Neurophysiology

Making The Connections

Embryology of the Brain

Primitive Streak → Notochord → Spinal cord

In the first trimester…

- Notochord visible by three weeks
- Brain fully formed by 8 weeks
- Brain is active early with movements, especially reflexes
- Swallowing is an intrauterine reflex
- Brain is active in formation of amniotic fluid

Amniotic Fluid

- **80%** is a filtrate of mom's plasma
  - Fetus SUBTRACTS by swallowing the fluid,
  - Fetus must absorb and digest the fluid
- **20%** is added by the fetus
  - Fetus then urinates the additional fluid into the sac

Polyhydramnios

- Neuromuscular disease
  - Autonomic dysfunction
  - Muscle disease
- GI obstruction

Oligohydramnios

- Renal agenesis
- Urinary outlet obstruction

- **Potter's syndrome**

Spinal Cord

- Develops from the notochord
- Goes down as far as L-1 or L-2
- Ends as the **Conus Medullaris**
- Nerves come off to the sides as the **cauda equina**
- **Filum terminalis**: anchors the tip of the conus medullaris to base of the spinal canal

Vertebral Arches

- Fuse ventral to dorsal
- Fusion begins at the cervical level and proceeds bidirectionally
- If child born prematurely, a hole can be still present at either end

Upper vertebral arch defects

- Anencephaly
- Encephalocele
- Encephalomeningocele
- encephalomeningomyelocele

Lower vertebral arch defects

- Spina Bifida Occulta
- Spina Bifida Aperta
- Meningocele
- Meningomyelocele
  - Arnold Chiari Malformation
  - Syringomyelia

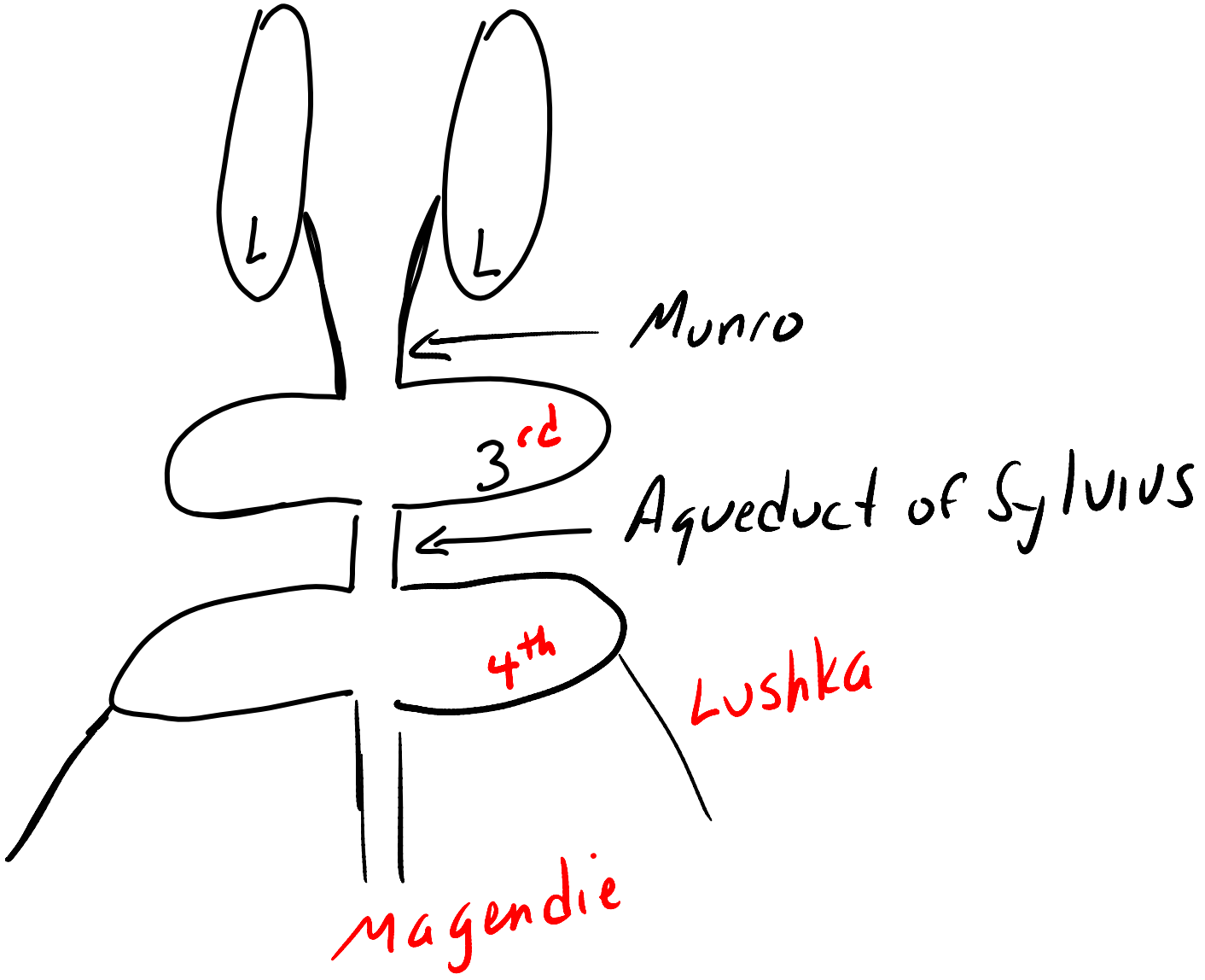
Now you need some CSF

CSF

- A filtrate of plasma
- Made by the Choroid Plexus in each ventricle
- Requires vitamin A
- Requires carbonic anhydrase

How CSF differs from plasma

- Less HCO3
- More CL
- Lower pH 7.34
- Up to 25 WBCs normal in first month of life only; after that, only up to 3 WBCs normal


L
L
Munro
3rd
Aqueduct of Sylvius
4th
Lushka
Magendie

CSF Flow

- Lateral ventricles > foramen of Munro > 3rd ventricle > aqueduct of Sylvius > 4th ventricle > foramina of Lushka and Magendie > subarachnoid layer > spinal canal > dural sinuses > back into plasma

Vomiting Centers

- **Chemotactic Trigger Zone**: located on the floor of the 4th ventricle
  - Responds to any increase in ICP
  - Uses dopamine
- **Area Postrema**: located on the blood side of blood:brain barrier
  - Responds to offensive smells or particles
  - Uses dopamine

Hydrocephalus

- Noncommunicating: due to an obstruction
- Communicating: overproduction of CSF

- Applies pressure on the brain

Communicating Hydrocephalus

- **Newborns**: mainly in premature newborns
  - Intraventricular hemorrhage
- **Children**: due to inflammation
  - meningitis
- **Adults**: overingestion of vitamin A
  - Pseudotumor Cerebri
- **Elderly**: due to brain atrophy
  - Normal Pressure Hydrocephalus

Normal Pressure Hydrocephalus (NPH)

- ventricles expands as the brain atrophies
- Enlarged ventricles then compress the long midline fibers that go to the bladder and legs

- Dementia
- Incontinence
- ataxia

To treat NPH…

PLACE A VP SHUNT

Noncommunicating Hydrocephalus

- Due to some form of obstruction
- In newborns
  - Aqueductal stenosis
  - Dandy-Walker cyst
- In children: meningitis, especially TB
- In adults: cancer
- In elderly: cancer

The role of CSF

- To add cushion for the brain
- Shock absorption

- Head Injury
  - Coup lesions
  - Contracoup lesions

Embryology of the brain

- Prosencephalon
  - Telencephalon — Cerebrum
  - Diencephalon
    - Thalami
    - Basal ganglia
- Mesencephalon — Mesencephalon — MIDBRAIN
- Rhombencephalon
  - Metencephalon
    - PONS
    - Cerebellum
  - Myelencephalon — Medulla

How to organize Neurophysiology

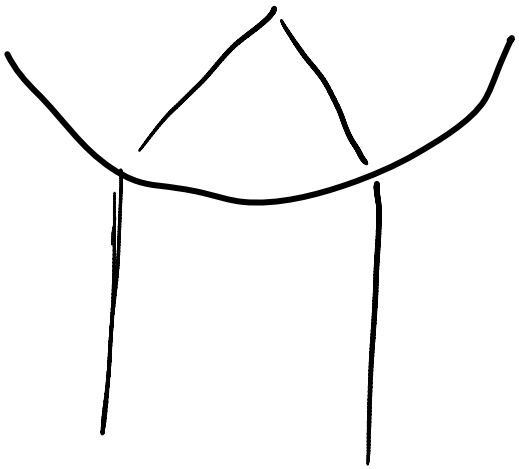
Visual Cortex

- Remember that everything is REVERSED
- Temporal fibers see the nasal visual field
- Nasal fibers see the temporal visual field
- Light must hit the retina by 3 months of age or the child is blind for life
- You must verify that a child has a RED reflex on eye exam at birth

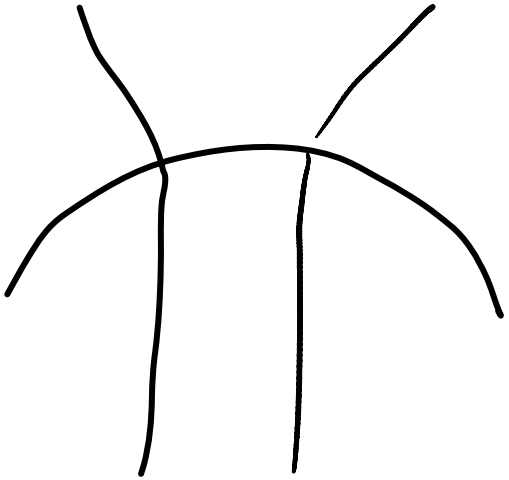
Abnormalities of the Eyes

- **Anisocoria**: unequal pupil size
- **Amblyopia**: difference in visual acuity
- **Strabismus**: misalignment of the eyes
- **Stigmatism**: corneal defect
- **Myopia**: nearsightedness
- **Hyperopia**: farsightedness
- **Presbyopia**: loss of accomodation seen with aging

CONVEX



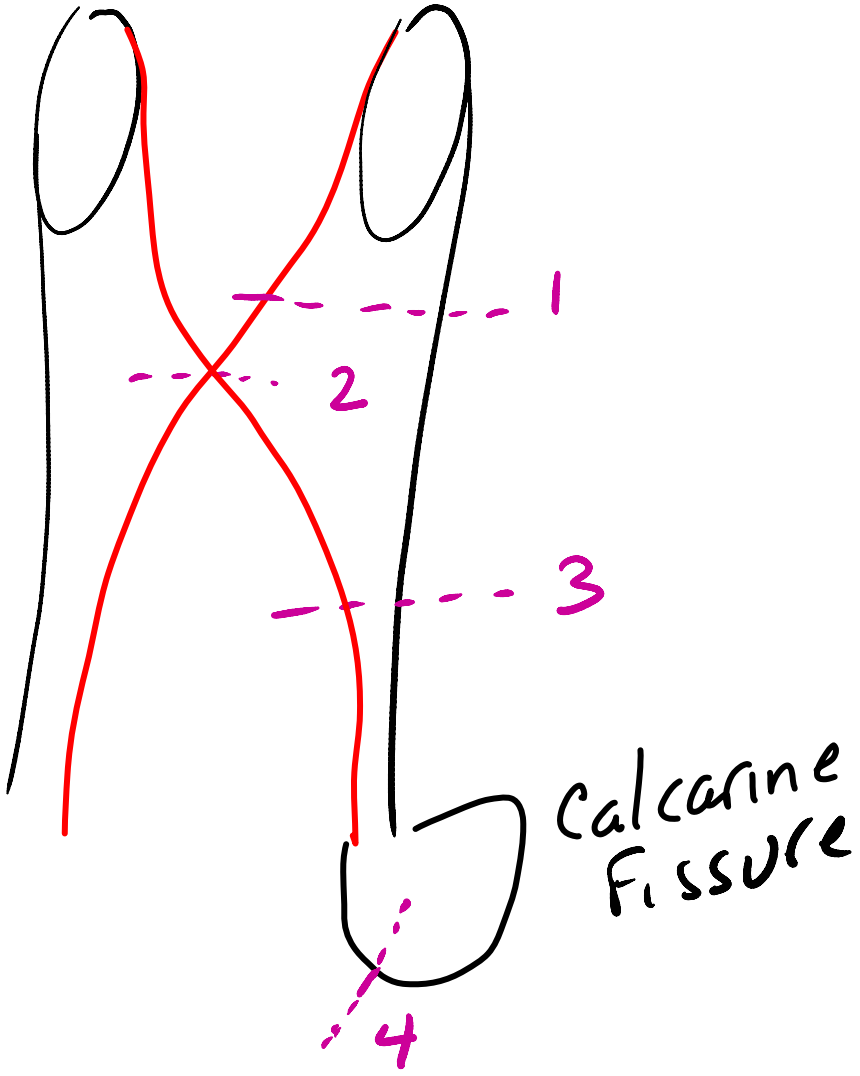
CONCAVE



Stigmatism

Straight Line Test

Visual field deficits



White Reflex

- Cataracts: opacification of the lens
  - Does not allow light to hit the retina
  - Must be removed
  - Increased incidence with high glucose or galactose (sorbitol or galactitol accumulates)

  - Idiopathic: 90%
  - Diabetes or galactosemia
  - Rubella

White Reflex

- Retinoblastoma (rare)
  - Rb gene
  - Cancer
  - High association with Ewing's sarcoma

Monocular blindness

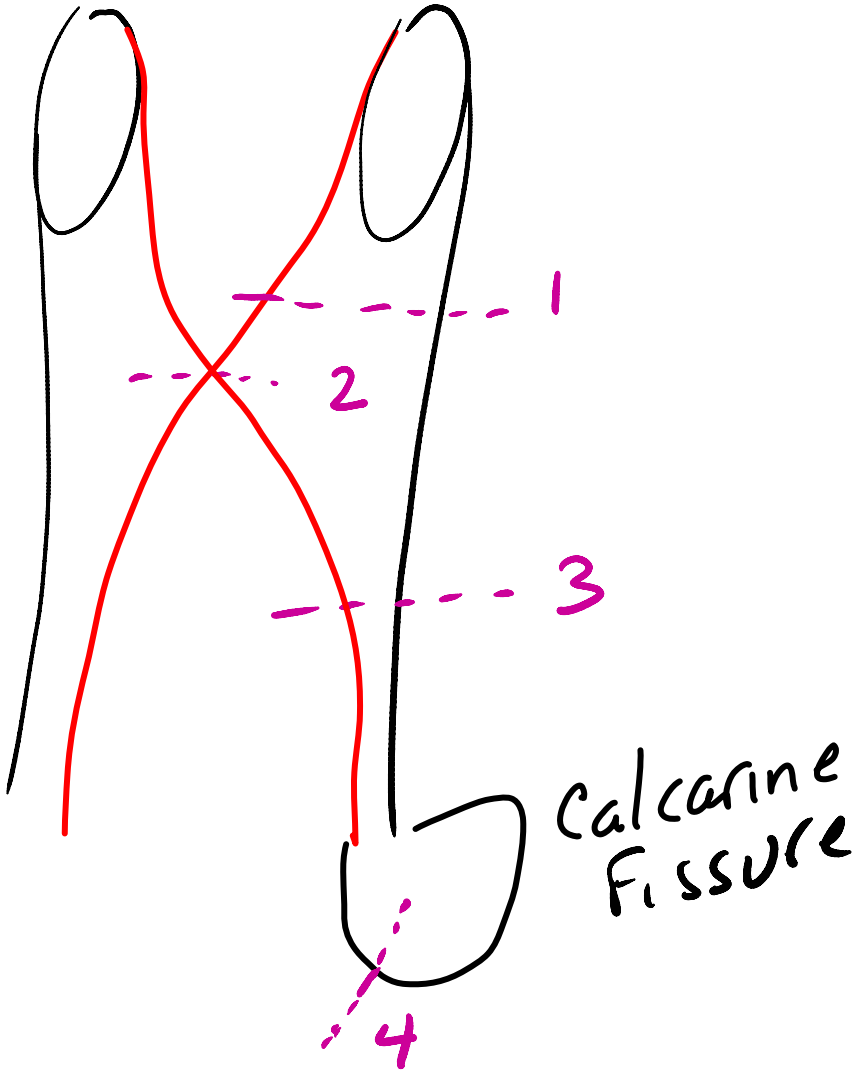
- Newborns: cataracts or retinoblastoma
- Children: optic nerve gliomas
  - Neurofibromatosis
  - MEN III
- Adults: embolic phenomena
  - TIA
  - Acute retinal artery occlusion
  - Acute retinal vein occlusion
- Elderly: macular degeneration

Optic Chiasm Lesions

- Loss of nasal fibers bilaterally
- Bitemporal hemianopsia

- Pituitary tumors: 90%
  - Pituitary sits just beneath the chiasm
- Pineal tumors
  - Pineal gland sits just lateral to the chiasm

Visual field deficits

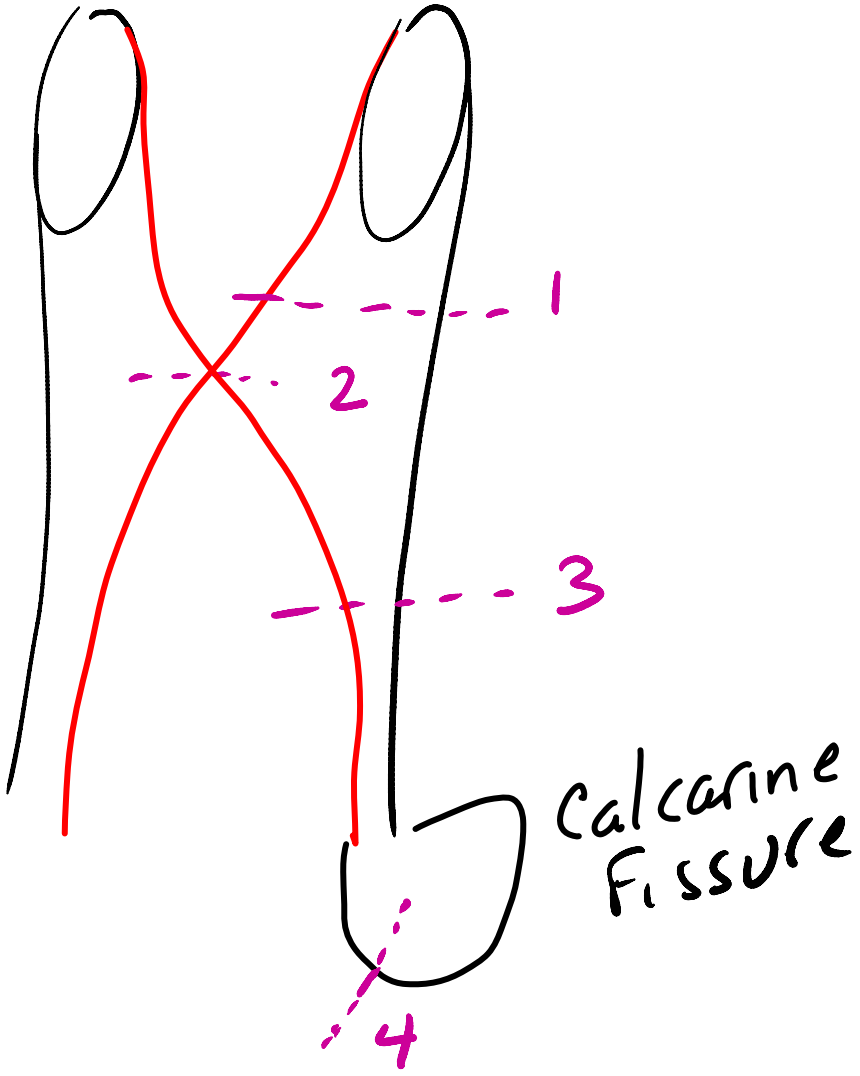


Optic Tract Lesions

- Lesion of IPSILATERAL temporal fibers and CONTRALATERAL nasal fibers
- Homonymous Hemianopsia

- Mcc: cancers and tumors

Visual field deficits



Quadranopsia

- Only way to get such a lesion is back in the calcerine fissure
- Pie in the sky deficit
- Make sure you reverse BOTH words

What unique information does each cortex contain?

Frontal Lobe (Precentral Gyri)

- CST (motor fibers) originates from here
- Unique information:
  - Personality
  - Abstract reasoning

Frontal Lobe Lesions

- Atonic seizures
- Dimentias
  - Alzhiemer's
  - Pick's disease
- Schizophrenia: loss of asymmetry
- Frontal lobotomies

Temporal Lobe

- Hearing
- Balance
- Hallucinations (controlled by serotonin)

- Posterior temporal lobe: Wernicke’s area

Temporal Lobe Lesions

- Temporal lobe seizures
- Schizophrenia
- Dementias
- Drugs
  - SSRI
  - Amphetamines

Amphetamines

- Taken up presynaptically; cause release of catecholamines
- Clue: vertical nystagmus

Amphetamines

- Used in ADD
  - Methylphenidate
  - Pemoline
  - Adderal
  - dexadrine
- OTC for weight loss
  - dexatrim
- Cause hallucinations
  - LSD
  - PCP
  - ECSTACY

SSRI's

- Fluoxetine
- Paroxetine
- Luvoxetine
- Sertraline
- Nefazadone
- Trazadone

Parietal Lobes

- Dominant lobe: long term memory; all the things you learned since kindergarten
  - left side is dominant in 90% of right-handed and left-handed people
- Nondominant lobe: apraxia and hemineglect
  - Right side is nondominant in 90% of right-handed and left-handed people

THALAMI

- Epithalamus
- Thalamus
- Hypothalamus
- Subthalamic Nucleus

Epithalamus

- The ONLY nucleus with NO known function

Thalamus

- ALL SENSORY information in and out of the brain MUST stop here
- ALL information about the ARMS stay LATERAL
- ALL information about the LEGS stay MEDIAL

Thalamic Infarct

- ALL sensory information from the body is lost, but motor information is intact

Hypothalamus

- Controls hunger
  - Hunger center: lateral
  - Satiety center: medial
- Controls menstrual cycle
- Controls temperature
  - Anterior: cools
  - Posterior: warms
- Controls stress response

Stress Response

- Parasympathetic discharge always first
- Sympathetic discharge always second

- Stress ulcers
- Curling’s ulcers
- Cushing’s ulcers
- IBS

Acetomenophen

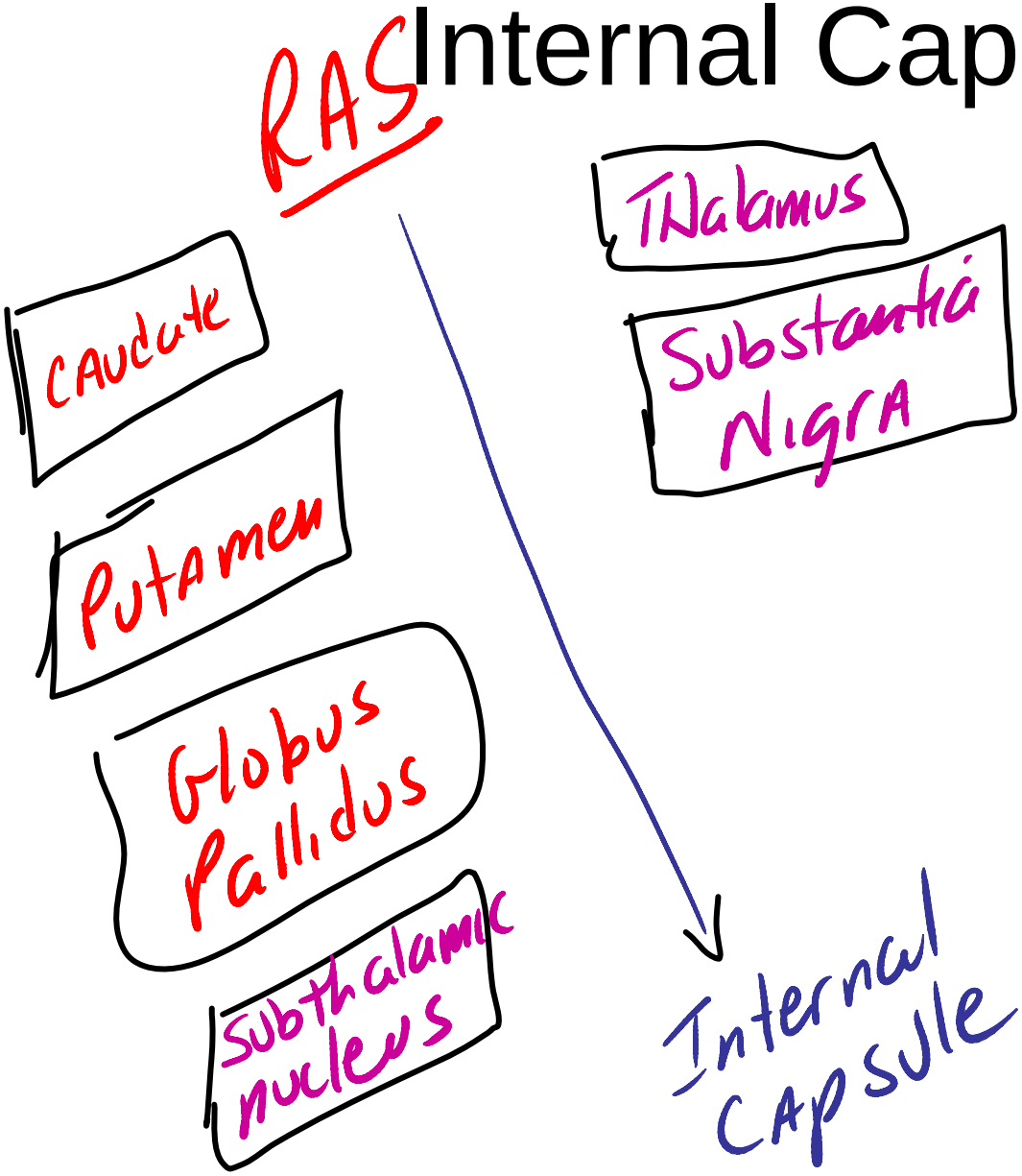
- Works at the level of the hypothalamus
- First, it cools the body (stimulates anterior hypothalamus) then it resists fever (blocks posterior hypothalamus)

- Oxidizes the liver (toxicity)
  - Treat with n-acetylcystiene (reducing agent); the four hour level is the most important factor

Subthalamic Nucleus

- Final relay station for coordinating fine motor movements
- Lesion: Ballismus and Hemiballismus

Internal Capsule



Substantia Nigra

- Responsible for INITIATING movements
- Uses DOPAMINE for neurotransmitter
- Receives inhibitory signals from basal ganglia via ACH or GABA

Parkinson's Disease

- Loss of DOPAMINE fibers from substantia nigra to striatum (caudate and putamen)
- Unable to initiate activities

- Mask like facies
- Bradykinesia
- Shuffling gait
- Fenestrating gait
- Pill rolling tremor
- Autonomic dysfunction: Shy Dragger syndrome

Parkinson's Disease, cont

- Treatment: L-dopa/ carbidopa
  - Bromocryptine
  - Amantadine
  - selegyline

Movement disorder in middle-aged people

- **Huntington's disease**
  - 90%
  - Autosomal dominant
  - Trinucleotide repeats
  - Caudate nucleus involved
  - Anticipation
  - Decreased GABA fibers
  - Treat with DA blockers
- **Wilson's disease**
  - < 10%
  - Autosomal recessive
  - Ceruloplasmin def
  - Copper excess
  - Lenticular nucleus involved
  - Kayser-Fleischer rings
  - Liver involvement
  - Treat with penicillamine

Internal Capsule

- ALL MOTOR fibers going in and out of the brain goes through here
- Blood supply comes from the lenticulostriate arteries (smallest arteries in the brain)
- Lacunar hemorrhages: due to HTN
  - Causes significant MOTOR deficits

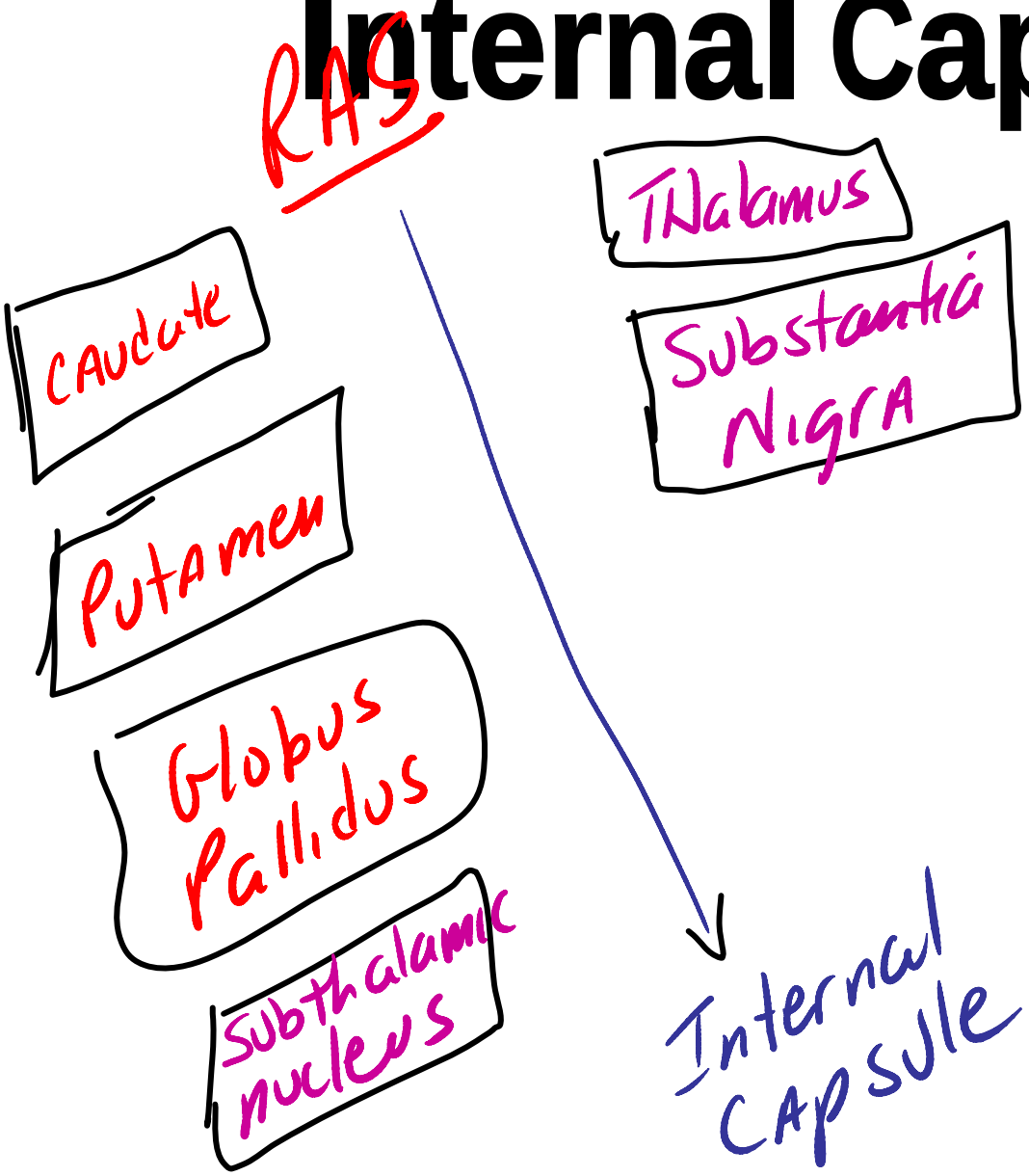
Reticular Activating System (RAS)

- Maintain FOCUS on one item at a time
- Requires NE and Serotonin
- C-AMP second messenger
- Has a refractory period first thing in the morning

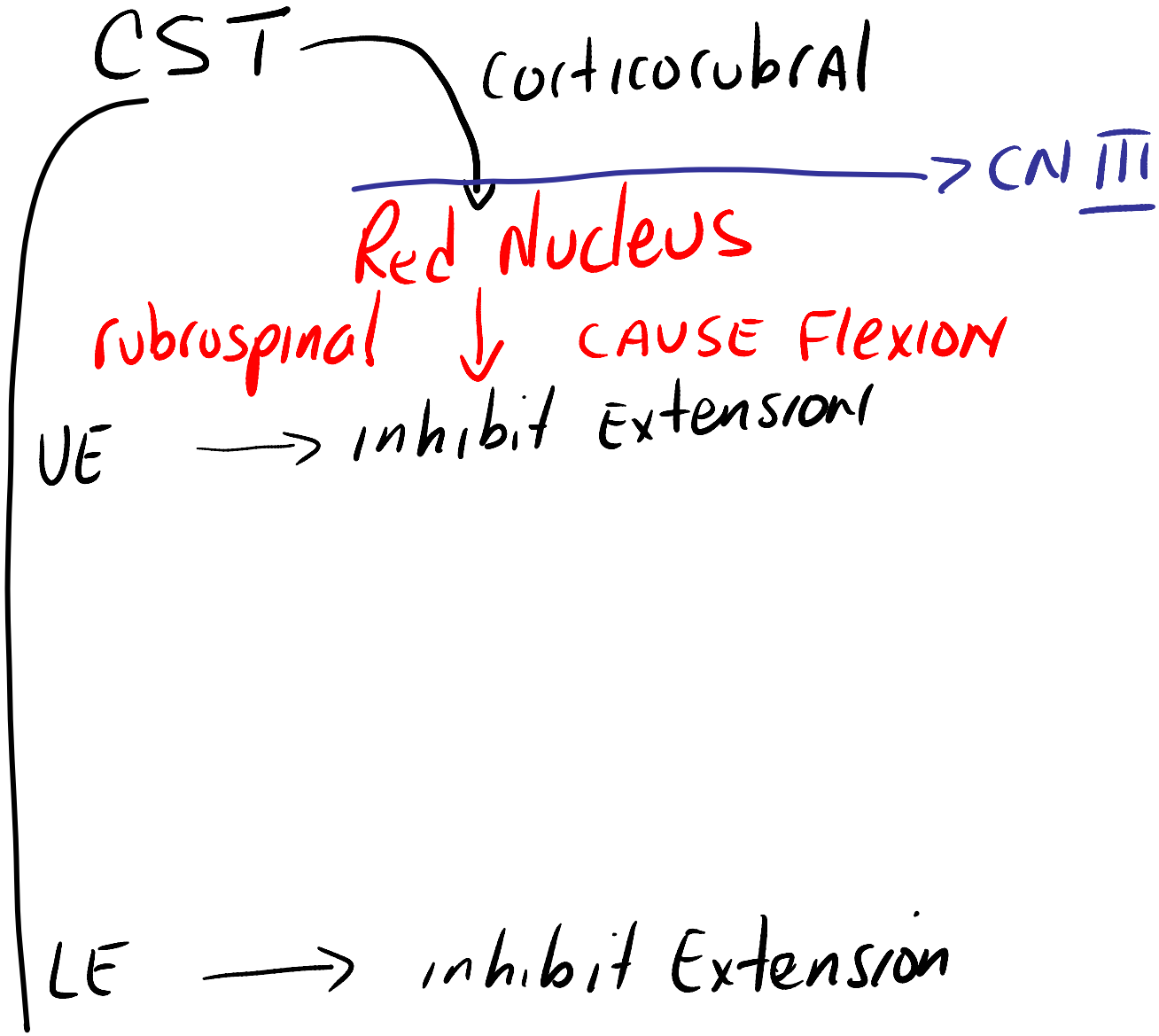
Attention Deficit Disorder

- ADD or ADHD
- RAS not working
- Poor attention and focus
- Restlessness
- Unable to sit long enough to complete a task
- Tx: methylphenidate; pemoline; dexadrine; adderal

Internal Capsule



Midbrain


CST
Corticorubral
CN III
Red Nucleus
rubrospinal
CAUSE Flexion
UE → inhibit Extension
LE → inhibit Extension

Corticospinal Tract

- Responsible for fine motor activity
- Has to inhibit extension so that smooth flexion can occur

- Spasticity
- Babinski
- Hyperreflexia
- Clonus

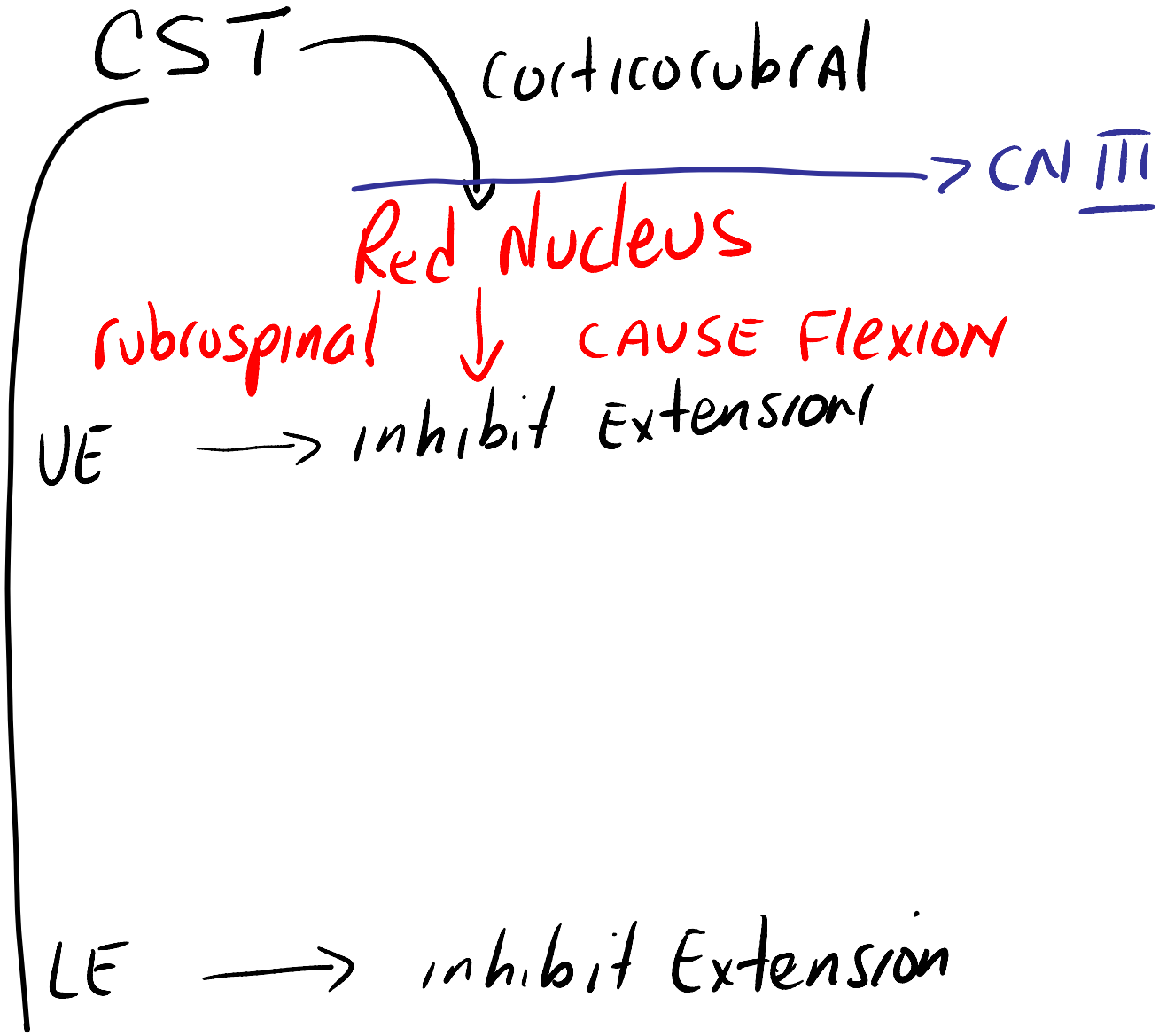
Corticospinal Tract, cont

- Fibers originate from the frontal lobes, the precentral gyri
- Fibers descend through the internal capsule and CROSS at the medullary pyramids

CST Pathology

- Atonic seizures: depolarization goes across the frontal cortex
- B-12 deficiency
- ALS

Midbrain


CST
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Red Nucleus
rubrospinal
CAUSE Flexion
UE → inhibit Extension
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Increased Intracranial Pressure

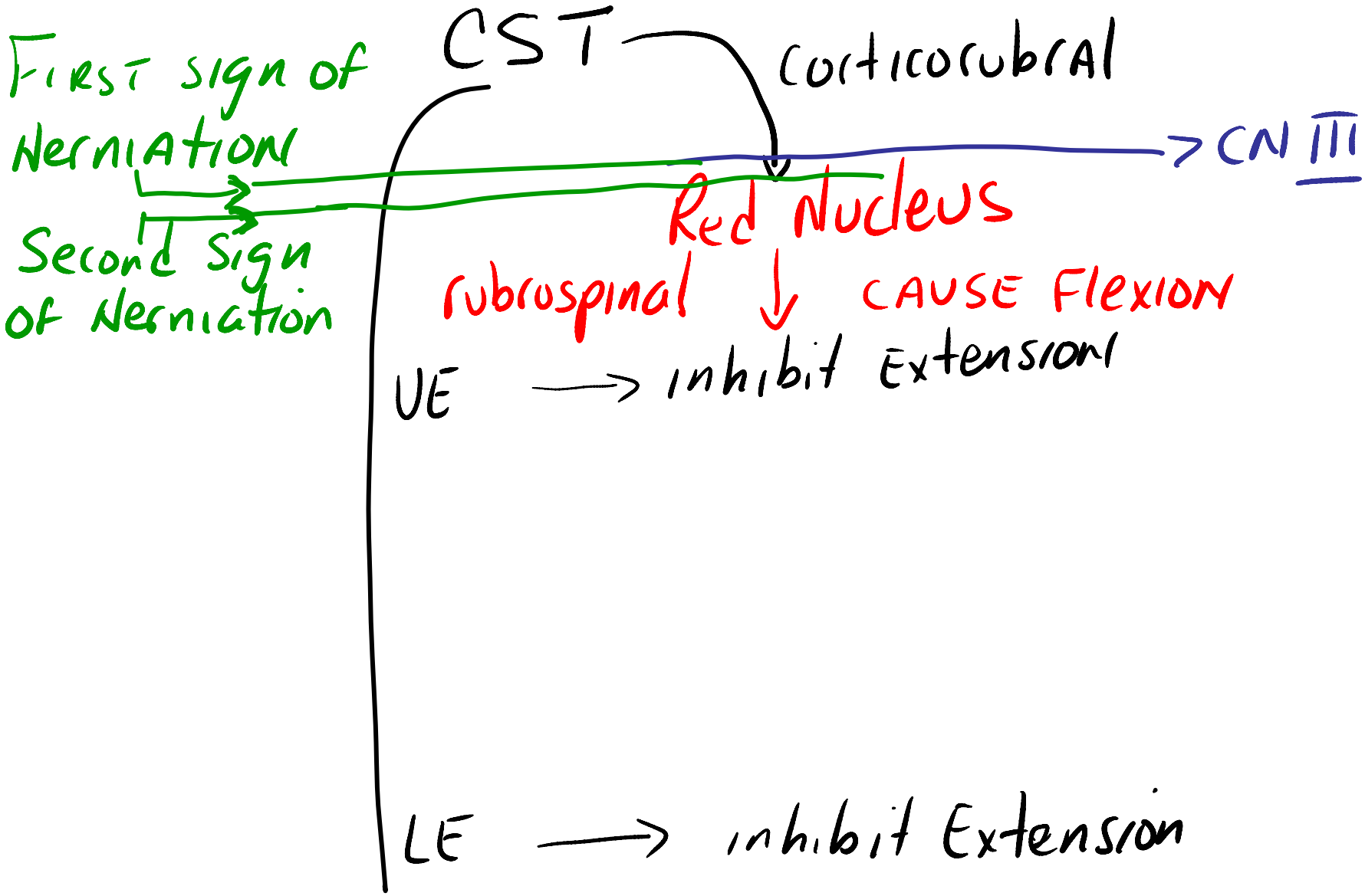
- First sign: papilledema
- First symptom: headache

- Second sign: esotropia (CN VI paralysis)
- Second symptom: diplopia or blurred vision

Increased Intracranial Pressure

- First sign of herniation: (CN III paralysis) loss of pupillary reflex; anisocoria
- Herniation is down to level just above the red nucleus
- CST and Corticorubral pathways are both compressed

Midbrain


CST
Corticorubral
First sign of Herniation
Second Sign of Herniation
CN III
Red Nucleus
rubrospinal
CAUSE Flexion
UE → inhibit Extension
LE → inhibit Extension

If Herniation Continues…

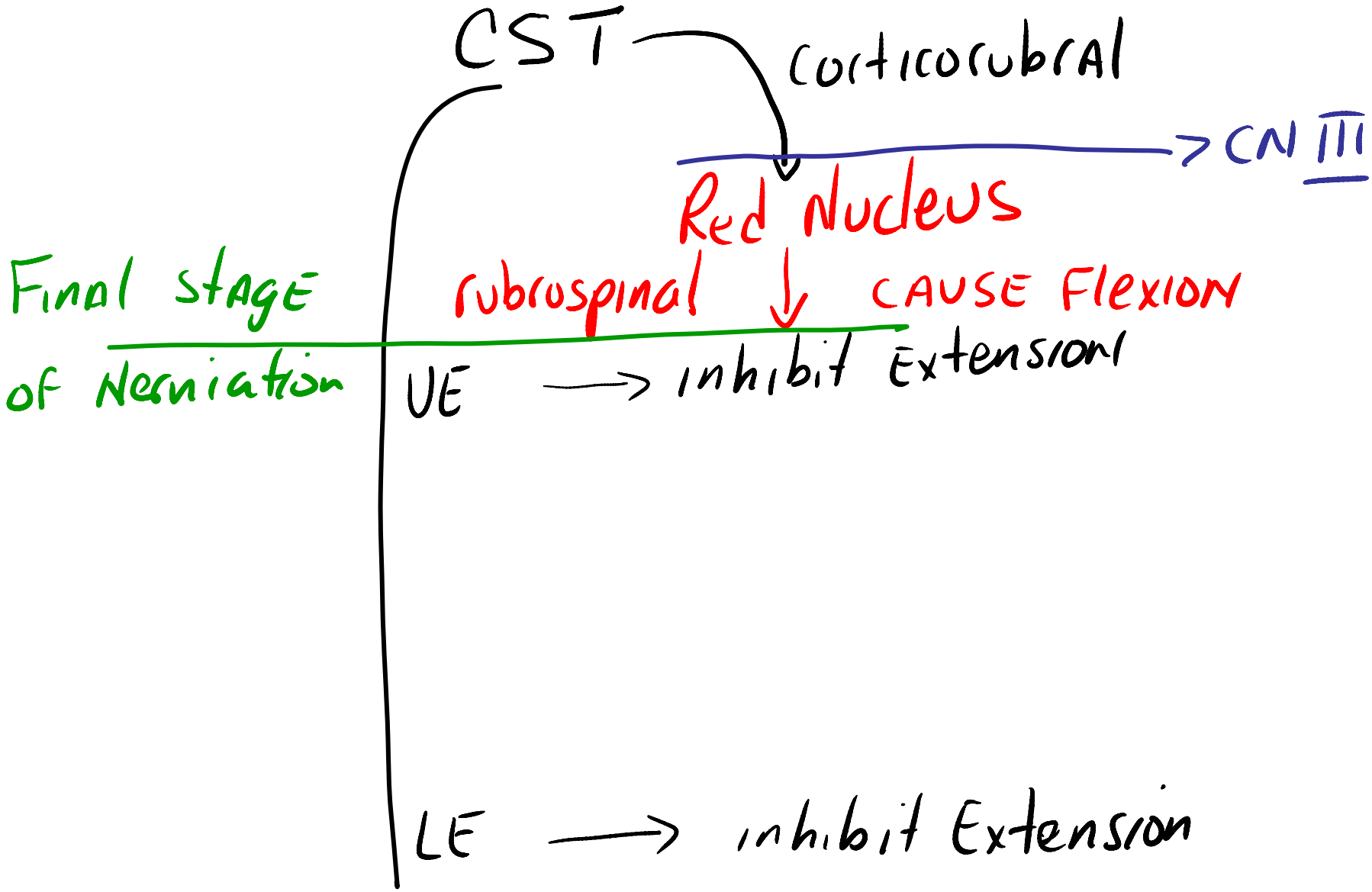
- Second sign of herniation: DECORTICATE posturing
- Compression has ocurred to below CN III but above the red nucleus
- Red nucleus still makes the upper extremities flex while the legs extend
- UNTIL…

The Final Push

- Herniation goes beyond the red nucleus
- CST and Corticorubral and rubrospinal tracts are all lost
- All extremities will extend by default
- Medulla is pushed through the foramen magnum.

- DECEREBRATE posturing

Midbrain


CST
Corticorubral
CN III
Red Nucleus
Final stage
of Herniation
rubrospinal
CAUSE Flexion
UE → inhibit Extension
LE → inhibit Extension

Dorsal Columns

- Vibratory sensation
- Two-point discrimination
- Position sense
- Conscious proprioception
- The only sensory pathway with four synapses

Dorsal Columns, cont

- Fasciculus: made up of a few fibers
- Tractus: more fibers than a fasciculus

- Gracilis: carries leg fibers; located MEDIALLY
- Cuneatus: carries arm fibers; located laterally

Dorsal Columns, cont

- FIRST SYNAPSE: dorsal root ganglion
- Forms fasciculus gracilis, then tractus gracilis (lower extremities)
- Forms fasciculus cuneatus, then tractus cuneatus (upper extremities)
- SECOND SYNAPSE: nucleus gracilis and nucleus cuneatus in MEDULLA

Dorsal Columns, cont

- THIRD SYNAPSE: THALAMUS
- FOURTH SYNAPSE: parietal lobes (postcentral gyri)

Dorsal Column Pathology

- Syphilis
- Vitamin B-12 Def
- Brown-Sequard

Spinothalamic Tract

- Pain and Temperature
- The only pathway that CROSSES in the spinal cord
- Fibers enter the spinal cord, ascend two levels, then cross to opposite side via the anterior white commissure

Spinothalamic Tract

- FIRST SYNAPSE: dorsal root ganglion
- SECOND SYNAPSE: thalamus
- THIRD SYNAPSE: parietal lobes (postcentral gyri)

Spinothalamic Tract Pathology

- Syringomyelia

Spinocerebellar Pathway

- The only pathway in the spinal cord that crosses twice (equivalent to ipsilateral)
- Responsible for depth perception
- Signs of damage:
  - INTENTION TREMOR
  - DYSMETRIA or PRONATOR DRIFT
  - DYSDIODOKINESIS
  - ROMBERG SIGN

Spinocerebellar Pathway, cont

- This pathway does NOT reach the cortex
- Unconscious proprioception
- FIRST SYNAPSE: dorsal root ganglion
- SECOND SYNAPSE: thalamus
- THIRD SYNAPSE: cerebellum

Spinocerebellar Pathway Pathology

- Alcohol attacks the vermis (midline) of the cerebellum while other diseases attack the hemispheres
- Fredrieck’s Ataxia
- Ataxia Telangiectasia
- adrenoleukodystrophy

PONS

- Responsible for responding to the environment
- Contains the PNEUMOTACTIC and APNEUSTIC center
- CNS area most sensitive to osmotic shifts

- Prosencephalon
  - Telencephalon — Cerebrum
  - Diencephalon
    - Thalami
    - Basal ganglia
- Mesencephalon — Mesencephalon — MIDBRAIN
- Rhombencephalon
  - Metencephalon
    - PONS
    - Cerebellum
  - Myelencephalon — Medulla

Pons – Pathology

- Locked-in Syndrome
- Central Pontine Demyelinolysis

Medulla

- Controls ALL basic functions

Make sure you know the cranial nerves !

Midbrain

3 4

Pons

5 6 7 8

Medulla

9 10 11 12

How Do I Figure Out Any Lesion?

You know it's a spinal cord lesion when…

- Pain and temperature loss is opposite to all other deficits
- Level of the lesion is two dermatomes above where pain and temperature loss begins and on the opposite side

You know it's a CNS lesion when…

- UMN signs on one side of the body (upper and lower extremities)
- The lesion is on the opposite side of the brain
- Use the cranial nerves to locate the level of the lesion

The most important organ!!!

- The Brain

- The End The End The End The End