Neurophysiology
Making The Connections
Embryology of the Brain
Primitive Streak $\rightarrow$ Notochord $\rightarrow$ 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
Aqueduct of Sylvius

Munro

3rd

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

Mesencephalon — Mesencephalon — Midbrain

Rhombencephalon

Telencephalon — Cerebrum

Diencephalon — Thalamus

BASAL GANGLIA

Metencephalon — Cerebellum

Myelencephalon — Medulla

PONS
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 accommodation seen with aging
Convex

Concave
STigmatism

Straight Line Test
Visual field deficits

Calcarine Fissure
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

Calcarine Fissure
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
  – Alzheimer’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-acetylcysteine (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
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

- CAudate
- Putamen
- Globus Pallidus
- Subthalamic nucleus
- Thalamus
- Substantia Nigra

RAS

Internal Capsule
Midbrain

CST → corticorubral

rubrospinal ↓ cause flexion

Red Nucleus → CN III

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
- Corticorubral
- Red Nucleus
- Rubrospinal → Causes Flexion
- UE → Inhibit Extension
- LE → Inhibit Extension
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

First sign of Herniation

Second sign of Herniation

CST → Corticorubral

Red Nucleus

Rubrospinal → CAUSE Flexion

UE → Inhibit Extension

LE → Inhibit Extension
If Herniation Continues...

- Second sign of herniation: DECORTICATE posturing
- Compression has occurred 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.

- DECELERATE posturing
Midbrain

CST → corticorubral

Red Nucleus

rubrospinal \( \downarrow \) CAUSE Flexion

Final stage of Nerniation

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 MEDIANALLY
- 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
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