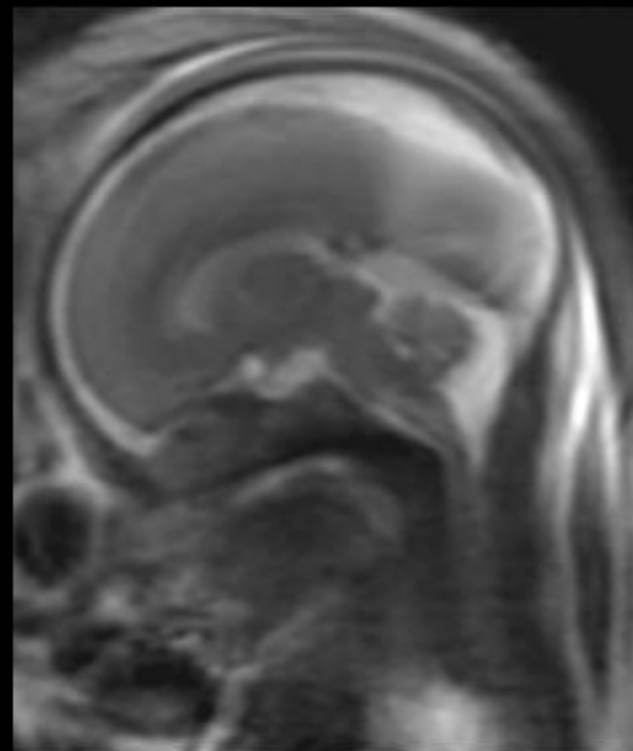


MRI Evaluation of the Normal Fetal Brain

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Chief of Fetal Imaging
Department of Radiology
and Pediatrics
Children's Hospital Medical
Center



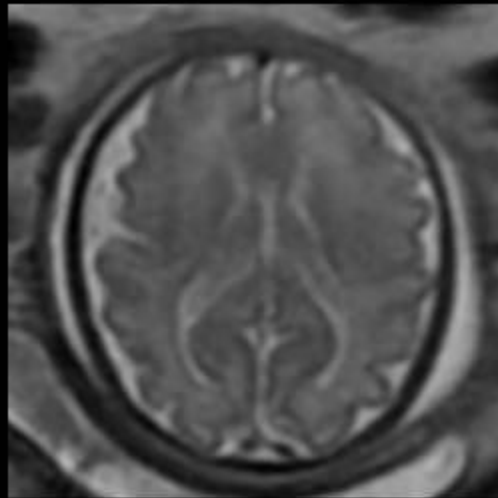
Outline

- Imaging
- Embryology/anatomy
 - Cerebrum
 - Posterior Fossa
- Myelination

Imaging

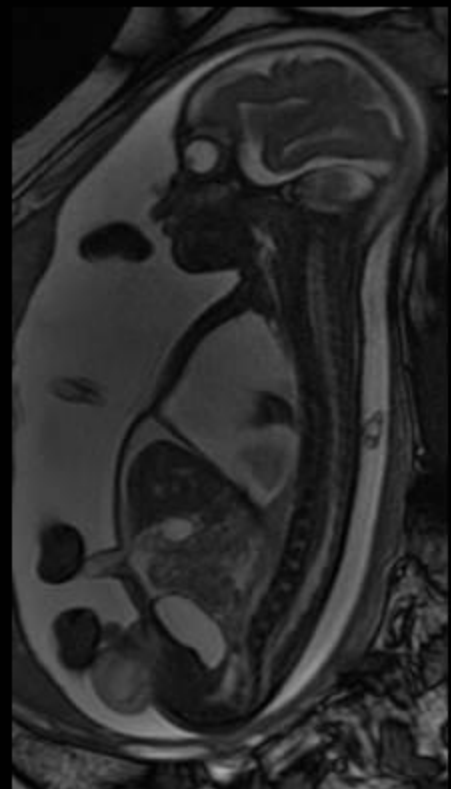
- **SS-FSE/HASTE**

- MR Fetography
- 2-4mm
- Smallest FOV possible
- Anatomic planes (X2)



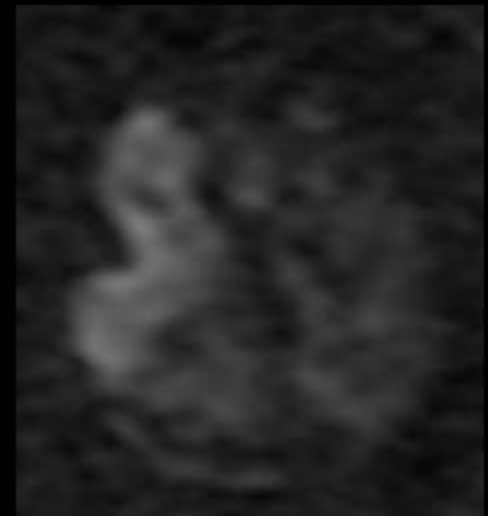
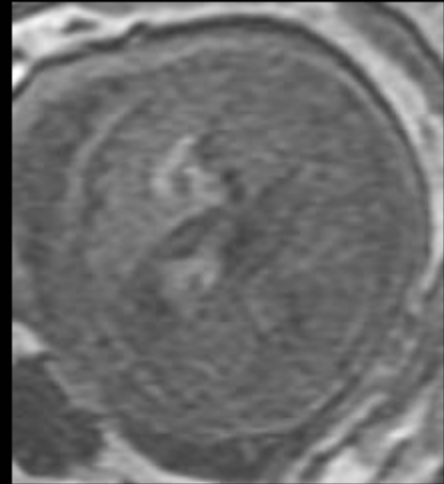
- **Fiesta/TrueFISP**

- Slice 3-4mm
- Resolution is great
- Heavy T2 weighting
 - Midline brain/sulcation
 - Cleft palate
 - Inner ear
- Bright blood



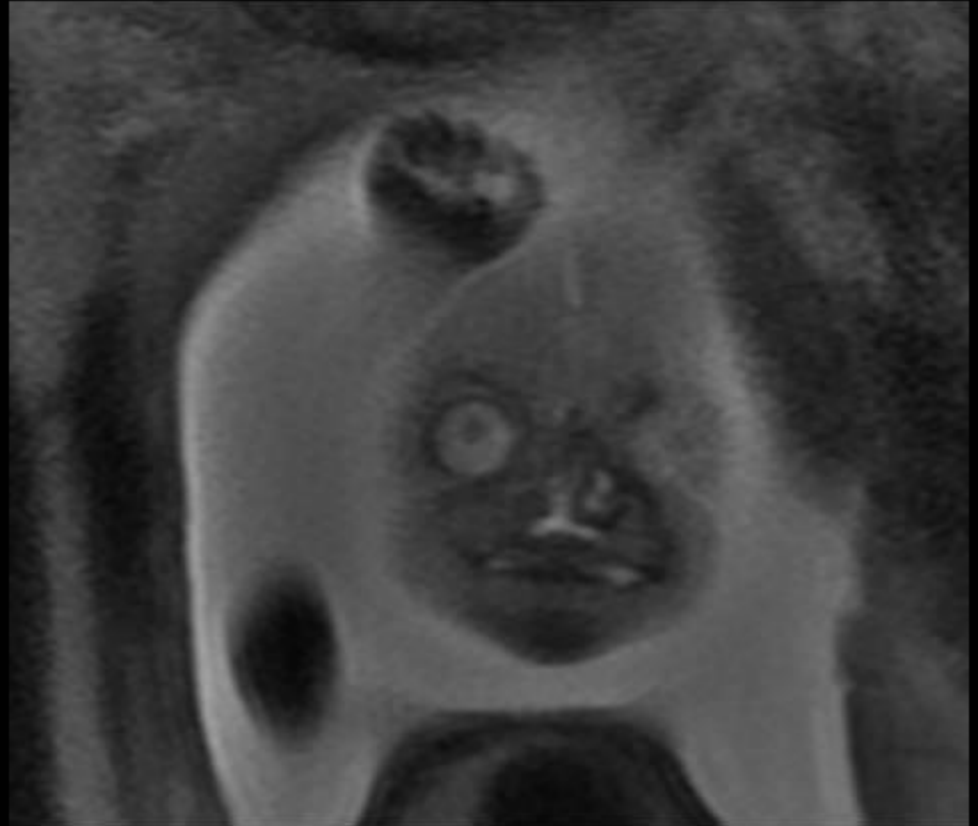
Imaging

- Gradient echo T1 Images
 - Hemorrhage
 - Fat
- Gradient echo T2
 - hemosiderin
- EPI diffusion
 - Artifacts & limited spatial resolution
 - Brain ischemia/injury



Face/ Body Imaging

- Face
 - Orbits
 - Nose
 - Lips
 - Mandible
- Body
 - SS-FSE/Fiesta
 - 4 mm
 - All planes

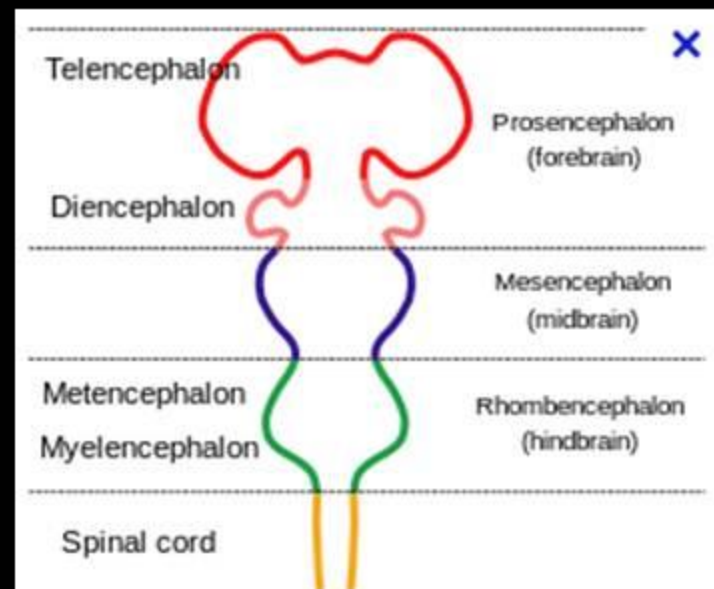


Fetal MRI

- Fetal MR is imaging embryology... So, one needs to know normal development
- Dating can be determined by
 - Germinal matrix
 - Brain parenchyma
 - Sulcation

Fetal Development 4-5 w

- Persistence of the neural canal in the brain vesicles give rise to the ventricular system
 - Telencephalon-----lateral ventricles
 - Diencephalon-----3rd ventricle
 - Mesencephalon-----cerebral aqueduct
 - Rhombencephalon---4th ventricle



en.wikipedia.org

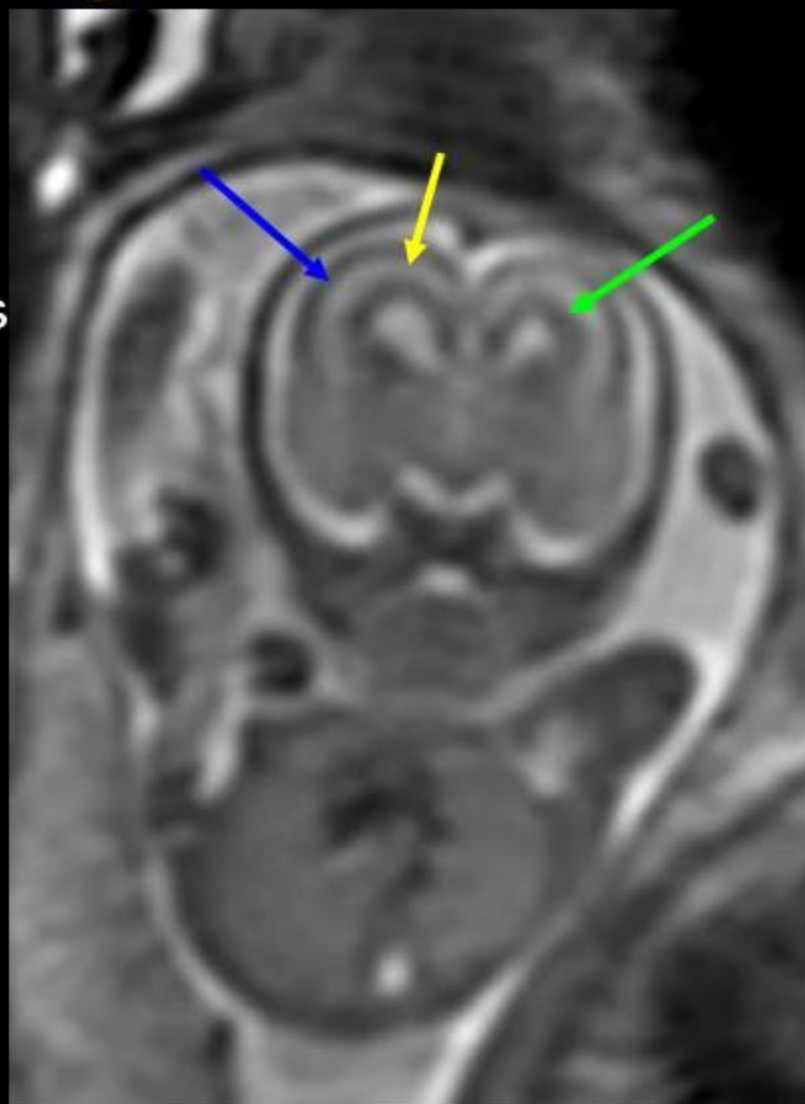
Cerebral Cortical Development

- 5-14 w ventricular zone (VZ)
 - Ependymal
 - Single layer ventricular wall
 - 80% cortical neurons (radial)
- 15-36 w Subventricular zone (SVZ)
 - Subependymal/deep white matter
 - Ganglionic eminences/ventricular
 - 20% cortical neurons (tangential)
 - Basal ganglia/thalamus
 - Amygdala/hippocampus
 - Lateral sparse/dense cellular
 - Glial cells

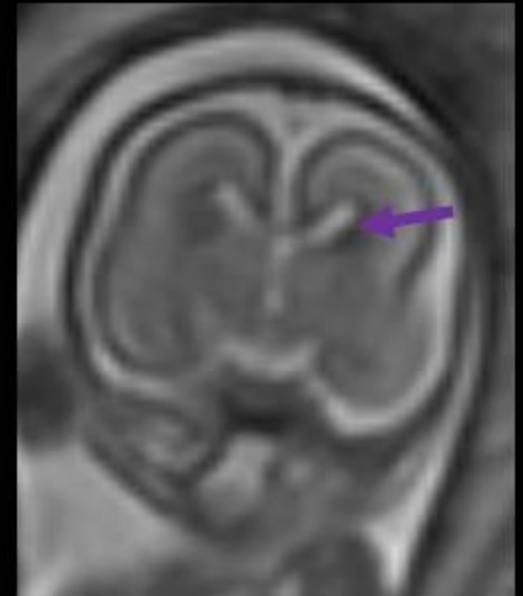
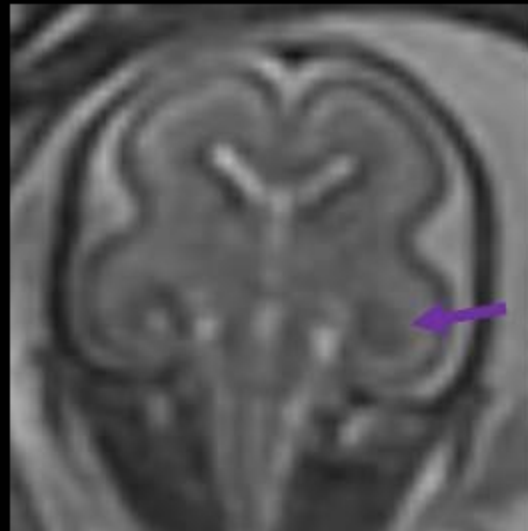


Cerebral signal

- Fetal brain MR signal
 - Water content
 - 40% extracellular fetal versus 20% adult
- T1 and T2 shortening
 - High neuronal cellularity
 - Germinal matrix
 - Cortex
 - Myelination
- T1 and T2 prolongation
 - High water content
 - White matter

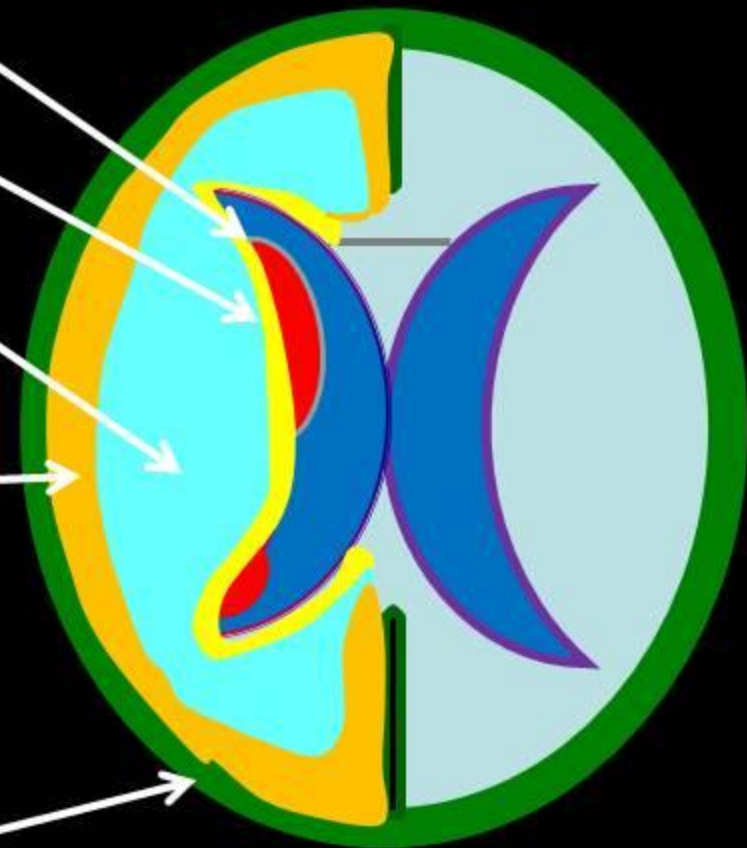


Cerebral < 20 w

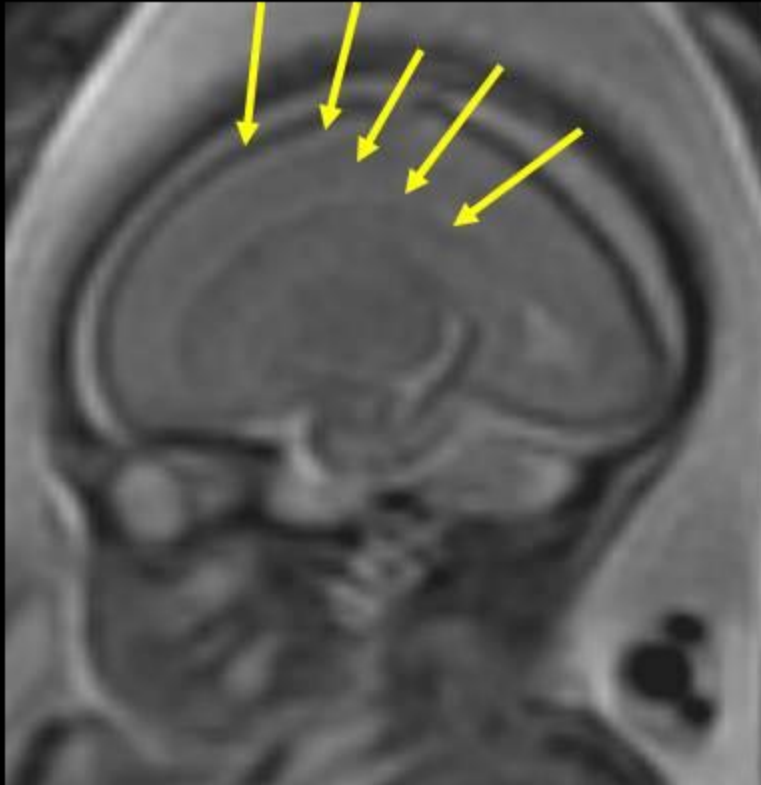


Cerebral Cortical Development

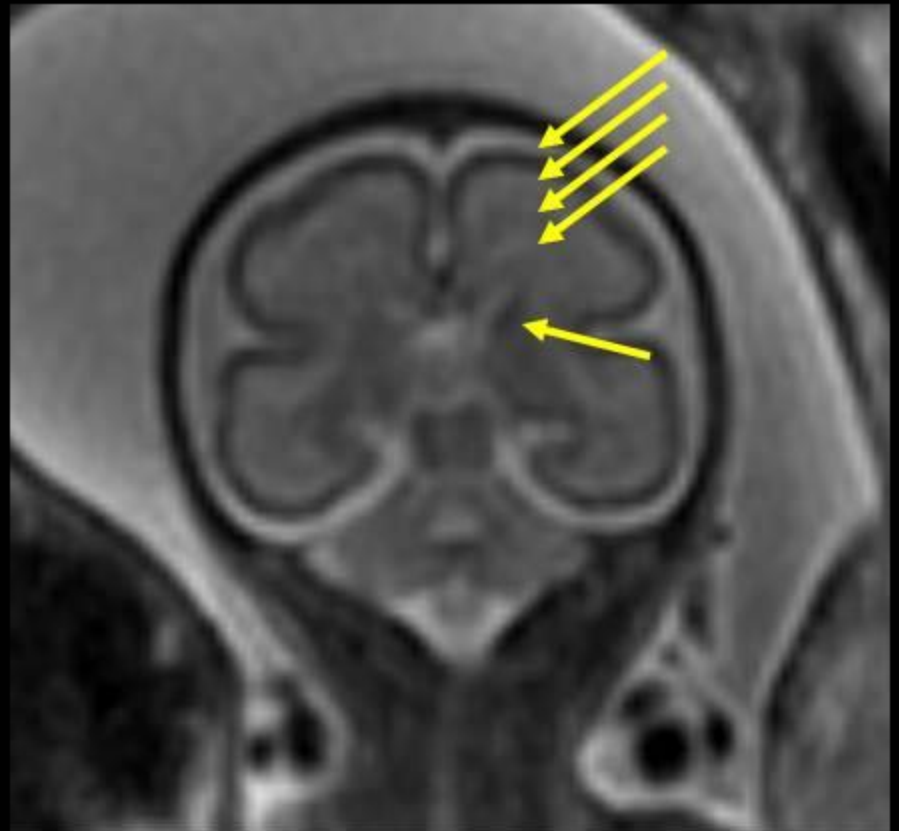
1. VZ/SVZ, germinal matrix
2. Periventricular fiber rich zone/SVZ (axons CC)
3. Intermediate zone/SVZ
 - Neuronal migration
 - Astrocyte proliferation
 - Oligodendrocytes
4. Subplate zone
 - Neuron rich large extracellular matrix
 - Synapses between subcortical fibers (thalamus, brainstem, basal forebrain) not yet final destination in the cortical plates
5. Cortical plate



Cerebrum 20-28 w

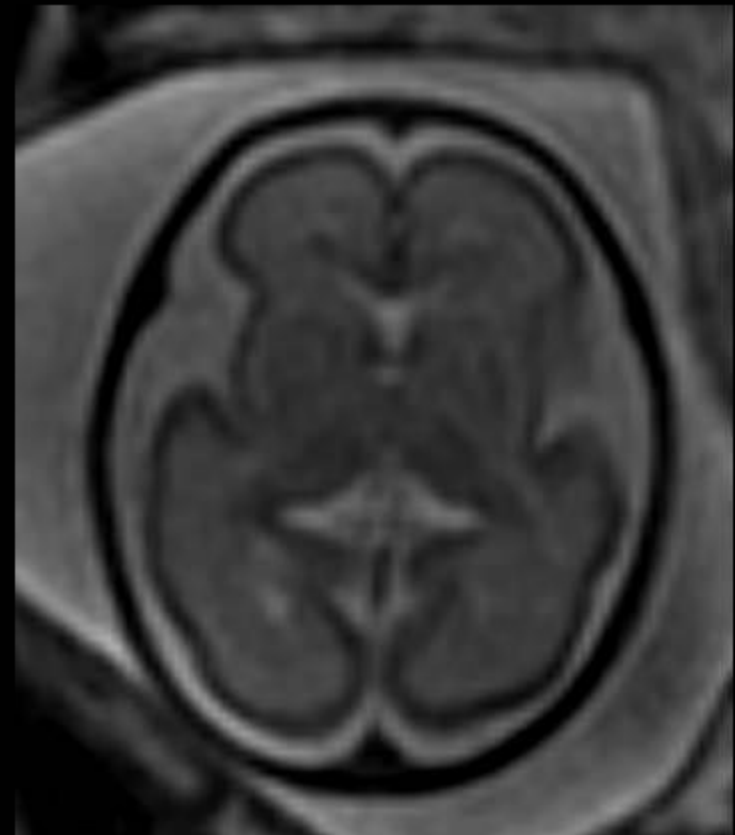


26 w



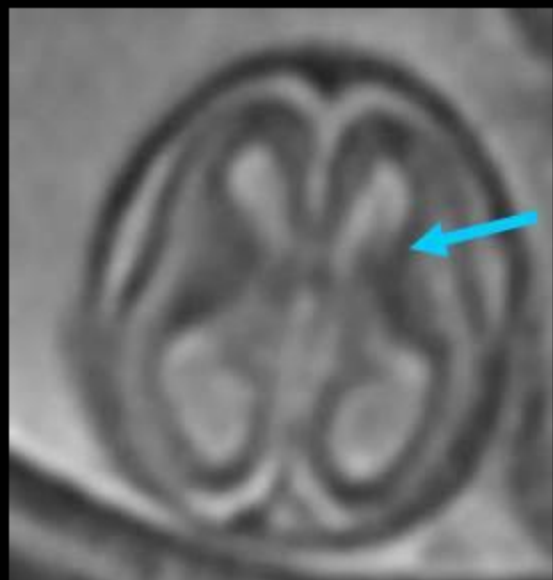
Periventricular crossroads 22 w

- Periventricular rich/intermediate
 - Axonal guidance
 - Hydrophilic extracellular matrix
 - 6 locations
 - Frontal lateral to frontal horn
 - Posterior at fountainhead posterior limb internal capsule

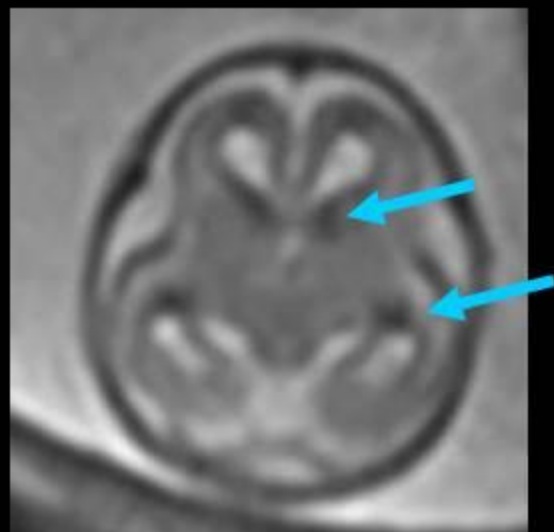


Cerebral Germinal Matrix Involution

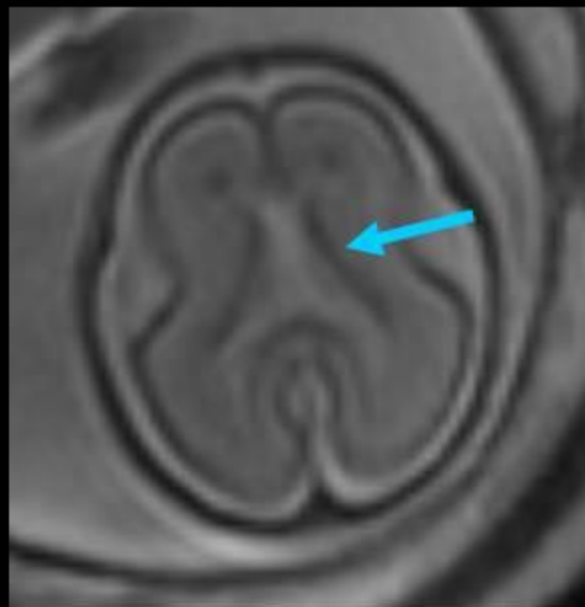
- VZ (ependymal)
 - 27 w
- SVZ (subependymal)
 - 34 to 36 w
 - 33 w
 - Roof of temporal horns
 - Lateral wall of the occipital horn
 - 36 w
 - caudate head, ganglionic eminence
 - Postnatal
 - frontal periventricular area



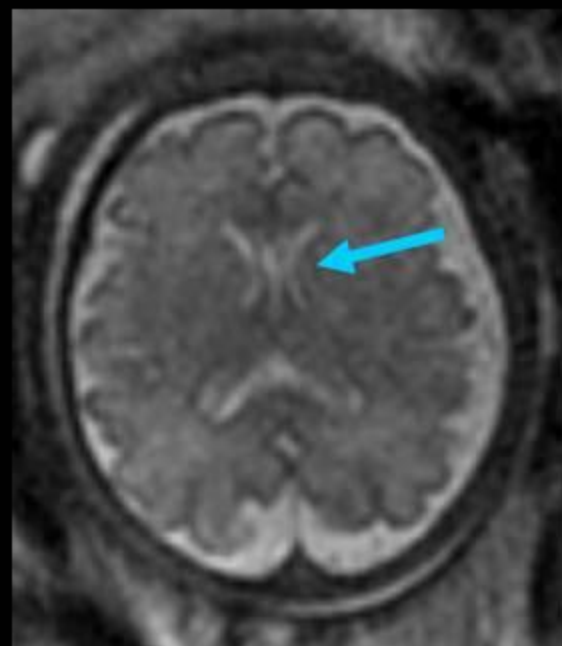
16 w



25 w



35 w



Corpus callosum

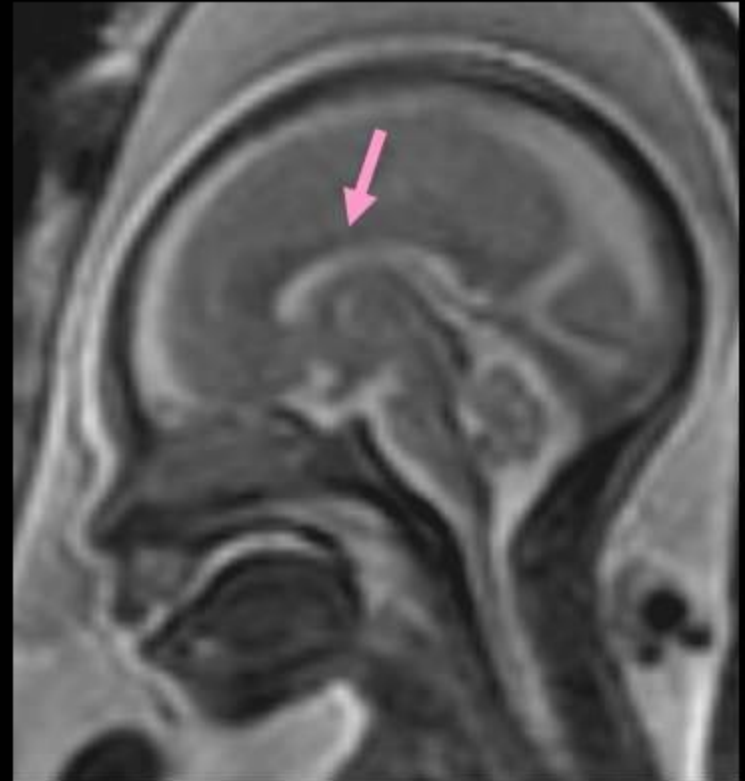
- 10 w - lamina terminalis/lamina reunions
- 14-15 w – anterior to hippocampal commissure
- 16 w - splenium
- 20 w- Final /5% of size

- Septum pellucidum
 - 18 w

Corpus Callosum



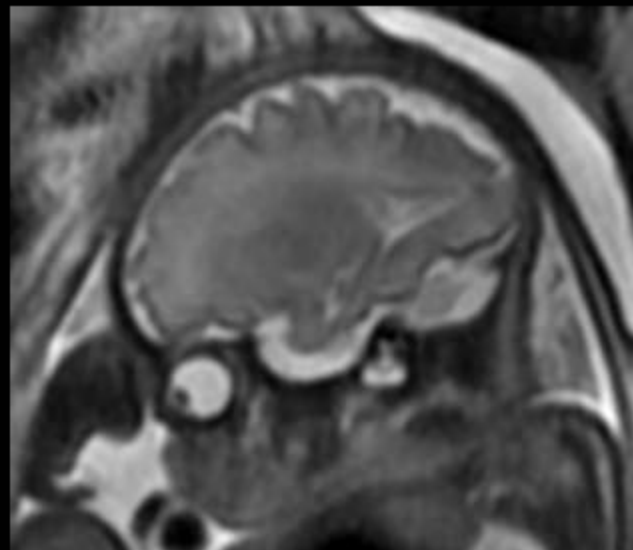
16 w



24 w

Sulcation

- Cortical development follows a predictable pattern
 - Sulcus indicator of fetal maturity
- Time lags between MR imaging and anatomic/pathologic model
 - 1.9 +/- 2.2 w (Levine and Barnes, Radiology, 1999)
 - Abnormal brain can lag more in cortical development than normal fetus
 - Twin gestations



Sulcation

16 w

- Interhemispheric
- Sylvian

22-25 w

- Parietooccipital
- Callosal
- Calcarine
- Cingulate

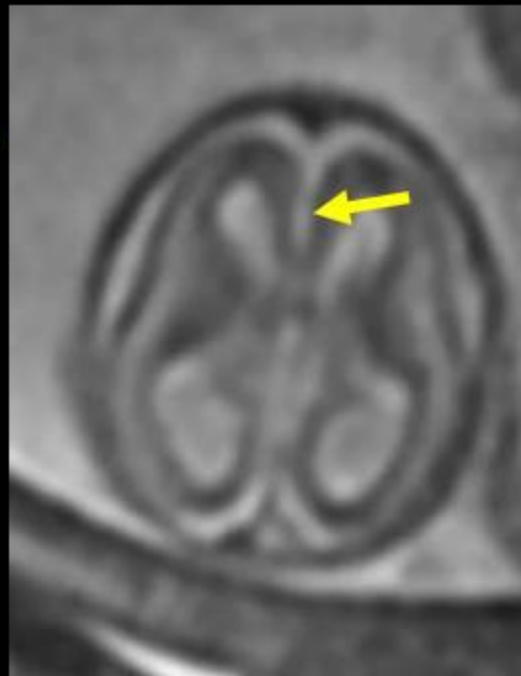
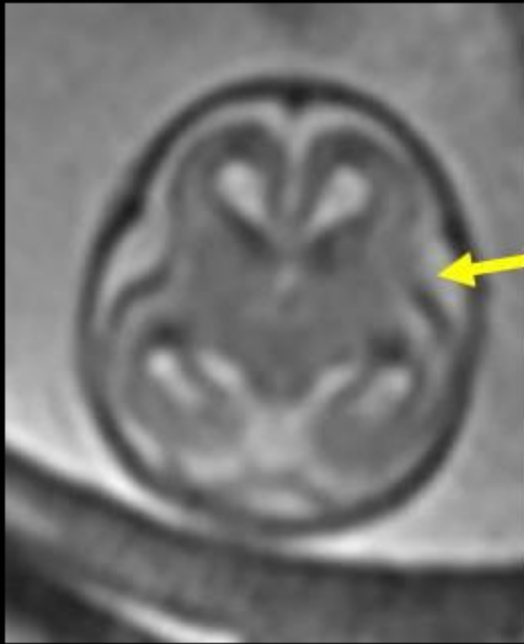
26-28 w

- Central (26)
- Precentral (27)
- Superior Temporal
- Marginal
- Postcentral (28)

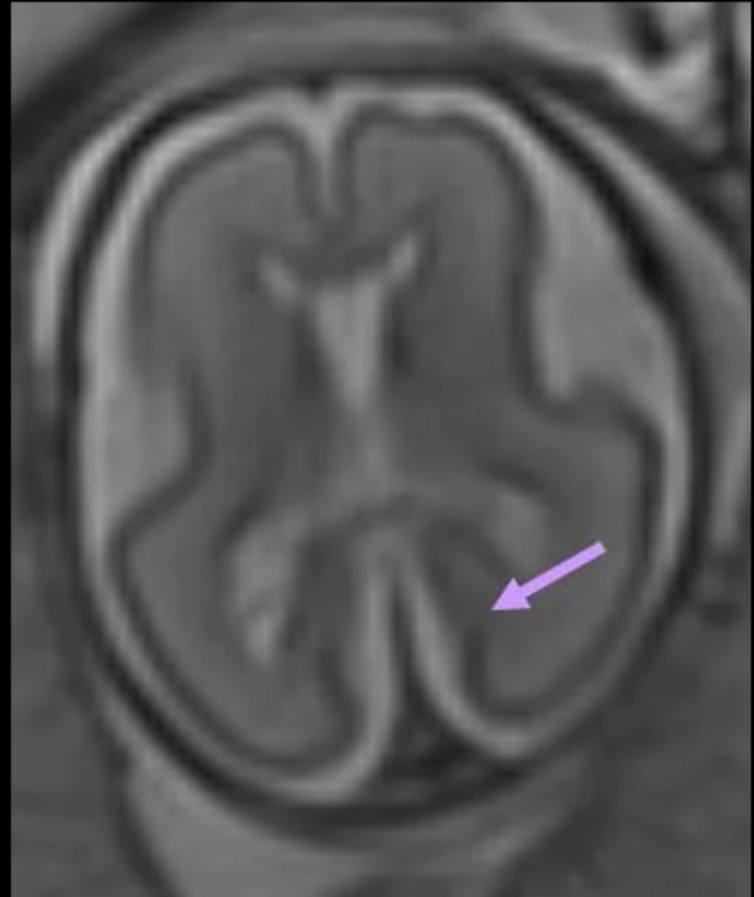
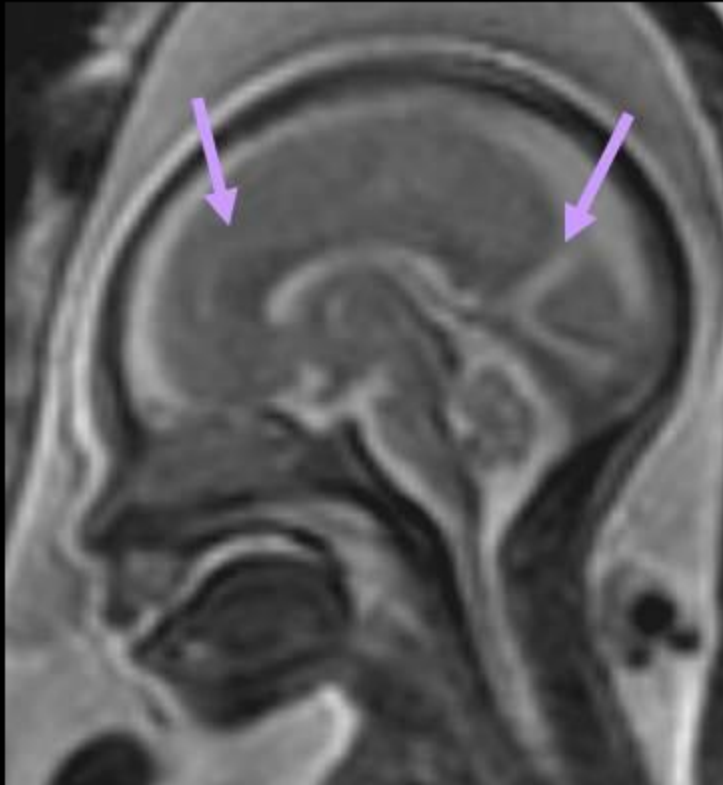
29-34 w

- Superior frontal
- Inferior frontal
- Inferior temporal

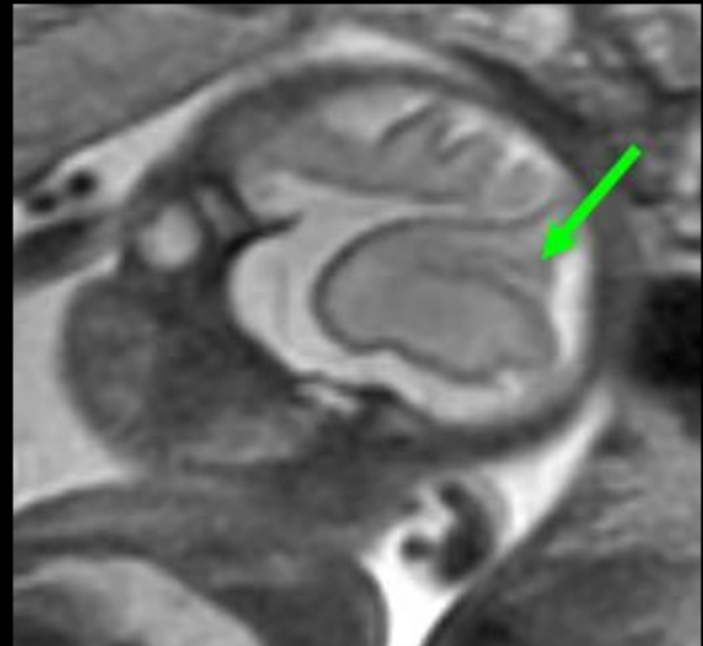
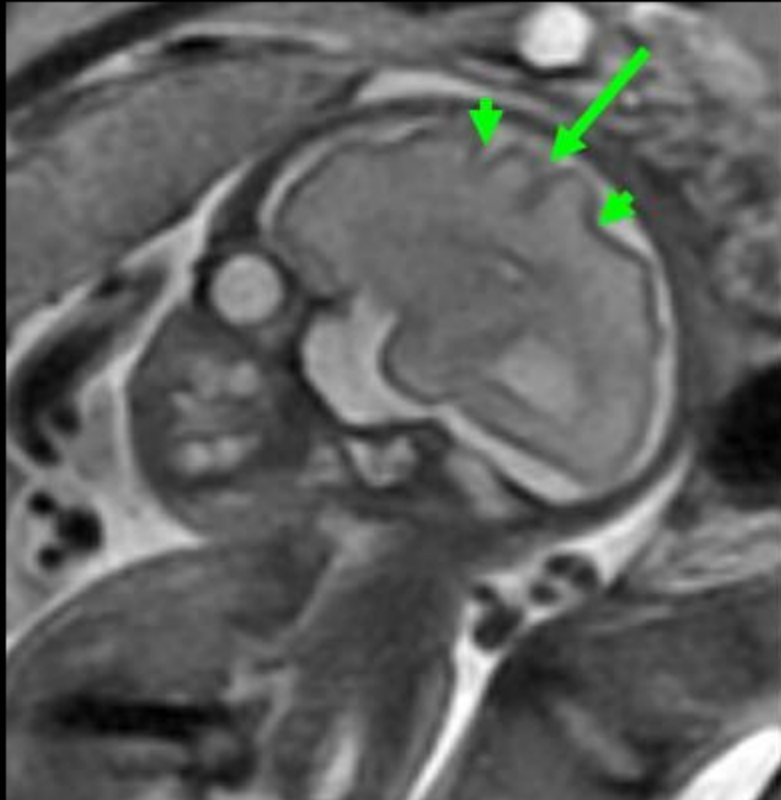
Sulcation 16 w



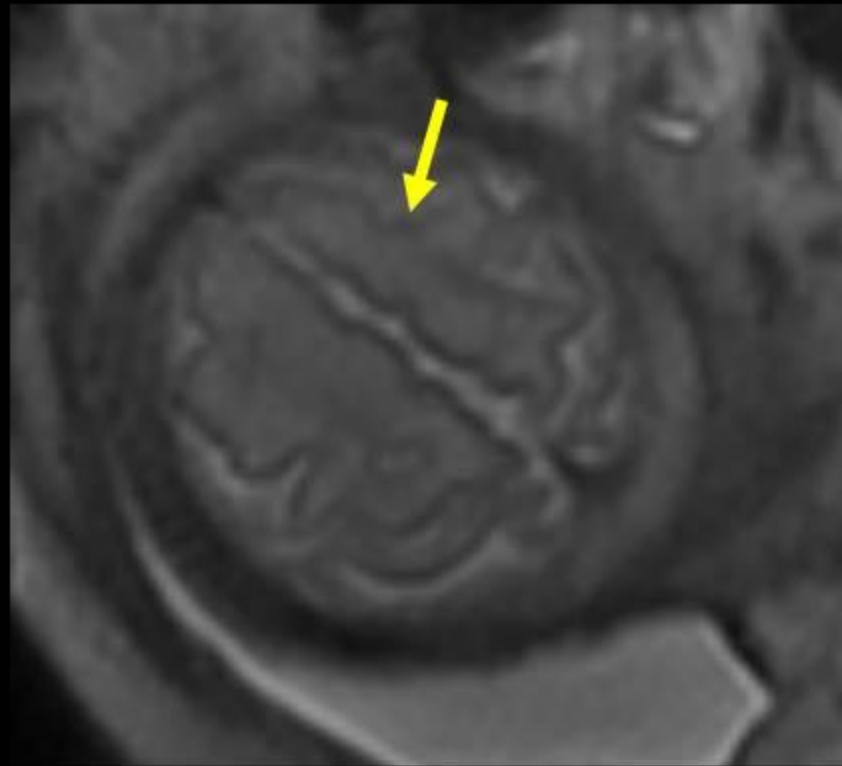
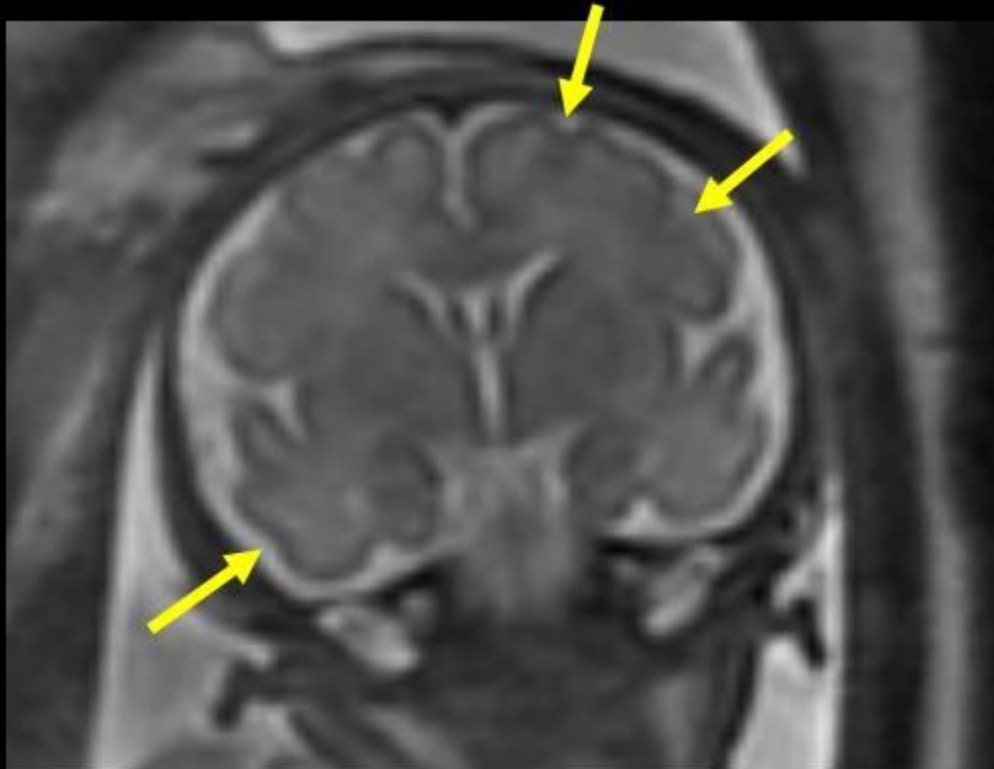
Sulcation 24 w



Sulcation 28 w



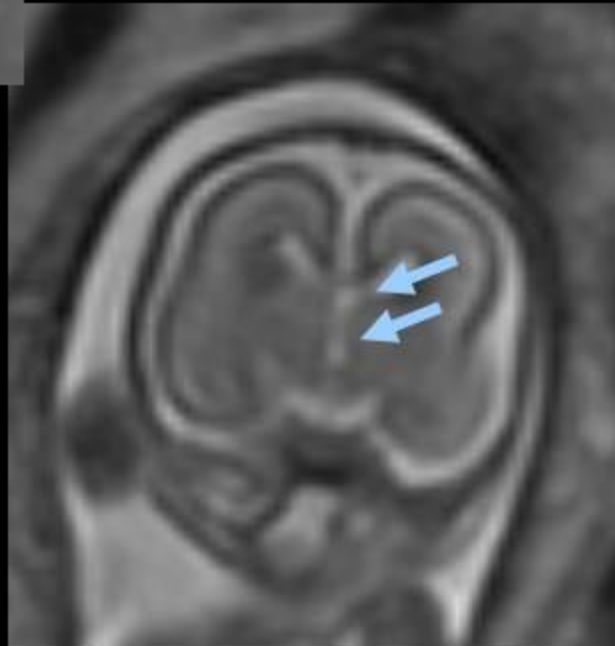
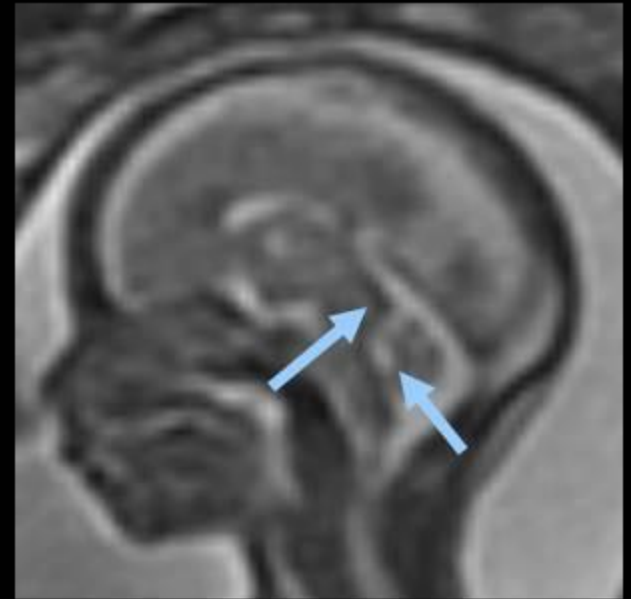
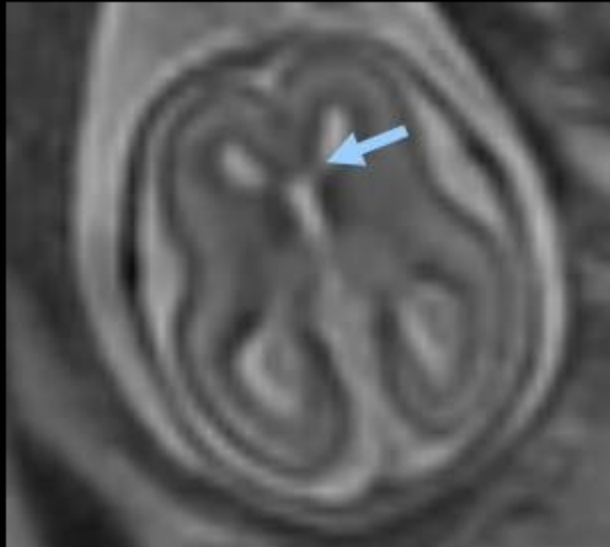
Sulcation 32 w



Ventricles/Extraaxial Spaces

- Ventricles
 - Constant in size 14-40 w
 - Normal by ultrasound 7.6 +/- .6 mm
 - Upper limit is 10mm
 - Septum pellucidum et vergae (29 to 33 w)
- Extraaxial spaces
 - Constant to 30 w, then decrease

Ventricles



18 w

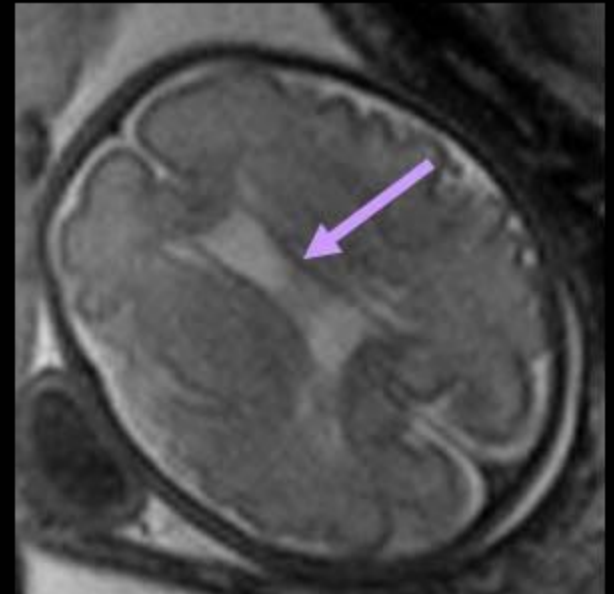
Ventricles and Extraaxial Spaces



16 w



23 w



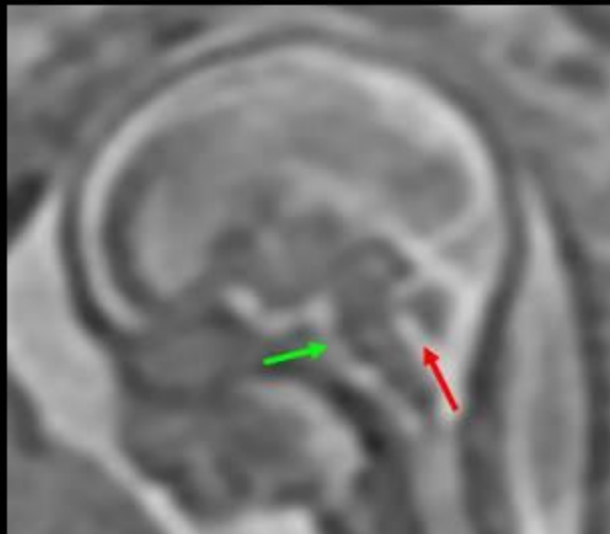
33 w

Posterior Fossa-Cerebellum

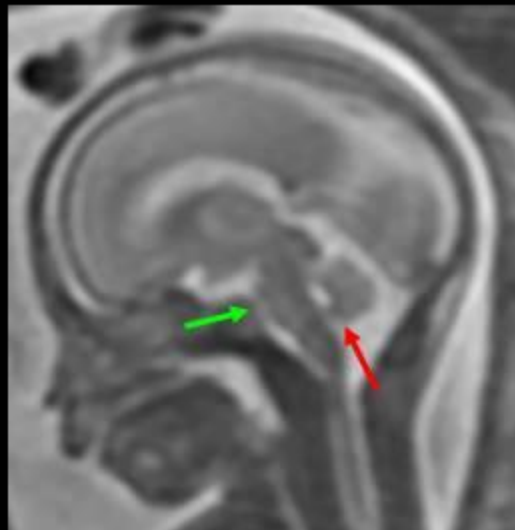
Week	Embryologic event
5	Rhombic lips
6/7	Tuberculum cerebelli-hemispheres and flocculi (posterolateral fissure)
9	Tuberculum cerebelli-vermis
11-12	Primary fissure-medial to lateral
14	Main fissures 9 vermian subdivisions

Fetal MR Posterior Fossa

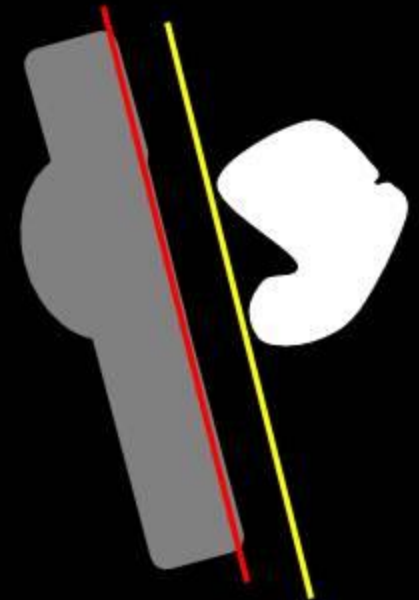
- Brainstem
 - Pons
- Vermis
 - 18-20 w cover fourth ventricle
 - Tegmento-vermian angle close 0



16 W

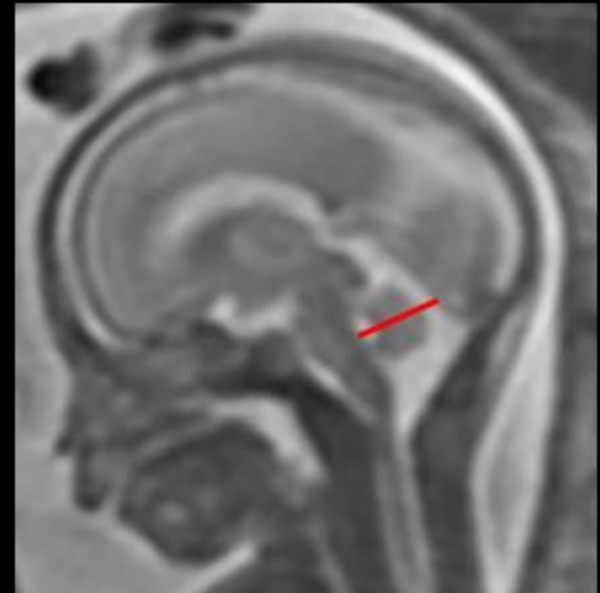


22 W



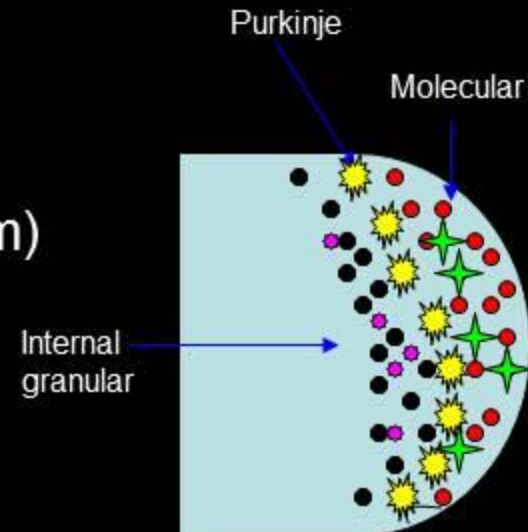
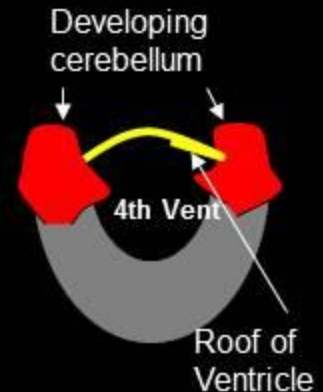
Fetal MR Posterior Fossa

- Measurements
 - Vermis
 - Pons
 - Transverse cerebellum
- Vermis
 - Fastigial declive line
 - Superior/inferior
 - 47/53%
 - 1:2



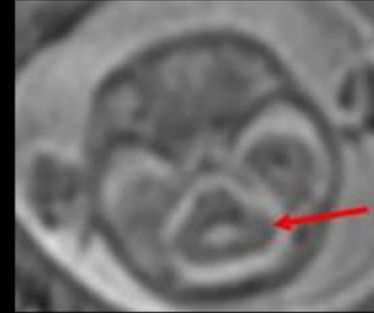
Cerebellar Germinal Zones

- 9-13 w roof of the IV ventricle (radial)
 - Cerebellar nuclei (dentate nuclei)
 - **Purkinje** layer
 - Late embryonic/postnatal –inside out/Interneurons
 - Granular –**Golgi**
 - Molecular-**Stellate** and **basket**
- 8-13 w rhombic lips (tangential)
 - Upper
 - Cerebellar nuclei
 - External granular layer (surface of cerebellum)
 - 16 w-**Internal granular** layer
 - Lower
 - Pontine nuclei and inferior olivary nucleus

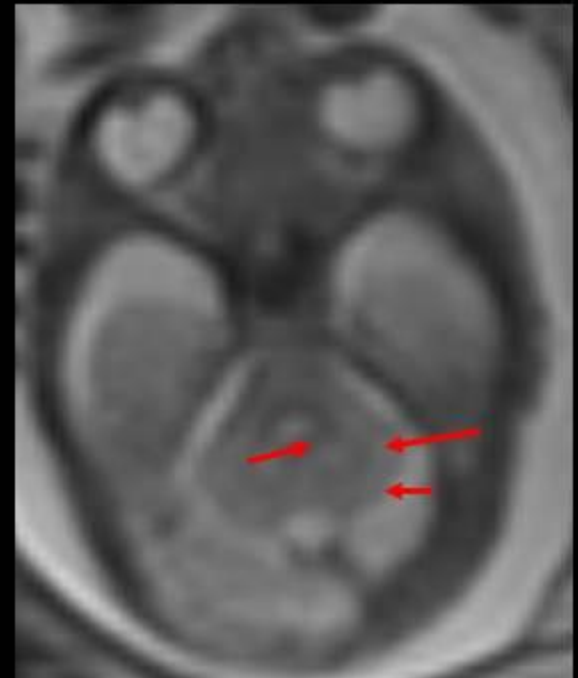


Fetal Brain Signal/Cerebellum

- 16-19 w homogeneous



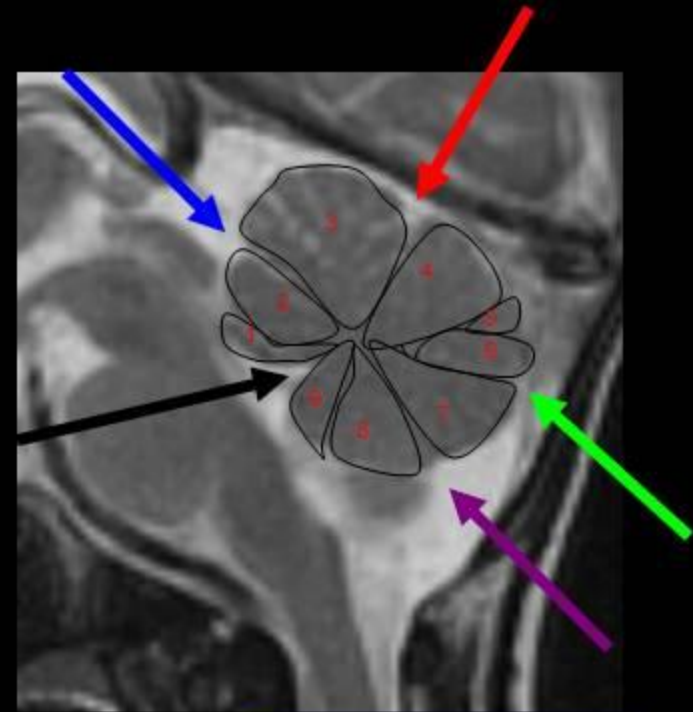
- 20-30 w
 - low signal in cortex
 - Three layer
 - Inner thin low signal dentate
 - Middle high white matter
 - Outer low cerebellar cortex



Sulcation Vermis/Cerebellum

- Vermis

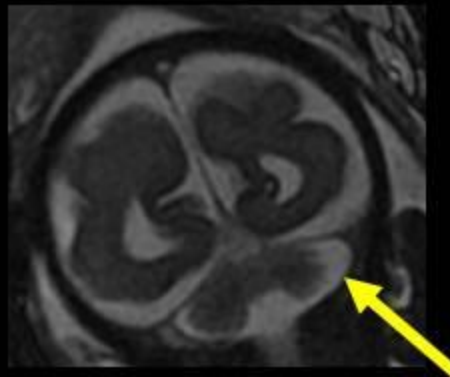
- Fastigial point should be acute (black)
- 18-20 w
 - primary fissure (red)
- 21-24 w
 - (21) prepyramidal (green)
 - (21-22) preculminate (blue)
 - (24) postpyramidal or secondary fissure (purple)



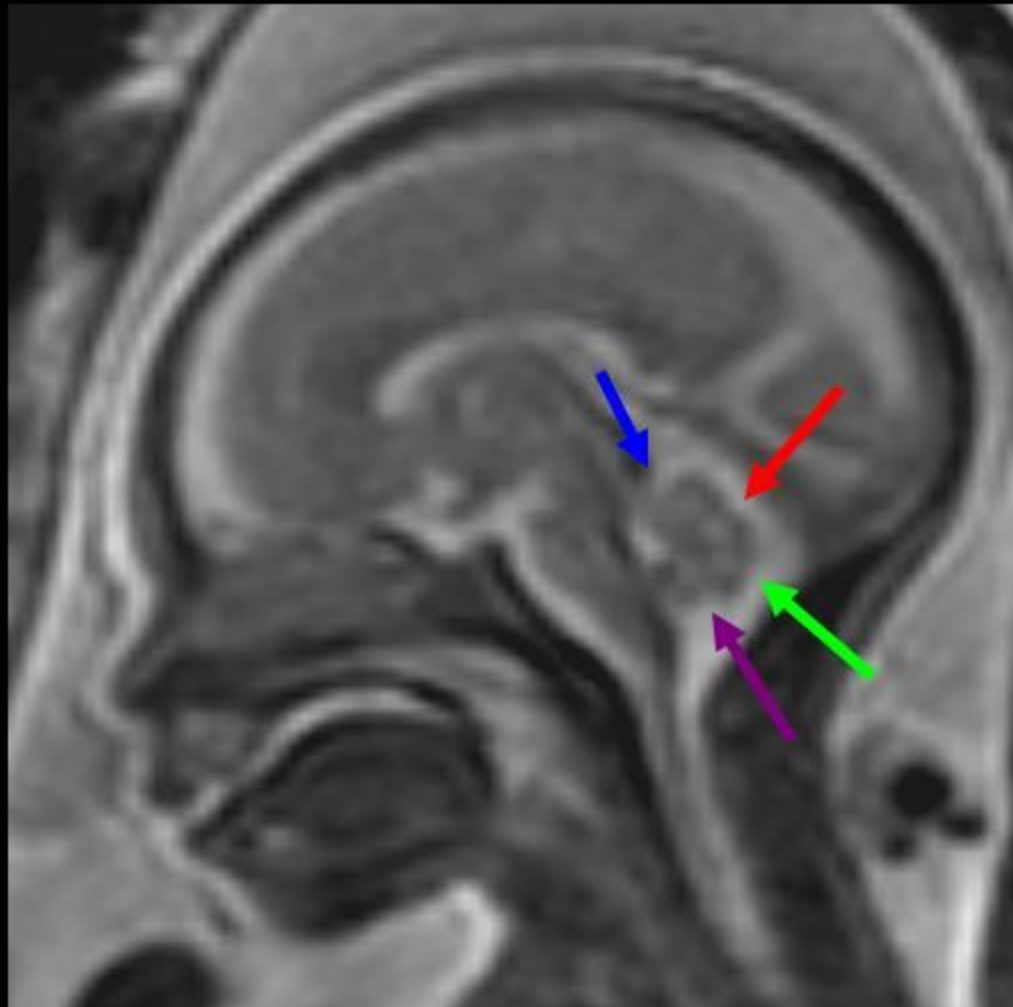
1. Lingula
2. Central lobule
3. Culmen
4. Declive
5. Folium vermis
6. Tuber vermis
7. Pyramis
8. Uvula
9. Nodularis

- Hemispheres

- 24-29 w

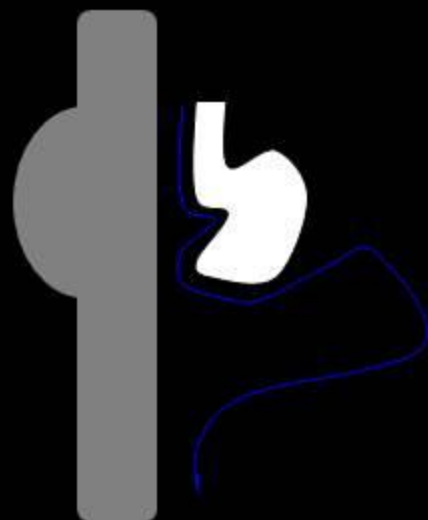


Vermis at 27 w

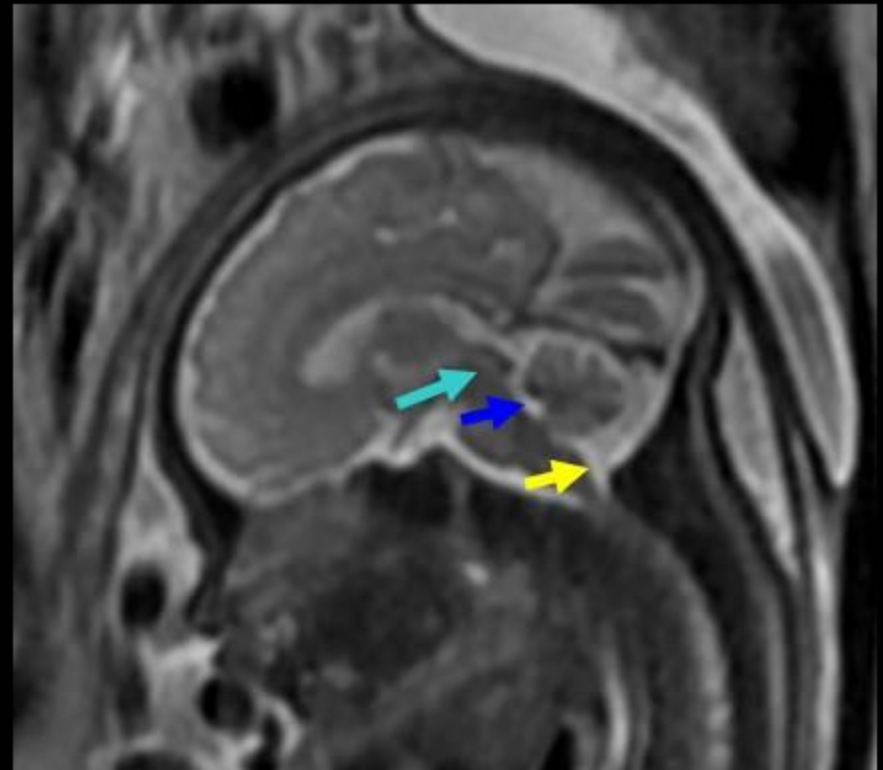
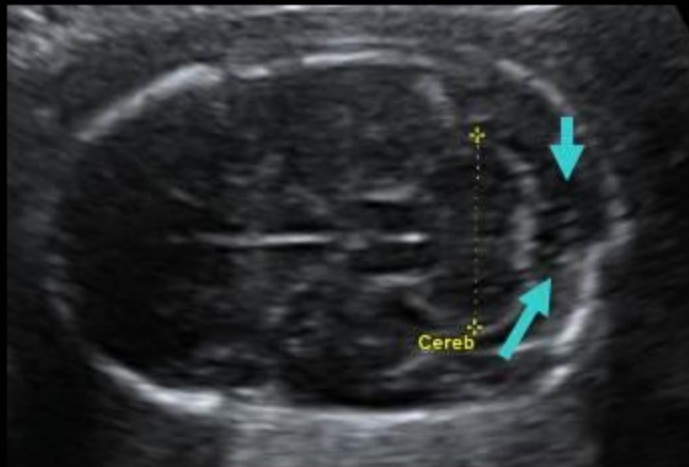


Ventricles/Subarachnoid spaces

- Cisterna magna/craniocervical junction
- Ventricles/persistence neural canal
 - Mesencephalon-----cerebral aqueduct
 - Rhombencephalon---4th ventricle
 - Focal dilatation of central canal
 - Rhombencephalic vesicle—Blake's pouch
 - » Inferior/dorsal ependyma lined diverticulum
 - » Fenestrates to obex 12 w
 - » Foramen Magendie



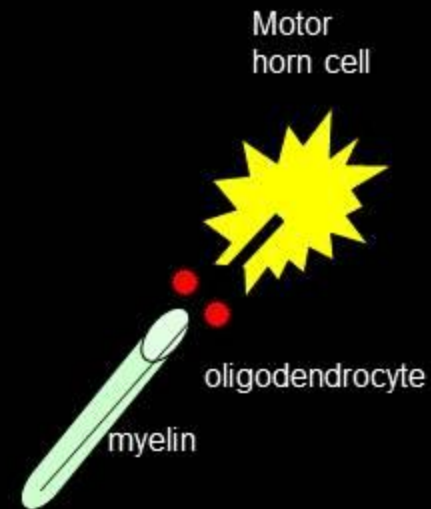
Ventricles/Subarachnoid Spaces



34 W

Myelination - 5th month

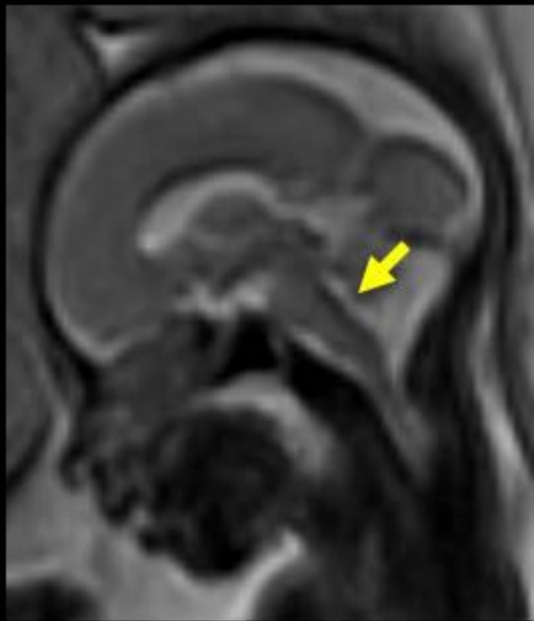
- Proliferation and differentiation of oligodendrocytes
 - Decrease in water content, increase in cellular density and increase in lipid
- Begins 12-13 w in spinal cord
- CNS
 - Caudal to rostral
 - Sensory prior motor
 - Cortex concentric > subcortical functional
 - Telencephalon
 - Central sulcus toward poles
 - Posterior prior to anterior



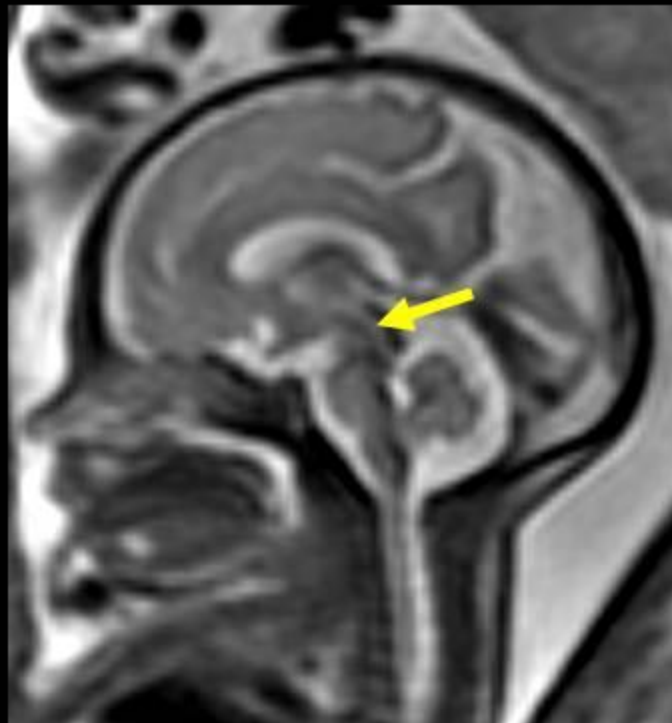
Myelination

- Posterior brainstem
 - 20 w posterior medulla/pons
 - 32 w midbrain
- 29 w
 - Superior and inferior cerebellar peduncles
- 33 w
 - Inferior colliculi
 - Lateral putamen and ventrolateral thalami
 - Posterior limb of internal capsule
- 35 w
 - T1 Posterior limb of internal capsule
 - central white matter and optic tracts
 - Perirolandic, calcarine, medial temporal lobes
 - Prenatal to postnatal 2 months

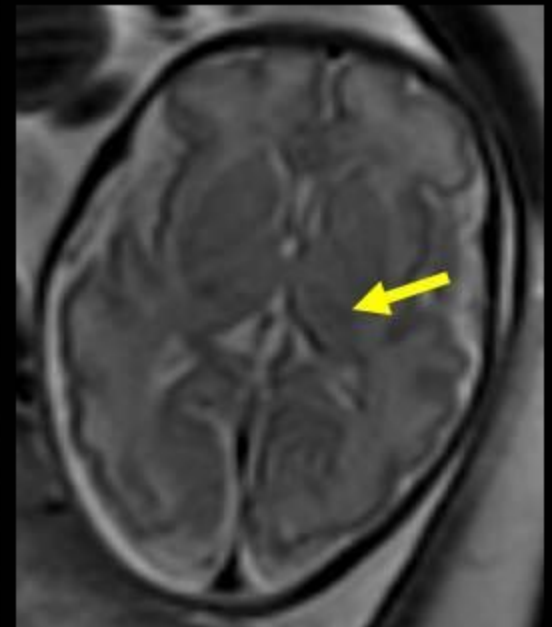
Myelination



23 w

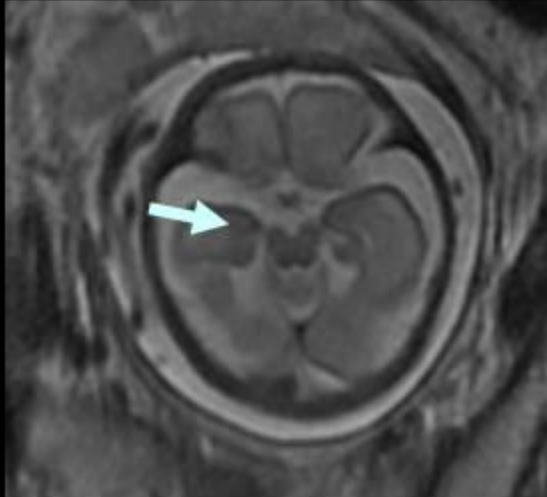


33 w

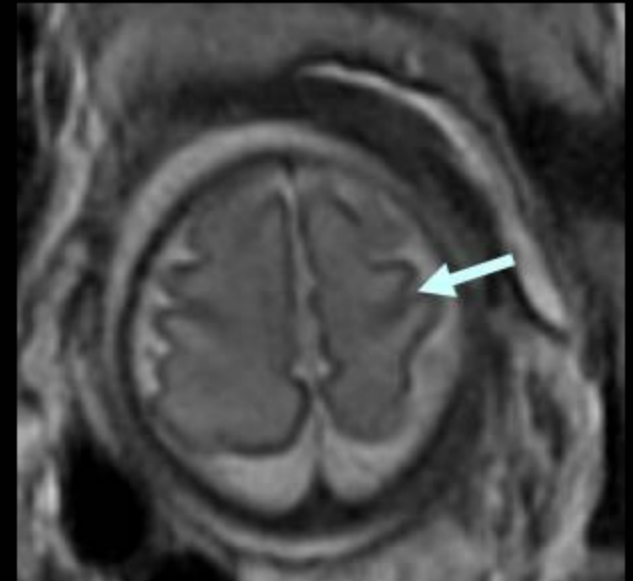
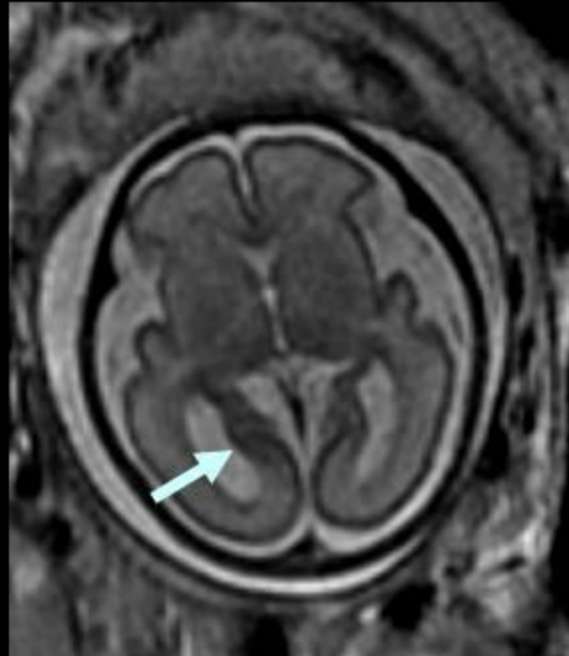


33 w

Myelination



29 w



Organized approach

- Ventricles - ? septum pellucidum
- Germinal matrix
- Brain parenchyma
- Myelination
- Sulcation
- Extraaxial fluid spaces

USE BOTH SIDES OF BRAIN

Summary

- Organized approach
 - Anatomic planes are crucial
- Familiar normal fetal brain anatomy
- Use all resources