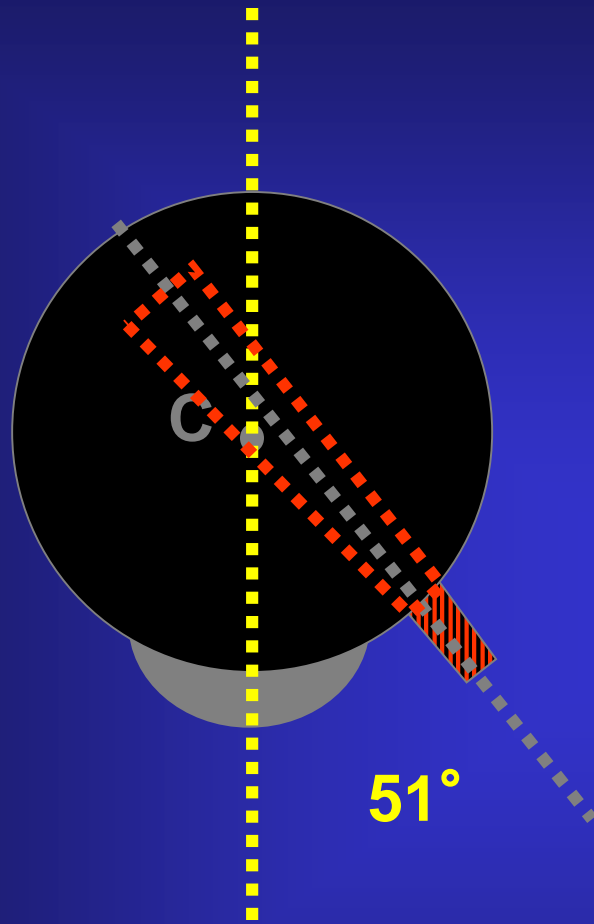
Innervation:

Trochlear Nerve

Temporal

Nasal

Inferior Oblique



Main Action: exycloduction

Secondary: supraduction
abduction

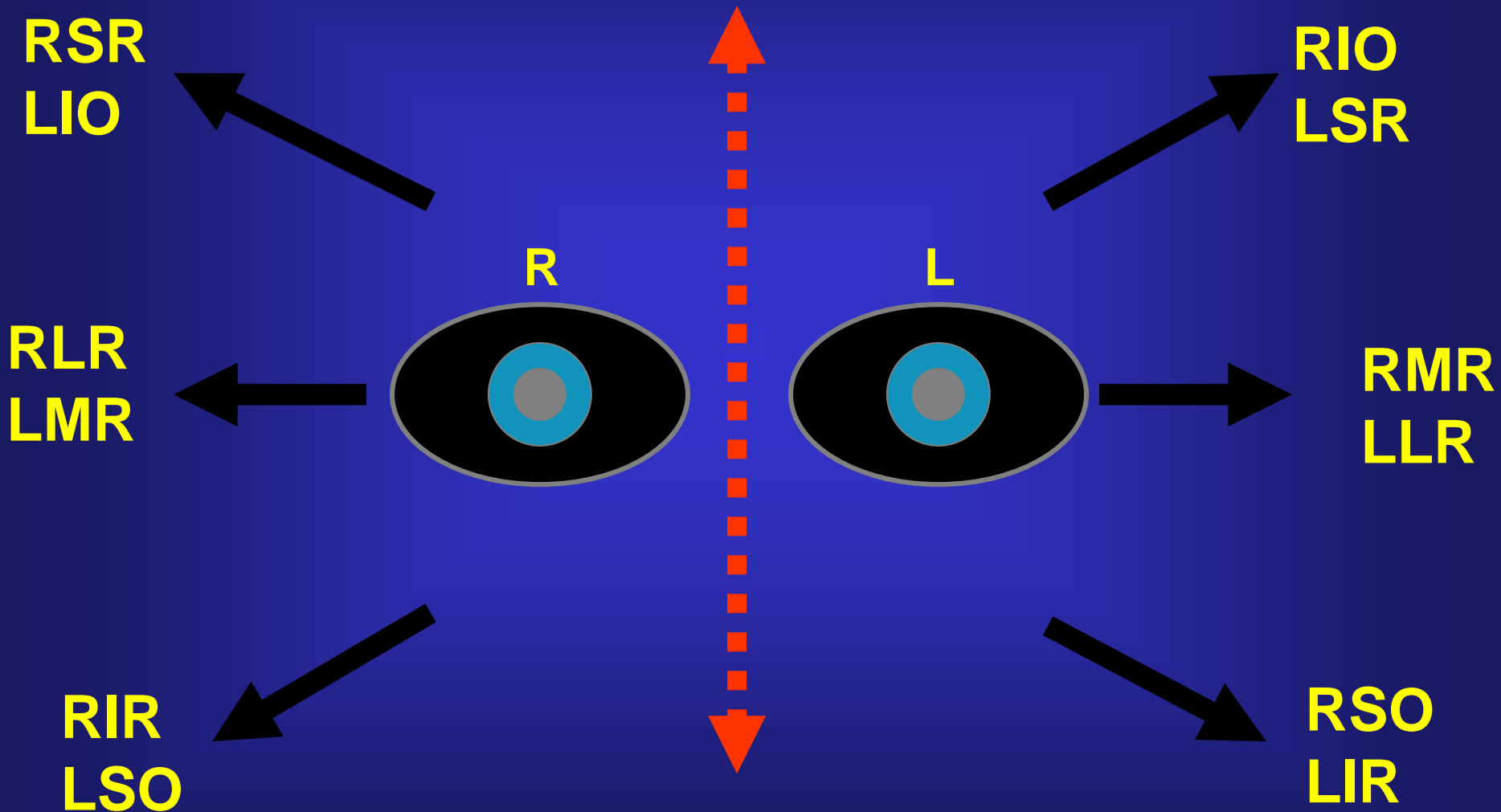
Innervation:

Inf. Div of Oculomotor Nerve

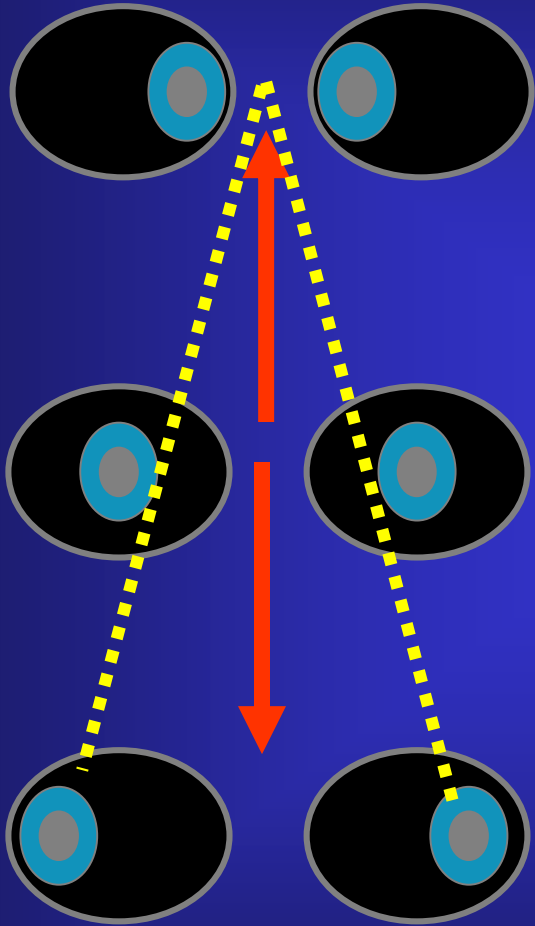
Temporal

Nasal

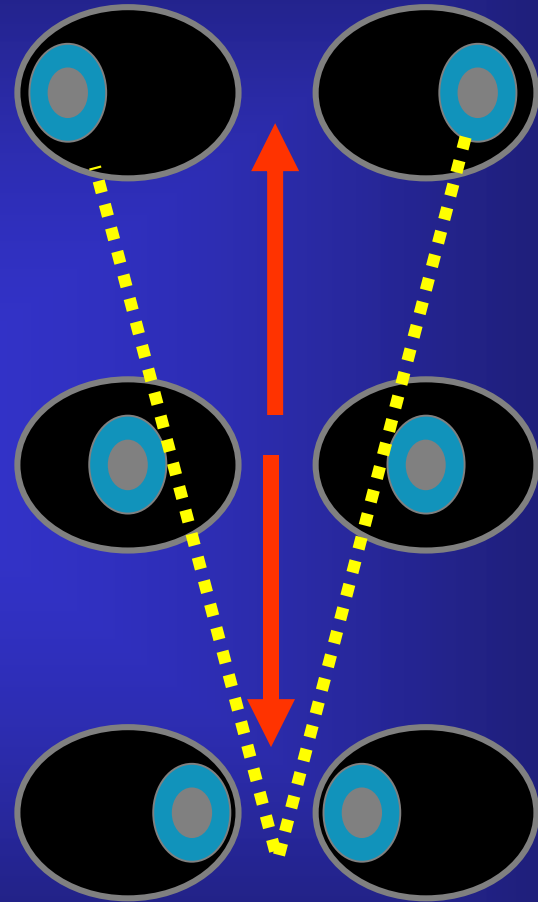
The Diagnostic Positions of Gaze

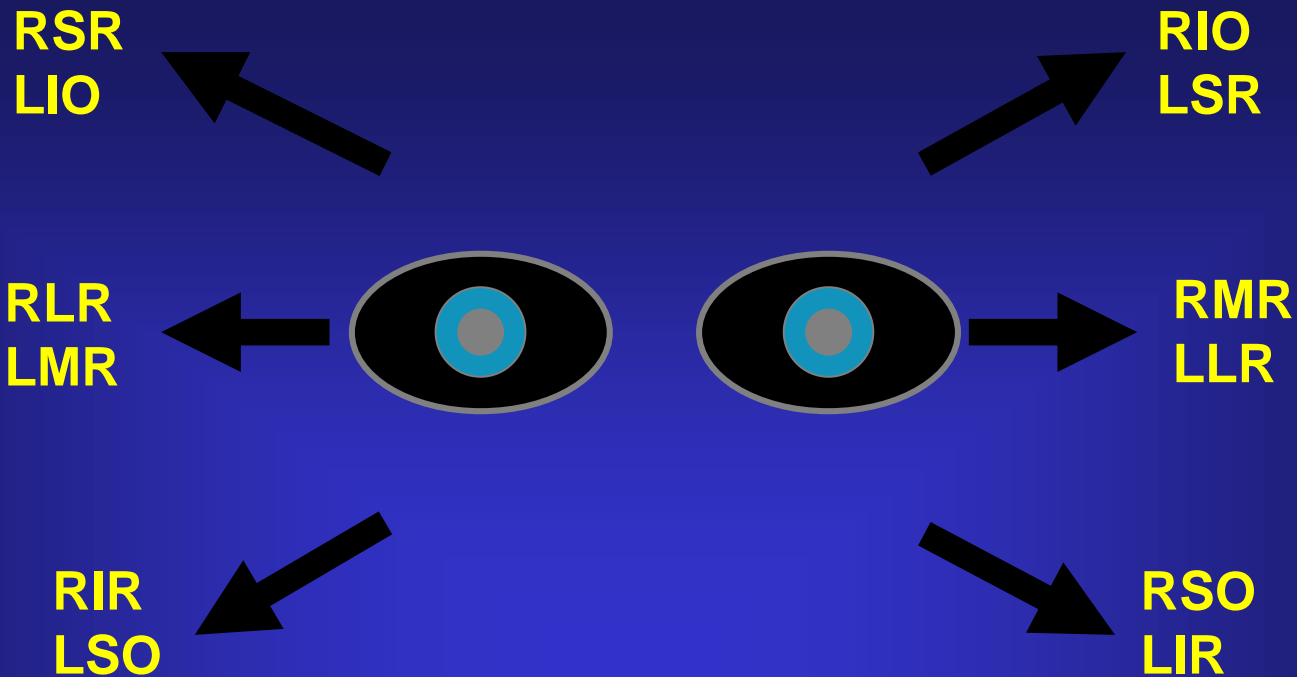


'A' Pattern



'V' Pattern

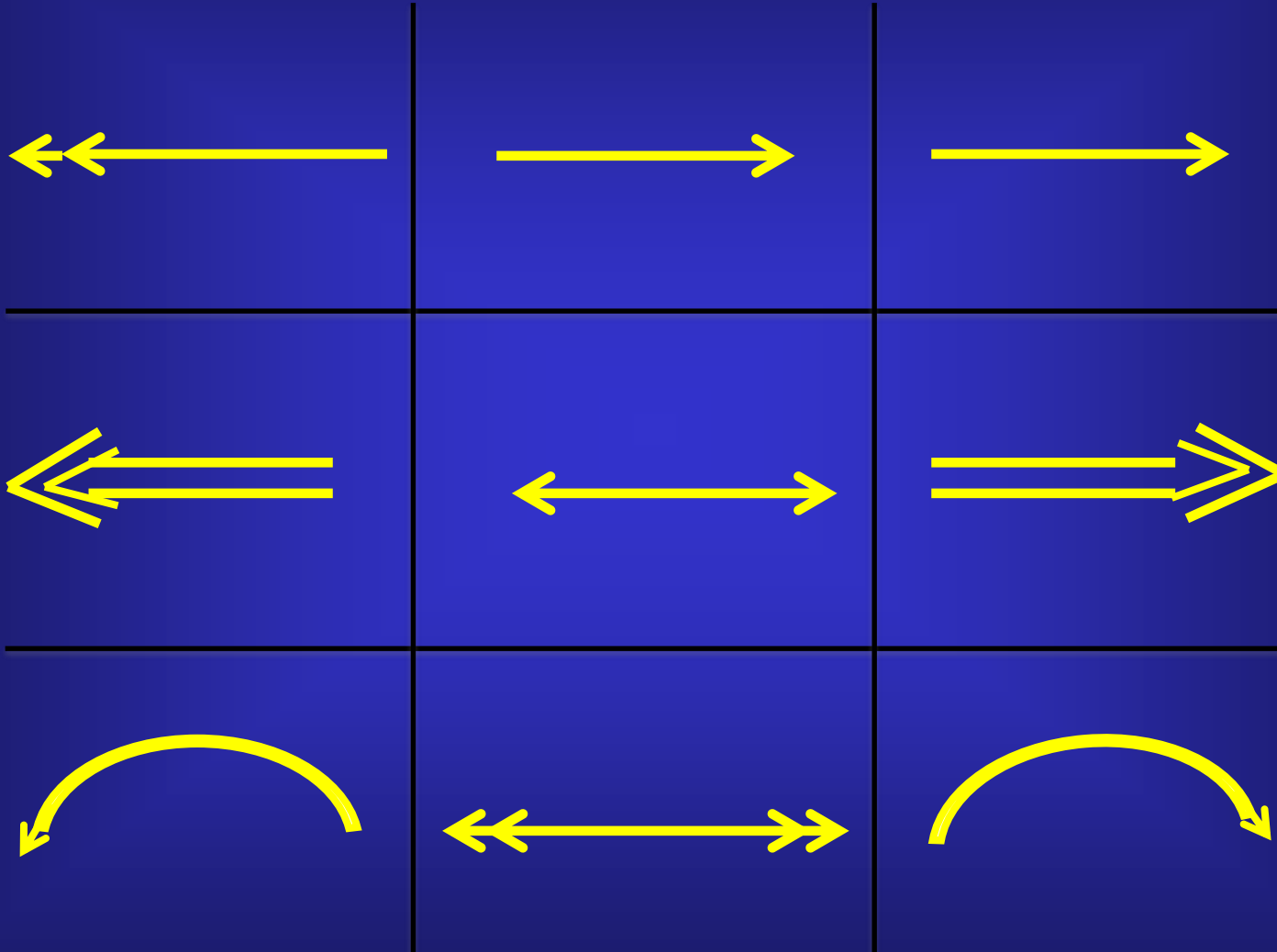




Yoke Muscles

R	L
Medial Rectus	Lateral Rectus
Lateral Rectus	Medial Rectus
Superior Rectus	Inferior Oblique
Superior Oblique	Inferior Rectus
Inferior Oblique	Superior Rectus

Figure 5 - Nystagmus In Nine Positions Of Gaze



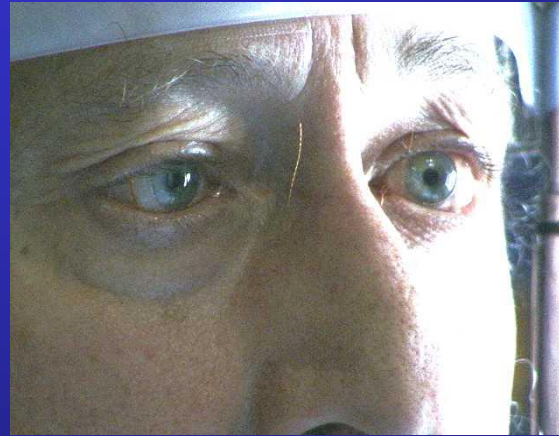
Eye Movement Recordings

• Methods

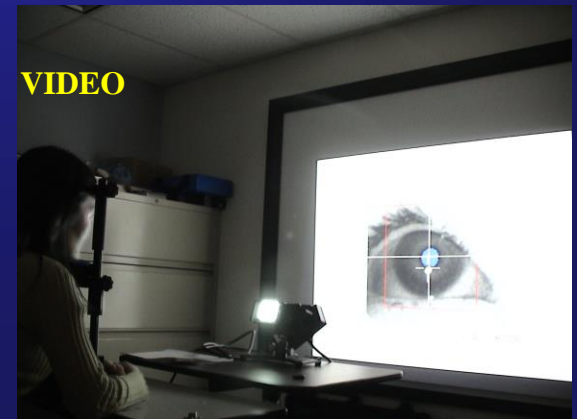
- “Contact”
electrooculography
- Infrared reflectance
- Remote Video
- Scleral contact
lens/magnetic search
coils.



COIL



VIDEO

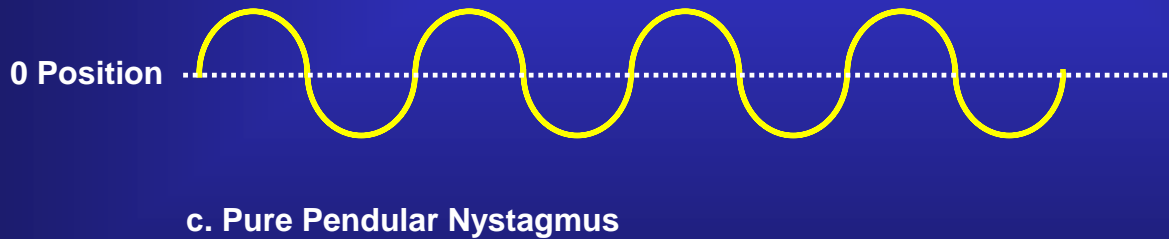
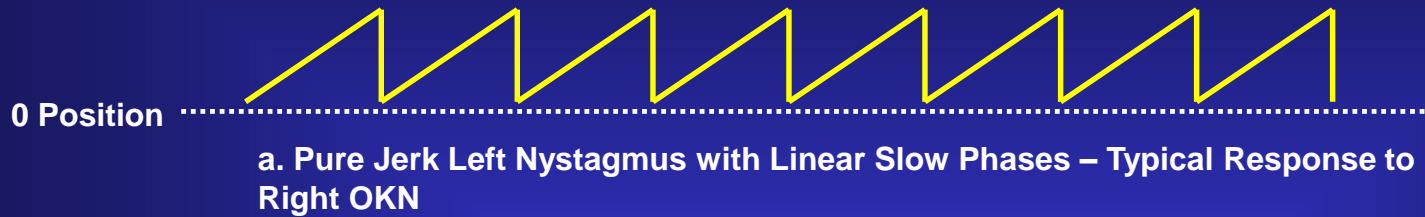


IR

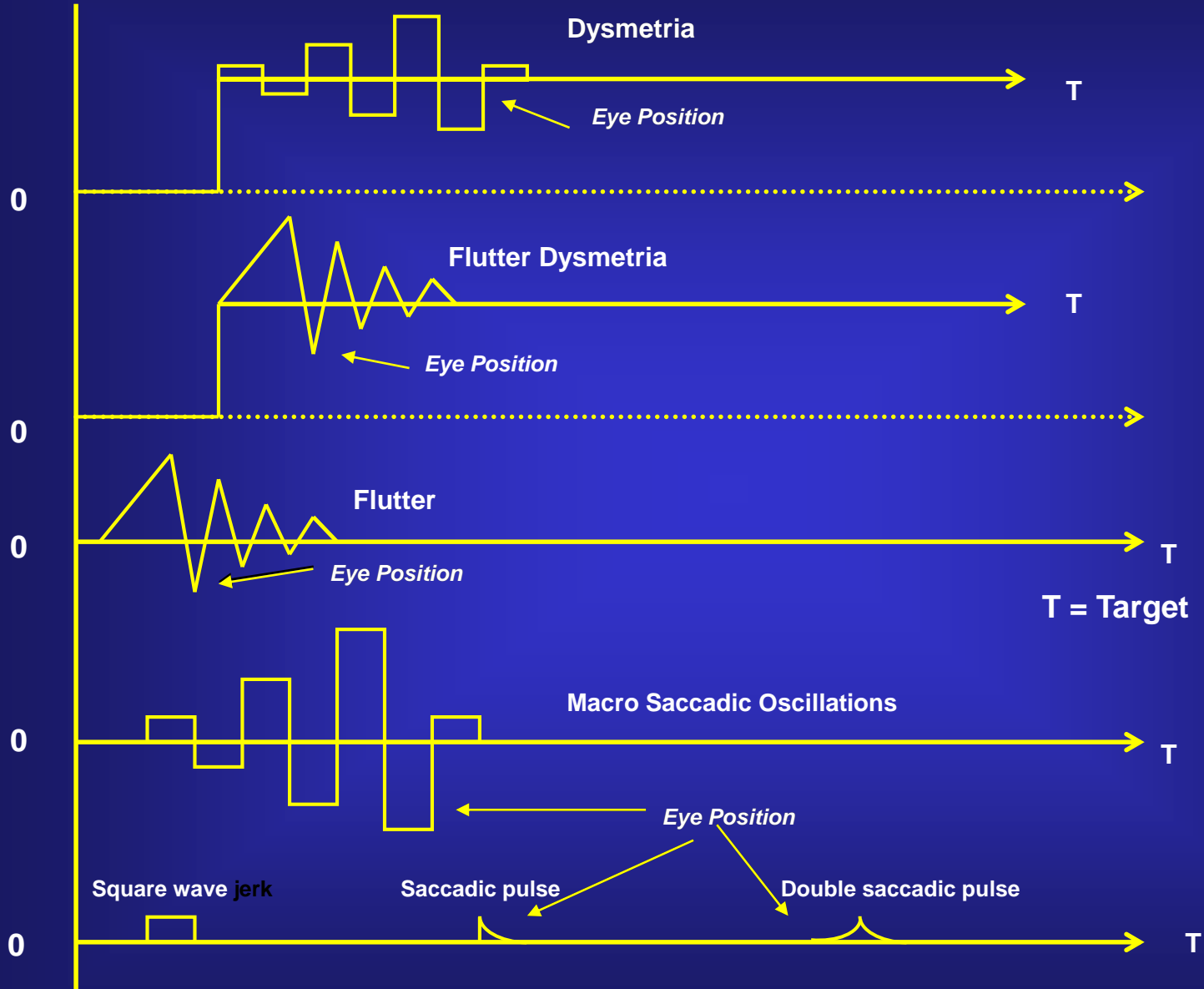


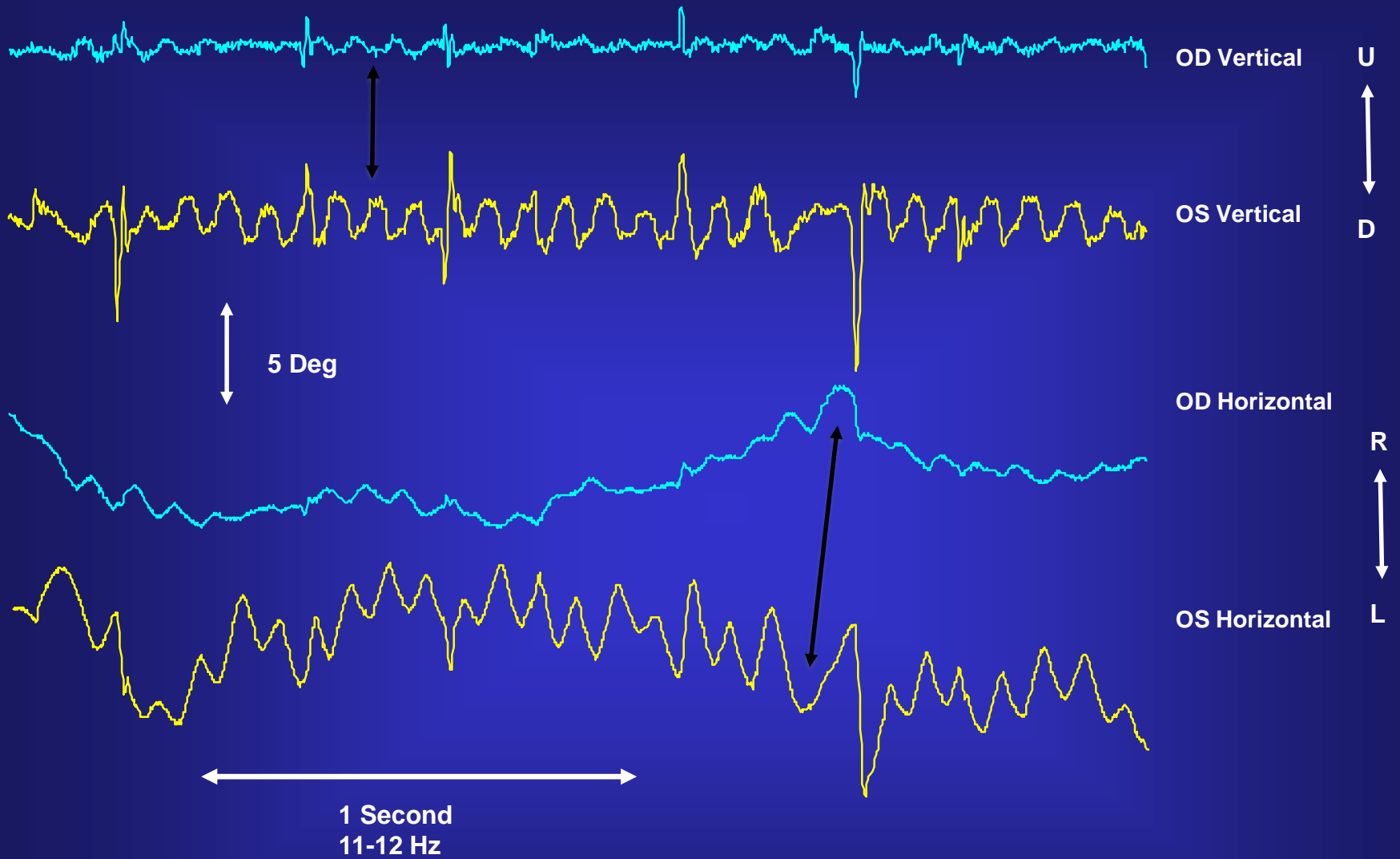


Ocular Oscillations



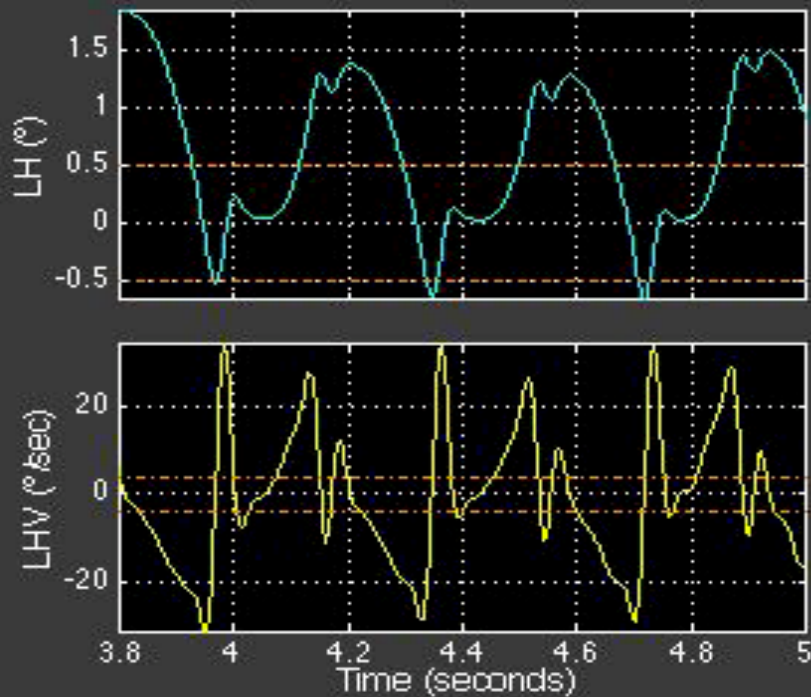
Saccadic Intrusions



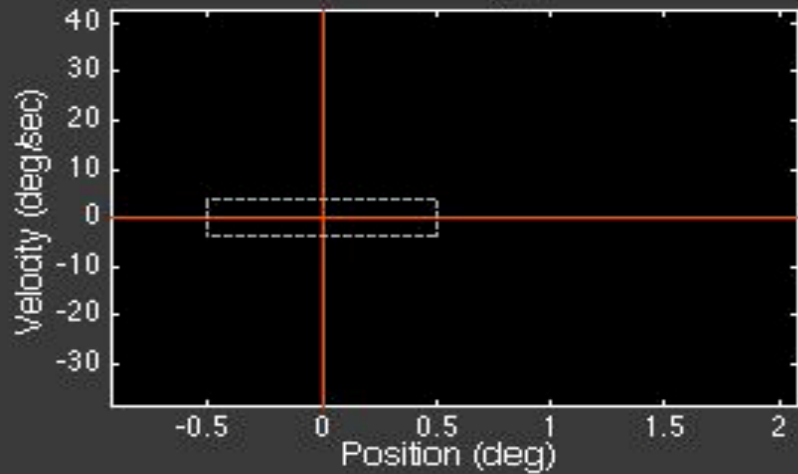


Ocular Motility Recordings of Spasmus Nutans

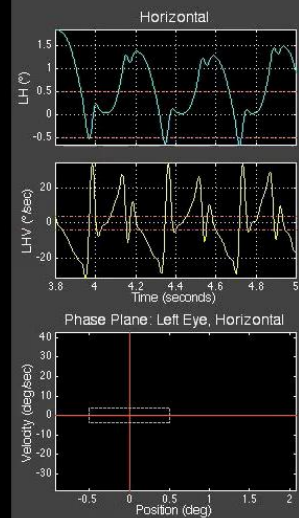
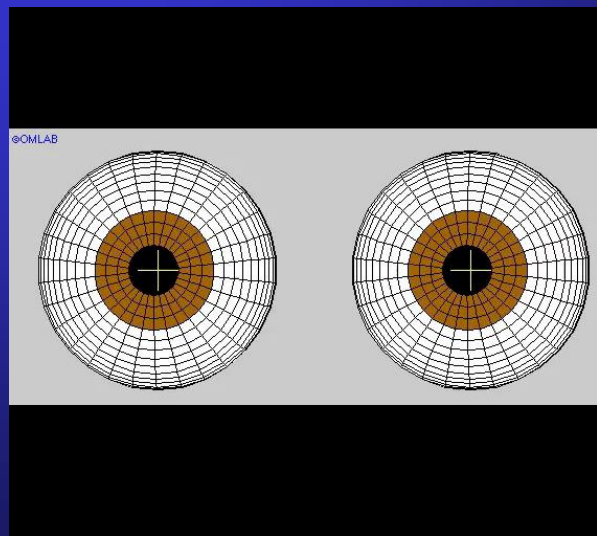
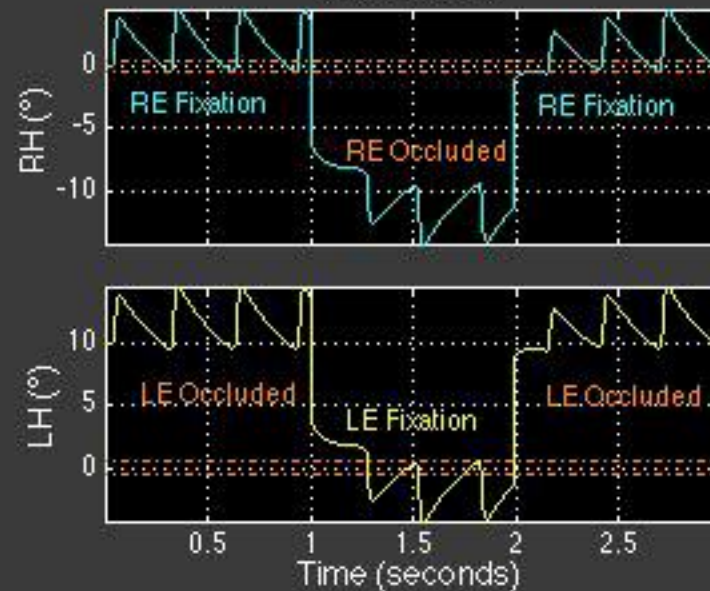
Horizontal



Phase Plane: Left Eye, Horizontal

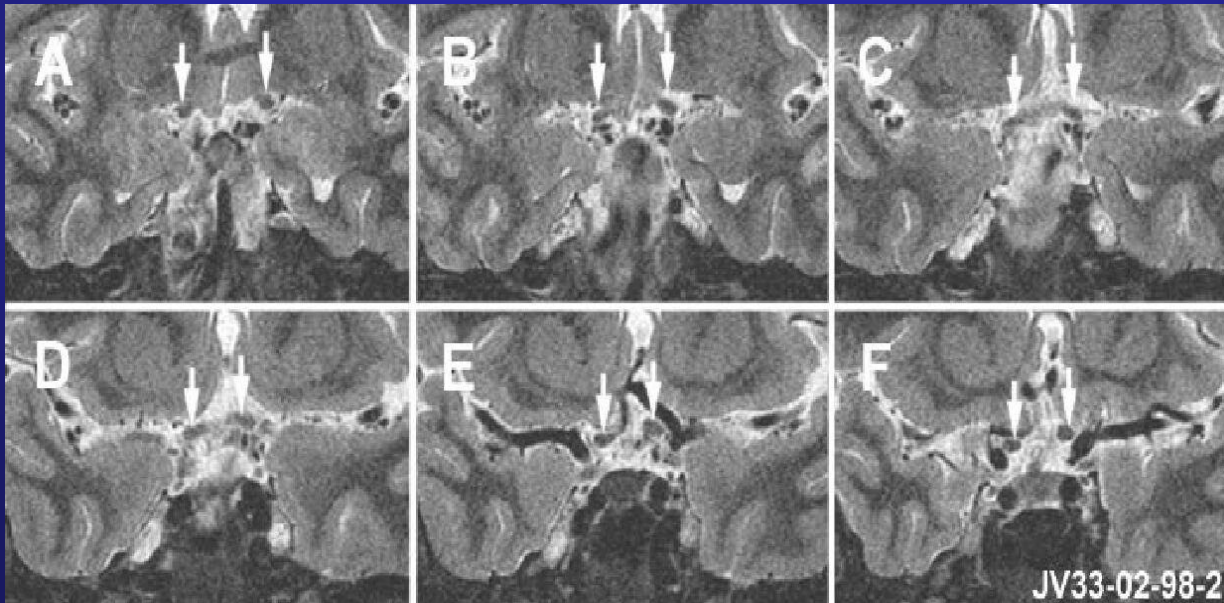


Horizontal



VII. Imaging

- CAT Scan.
- MRI (Cine, Orbital, Flare, Contrast, DWI).
- PET Scan (Positron Emission. Tomography)
- FMRI (Functional Imaging).
- OCT (Optical Coherence Tomography)



VIII. Laboratory Studies

- **Infectious Inflammatory Disease.**
 - TORCH Infections
- **Immune Inflammatory Diseases.**
 - Multiple Sclerosis
 - Leukodystrophies
- **Genetic Diseases.**
 - “Storage” Diseases
- **Chromosomal Disorders and Systemic Syndromes.**

**A Classification of Eye Movement Abnormalities
and Strabismus (CEMAS)--Report of a National Eye Institute
Sponsored Workshop**

Summarizes the results from a two-day workshop in February 2001 on the National Institutes of Health Campus, Bethesda, MD, that brought together some of the Nation's most experienced clinical and basic science investigators in the diagnosis, treatment, and etiology of eye movement abnormalities and strabismus.

<http://www.nei.nih.gov/news/statements/cemas.pdf>



ORGANIZATION (122 Disorders)

- I. Ocular Motor Aspects of Vision**
- II. Sensory Aspects of Binocular Vision**
- III. Horizontal Heterotropias**
- IV. Horizontal Heterophorias**
- V. Cyclovertical Heterotropias and Special Forms of Strabismus**
- VI. Cyclovertical Heterophorias**
- VII. Accommodative Disorders**
- VIII. Nystagmus and Other Ocular Motor Oscillations**

ESODEVIATIONS

Comitant

Infantile
ET Syndrome

Accommodative

Basic ET

Monofixation
Syndrome

Intermittent

Divergence
Insufficiency

Pure Refractive

Non-Refractive

Mixed

Healthy

+ Brain/Eye
Disease

ESODEVIATIONS

Non-Comitant ("Topical" Diagnosis)

Brainstem/Nerve

**Nuclear
Fasicular
Arachnoid/Sinus
Orbit**

Neuro-Muscular

Myasthenia

Muscular

**Tumor
Trauma
Inflammation
Anomalies**

Orbital

**"Pulley"
Trauma
Inflammation
Anomalies**

ESODEVIATIONS

Comitant

**Infantile ET
Syndrome**

**Early Infancy Onset
Healthy Infant
Constant, Large Angle
No Response to + Lenses**

ESODEVIATIONS

Comitant

Accommodative ET

"Pure" Refractive

Hyperopia
Dist ET = Near ET
Rx c Distance
Specs

Non-Refractive

+/- Hyperopia
0 Dist ET + Near ET
Rx c Bifocals
Only

Mixed

+/- Hyperopia
Dist ET < Near ET
Rx c Dist Specs
& Bifocals

ESODEVIATIONS

Comitant

Basic ET

Variable Onset
Inconsistent Deviation
No Eye or Brain Disease
Not Infantile ET

"Sensory" ET

Variable Onset
Inconsistent Deviation
+ Eye or Brain Disease

Disease Name	MONOFIXATION ESOTROPIA SYNDROME [Old – Microtropia]
Criteria	Small angle esotropia to no tropia, macular scotoma in non-fixing eye with anomalous retinal correspondence.
Common Associated Findings	Can be primary, genetic or acquired after surgical treatment of infantile strabismus, can be associated with anisometropia, amblyopia often present, stereopsis present but poor, alternate cover test may reveal larger deviation than simultaneous cover test. Good fusional vergence amplitudes.
General Comments	Promotes stable ocular alignment and sensory status. Can deteriorate into constant, larger angle esotropia, requiring surgical treatment.

Disease Name	CO-CONTRACTIVE RETRACTION SYNDROMES 1-3 (CCRS TYPES 1-3) [Old Duane Syndrome]
Criteria	<p>Limitation of abduction and/or limitation of adduction, globe retraction (co-contraction), enophthalmos, palpebral fissure narrowing on adduction</p> <p>Type 1 - abduction markedly restricted, adduction normal or mildly restricted, orthotropia or esodeviation in primary gaze</p> <p>Type 2 - adduction markedly restricted, abduction normal or mildly restricted, ortho or exodeviation in primary gaze</p> <p>Type 3 - both abduction and adduction markedly restricted, esodeviation in abduction, exodeviation in adduction</p>
Common Associated Findings	<p>Non-comitant esotropia or exotropia that varies markedly in gaze and at distance and near, more common in females and left eye, hyperopia is common, compensatory head posture, may be unilateral or bilateral, upshoots and downshoots of affected globe common, may have diplopia in certain positions of gaze often good stereopsis and bifixation with good vision. Can be associated with craniofacial or neck anomalies.</p>
General Comments	Many remain stable.

CEMAS Nystagmus Types

1. Peripheral Vestibular Imbalance

- Meniere, drug toxicity

2. Central Vestibular Imbalance

- Downbeat, Upbeat, drug toxicity

3. Instability of Vestibular Mechanisms

- PAN

4. Disorders of Visual Fixation

- Vision Loss, SSN, drug toxicity

5. Disorders of Gaze Holding

- GEN, ?APN, drug toxicity

6. Acquired Pendular Nystagmus

- central myelin, oculopalatal, Whipple, drug toxicity

7. Saccadic Intrusions and Oscillations

- SWJ, MSO, opsoclonus

8. Miscellaneous Eye Movements

- SO Myokymia, OM neuromyotonia

9. Infantile Nystagmus Syndrome

- “congenital,” “motor,” “sensory,” idiopathic, nystagmus blockage

10. Fusion Maldevelopment Nystagmus Syndrome

- Latent, manifest latent, nystagmus blockage

11. Spasmus Nutans Syndrome

- Without optic pathway glioma
- With optic pathway glioma



Afferent System

Efferent System

DEVELOPMENT

DEVELOPMENT

Conception

Development

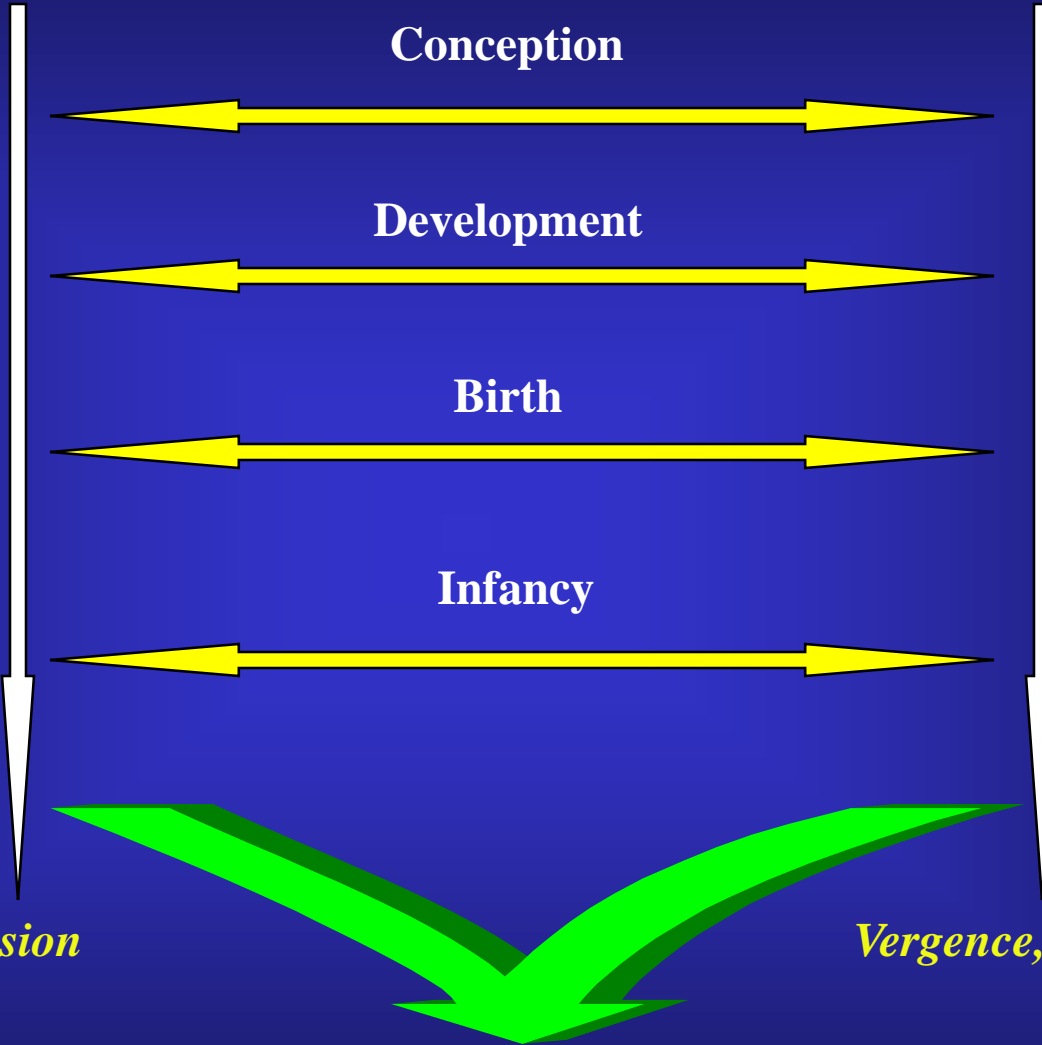
Birth

Infancy

Vision

Vergence, Versions

STABLE OCULAR MOTOR SYSTEM



Visuo-Vestibular



Time



**Motion
Sensitivity**



EFFERENT



“VISION”



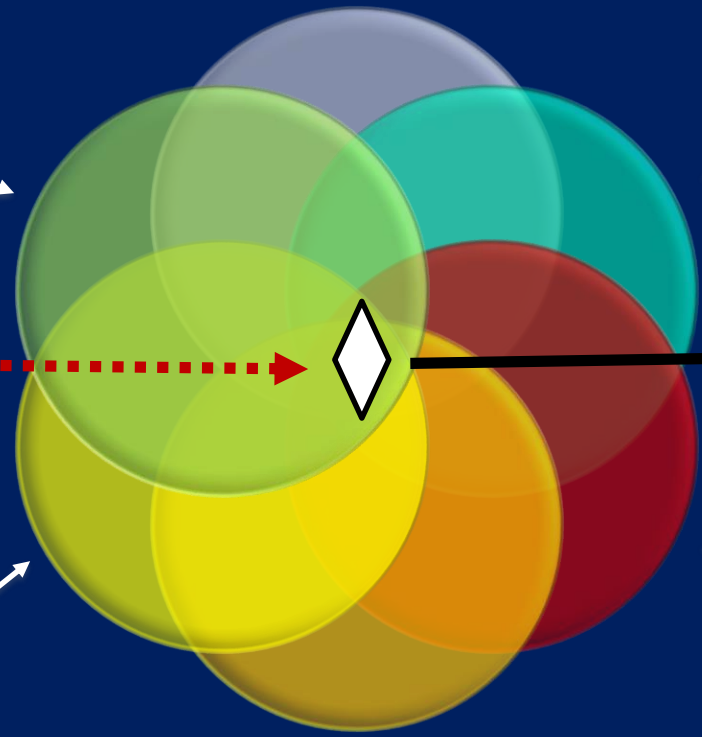
**Gaze
Dependent
Vision**

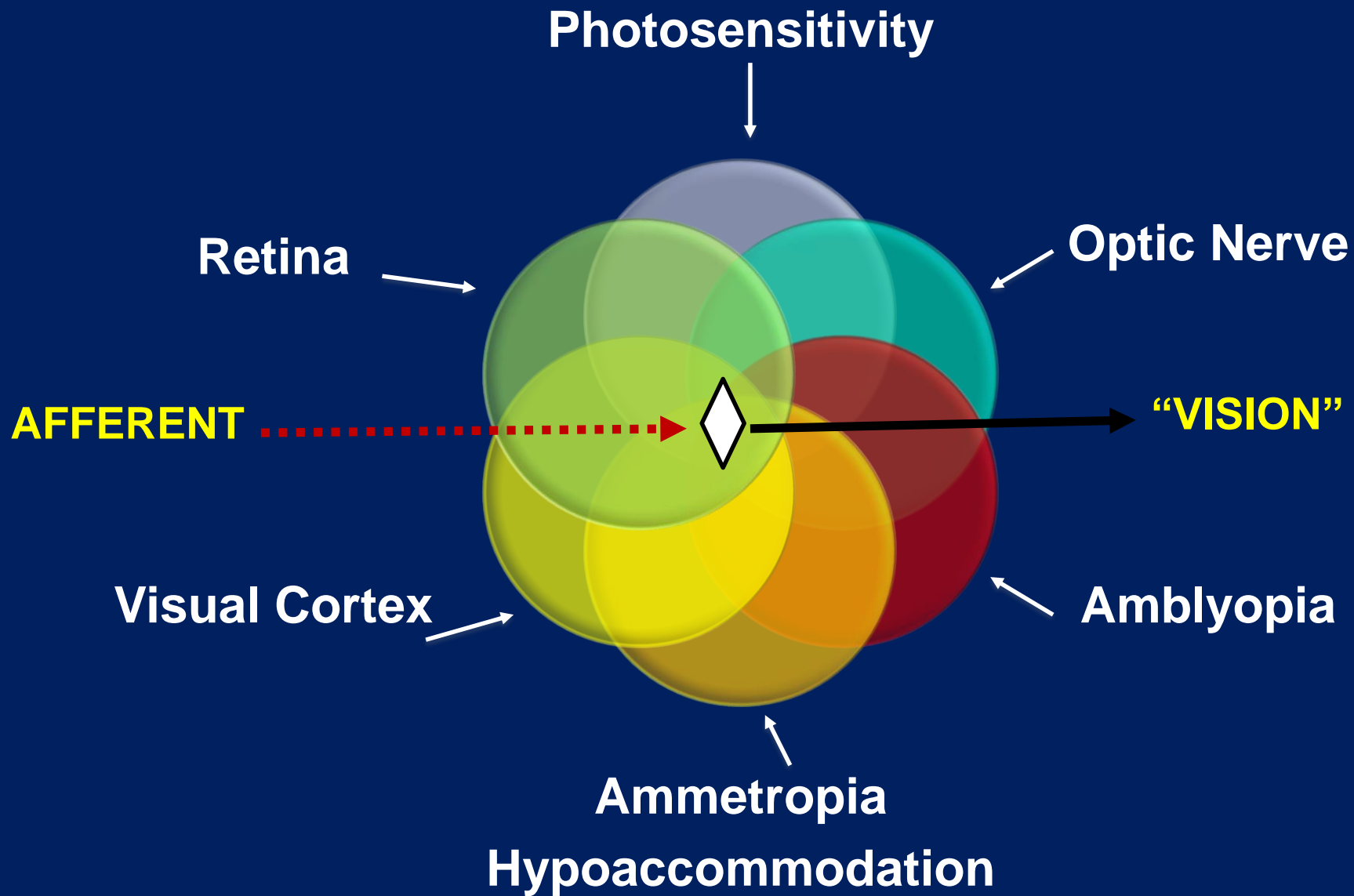


Contrast



**Visual
Recognition
Time**





Summary

- “Value” of “Work-Up”

- Diagnosis.
- Classification.
- Etiology.
- Therapy.
- Research.

