DEVELOPMENT OF CENTRAL NERVOUS SYSTEM

* C.N.S develops from **neural tube** which arises from the **ectoderm**:

1. It appears in the 3rd week as a median dorsal **thickening of the ectoderm** known as the **neural plate** extending from the buccopharyngeal membrane to the primitive knot.
2. The neural plate will form the **neural groove** which has 2 elevated lateral edges called **neural folds**.
3. The neural folds **fuse** together to form **neural tube** lying beneath the ectoderm in the median plane.
4. The surface **ectoderm regains its continuity** again.
5. The **fusion** of the folds starts at the midpoint of the groove then spread cranially and caudally but fusion is **absent** at the anterior & posterior **end**s of the tube leaving 2 openings on the ectoderm called **the anterior & posterior neuropores**.
6. Anterior neuropore closes at 23rd day while posterior neuropore **closed** at 25th day.
7. The closed neural tube develops into the **spinal cord and brain**.

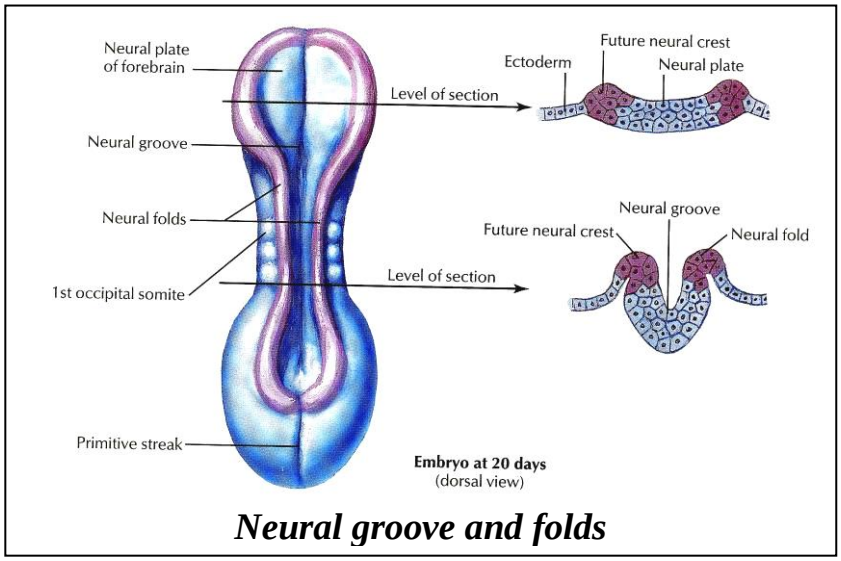
*THE NEURAL CREST :

★ ***Formation:***

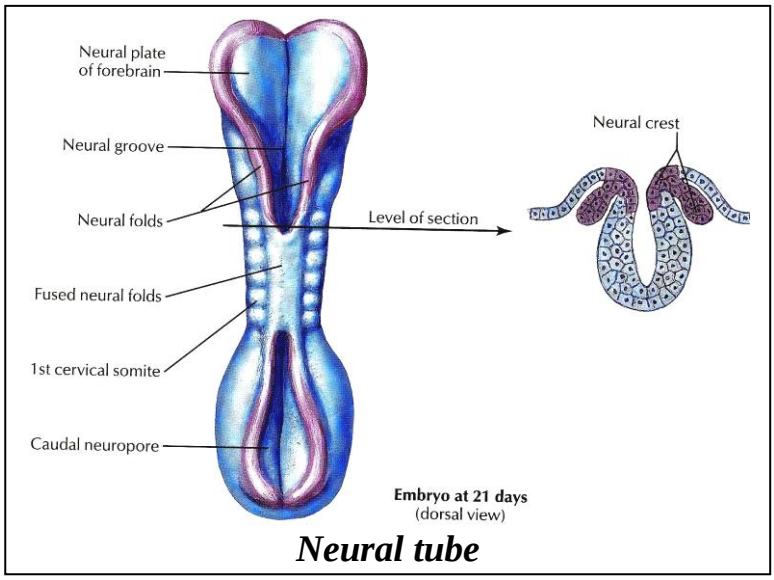
- It arises as a strip of ectodermal cells along the **lateral edge of the neural groove.**
- As the 2 edges of the **neural groove fuse** together forming the neural tube, the 2 ***neural crests*** **separate** as 2 longitudinal cords that **migrate ventrally** to lie one on each side of the neural tube.

★ ***Derivatives:***

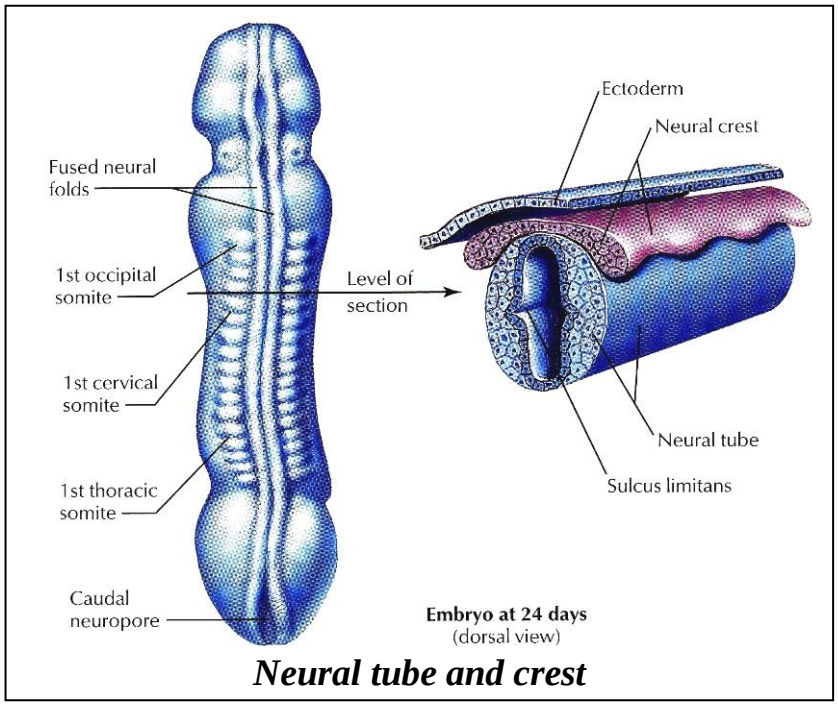
1. Sensory **ganglia** of the cranial nerves (5, 7, 9 & 10).
2. Dorsal root ganglia of all spinal nerves.



Neural groove and folds

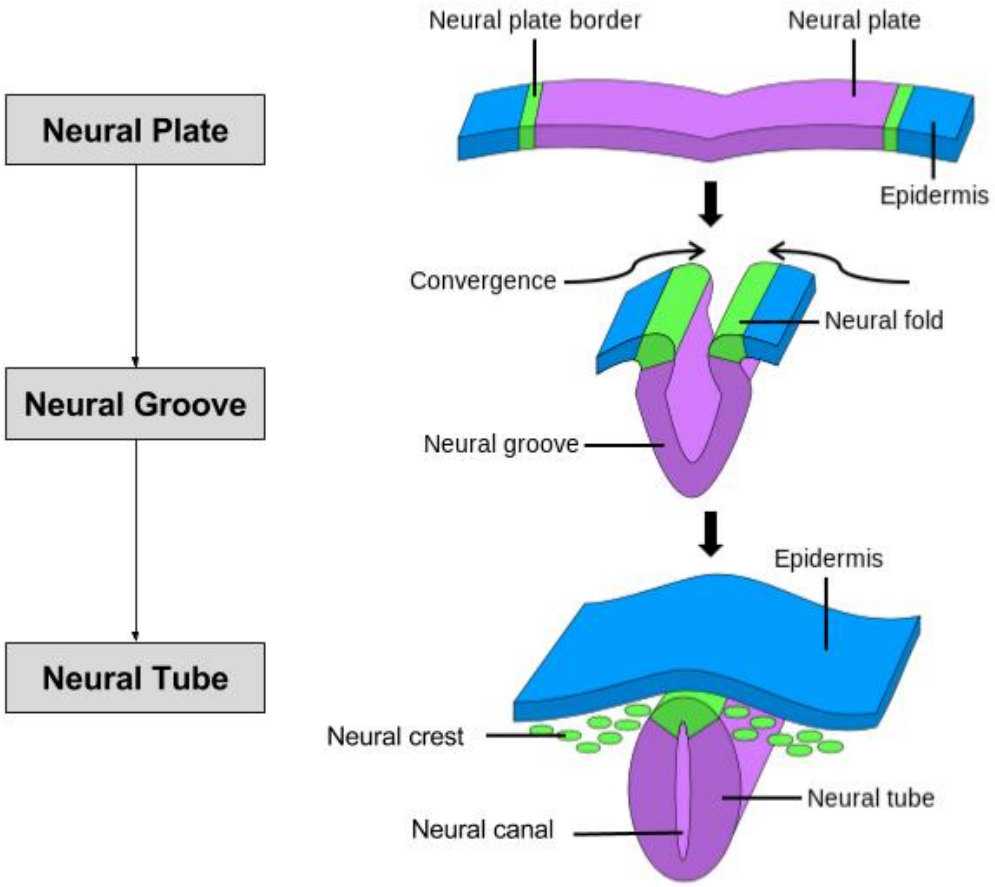


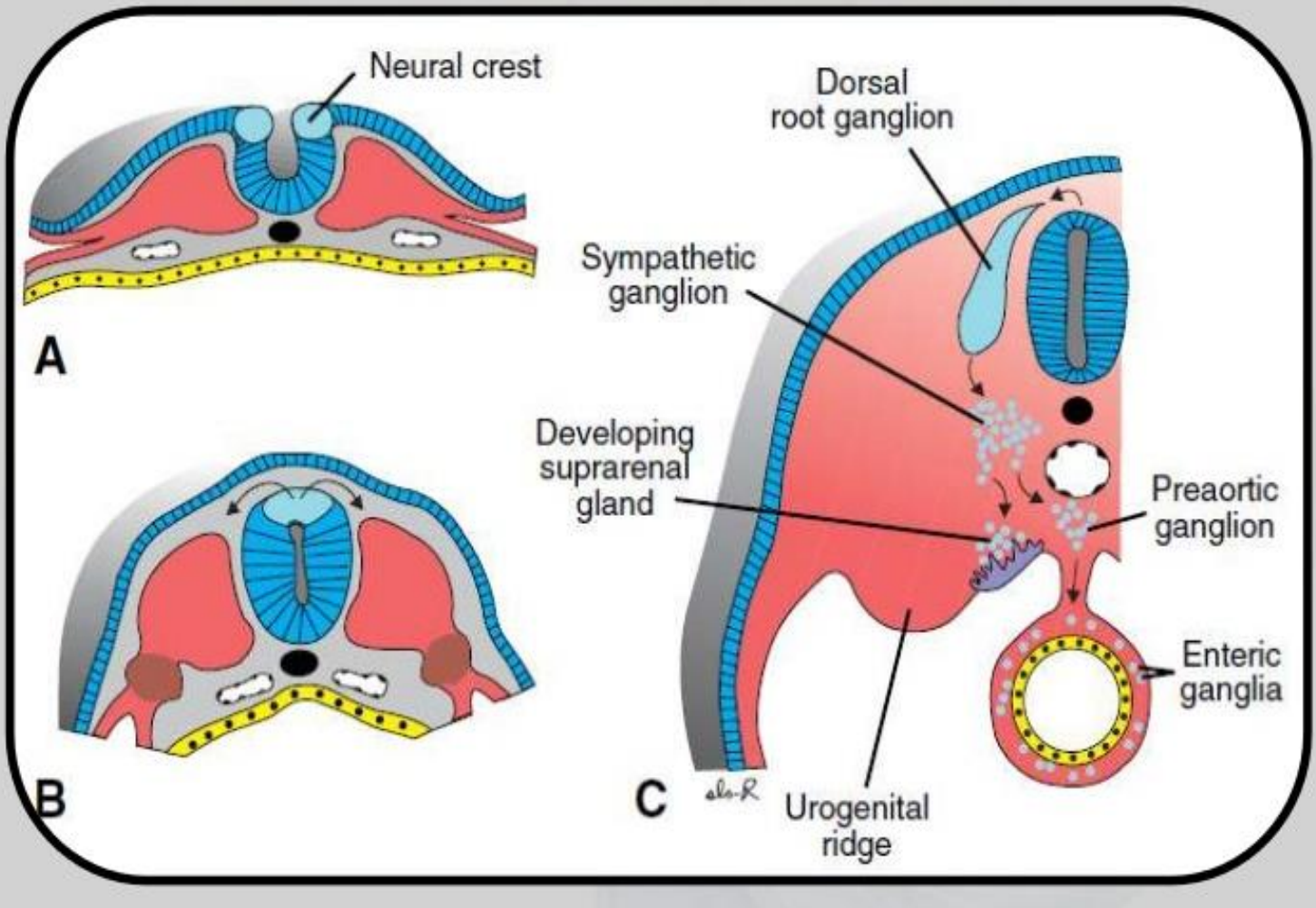
Neural tube



Neural tube and crest

3. Autonomic ganglia (sympathetic & parasympathetic)
4. Peripheral parasympathetic ganglia in the wall of gut (enteric ganglia).
5. Preaortic ganglia.
6. Share in the formation of the **septa** of the **heart**.
7. **Carotid body**.
8. Neurilemmal (**Schwann) cells** of peripheral nerves.
9. The medulla of the suprarenal gland (**chromaffin cells**).
10. **Skeletal structures**: bones and dermis of the face.
11. **Odontoblast**.
12. Connective tissue surrounding the eye; pupillary and ciliary muscles.
13. Melanoblasts of the skin.
14. Arachnoid & pia mater (which are ectodermal).
15. **Parafollicular C–cells of thyroid gland**.



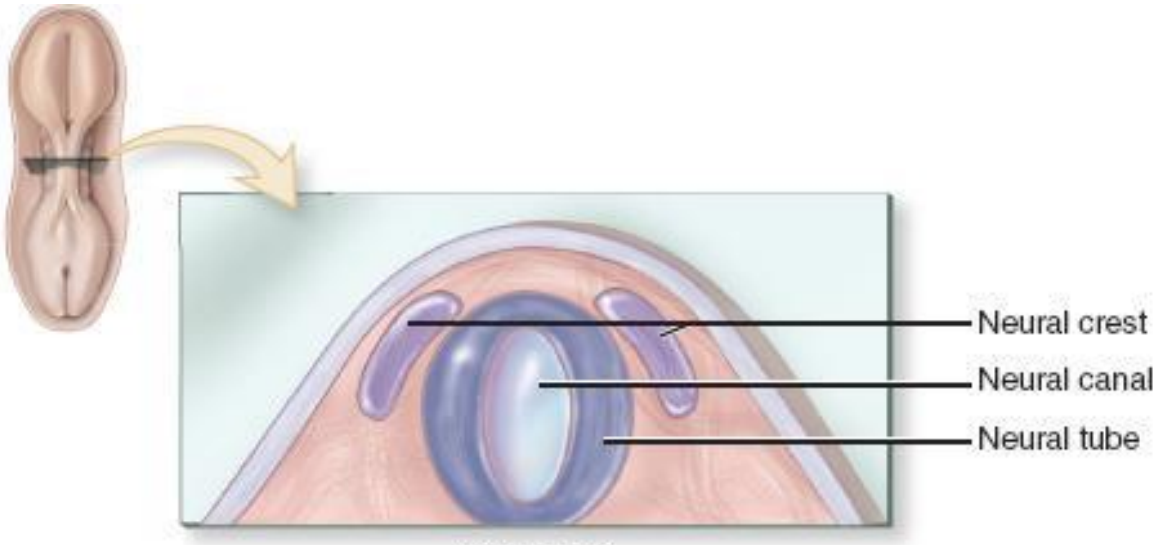


Formation of the neural groove, neural tube and neural crest

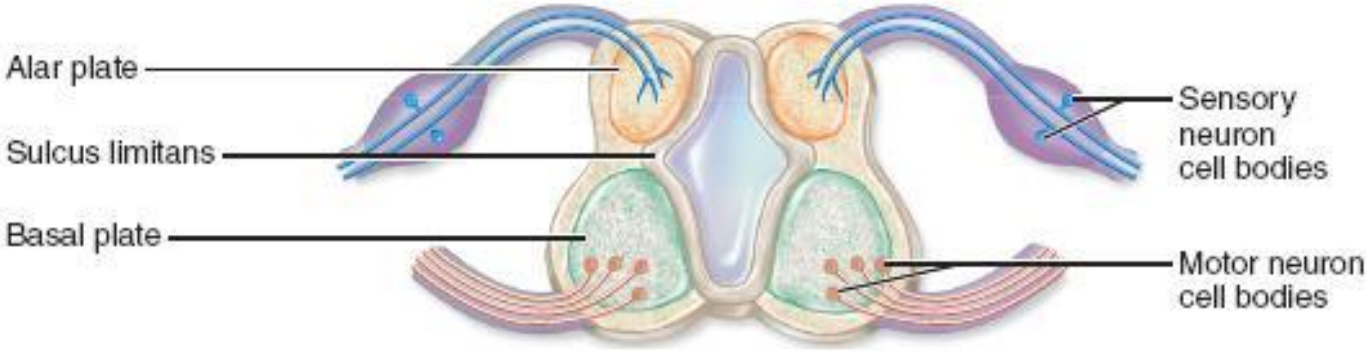
DEVELOPMENT OF SPINAL CORD

★ DEVELOPMENT:

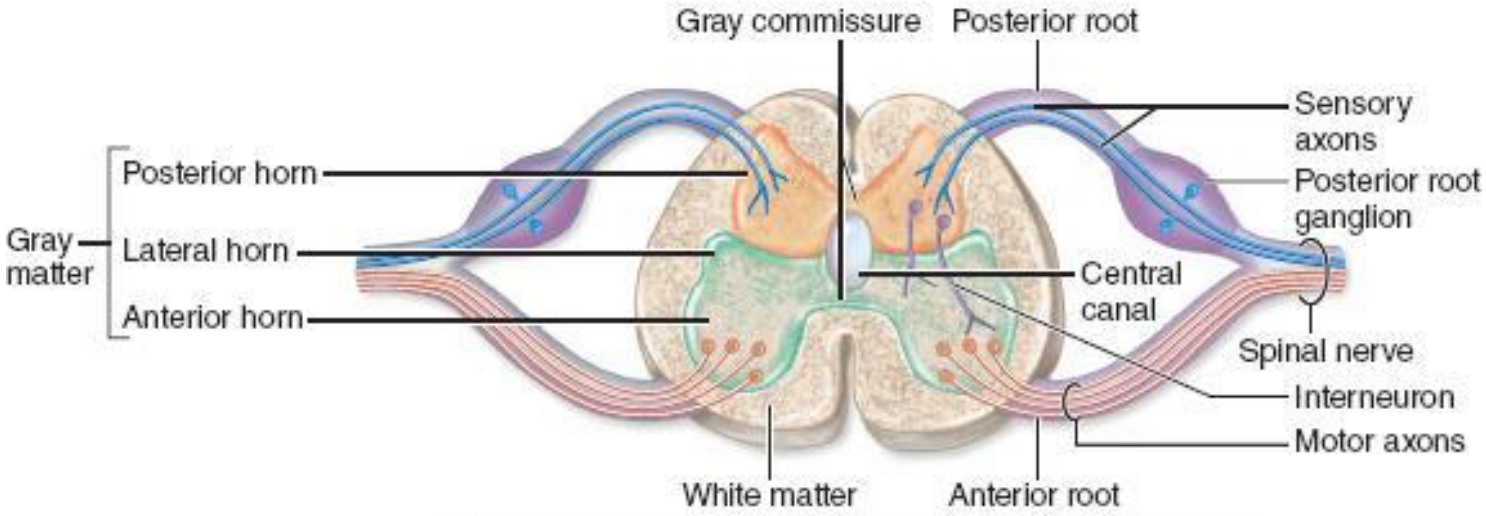
- The spinal cord develops from the most **caudal part of the neural tube**.
- Early , the neural tube is formed of **neuroepithelium** surrounding cavity of the neural tube .
- Then this neuroepithelium **proliferates** and the neural tube becomes formed of:
  - **Two lateral** thick walls.
  - Thin **roof** and **floor** plates.
- ***The lateral wall differentiates into 3 layers:***
  - ***Inner ependymal layer:*** gives rise to:
    - Ependymal cells **lining** the cavity of the neural tube.
    - Neuroblast cells which **migrate** to the mantle layer.
  - ***Middle mantle layer:*** formed of **neuroblasts** (nerve cells) and **spongioblasts** (neuroglial cells) which form the **grey mater**.
  - ***Outer marginal layer:*** formed of **nerve fibres** which form the **white mater**.
- ***A groove called sulcus limitans*** appears on the inner surface of the **lateral wall** on either sides dividing it into:
  - ***A dorsal alar plate:*** contains **sensory** cells and forms the **dorsal horn** of the spinal cord.
  - ***A ventral basal plate:*** contains **motor** cells and forms the **ventral horn** of the spinal cord.
- The lumen of the neural tube is narrowed to form ***central canal*** of spinal cord.
- ***The rate of growth of the spinal cord is slower than the vertebral canal:***
  - ***In the 3rd intra-uterine month:*** spinal cord occupies the **whole length** of the vertebral canal.
  - ***At time of birth:*** lower end of the spinal cord lies at the lower border of **L3**.
  - ***In the adult:*** the lower end of the spinal cord lies at lower border of **L1** ***leading to*** the formation of cauda equina and filum terminal **.**



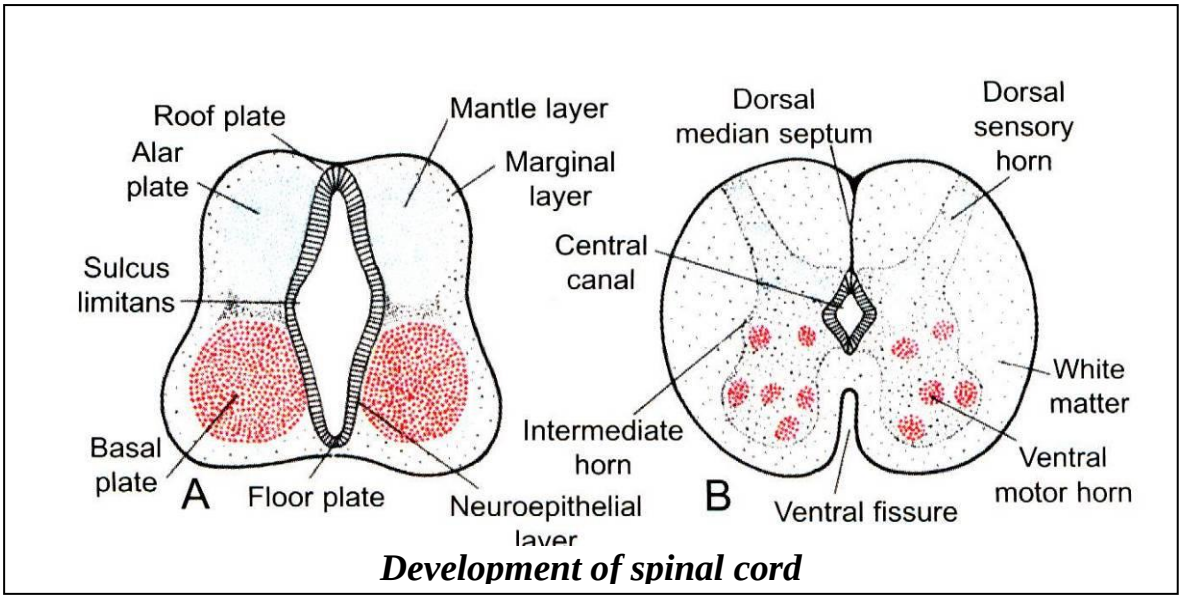
(a) Week 4



(b) Week 6: Basal and alar plates form

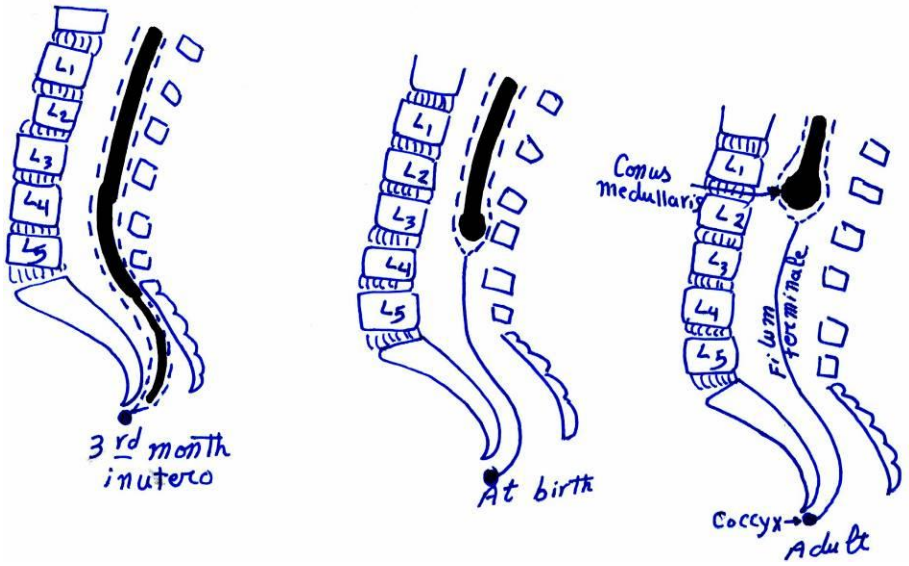


(c) Week 9: Gray horns form from basal and alar plates

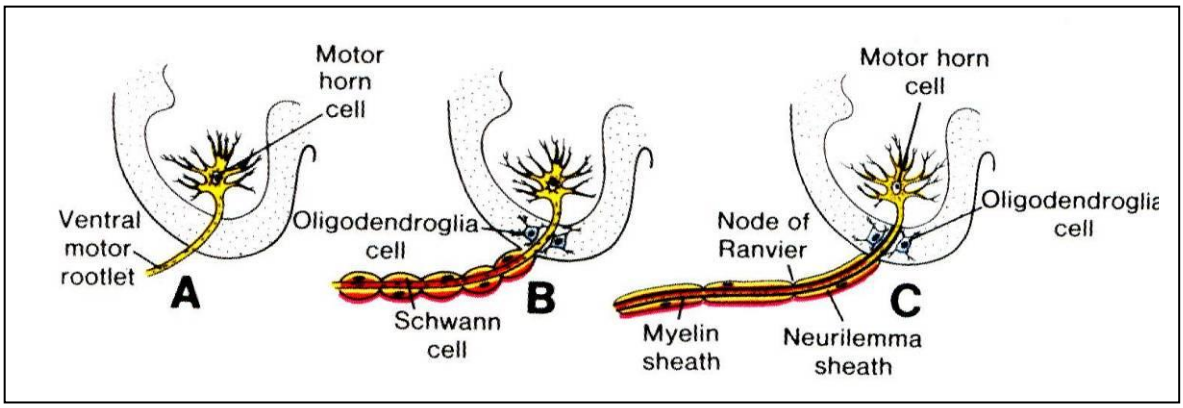


Development of spinal cord

The rate of growth of the spinal cord



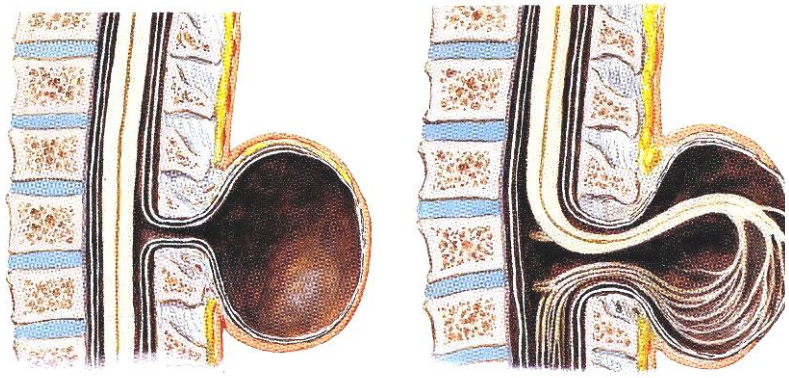
- ***Mylenation of the fibres in the spinal cord:***
  - Begins in the **4th month** of the intrauterine life.
  - Is completed by the end of **1st year**.



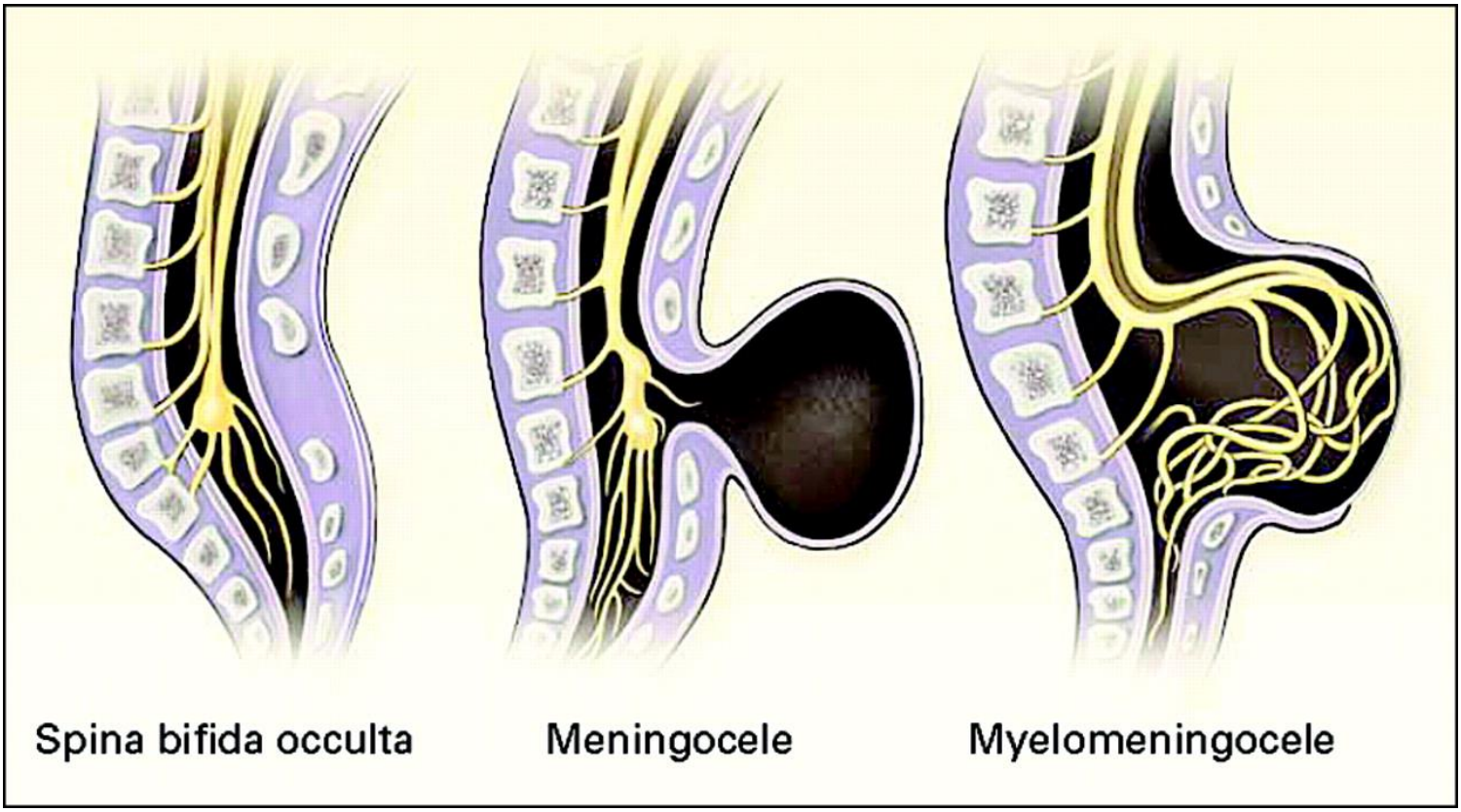
★ Congenital anomalies:

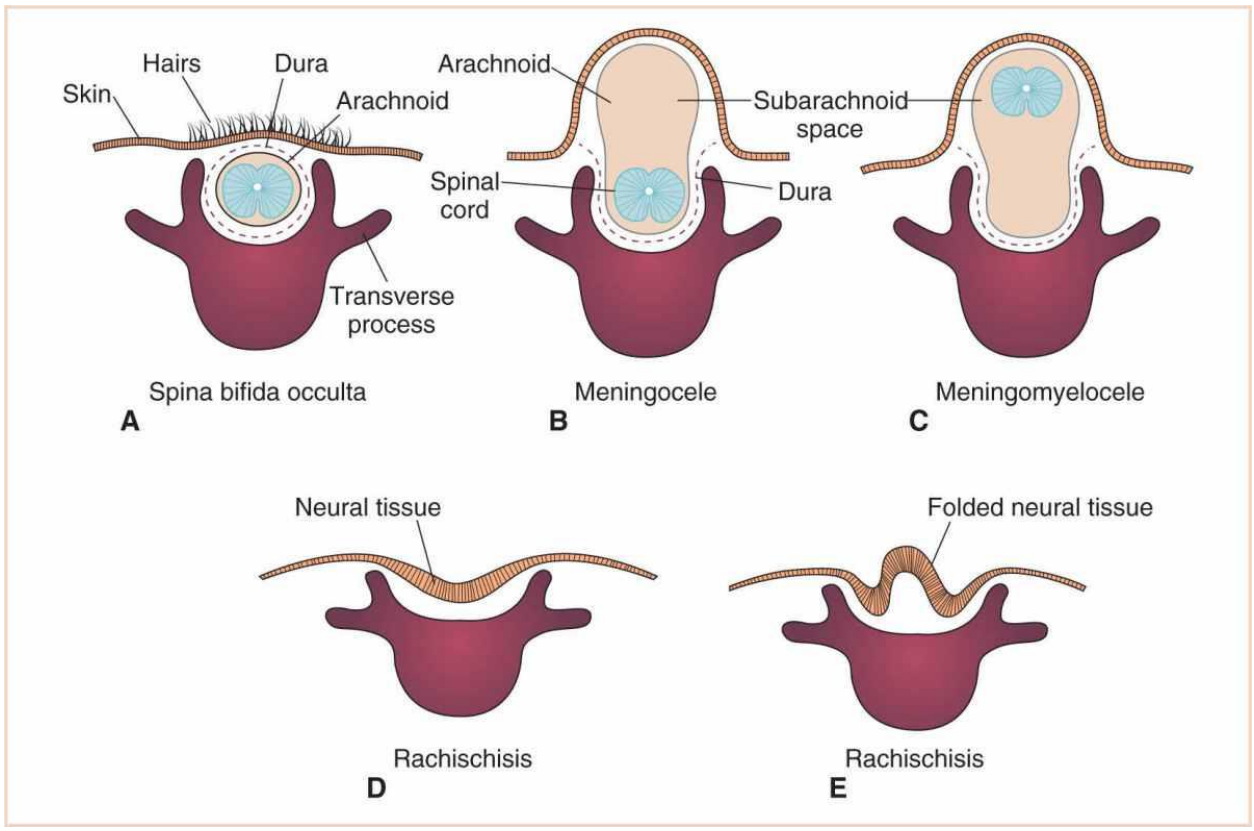
- ***Spina bifida occulta:*** Is due to failure of fusion of the dorsal parts of one vertebra.
- ***Meningocele:*** The meninges bulge through the defect.
- ***Meningomyelocele:*** The meninges and spinal cord bulge through the defect.
- ***Rachischisis:*** is due to failure of closure of the neural tube.

Meningocele



Types of spina bifida


Spina bifida occulta
Meningocele
Myelomeningocele


Hairs
Dura
Skin
Arachnoid
Transverse process
Spina bifida occulta
A
Arachnoid
Subarachnoid space
Spinal cord
Dura
Meningocele
B
Meningomyelocele
C
Neural tissue
Rachischisis
D
Folded neural tissue
Rachischisis
E


a
b

Rachischisis

DEVELOPMENT OF BRAIN

★ Formation of brain vesicle:

- The brain develops from the ***cranial end of the neural tube*** .
- Once the neural tube has **closed** , brain vesicle develops from the cranial end of tube and is divided into **three primary vesicles** by **three f1exures**.
- **The three primary vesicles are:**

1-Forebrain (prosencephalon): it is further subdivided by the ***developing eye*** into 2 secondry vesicles which are telencephalon (cerebrum) and diencephalon.

2-**Midbrain (mesencephalon)** which remain as it is without any subdivision .

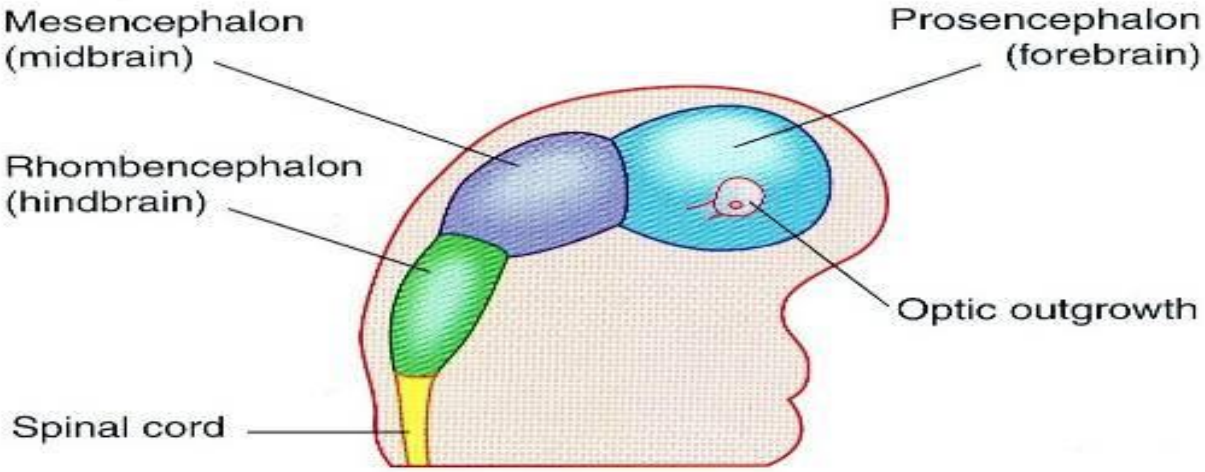
3-Hindbrain (rhombencephalon): it is further subdivided into 2 secondry vesicles which are metencephalon (pons and cerebellum) and mylencephalon (medulla oblongata).

- **The three flexures are:**

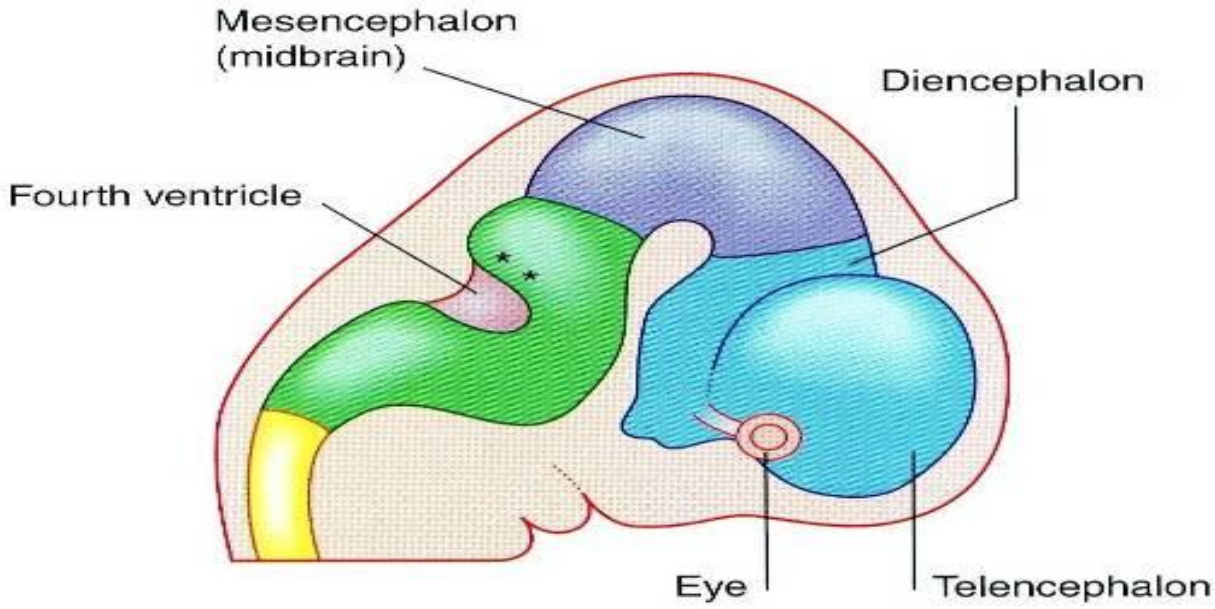
1- Mesencephalic flexure: is concave ventrally and lies between forebrain & midbrain.

2- Cervical flexure: is concave ventrally and lies between medulla & spinal cord.

3- Pontine flexure: is convex ventrally and lies between pons and medulla.

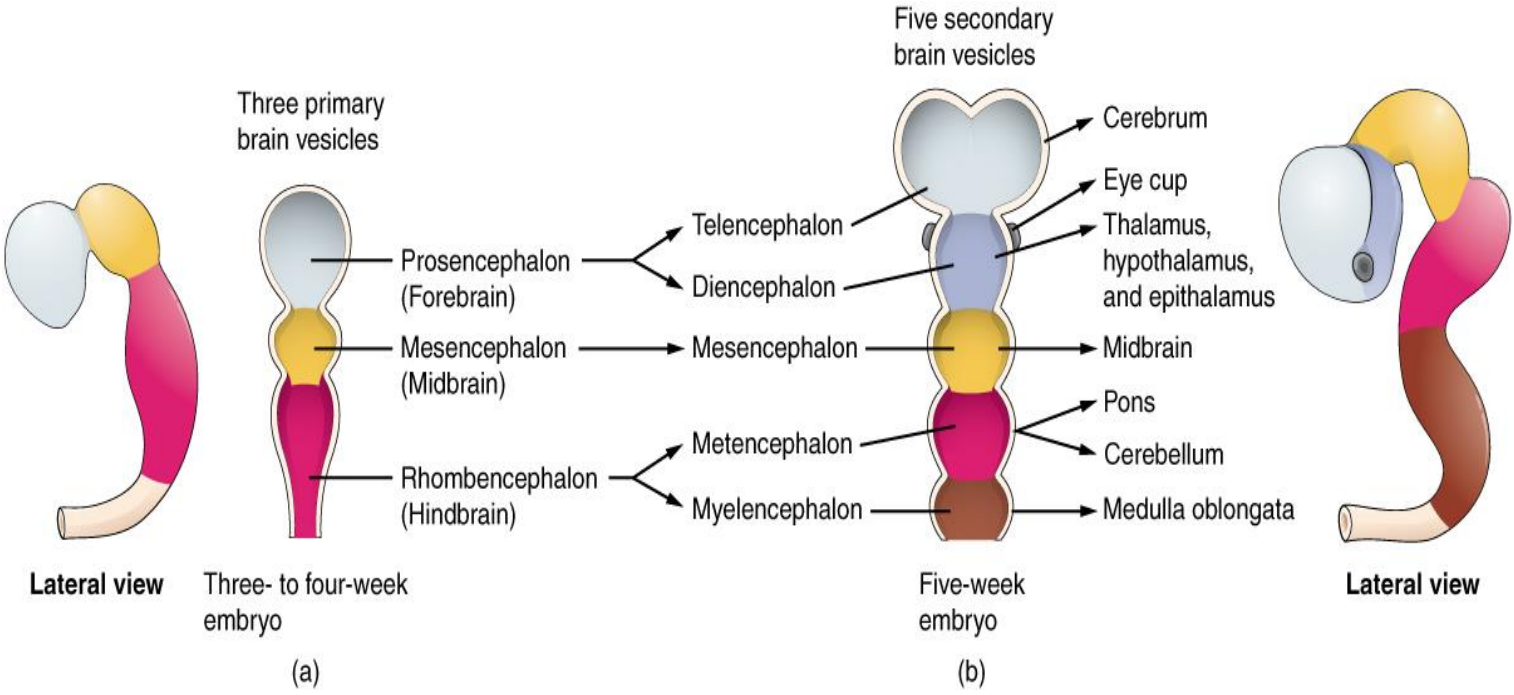


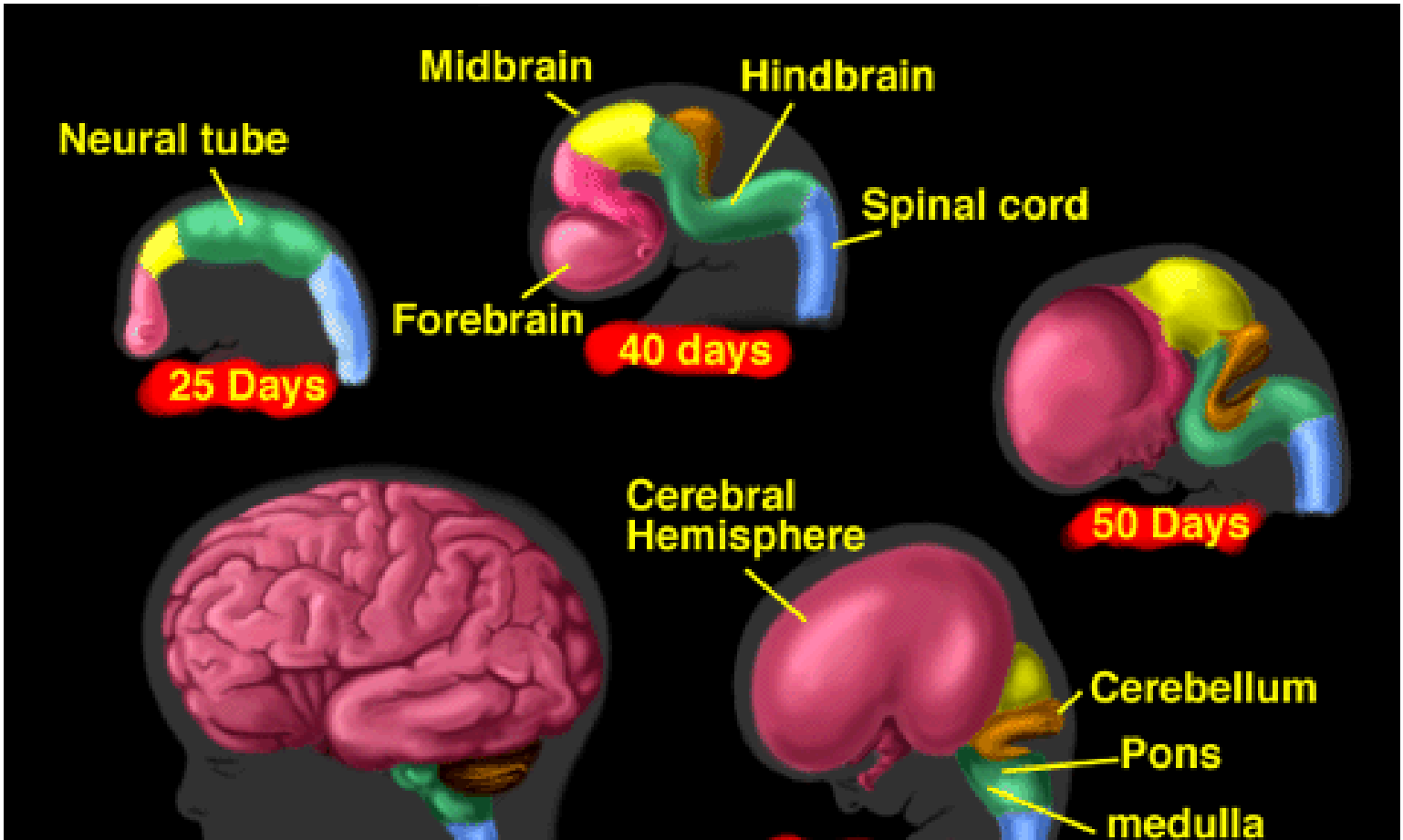
A 4 weeks

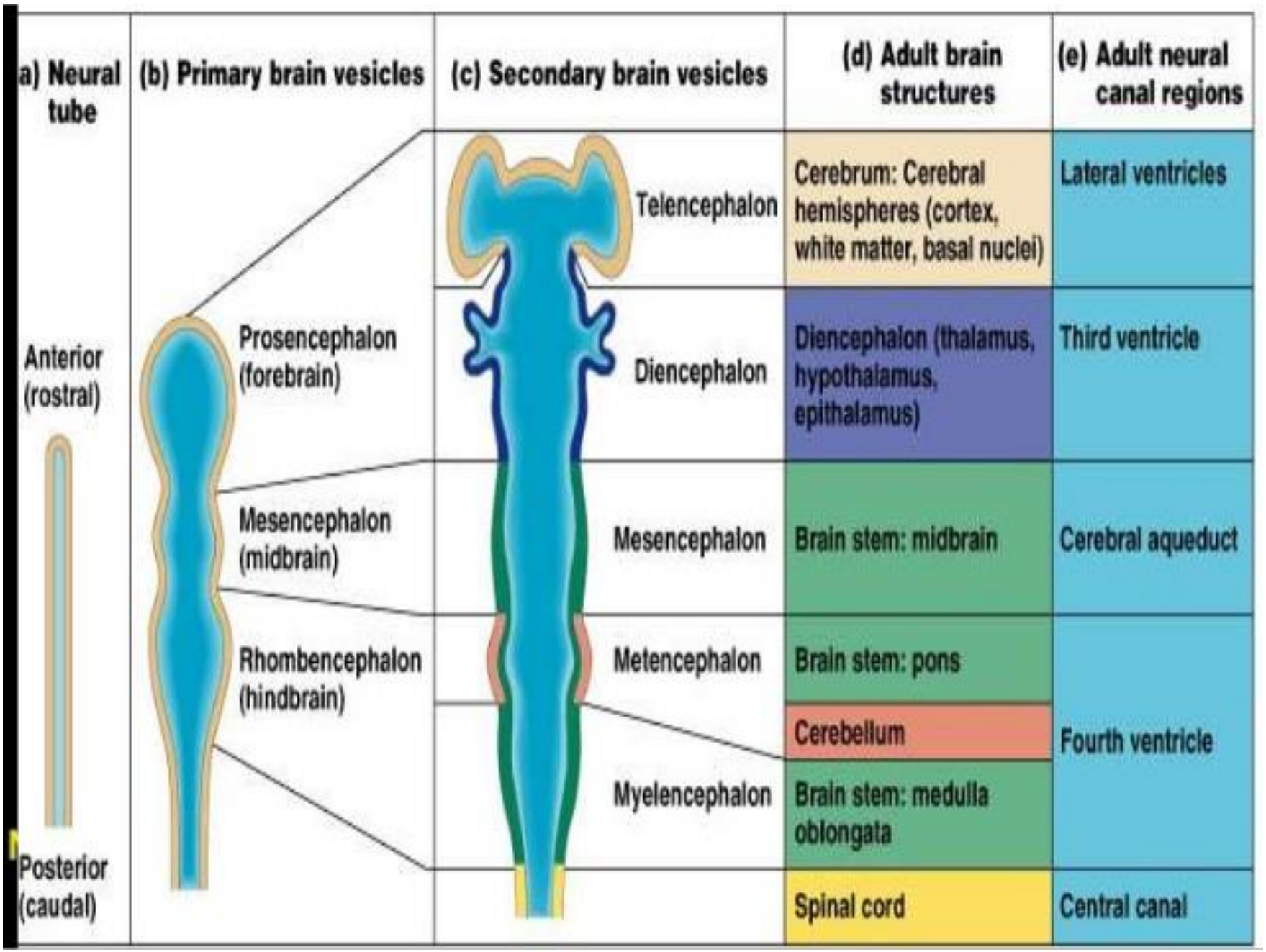


B 6 weeks

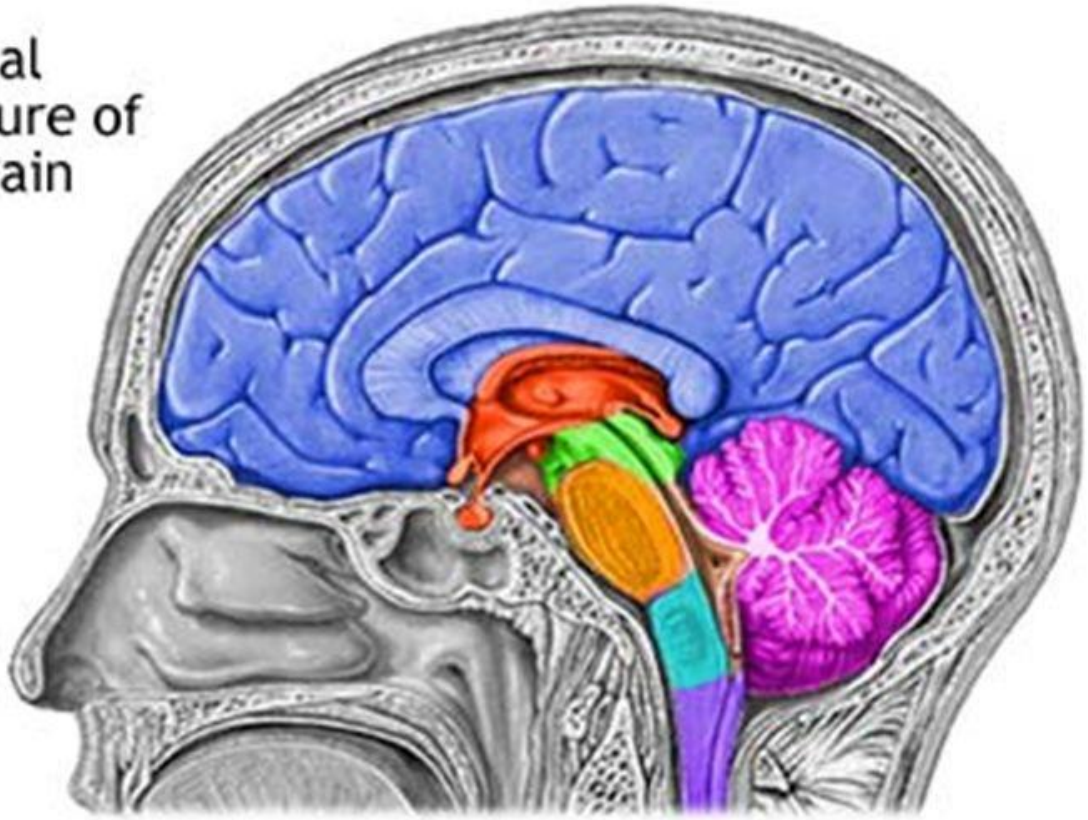
The three primary vesicles






a) Neural tube
(b) Primary brain vesicles
(c) Secondary brain vesicles
(d) Adult brain structures
(e) Adult neural canal regions
Anterior (rostral)
Posterior (caudal)
Prosencephalon (forebrain)
Mesencephalon (midbrain)
Rhombencephalon (hindbrain)
Telencephalon
Diencephalon
Mesencephalon
Metencephalon
Myelencephalon
Cerebrum: Cerebral hemispheres (cortex, white matter, basal nuclei)
Diencephalon (thalamus, hypothalamus, epithalamus)
Brain stem: midbrain
Brain stem: pons
Cerebellum
Brain stem: medulla oblongata
Spinal cord
Lateral ventricles
Third ventricle
Cerebral aqueduct
Fourth ventricle
Central canal

Internal structure of the brain



Spinal cord
Medulla Oblongata
Cerebellum
Midbrain
Diencephalon
Cerebral hemisphere
Pons

DEVELOPMENT OF THE BRAIN STEM

**The open medulla and pons :*

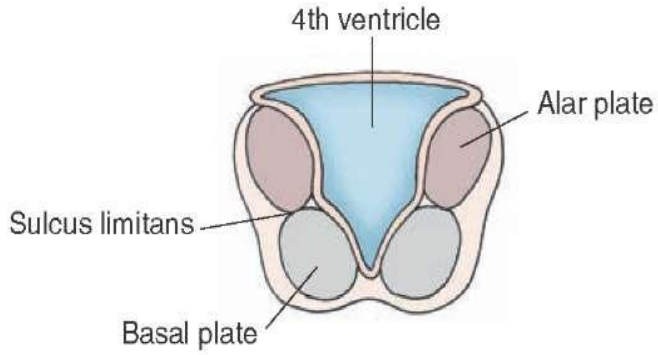
- **The cavity** of the neural tube in this regions is widened to form the ***4th ventricle***.
- **Their roof plate** is stretched, thinned forming the superior & inferior **medullary vela** .
- The caudal part of the roof plate becomes very thin (formed of ependyma & pia mater only) and invaded by the **choroid plexus** of the 4th ventricle.
- The roof plate is **absorbed** in the median plane & on both sides to form one median and 2 lateral aperatures of the 4th. ventricle .
- **Their alar plates** migrate laterally to lie lateral to the basal plates .
- **The dorsal edge of the alar plates** is called **rhombic lip**.

**The closed medulla and midbrain:*

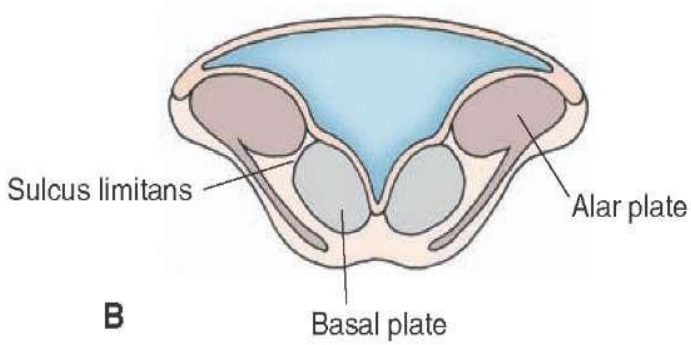
- The neural canal retains its site and diameter forming the central canal of closed medulla and cerebral aqueduct of midbrain .
- The two alar laminae and the two basal laminae retain their positions.

**The basal plates differentiates into three efferent columns :*

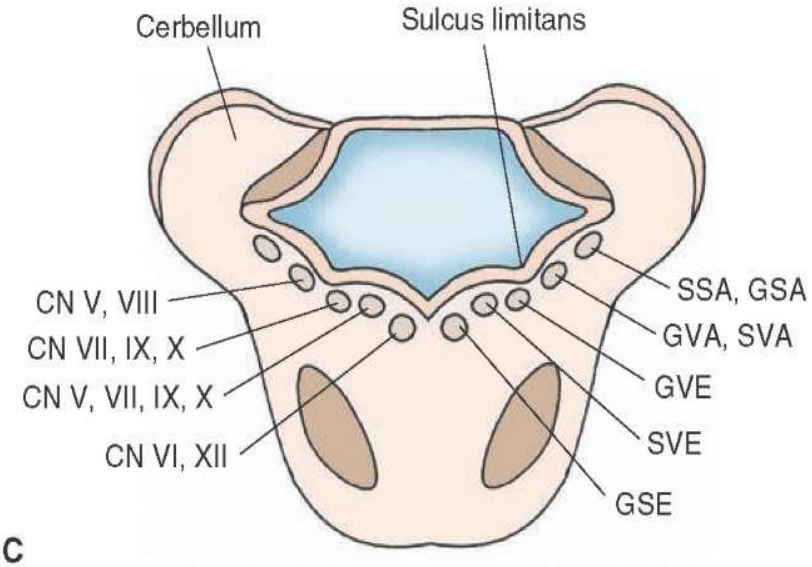
- **General somatic efferent column (GSE):** efferent to **muscles of the body**.
  a) 3rd and 4th cranial nerve nuclei in the midbrain.
  b) 6th cranial nerve nucleus in the pons.
  c) Hypoglossal nucleus in the medulla oblongata.
- **Special visceral efferent column (SVE):** efferent to ***muscles of visceral arches***.
  a) Motor nuclei of the 5th and 7th nerves in pons.
  b) Nucleus ambiguus for 9th, 10th, 11th nerves in the medulla oblongata.
- **General visceral efferent column (GVE i.e parasympathetic)**
  a) Edinger-Westphal nucleus of the 3rd. cranial nerve in the midbrain.
  b) Superior salivatory nucleus of the 7th cranial nerve in the pons.
  c) Inferior salivatory nucleus of 9th nerve and dorsal nucleus of 10th. in the medulla oblongata.


4th ventricle
Alar plate
Sulcus limitans
Basal plate

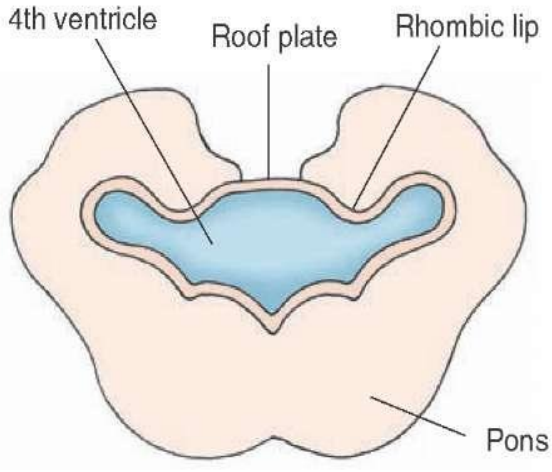
A


Sulcus limitans
Alar plate
Basal plate

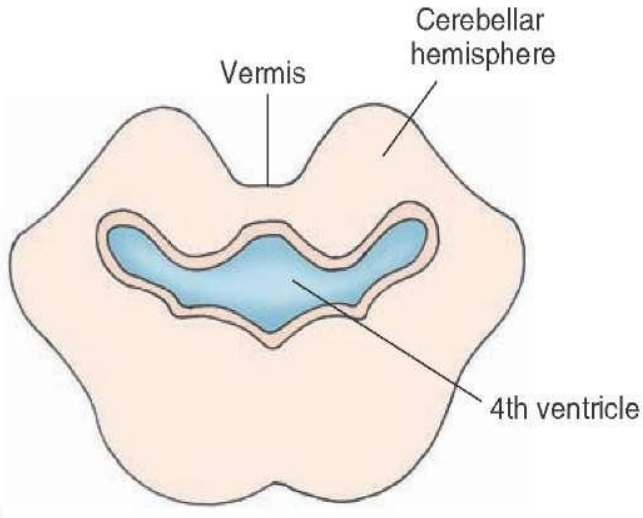
B


Cerebellum
Sulcus limitans
CN V, VIII
CN VII, IX, X
CN V, VII, IX, X
CN VI, XII
SSA, GSA
GVA, SVA
GVE
SVE
GSE

C


4th ventricle
Roof plate
Rhombic lip
Pons

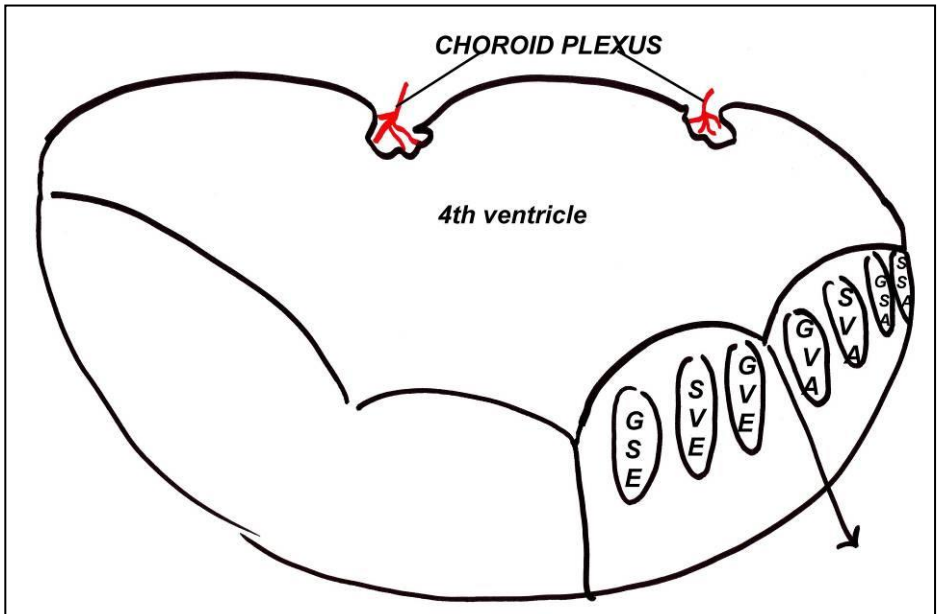
D


Vermis
Cerebellar hemisphere
4th ventricle

E

**The alar plates differentiates into four afferent columns :*

- **General visceral and special visceral afferent column:**
  a) They carry afferent from the viscera (GVA) and for the taste (SVA).
  b) They are represented by the ***nucleus solitarius*** in the medulla.
- **General somatic afferent column (GSA)** carries afferent from skin and muscles of **the head** :
  a) **Mesencephalic nucleus** in the midbrain.
  b) **Main sensory nucleus** in the pons.
  c) **Spinal nucleus of the trigeminal** nerve in the medulla oblongata.
- **Special somatic afferent column (SSA)** carries afferent from the **ear** & is represented by **cochlear and vestibular** nuclei at the ponto-medullary junction.



Arrangement of afferent and efferent columns

DEVELOPMENT OF THE CEREBELLUM

- **Rhombic lips** of both sides give rise to a **cerebellar swellings** which enlarge and fuse together in the middle line , dorsal to the roof of the 4th ventricle to form the cerebellum .
- The cerebellum grows and bulge dorsally.
- The ***posterolateral fissure*** appears ***separating the*** developing cerebellum into :

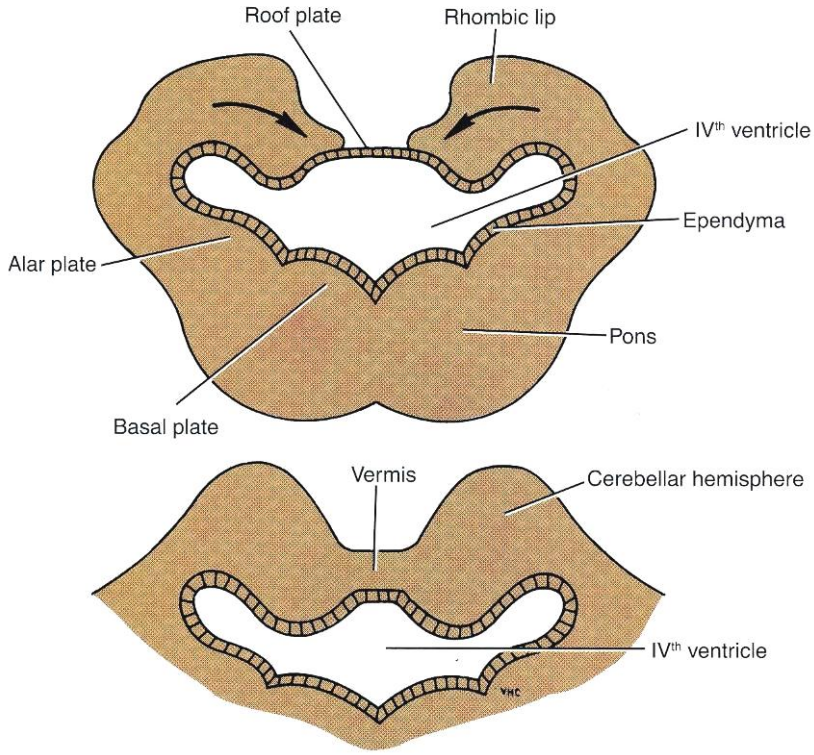
  1-A small portion : **flocculonodular lobes**.

  2-A large portion:

  a) It consists of a narrow median elevation forming the **vermis** connecting a 2 cerebellar hemispheres.

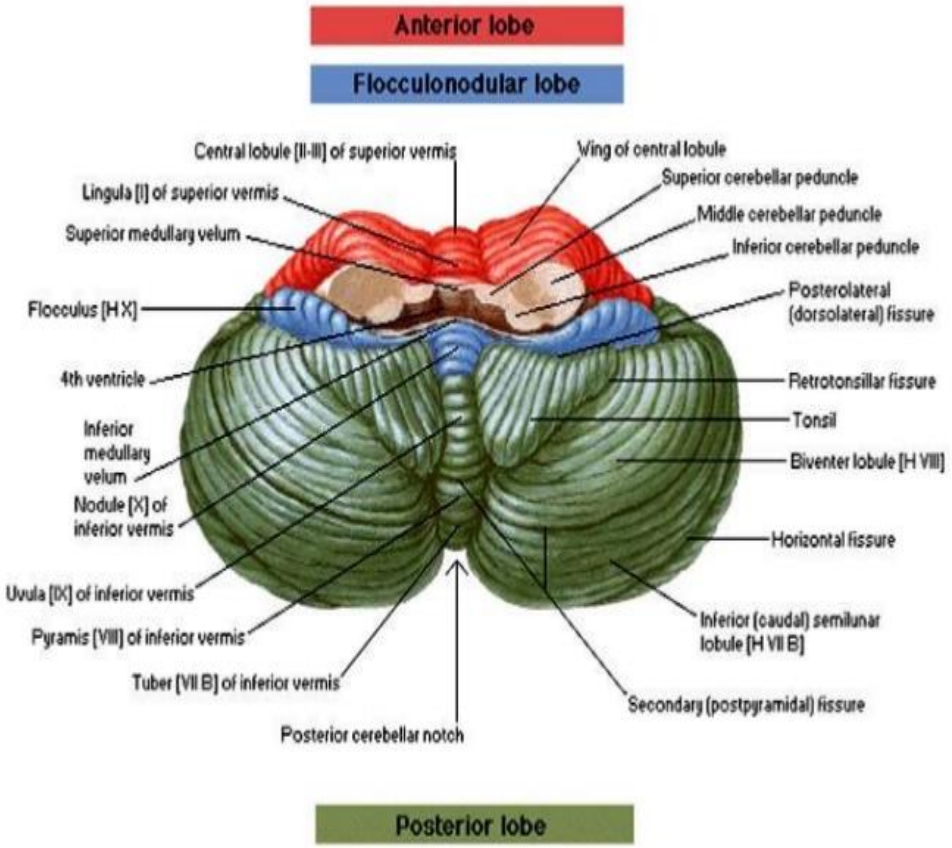
  b) The major **primary fissure** appears , deepens and divides the vermis and hemi-spheres into a cranial anterior lobe and a caudal posterior lobe.

  c) These lobes are further divided by the development of **many transverse sulci** and the surface of the cerebellum is thrown into **folia**.

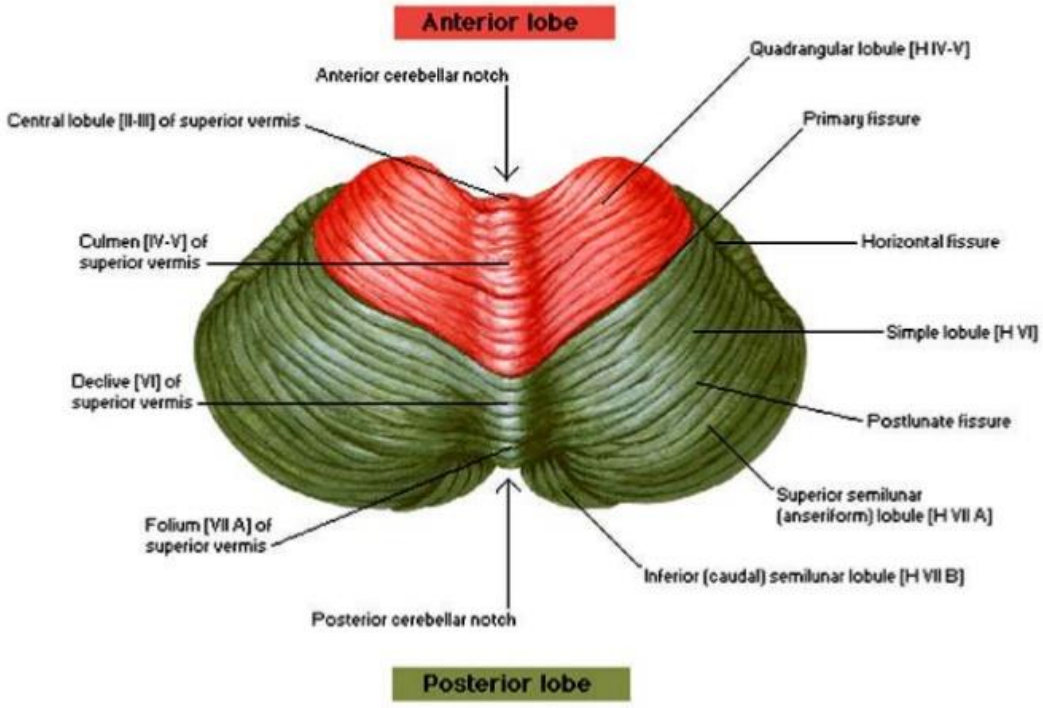


Development of cerebellum

Cerebellum
Inferior Surface



Cerebellum
Superior Surface



DEVELOPMENT OF THE PROSENCEPHALON

- The prosencephalon consists of diencephalon and telencephalon**.**

1-Development of the diencephalon

- **Its cavity** forms the 3rd ventricle.
- **Its roof plate** is thinned out and invaded by 2 **choroid plexus** of the 3rd ventricle.
- **Its floor plate** is **thickened** out and gives rise to **two structures**:

1- Its **anterior part** gives rise to the **stalk** & posterior lobe of the **pituitary** gland.

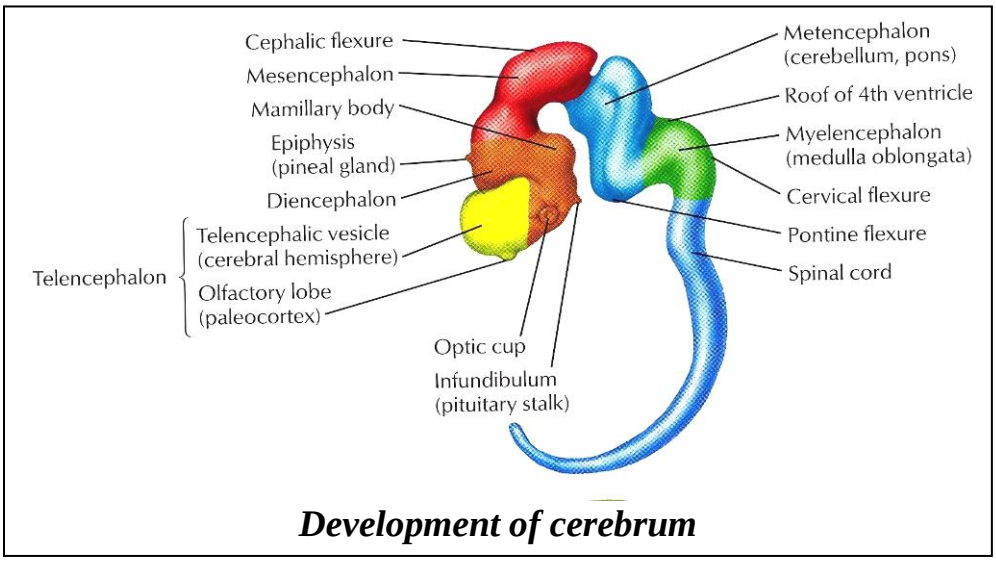
2- Its **posterior part** forms horizontal part of ***hypothalamus*** , which project into the interpeduncular fossa and form the ***floor of the 3rd ventricle***.

- **Its basal plates** disappear .
- **Its alar plates** form the ***thalamus, hypothalamus , metathalmus and epithalamus***.

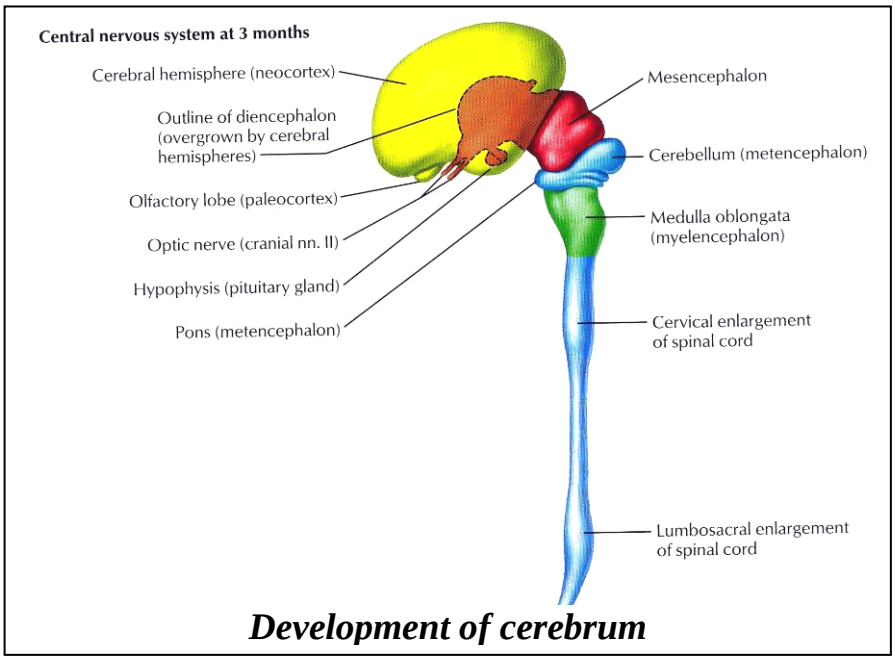
2-Development of the cerebral hemispheres

- The cerebral hemispheres develop from the ***telencephalon*** of the forebrain.
- The ***cavity*** of the telencephalon forms the ***lateral ventricle***.
- ***Neuroblasts migrate*** externally to form the cerebral ***cortex.***
- ***Some neuroblasts*** remain internally in the ***lower part*** of the cerebral hemisphere to form the ***basal nuclei*** (ganglia).
- The neurons of the cerebral cortex send and receive axons which form the ***internal capsule*** which splits the ***corpus striatum*** into two parts:
  a) Caudate nucleus ***medial*** to the internal capsule.
  b) Lentiform nucleus ***latera***l to the internal capsule.
- The cerebral cortex **expands** forwards, laterally and backwards to form the lobes of the cerebrum.
- As a result of this expansion of the cerebral cortex , the **medial surfaces** of the 2 hemispheres come very close to each other.
- The ***insula*** appears on the lateral surface of the cerebral hemisphere as an area of

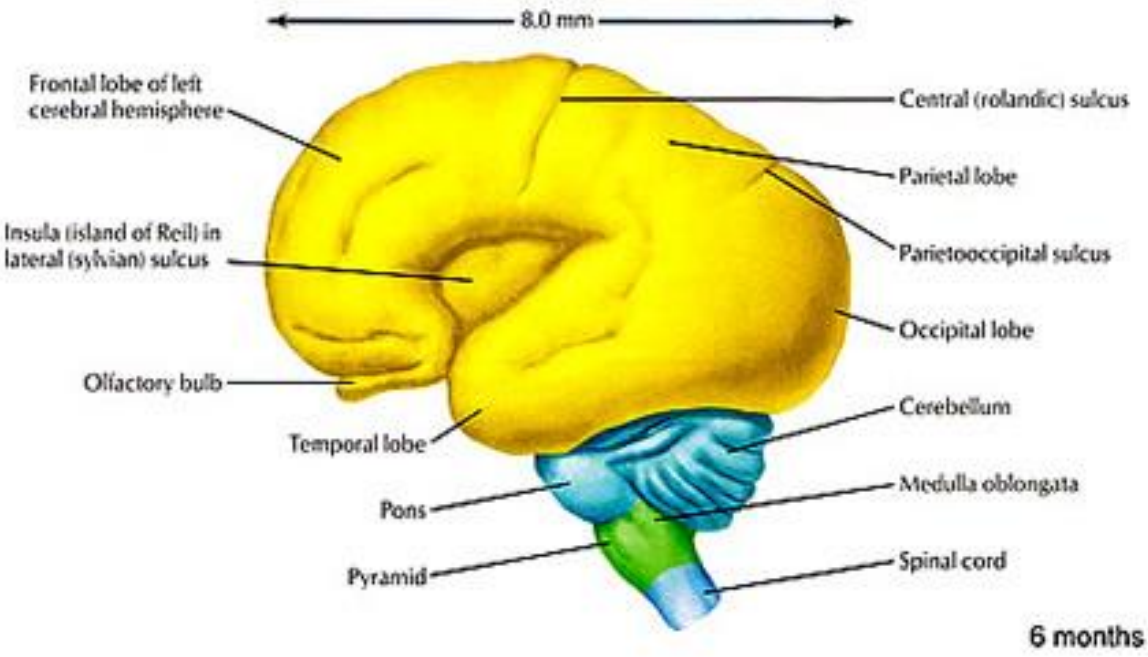
less active growth. The rapidly growing areas bordering the insula approach each other to form the **opercula**. The insula is consequently buried deep to the surface.



Development of cerebrum



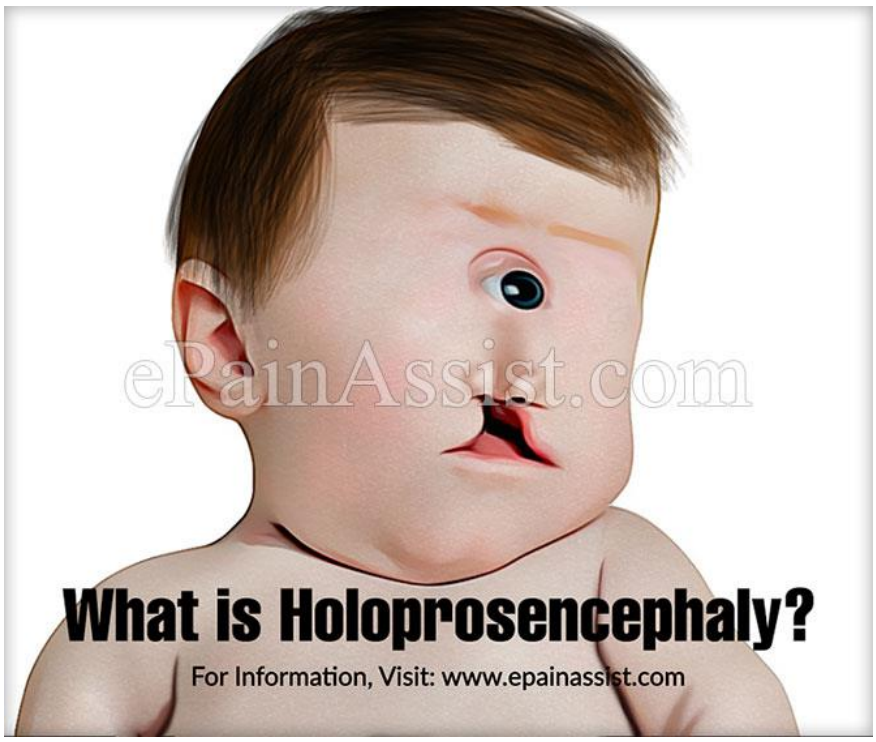
Development of cerebrum

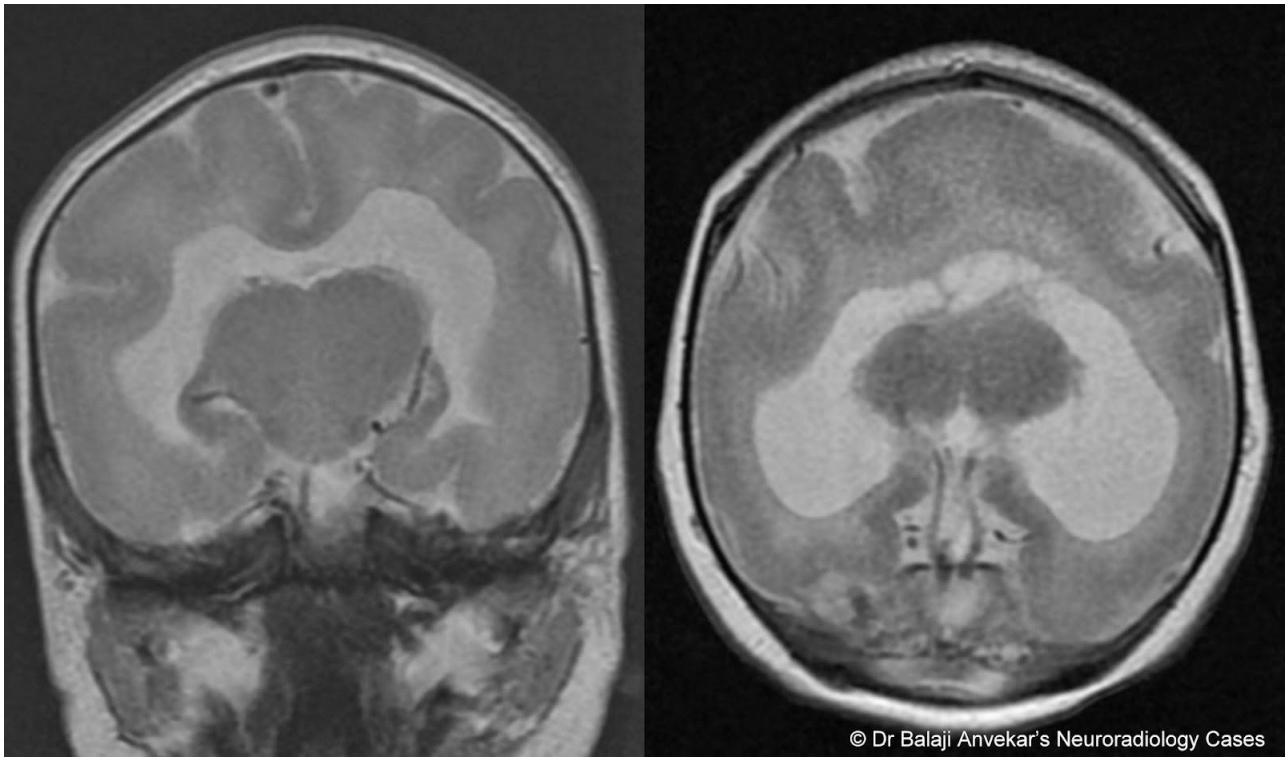


- In the **early** fetal life, the cerebral cortex is **smooth**. Later on due to rapid rate of growth of the cerebral cortex in relation to slower rate of growth of the skul, this leading to the development of the **sulci and gyri**.
- The two cerebral hemispheres become connected by many **commissures;** anterior commissure, corpus callosum and hippocampal commissure.

Cranial Defects

1. ***Holoprosencephaly:*** is a fetal abnormality of the brain in which the brain of the fetus remains **underdeveloped** and does **not divide** into two hemispheres results in malformations of the brain and face

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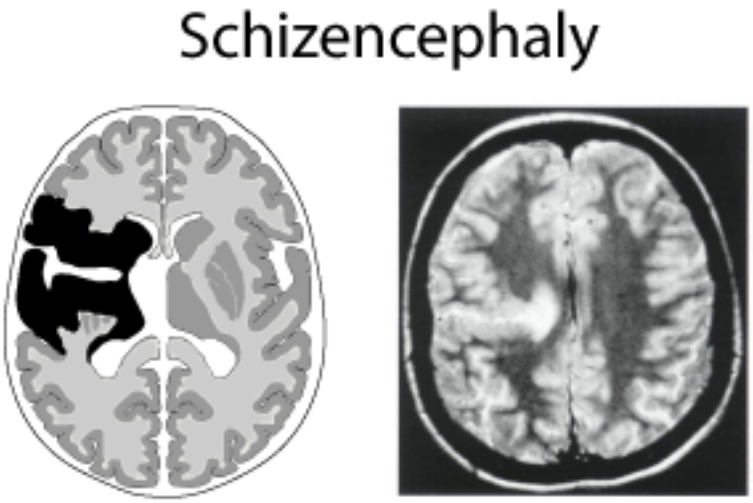
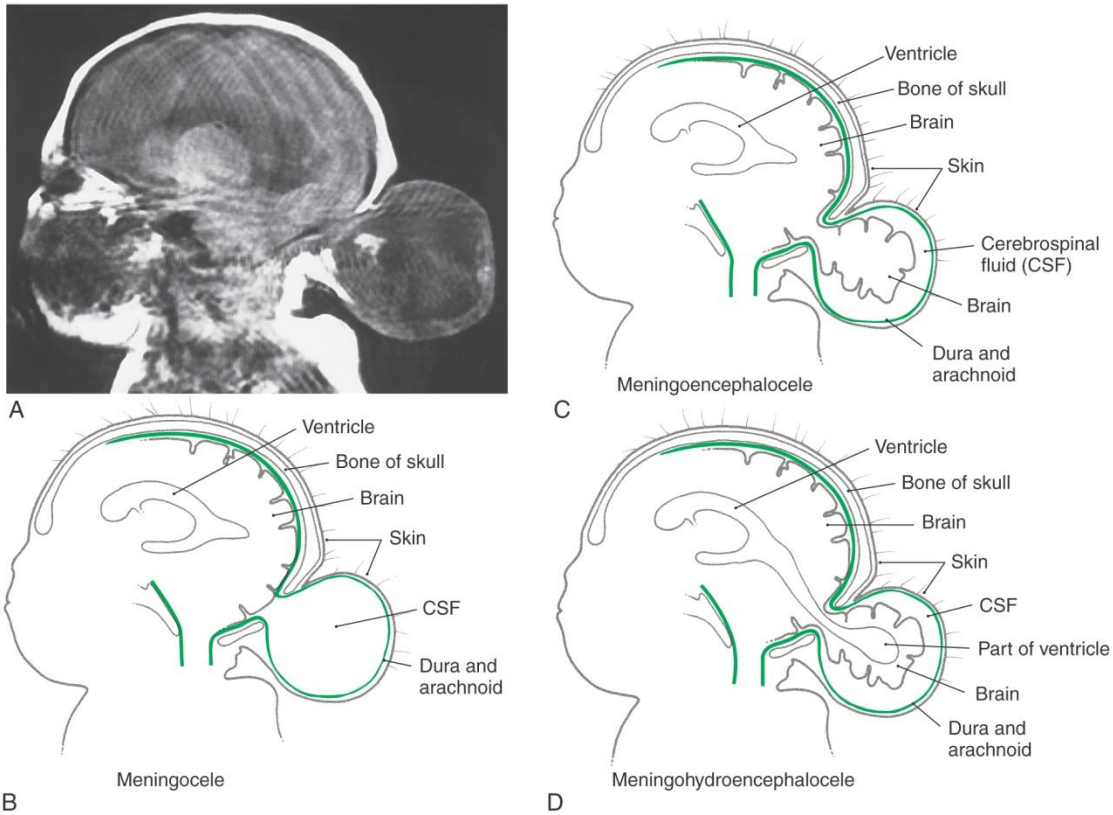
2. ***Schizencephaly*** : large clefts occur in the cerebral hemispheres.

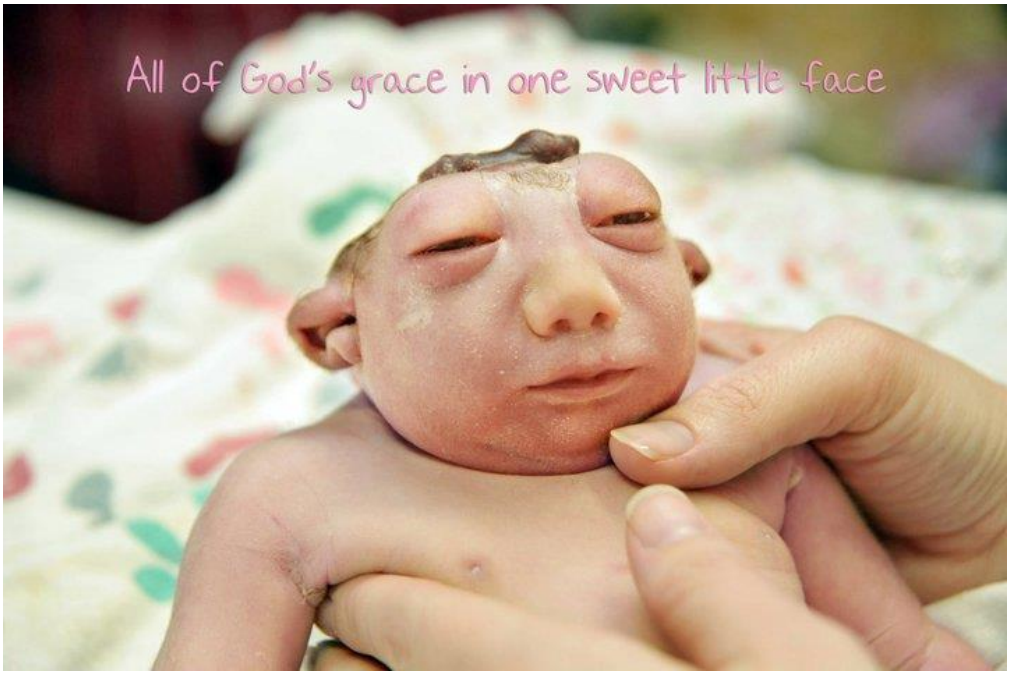


3. ***Meningocele, meningoencephalocele and meningohydroencephalocele*** : opening of the occipital bone
   a. If only meninges bulge (**meningocele**).
   b. If brain and meninges bulge (**meningoencephalocele**).
   c. If brain, meninges and part of the ventricle bulge (**meningohydro-encephalocele**).



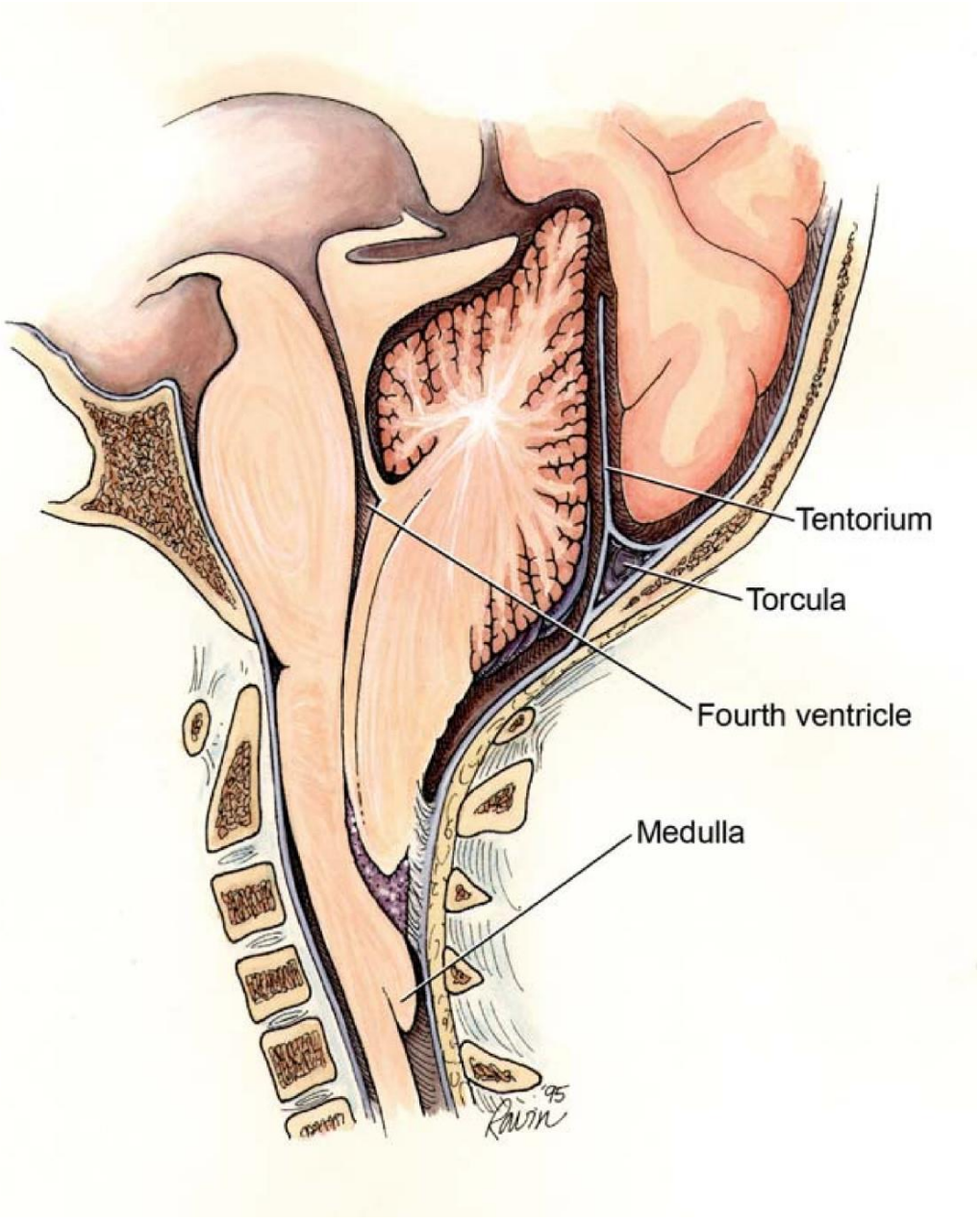
4. ***Exencephaly (anencephaly):***

- Is characterized by **failure** of the cephalic part of the **neural tube to close**.
- As a result, the **vault** of the skull does not form, leaving the malformed **brain exposed**.



5. Hydrocephalus is characterized by an abnormal dilatation the ventricular system with accumulation of cerebrospinal fluid within it .

6. ***The Arnold-Chiari malformation*** is caudal **displacement and herniation** of cerebellum structures through the foramen magnum.



7. ***Microcephaly*** : a cranial **vault** that is smaller than normal .