Development of the nervous system

- Development of the neural tube:
  - Beginning of the 3rd week an ectodermal thickening appears in the middle of the trilaminar germ disc known as the neural plate.
  - The neural plate invaginates to form a neural groove.
  - The lips of the neural groove approach each other & fuse together transforming the groove into a neural tube with an anterior & posterior neuropores which are obliterated on day 25 & 27 respectively transforming the neural tube into a closed tube.

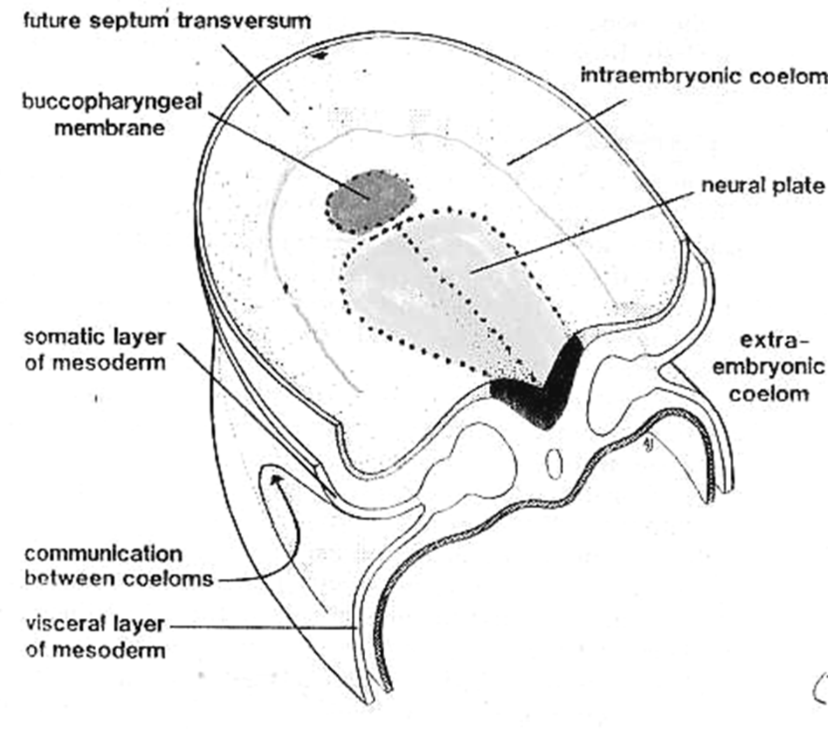


Fig. 2.6. Formation of the intraembryonic coelom.

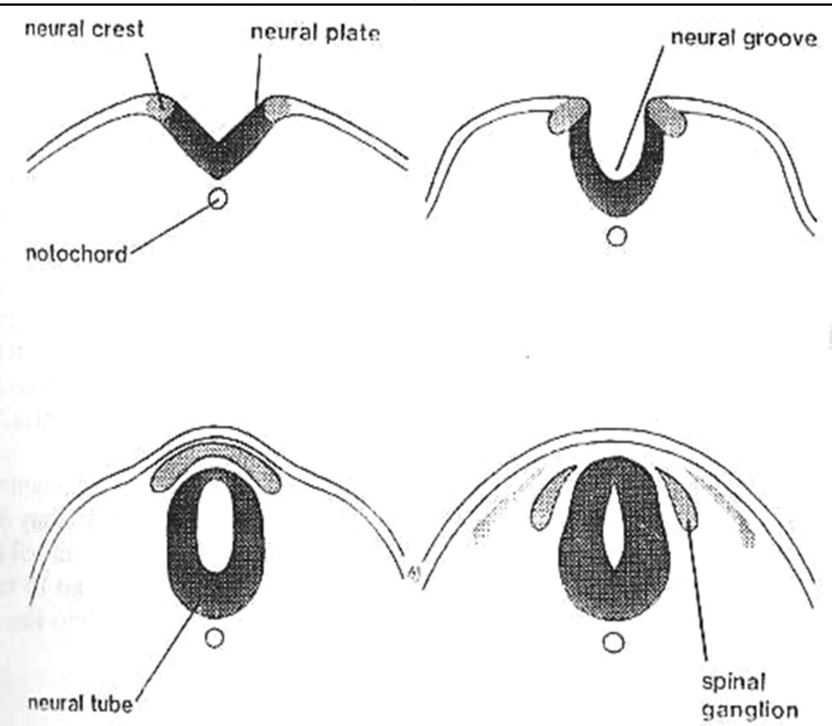
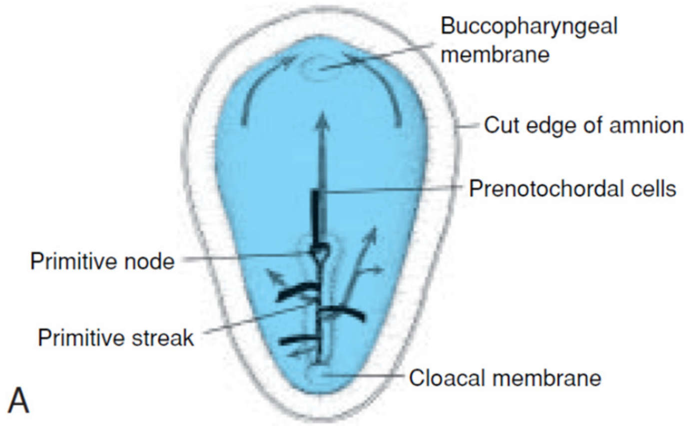
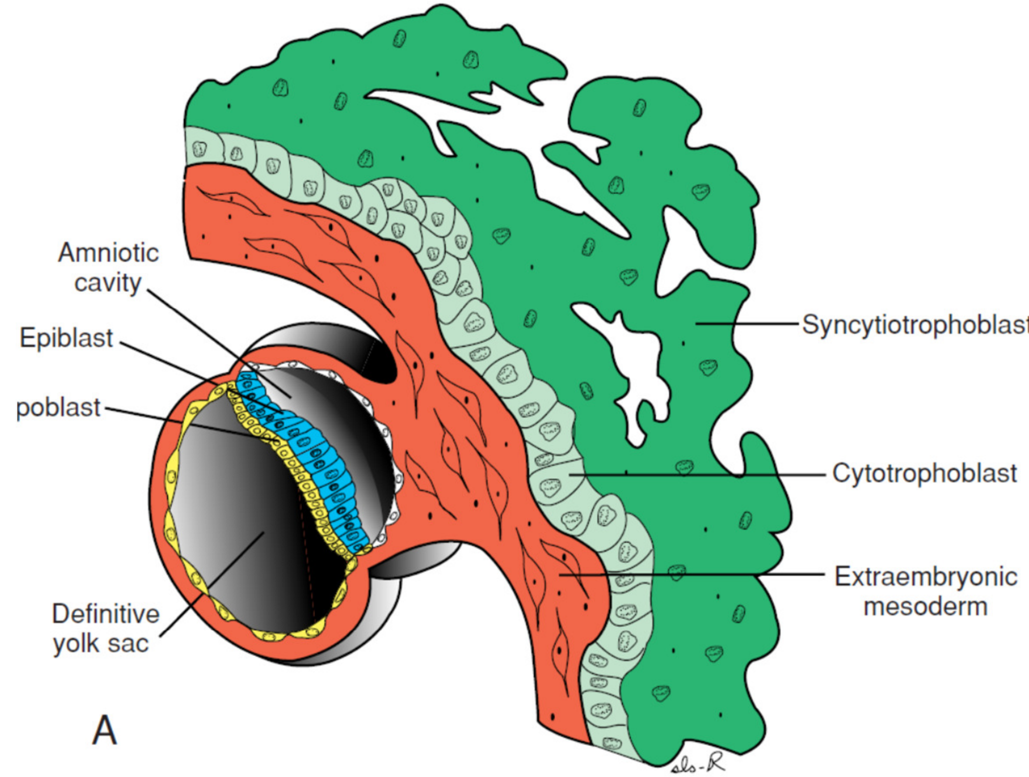
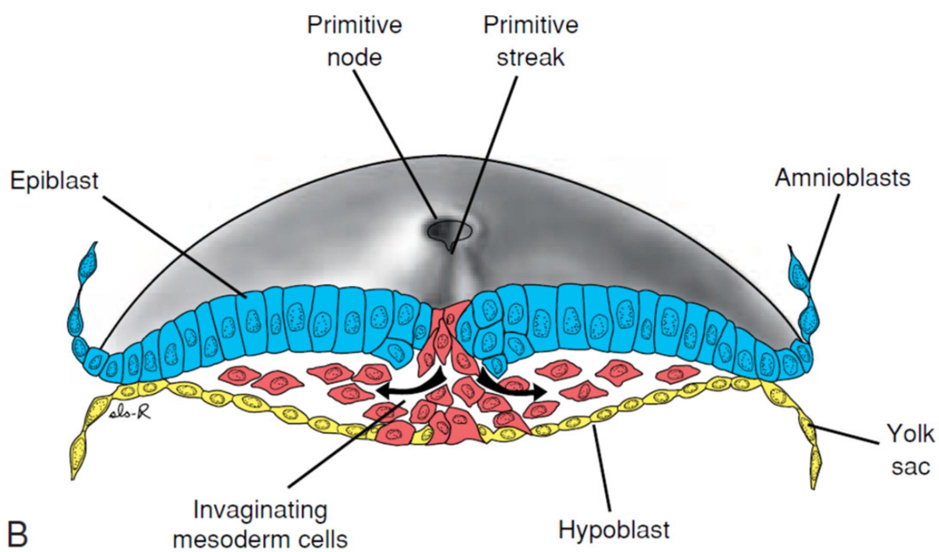
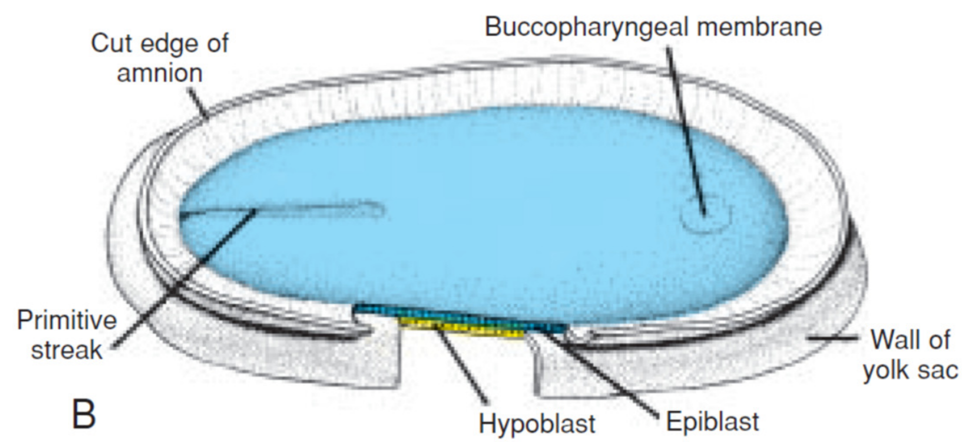


Fig. 2.7. Formation of the neural tube.


Buccopharyngeal membrane
Cut edge of amnion
Prenotochordal cells
Primitive node
Primitive streak
Cloacal membrane
A

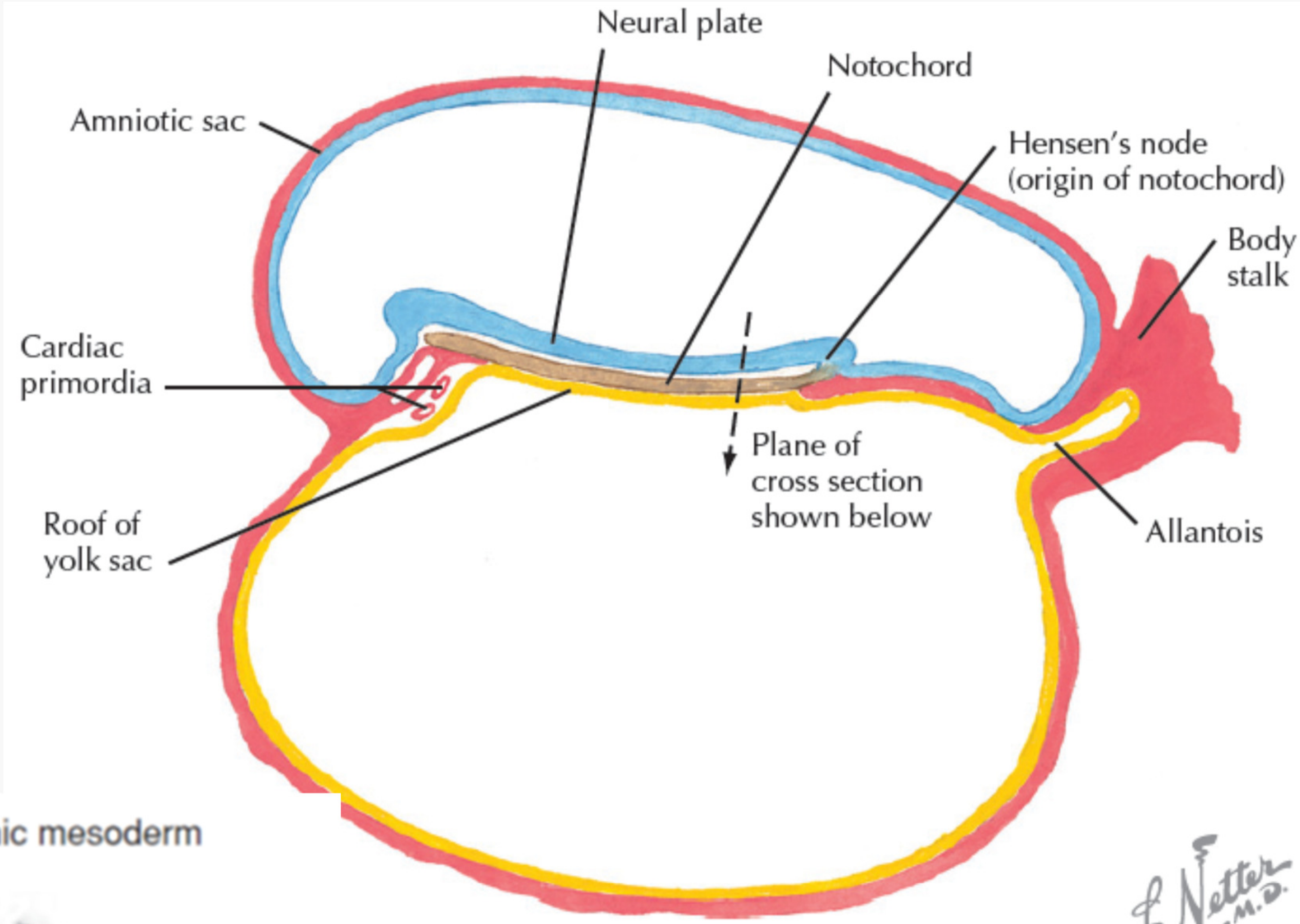

Amniotic cavity
Epiblast
poblast
Definitive yolk sac
Syncytiotrophoblast
Cytotrophoblast
Extraembryonic mesoderm
A

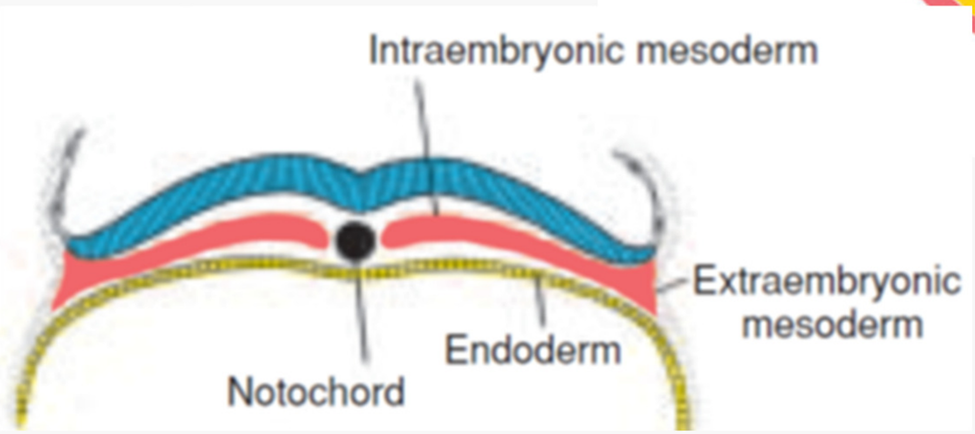

Primitive node
Primitive streak
Epiblast
Amnioblasts
Yolk sac
Invaginating mesoderm cells
Hypoblast
B


Cut edge of amnion
Buccopharyngeal membrane
Primitive streak
Wall of yolk sac
Hypoblast
Epiblast
B

Trilaminar embryo (Gastrula)

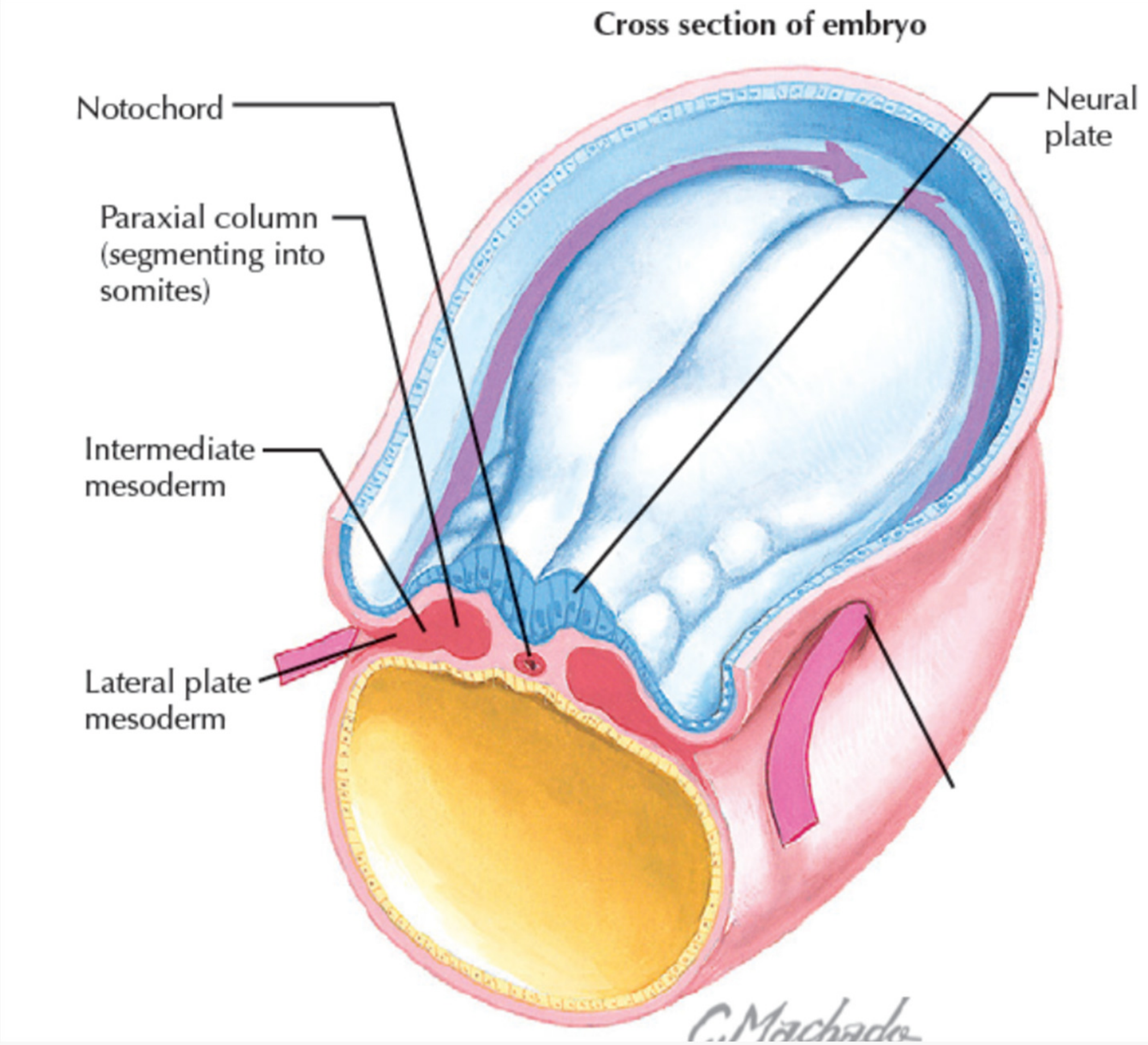
- 3 major germ layers form the initial developing embryo:
  - Ectoderm
  - Mesoderm
  - Endoderm





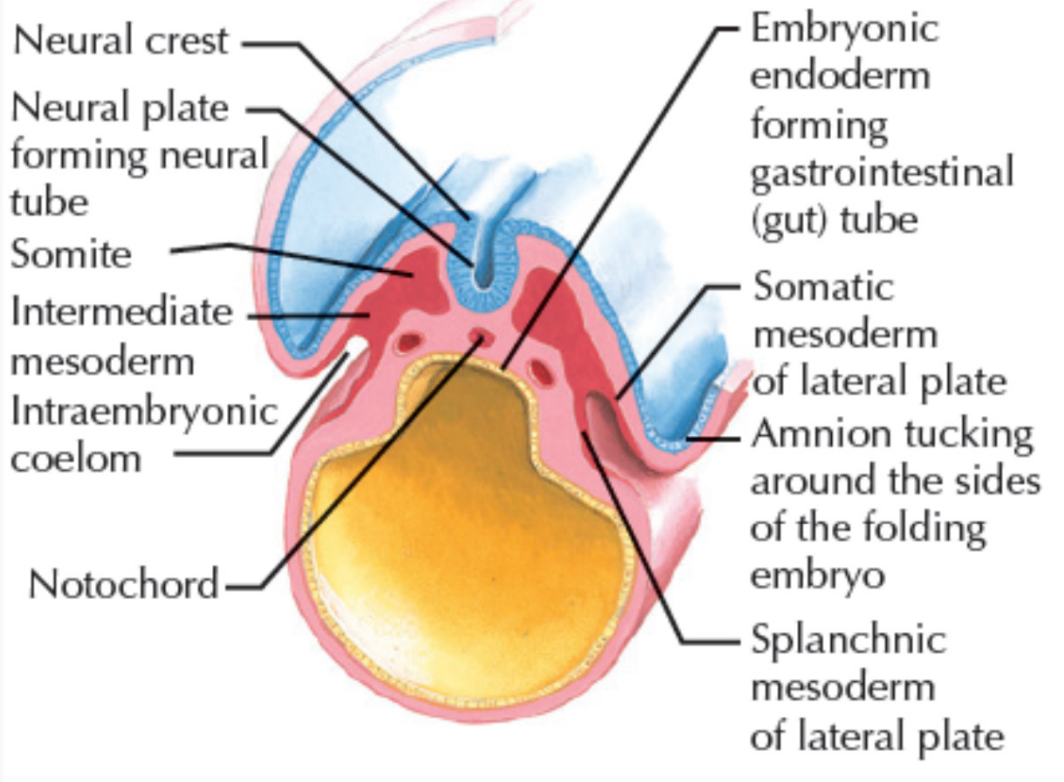
Neurulation

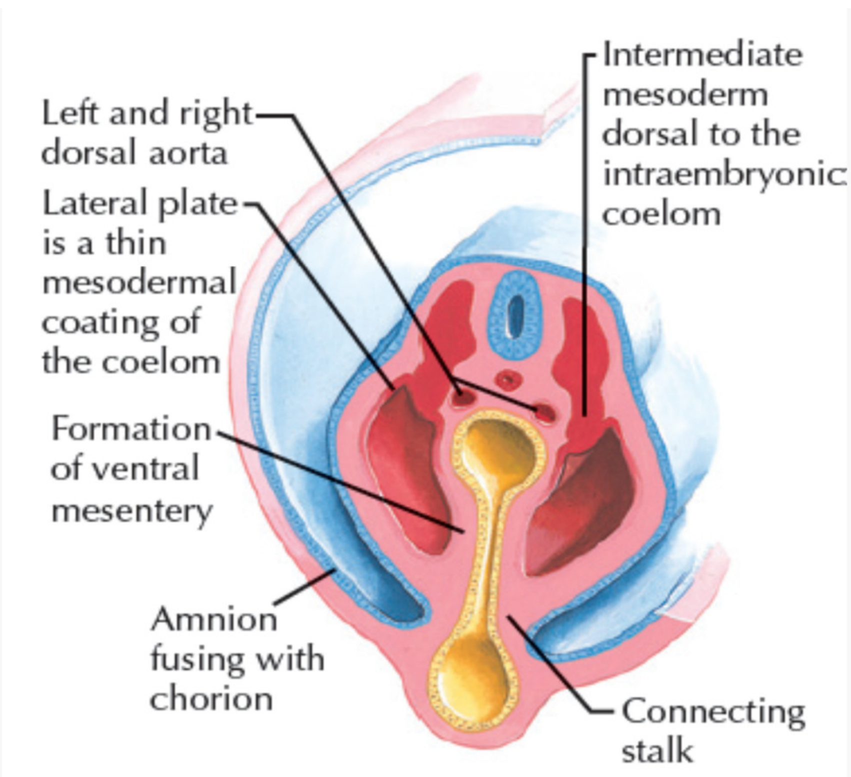
- **Neural plate**: thickened mass forms in the overlying ectoderm.
- **Neural groove**
  - A crease or fold soon appears in this plate
  - Rapidly deepens - precursor of the embryo's CNS



Neurulation

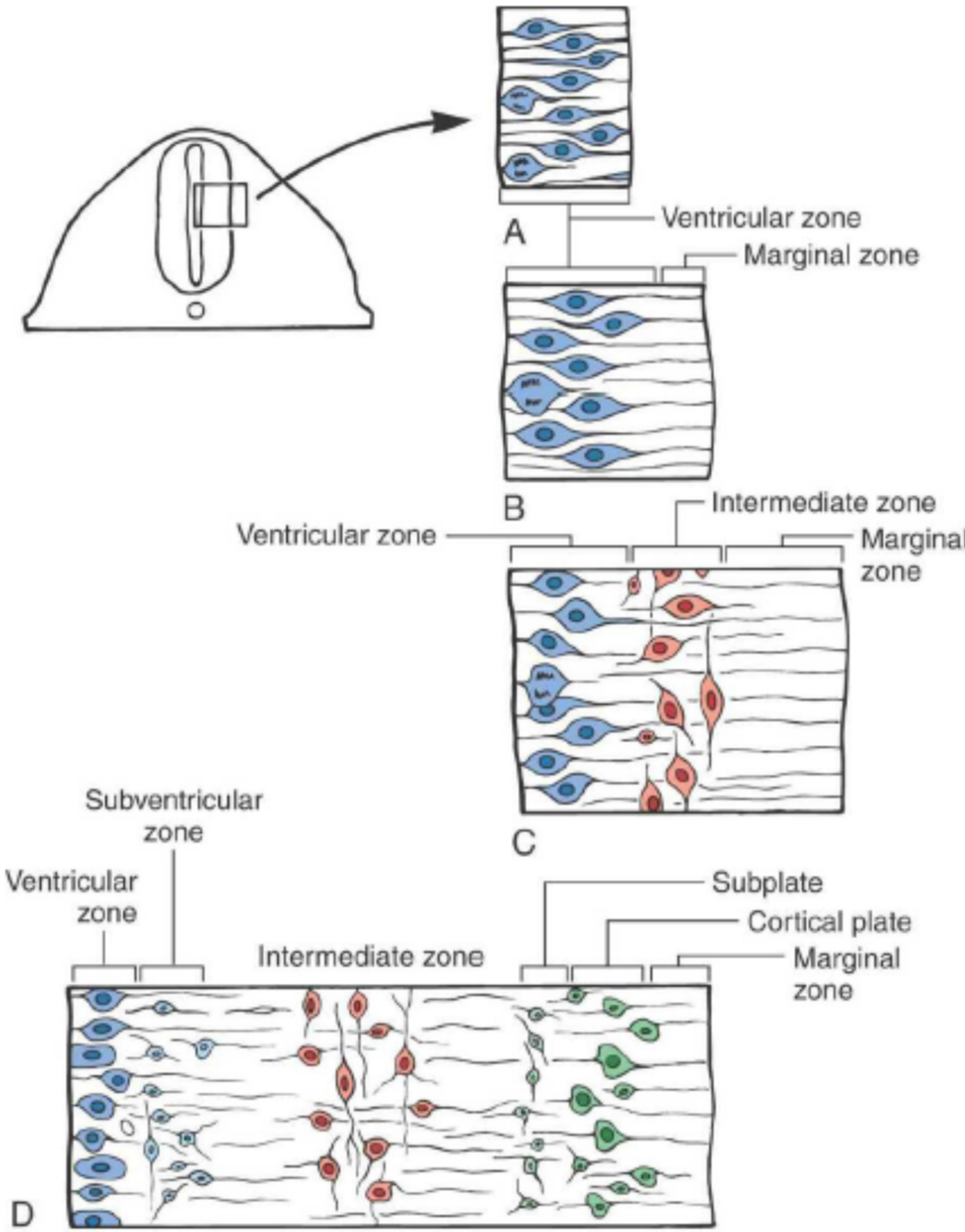
- **Neural folds**: arch over and fuse with each other at several points along the length of the neural tube
- **Neural tube:** "zippered closed" as by the neural folds, concomitant with the budding **somites**
- Cranial and caudal neuropores which are obliterated on day 25 & 27 respectively transforming the neural tube into a closed tube.





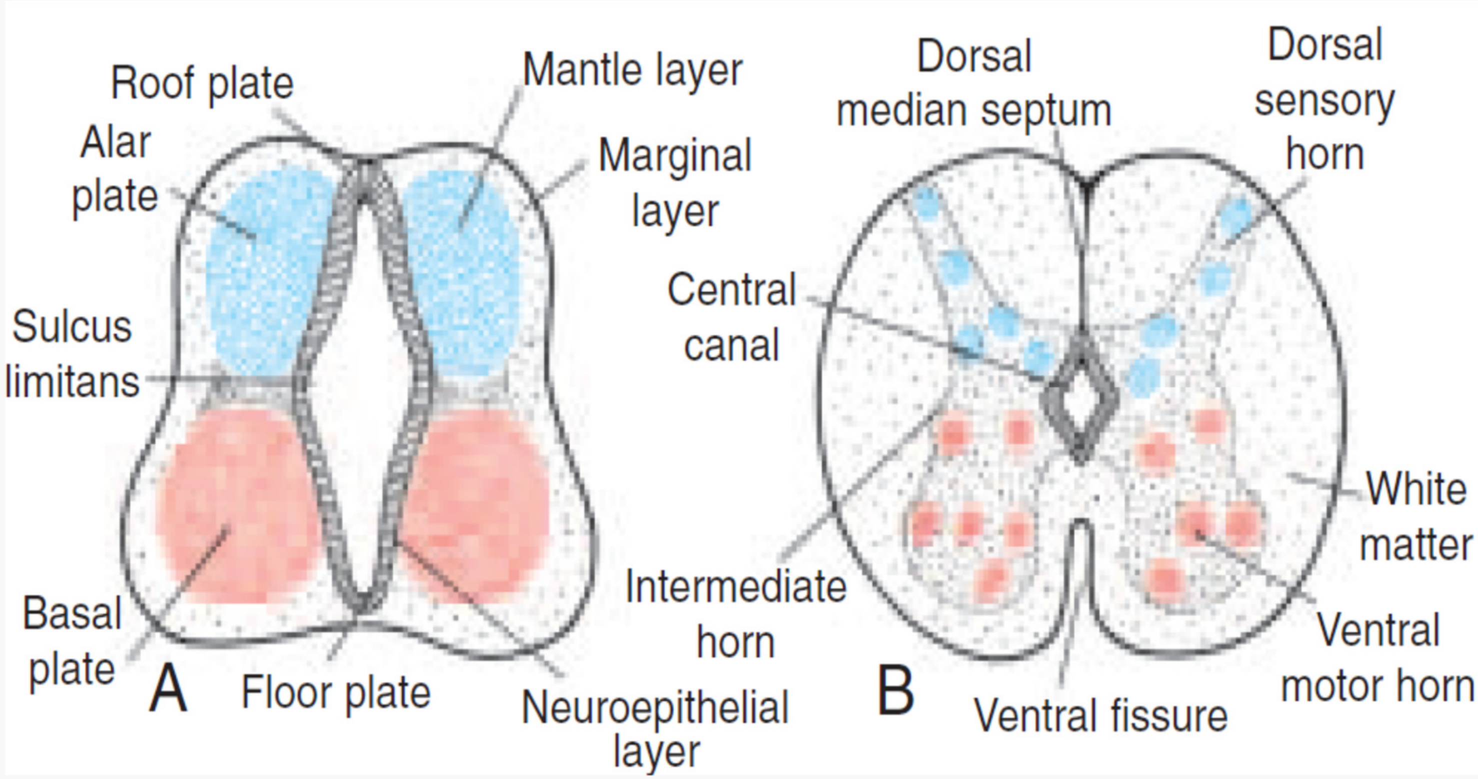
Development of the spinal cord

- The neural tube is lined by one cell layer called matrix.
- This epithelium, which extends from the cavity of the tube to the exterior, is referred to as the **ventricular zone**.
- Repeated division of the matrix cells results in an increase in length and diameter of the neural tube.
- cells migrate peripherally to form the intermediate zone (grey matter).



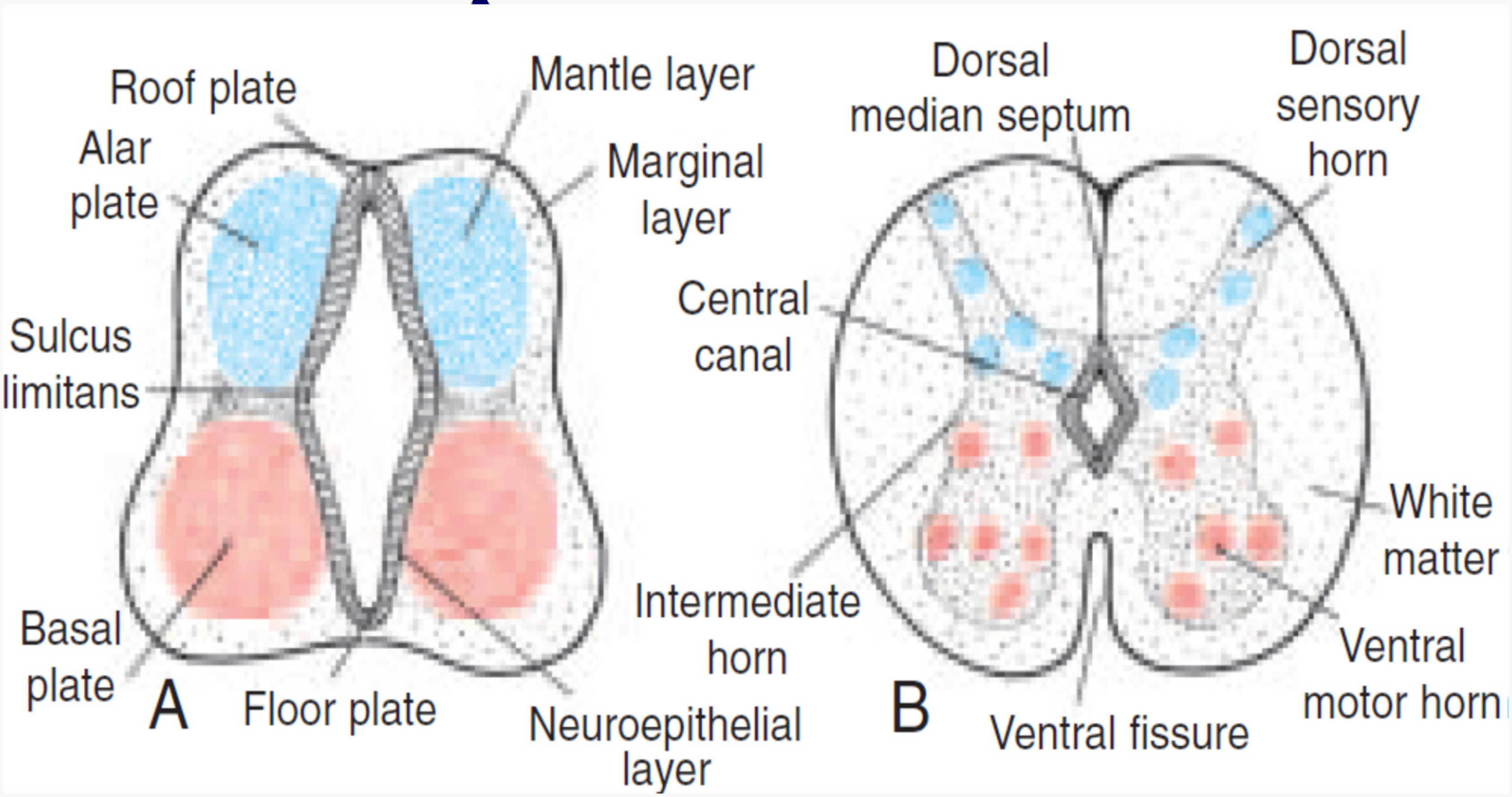
Development of the spinal cord

- Once the neural tube closes, neuroepithelial cells begin to give rise to neuroblasts
- Neuroblasts form the mantle layer, a zone around the neuroepithelial layer (later forms the gray matter of the spinal cord)



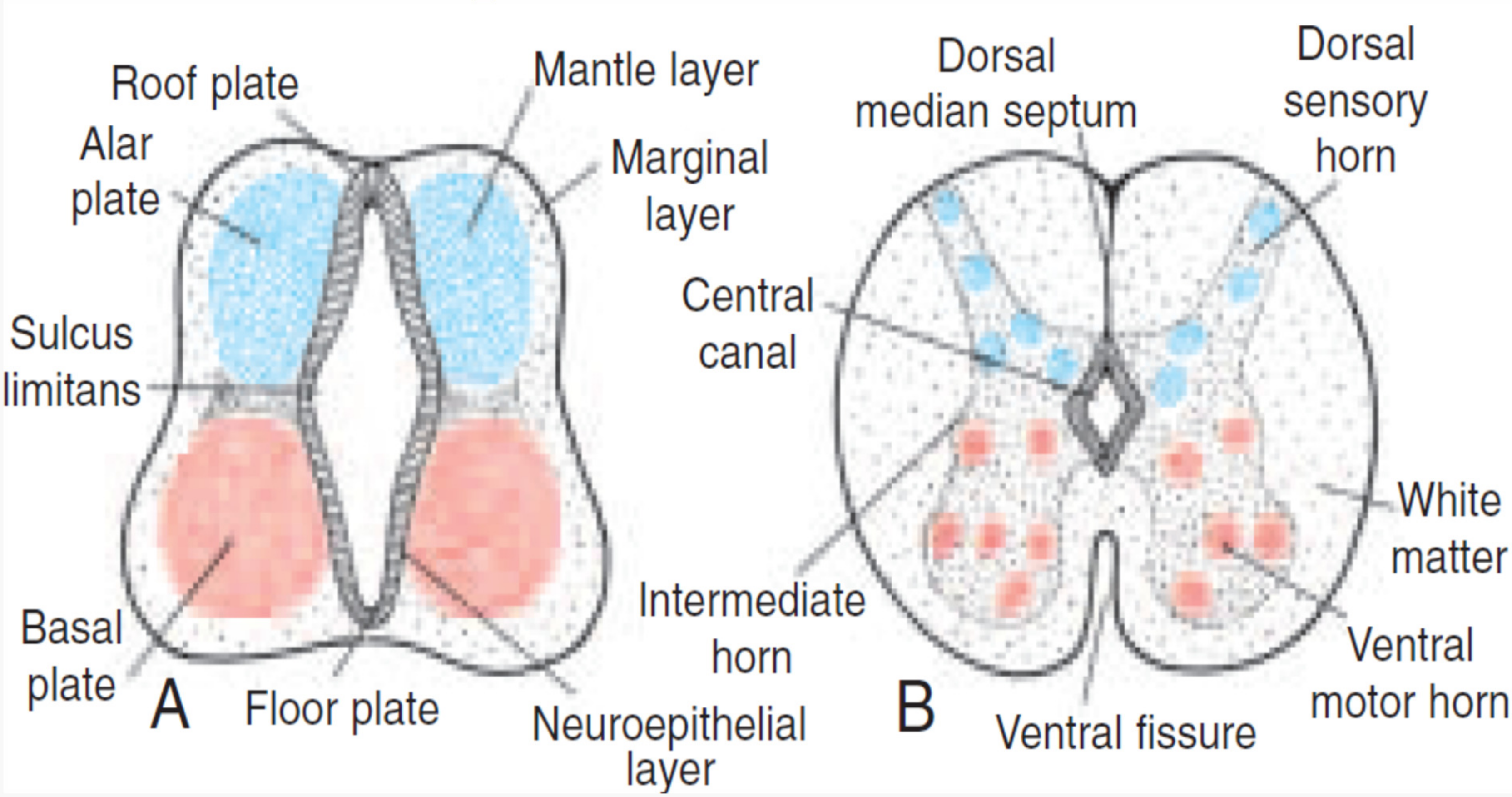
- The outermost layer of the spinal cord, the marginal layer, contains nerve fibers emerging from neuroblasts in the mantle layer. As a result of myelination of nerve fibers, this layer takes on a white appearance and therefore is called the white matter of the spinal cord

Development of the spinal cord



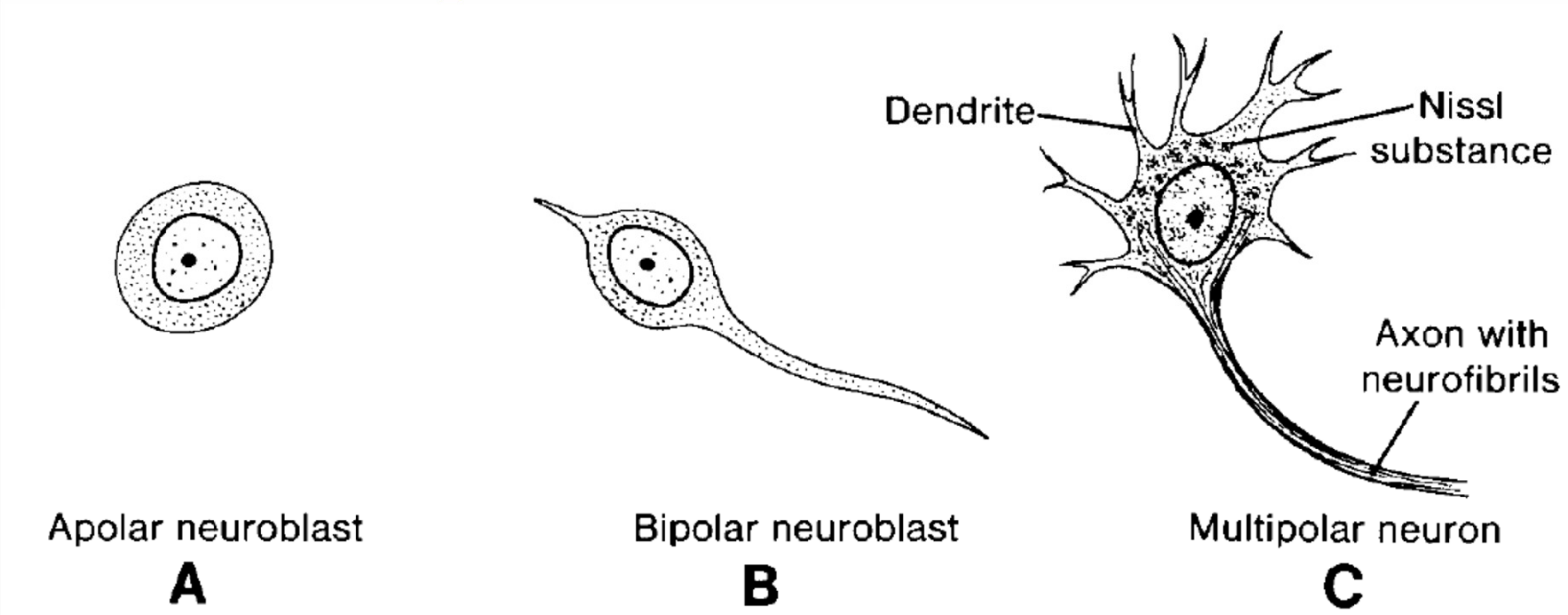
- Cells in the lateral wall of the neural tube are differentiated into 3 layers:
  - Inner ependymal layer: ependymal lining of the central canal & ventricles.
  - Middle Mantle Layer: Cellular layer which forms the grey matter of the spinal cord.
  - Outer Marginal Layer: forms the white matter of the spinal cord.

Development of the spinal cord



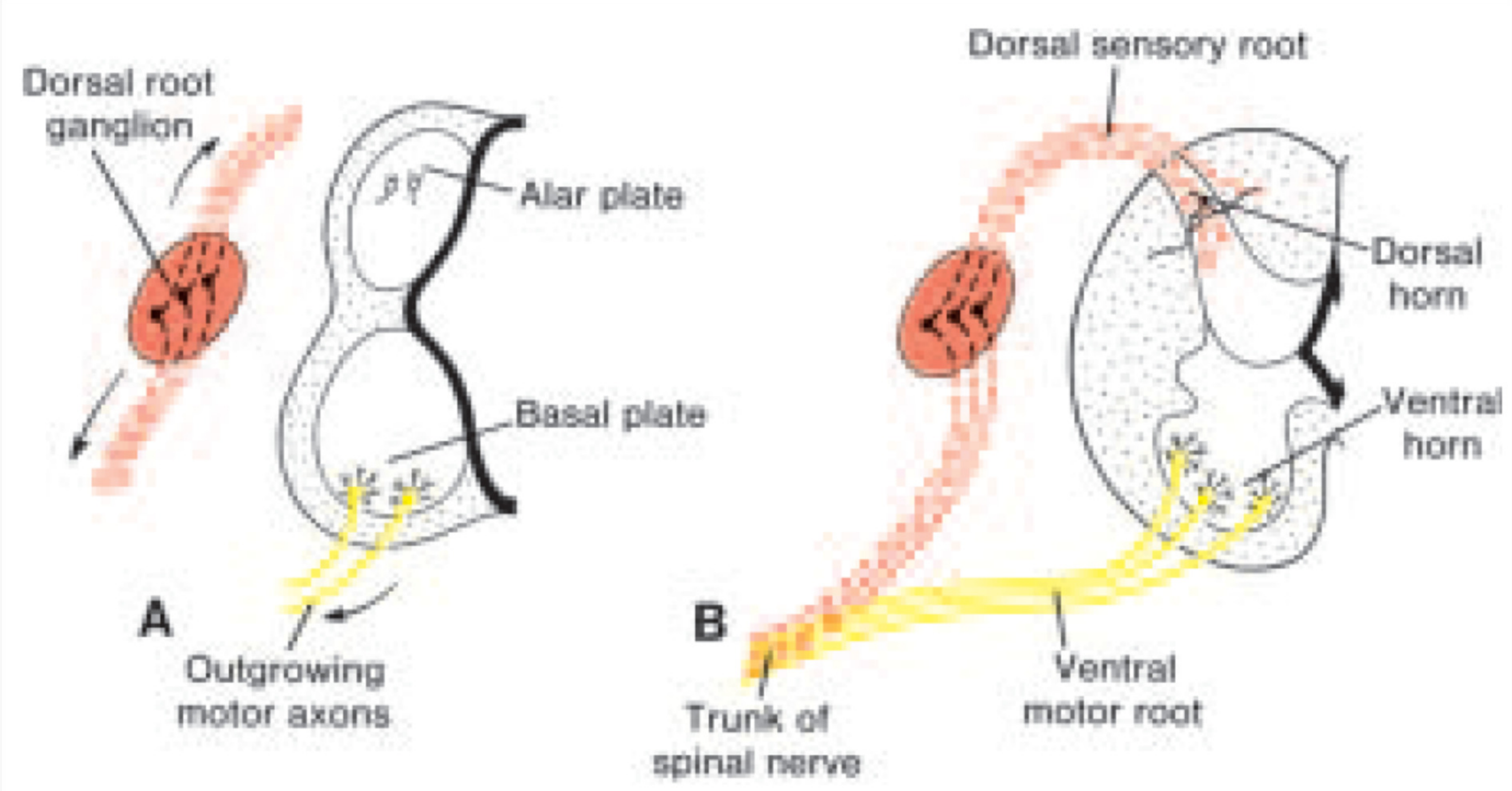
- The thick lateral walls are connected together by thin roof plate (dorsal) & floor plate (ventral).
- A groove (sulcus limitans) appears in the lateral wall dividing it into:
  - Dorsal part (Alar Plate) which expands to form the dorsal (sensory) horn.
  - Ventral part (basal plate) which expands to form the ventral (motor) horn.
- The cavity of the tube remains narrow & forms the central canal of the spinal cord.

Development of the spinal cord



- Neuroblasts: arise exclusively by division of the neuroepithelial cells
- Initially they have a central process extending to the lumen (transient dendrite), but when they migrate into the mantle layer, this process disappears, and neuroblasts are temporarily round:
  - Apolar
  - Bipolar neuroblast
  - Multipolar neuroblast

Development of the spinal cord



- Once neuroblasts form, they lose their ability to divide.
- **Ventral motor root of the spinal nerve**: Axons of neurons in the basal plate break through the marginal zone and become visible on the ventral aspect of the cord.
- Dorsal root ganglia: Neural crest cells

Neural crest

- Junction of neural plate with ectoderm
- Unite then pinched off as neural tube separates from ectoderm
- Neural crest cells migrate within mesoderm

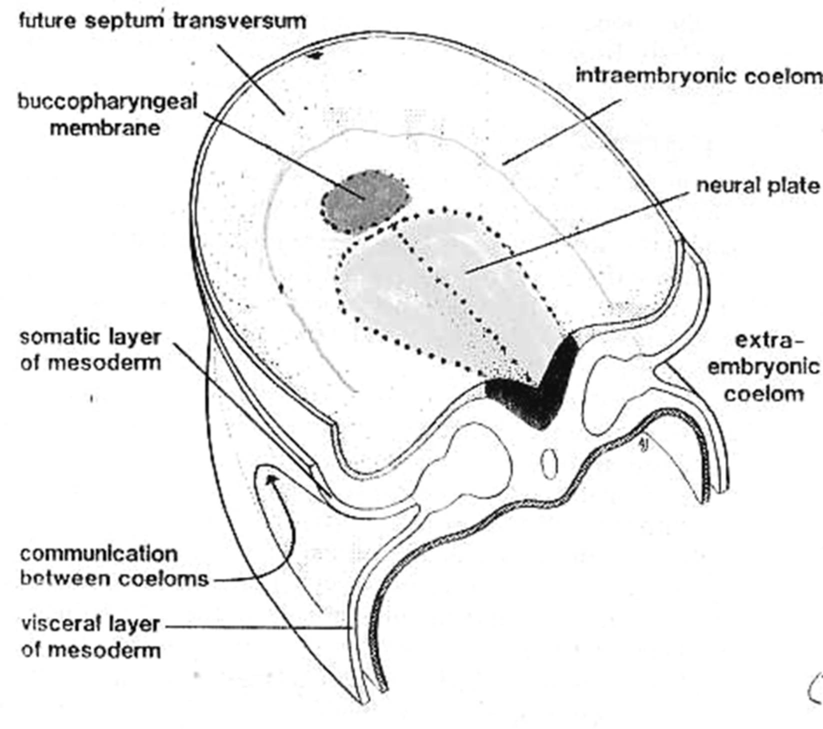


Fig. 2.6. Formation of the intraembryonic coelom.

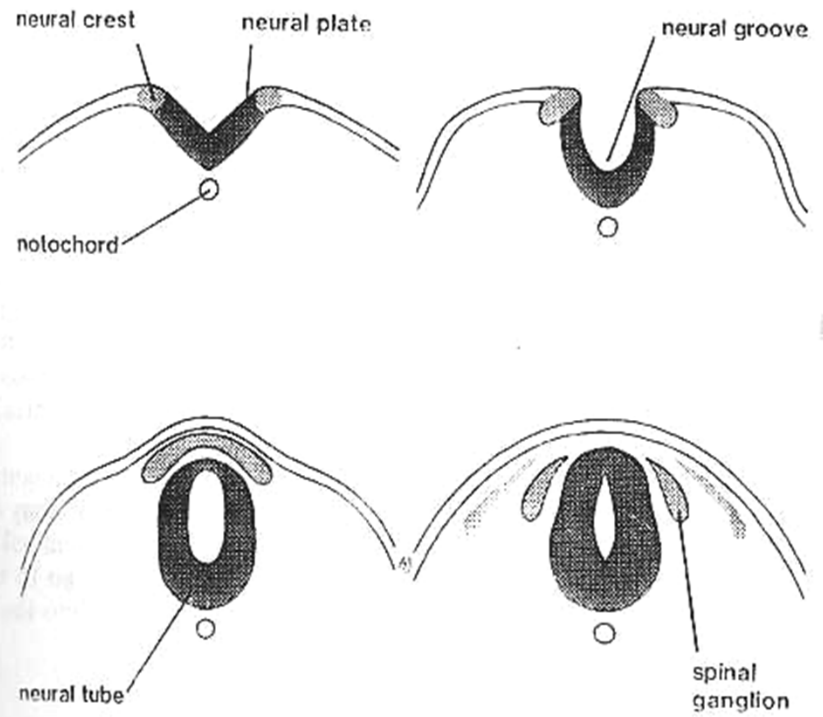
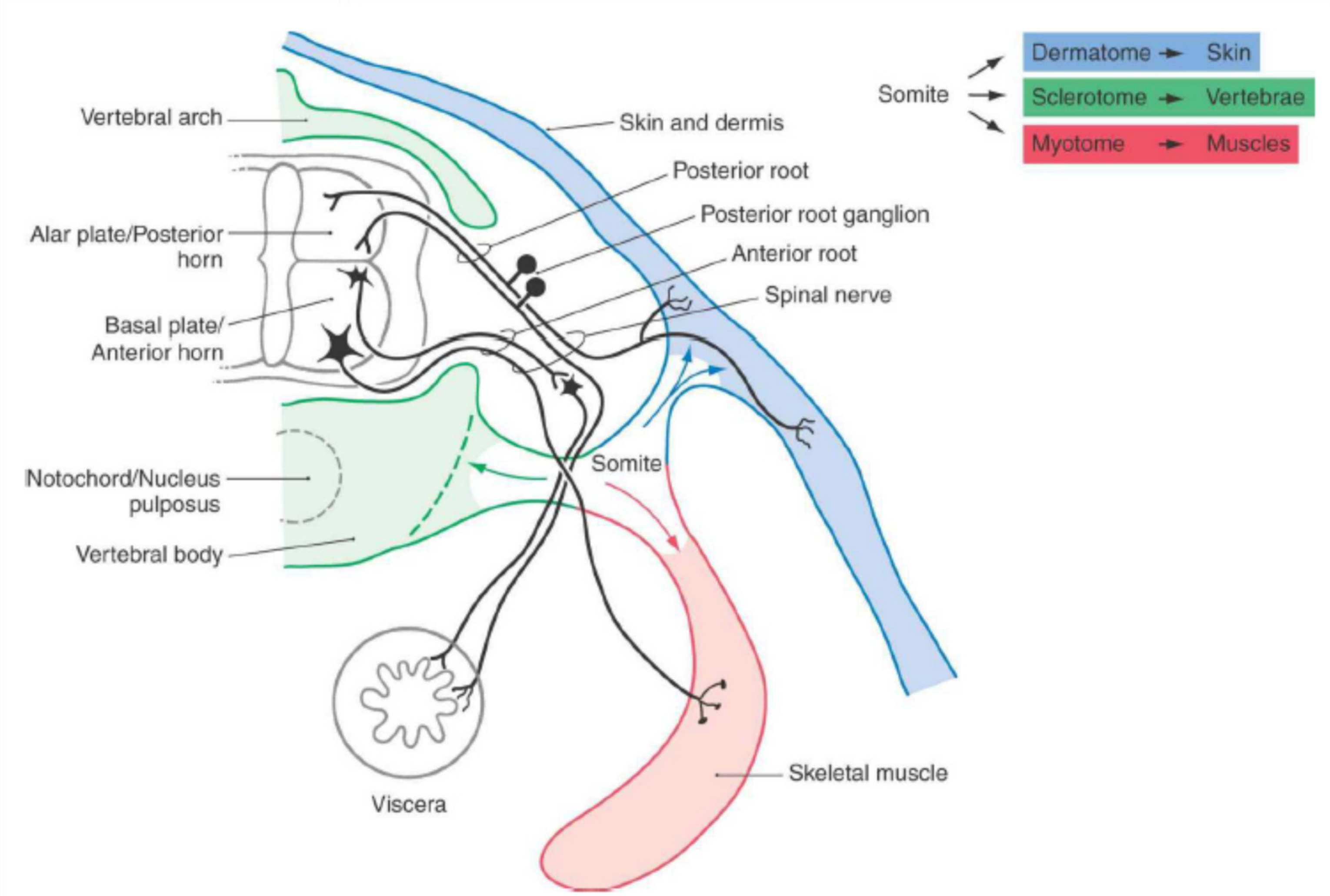


Fig. 2.7. Formation of the neural tube.

Development of the spinal cord

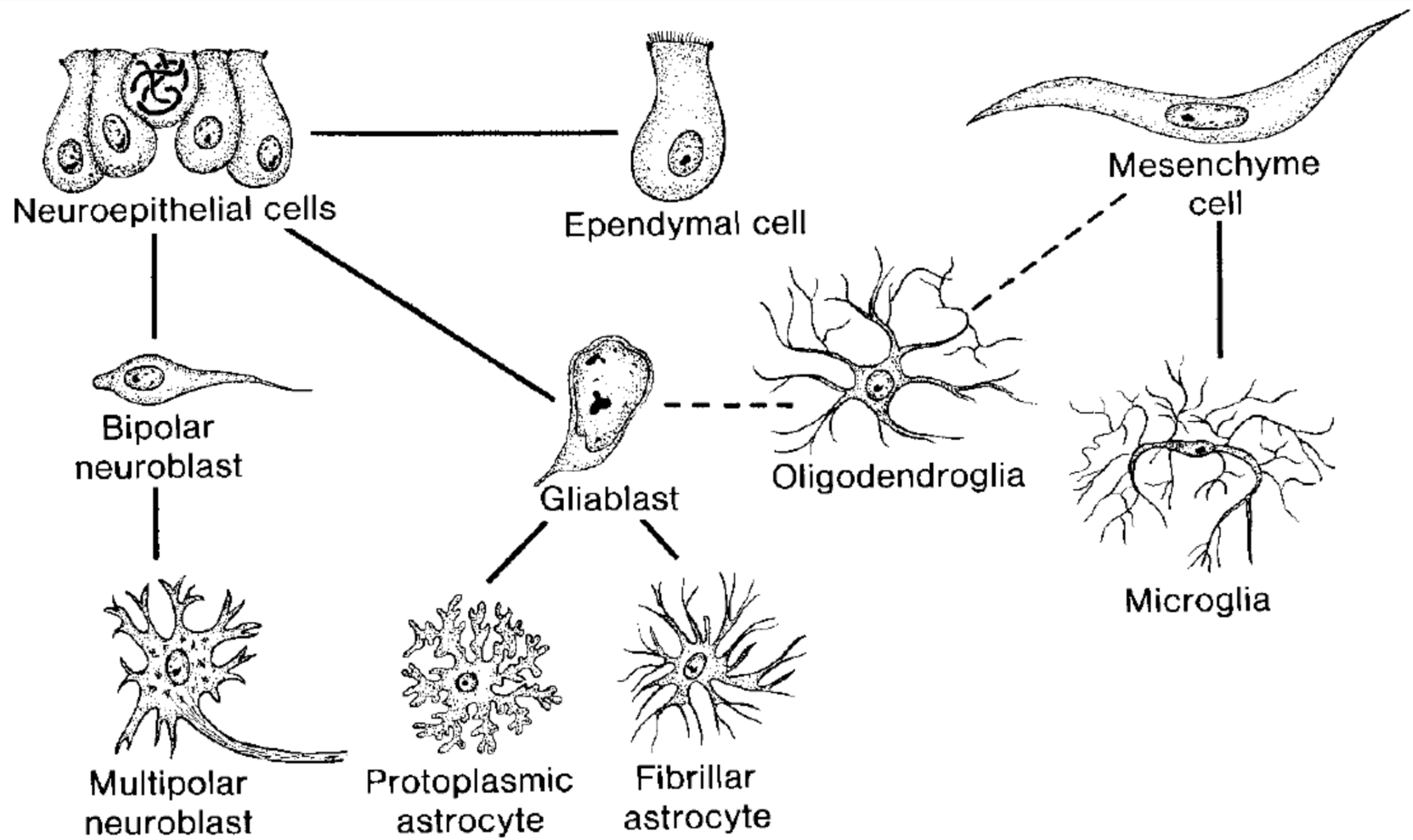


- Neuroblasts of the sensory ganglia form two processes:
  - **Central**: either end in the dorsal horn or ascend through the marginal layer to one of the higher brain centers
  - **Peripheral**: growing processes join fibers of the ventral motor roots and thus participate in formation of the trunk of the spinal nerve.

Neural crest

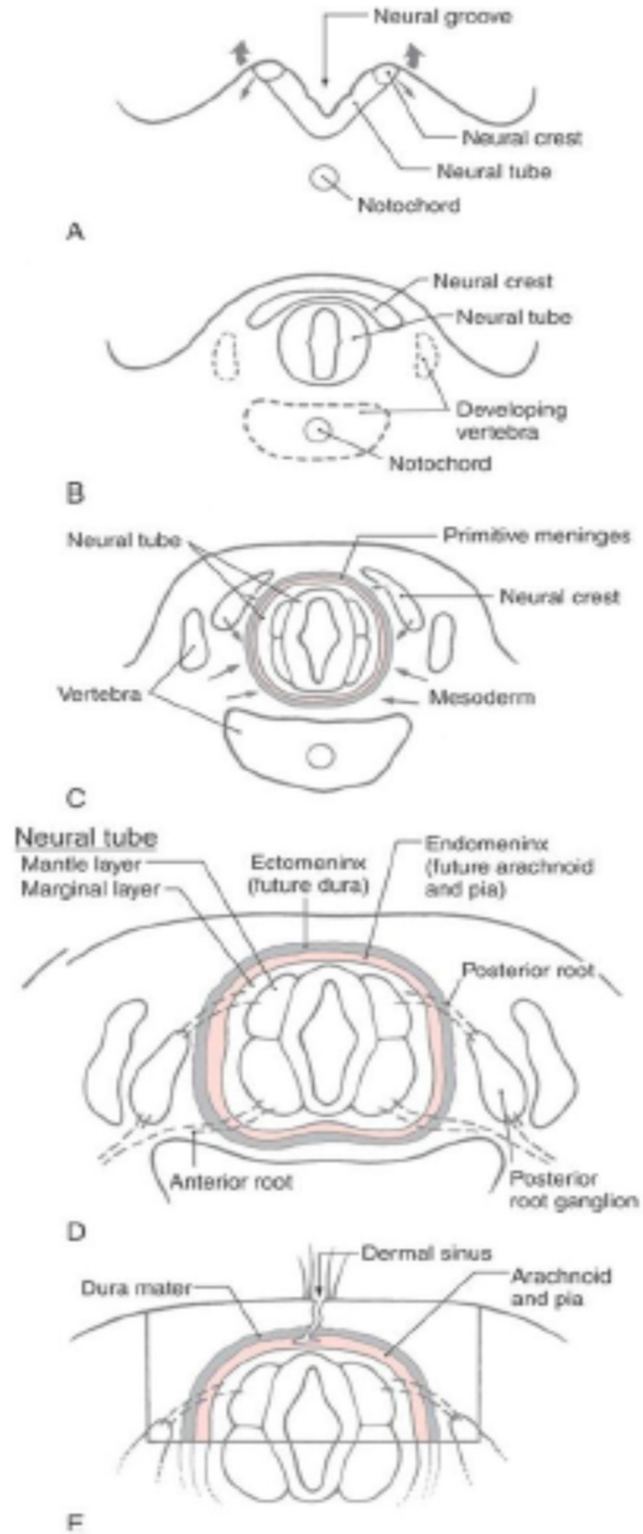
- Ectomesenchyme tissue in head region
  - Dermis of head region
  - All dental tissue except enamel
  - Branchial arches
    - Skeleton
    - Part of musculature
  - Pigment cells
    - Melanocytes
- Meninges
- Spinal & cranial nerve ganglia
- Sympathetic & parasympathetic systems
- Adrenal medulla
- Schwann cells

HISTOLOGICAL DIFFERENTIATION



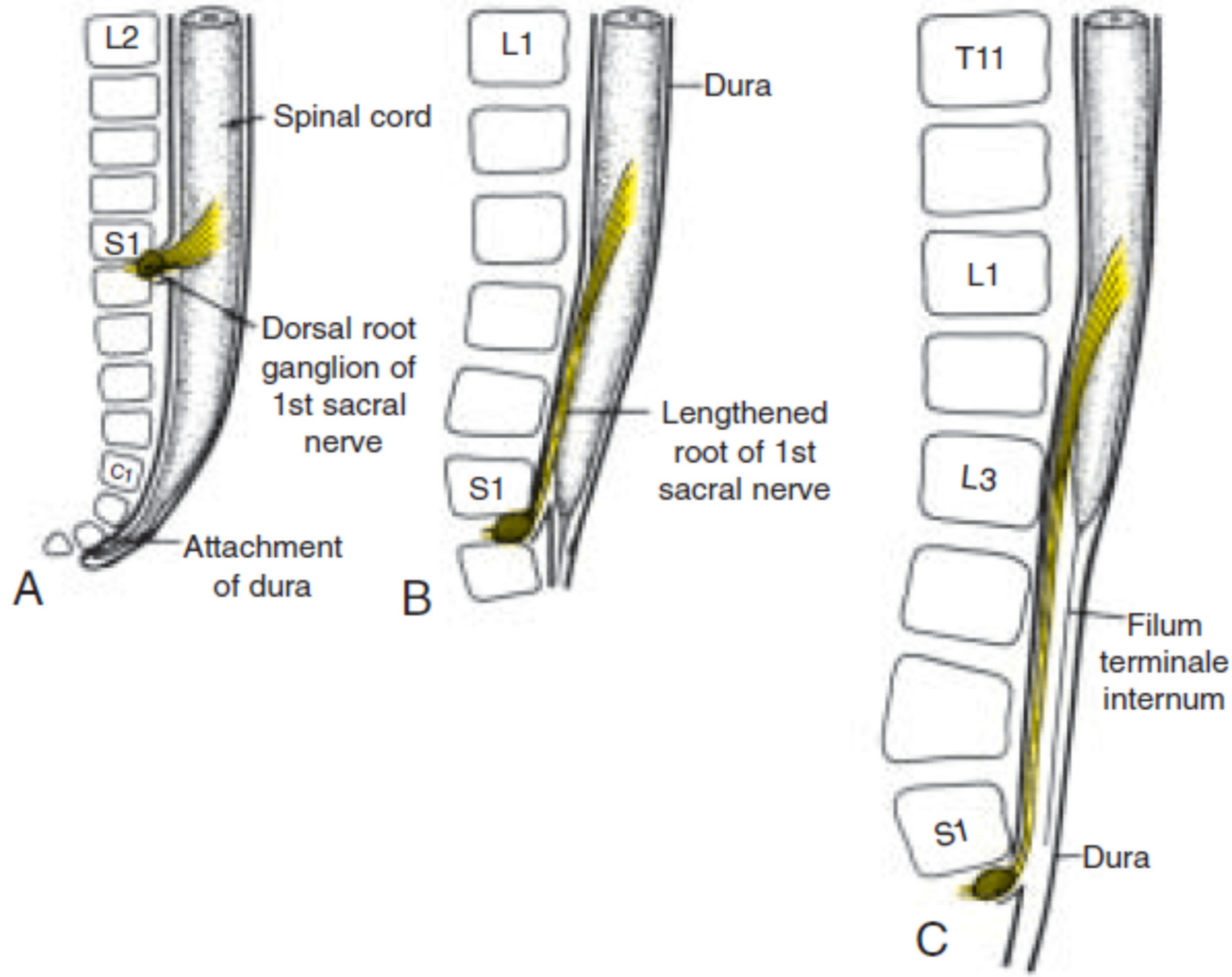
DEVELOPMENT OF THE MENINGES

- Neural crest and mesodermal cells form the primitive meninges (meninx primitiva). no obvious spaces
- Between 34 and 48 days the primitive meninges differentiate
  - **Outer**: ectomeninx, will become the dura mater
  - **Inner**: endomeninx, will form the arachnoid mater and pia mater
- By the end of the first trimester: the meninges is established.



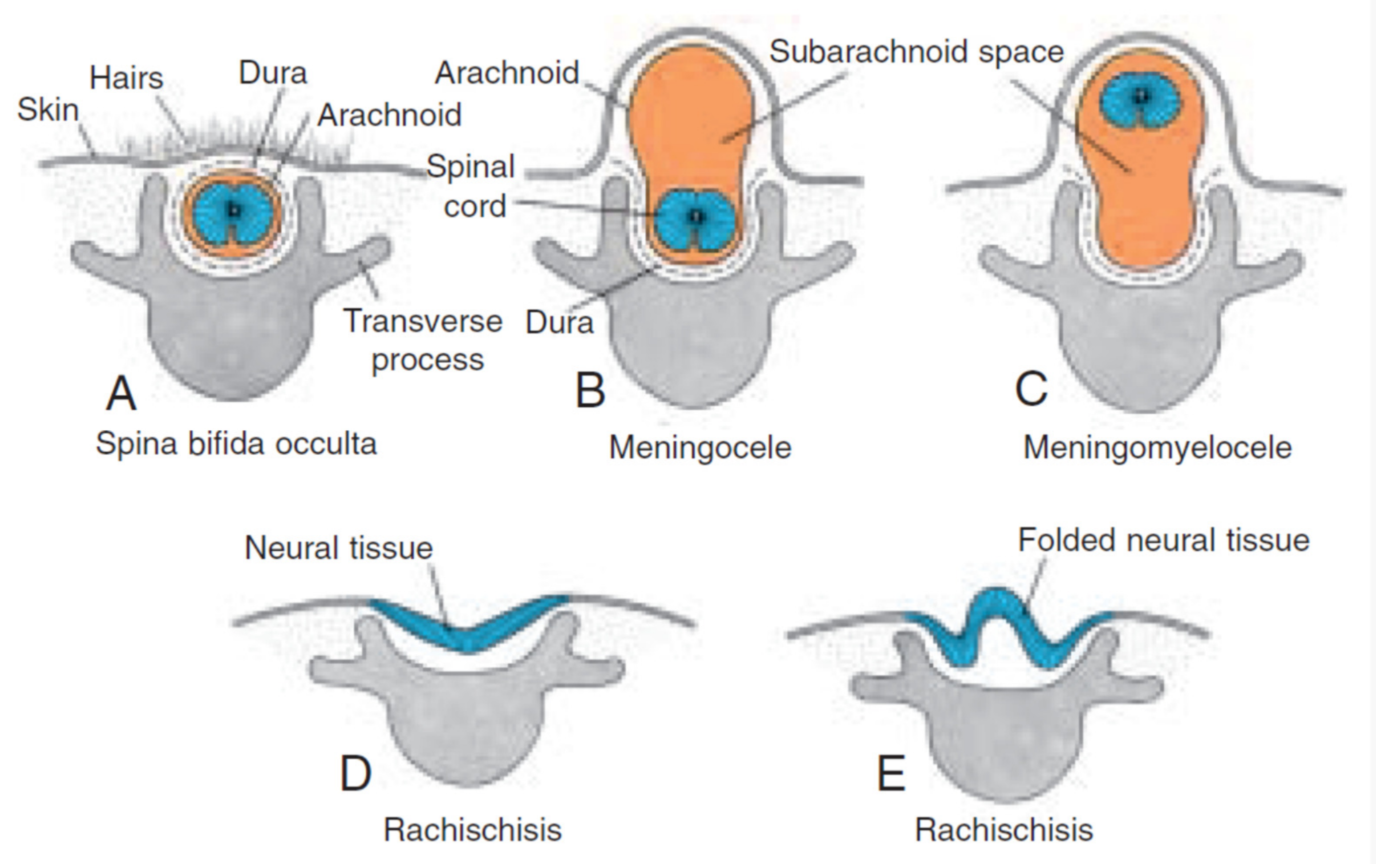
POSITIONAL CHANGES OF THE CORD

- **Third month**: spinal cord extends the entire length of the embryo
- **Fifth month**: S1
- **Newborn**: L3-L4
- **Adult**: L1-L2



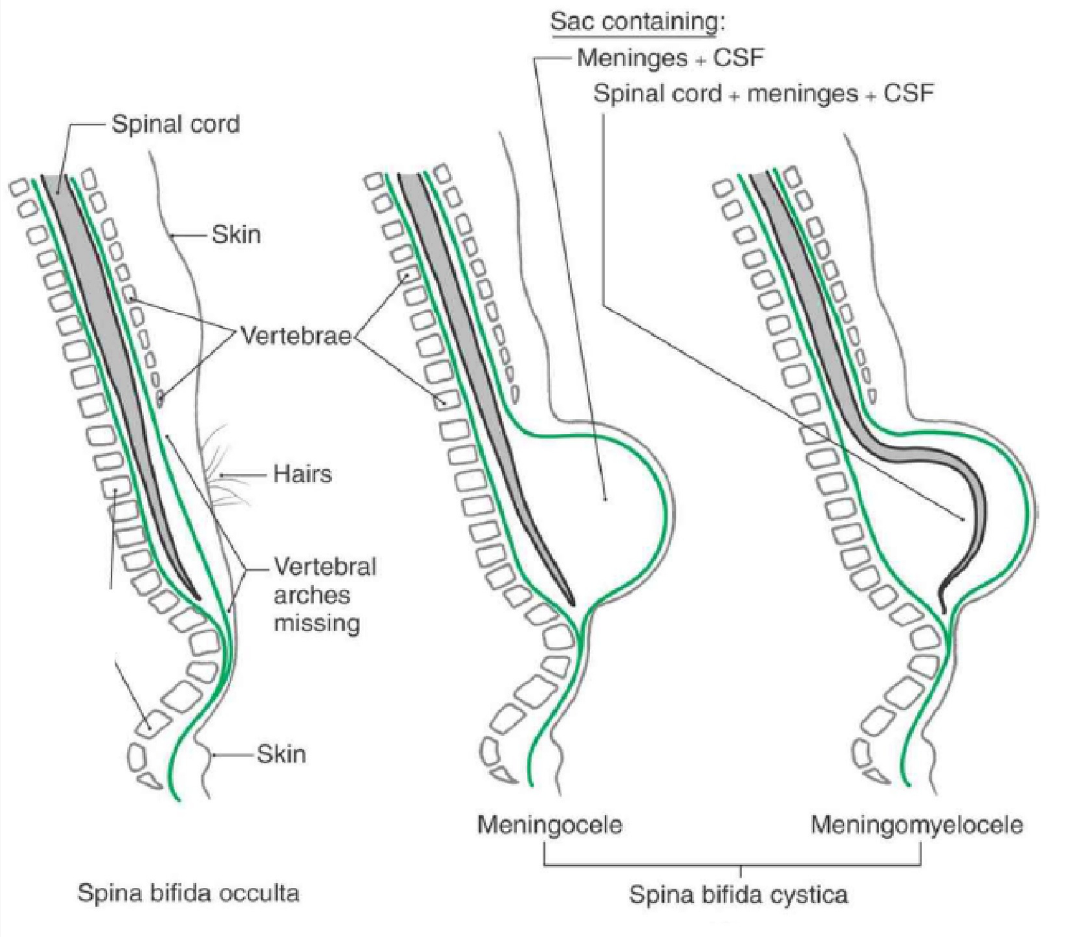
Congenital Malformations of spinal cord development

- **Spina bifida occulta:** Absent vertebral arch with normal spinal cord. It affects the lumbosacral area & is usually covered with hairy skin
- **Spina bifida cystica:**



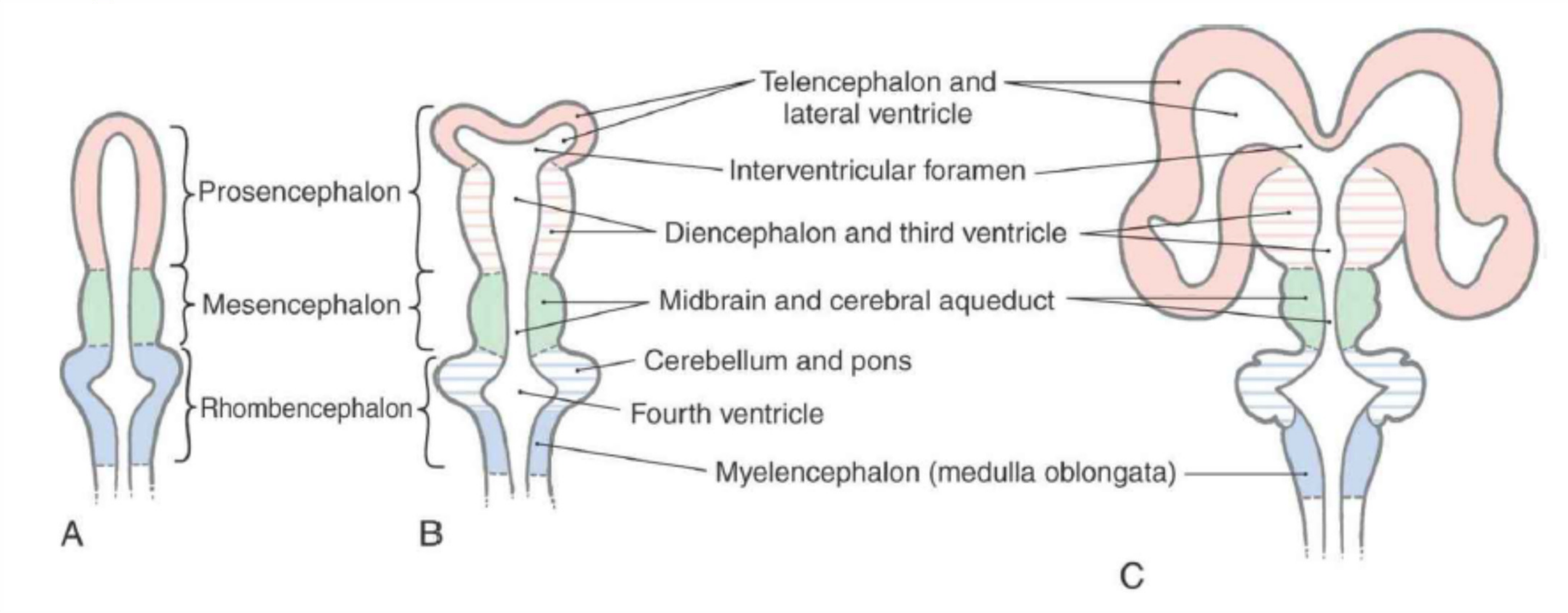
- Meningocele: The meninges herniates through the spina bifida to form subcutaneous sac filled with CSF.
- Meningomyelocele: The spinal cord herniates through the meningocele.
- Myelocele (Rachischisis): Failure of obliteration of the neural tube.

large meningomyelocele



Myelocele

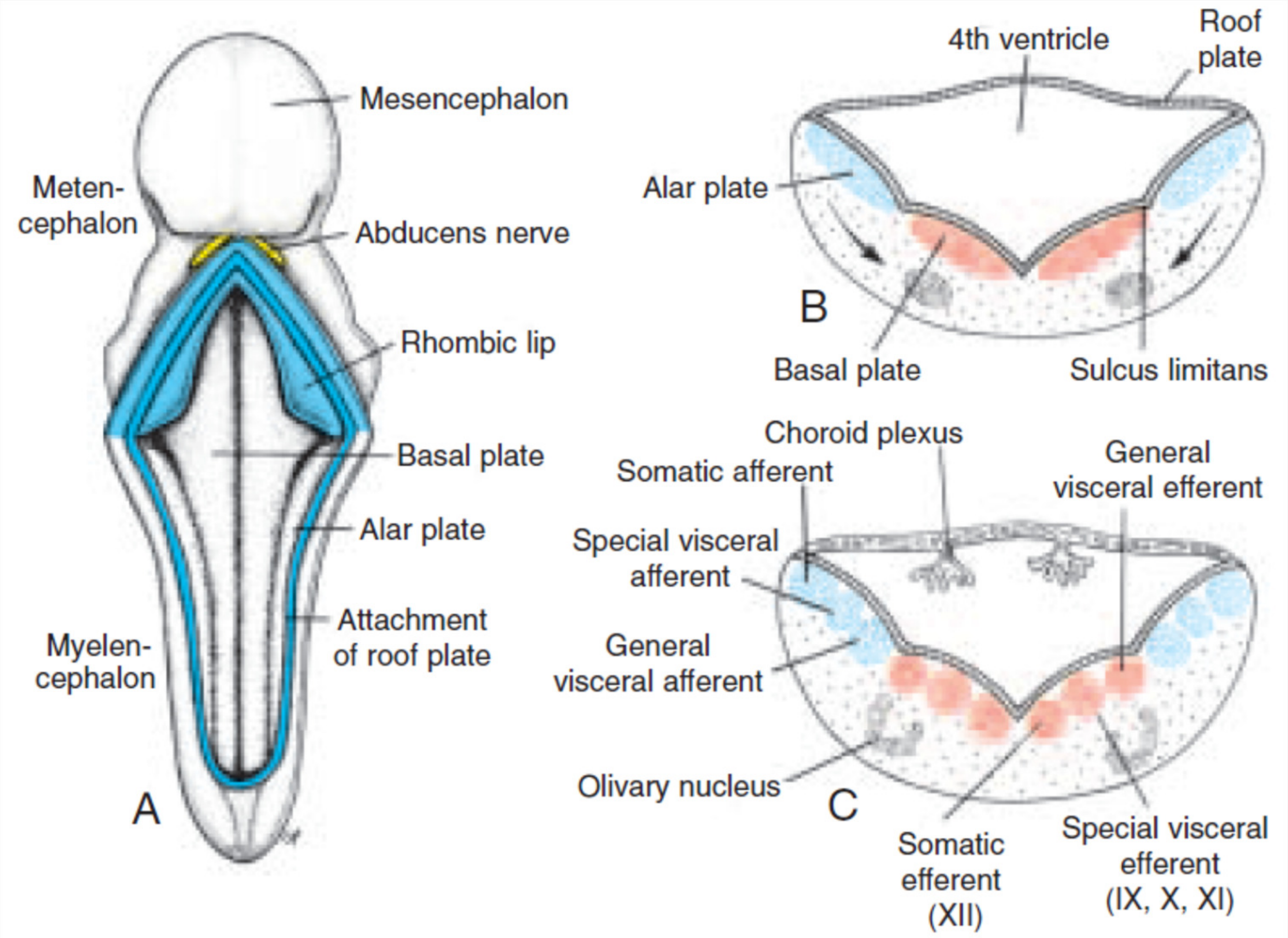
Development of the brain



- The cephalic end of the neural tube shows three **primary brain vesicles**:
- **Prosencephalon**: forebrain
  - Telencephalon: two lateral outpocketings, primitive cerebral hemispheres
  - Diencephalon
- **Mesencephalon**: midbrain
- **Rhombencephalon**: hindbrain
  - Metencephalon: which later forms the pons and cerebellum
  - Myelencephalon: which later forms medulla oblongata

DEVELOPMENT OF THE MEDULLA OBLONGATA

- Myelencephalon: which later forms medulla oblongata
- As in the development of the spinal cord the medulla will have an alar plate & a basal plate separated by a sulcus limitans & connected by a thin roof plate & a floor plate.
- The lateral walls move away from each other stretching the roof plate & enlarging its cavity which forms the 4th ventricle.



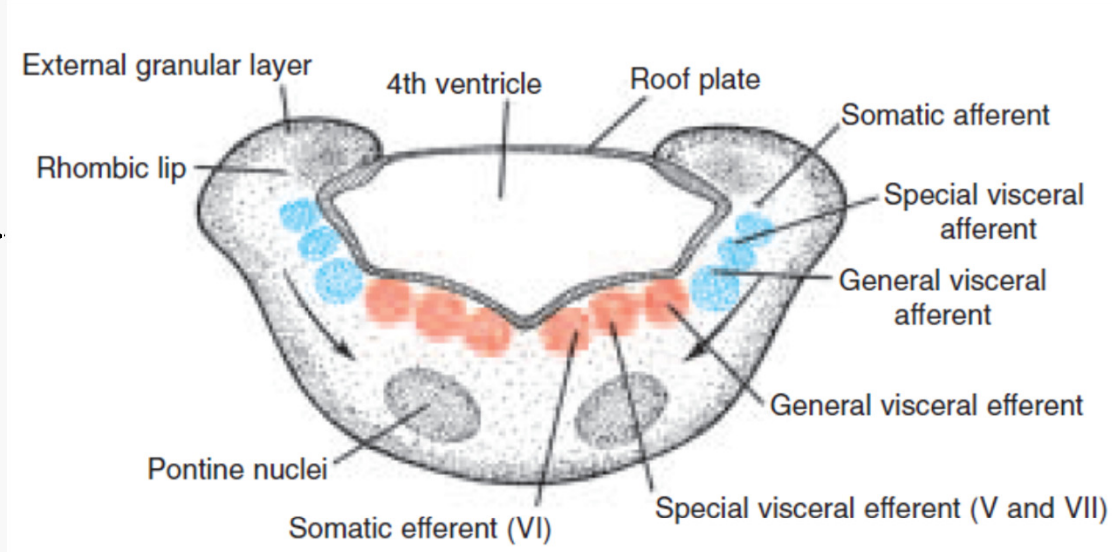
- The alar plate forms the sensory nuclei of the medulla & the basal plate forms the motor nuclei.
- Between the fourth and fifth months, local resorptions of the roof plate occur, forming lateral foramina of Luschka, and a median foramen of Magendie.

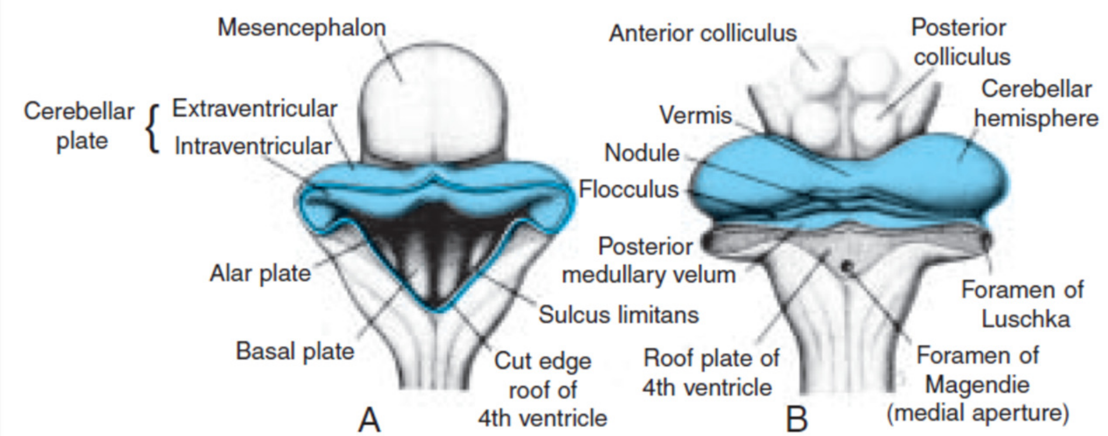
Table 11-1 The Letter Symbols Commonly Used to Indicate the Functional Components of Each Cranial Nerve

Component	Function	Letter Symbols
Afferent Fibers	**Sensory**	
General somatic afferent	General sensations	GSA
Special somatic afferent	Hearing, balance, vision	SSA
General visceral afferent	Viscera	GVA
Special visceral afferent	Smell, taste	SVA
Efferent Fibers		
General somatic efferent	Somatic striated muscles	GSE
General visceral efferent	Glands and smooth muscles (parasympathetic innervation)	GVE
Special visceral efferent	Branchial arch striated muscles	SVE

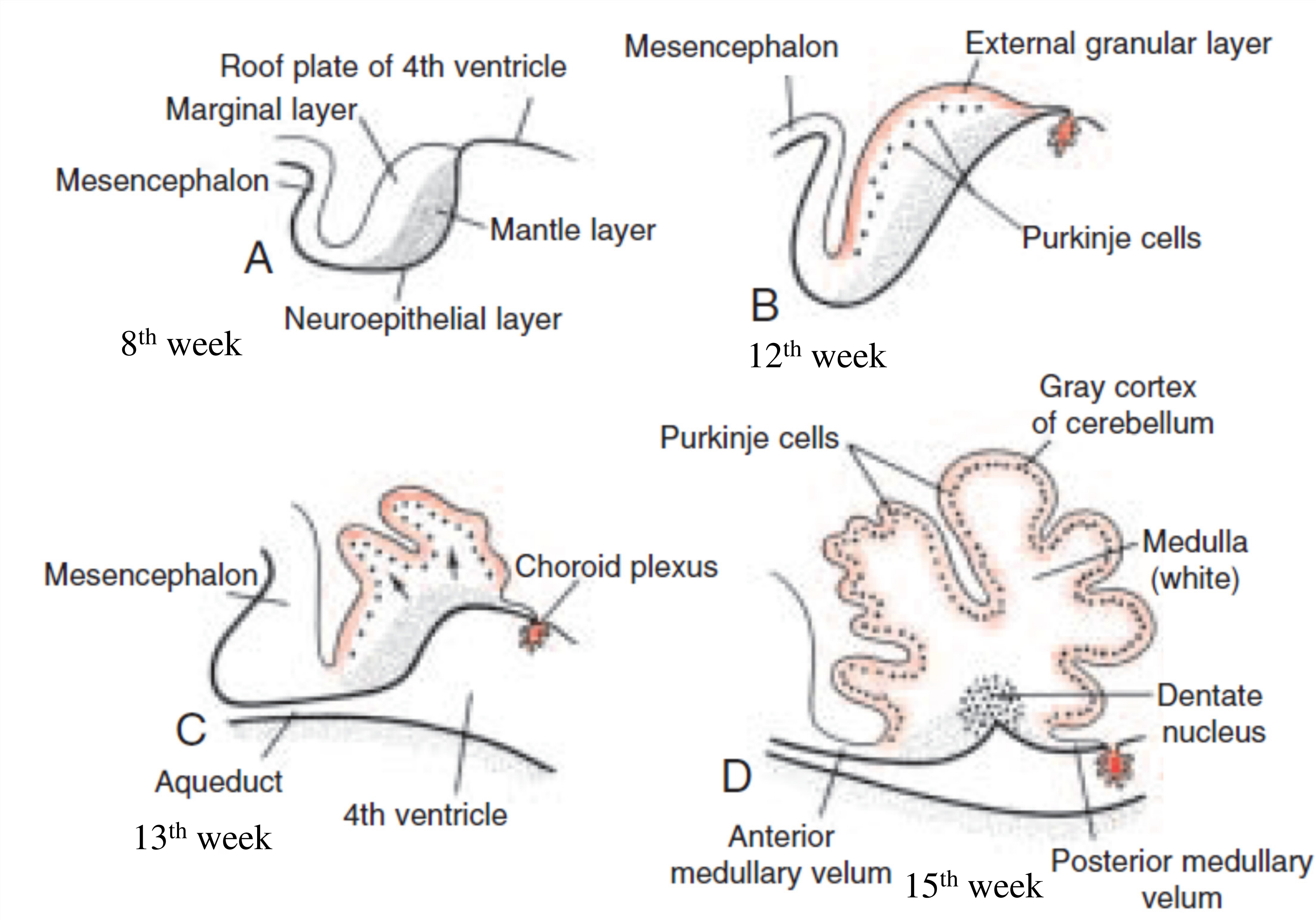
Development of the pons & cerebellum

- Metencephalon: which later forms the pons and cerebellum
- The same steps in the development of the medulla occur but the alar plates bend medially to form 2 rhombic lips.
- The rhombic lips approach each other & fuse together forming a cerebellar plate.
- The cerebellar plate differentiates into a median part which forms the vermis & 2 lateral masses which form the cerebellar hemispheres.
- The cavity forms part of the 4th ventricle

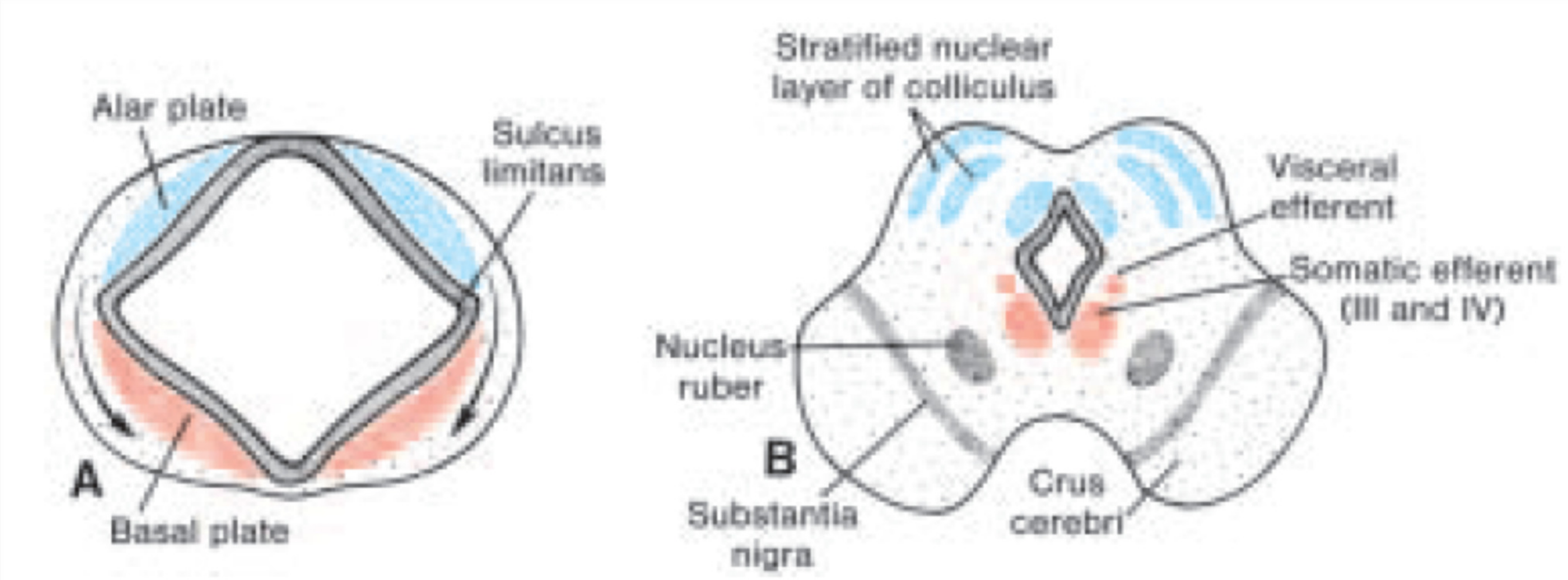




- **Basal plate:** 1) Medial somatic efferent 2) Special visceral efferent 3) General visceral efferent
- **Alar plates**: 1) Lateral somatic afferent 2) Special visceral afferent 3) General visceral afferent

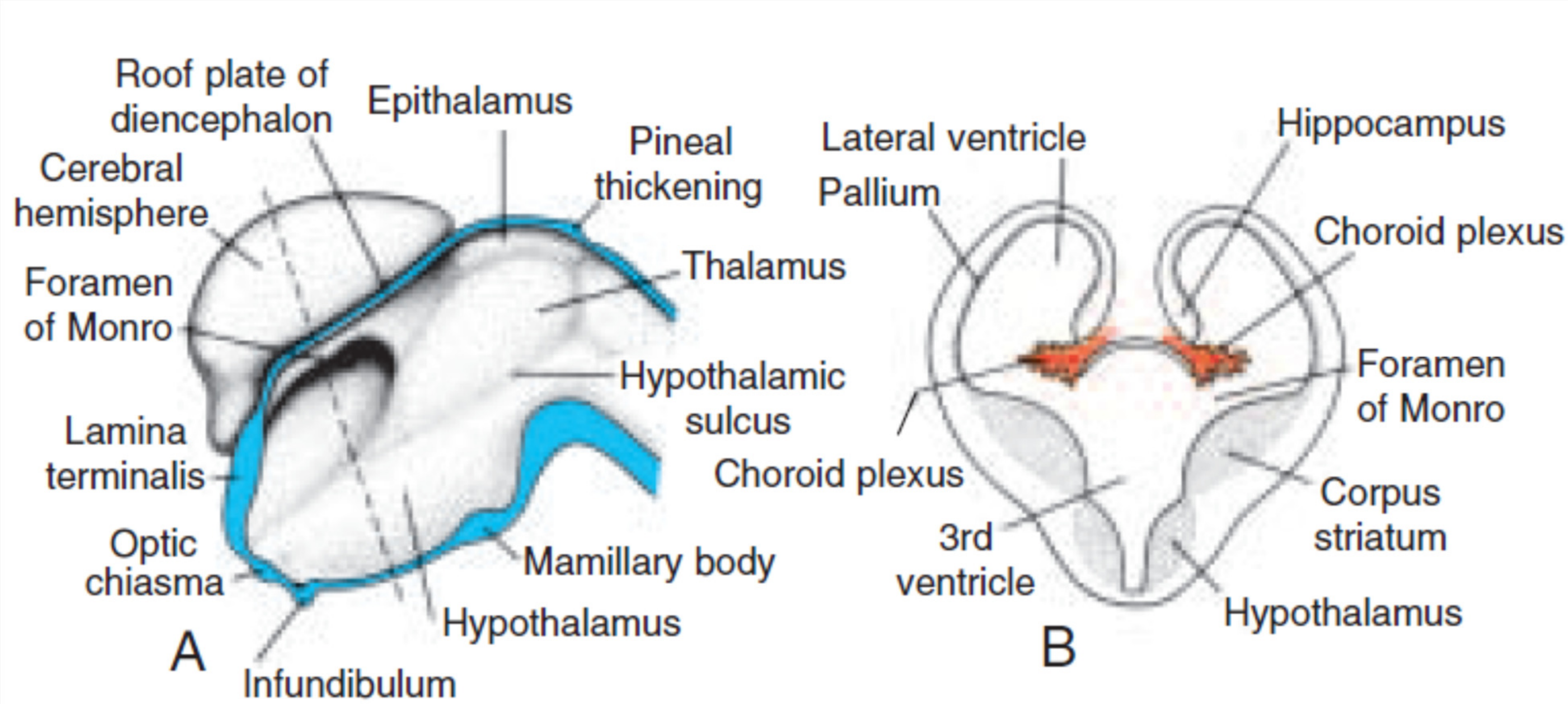

Roof plate of 4th ventricle
Marginal layer
Mesencephalon
Mantle layer
A
Neuroepithelial layer
8th week
Mesencephalon
External granular layer
Purkinje cells
B
12th week
Gray cortex
of cerebellum
Purkinje cells
Medulla
(white)
Mesencephalon
Choroid plexus
C
Aqueduct
4th ventricle
13th week
Dentate
nucleus
D
Anterior
medullary velum
15th week
Posterior medullary
velum

Development of Midbrain

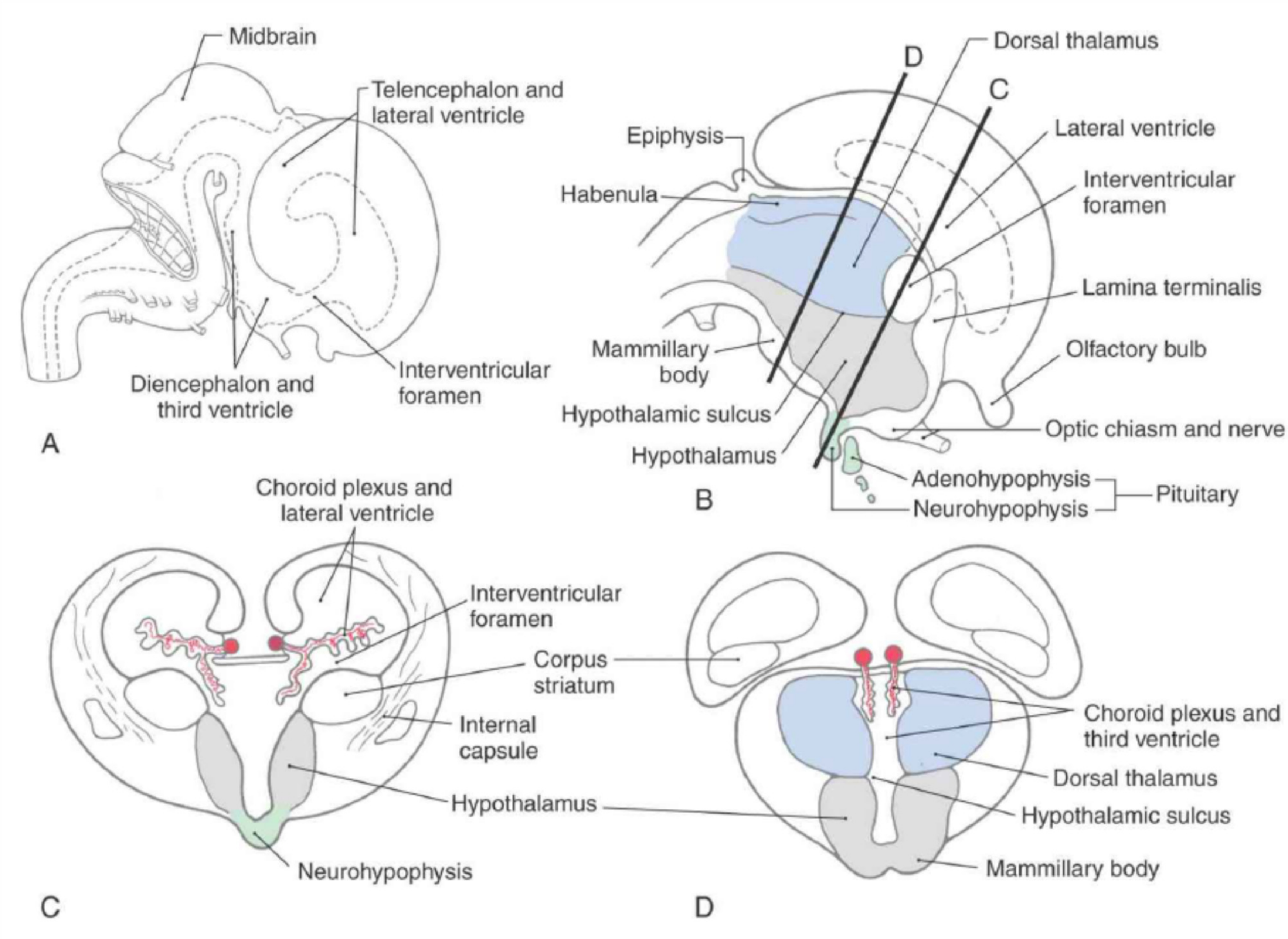


- As in the development of the spinal cord & the medulla the midbrain will have an alar plate & a basal plate separated by a sulcus limitans & connected by a thin roof plate & a floor plate.
- The alar plates develop to form the tectum which is divided by a vertical & transverse grooves into 4 colliculi.
- The basal plate forms the motor nuclei in the tegmentum of midbrain
- The marginal layer of the basal plate enlarges greatly to form the crus cerebri.
- Its cavity remains narrow & forms the cerebral aqueduct.

Development of the Diencephalon

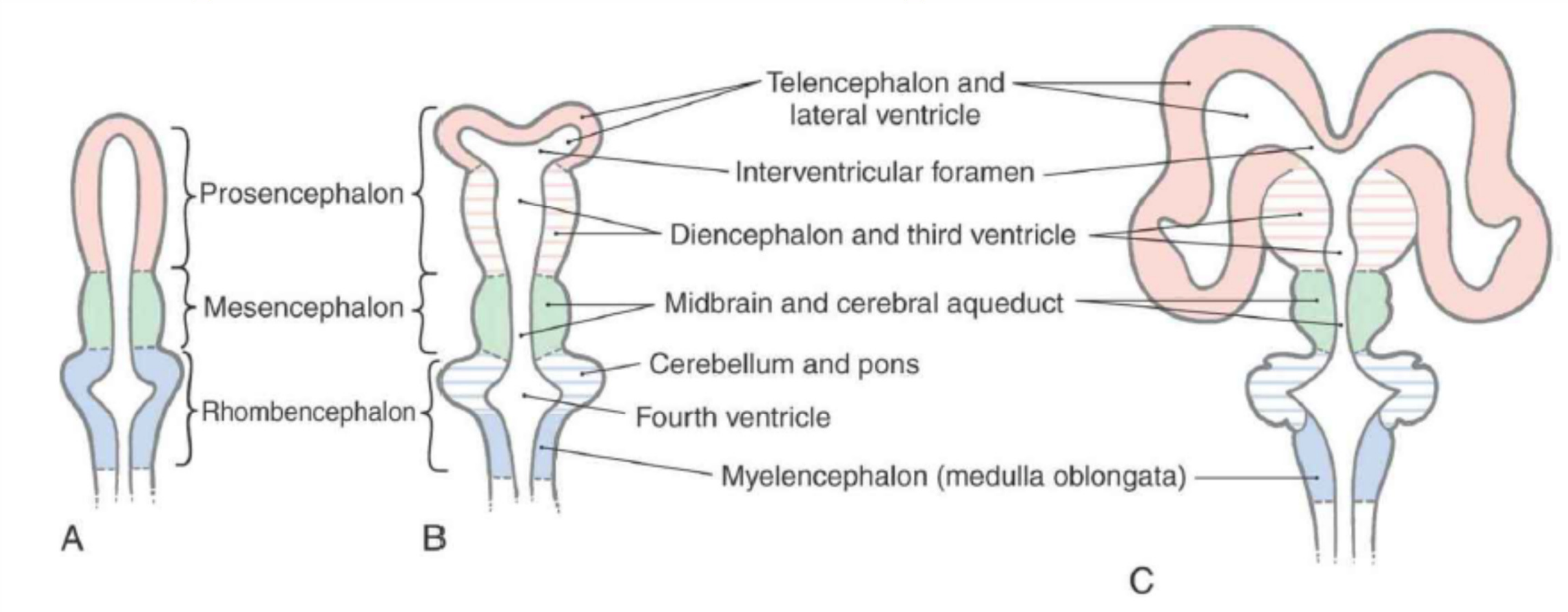


- It develops from the median part of the forebrain. It consists of 2 lateral walls connected by a roof plate & a floor plate, its cavity is called the 3rd ventricle.
- The roof plate:
  - Anterior part forms the choroid plexus of the 3rd ventricle.
  - Posterior part forms the pineal body.
- A hypothalamic sulcus appears in the lateral wall which separates the thalamus above from the hypothalamus below.
- The floor plate forms the posterior lobe of the pituitary gland.

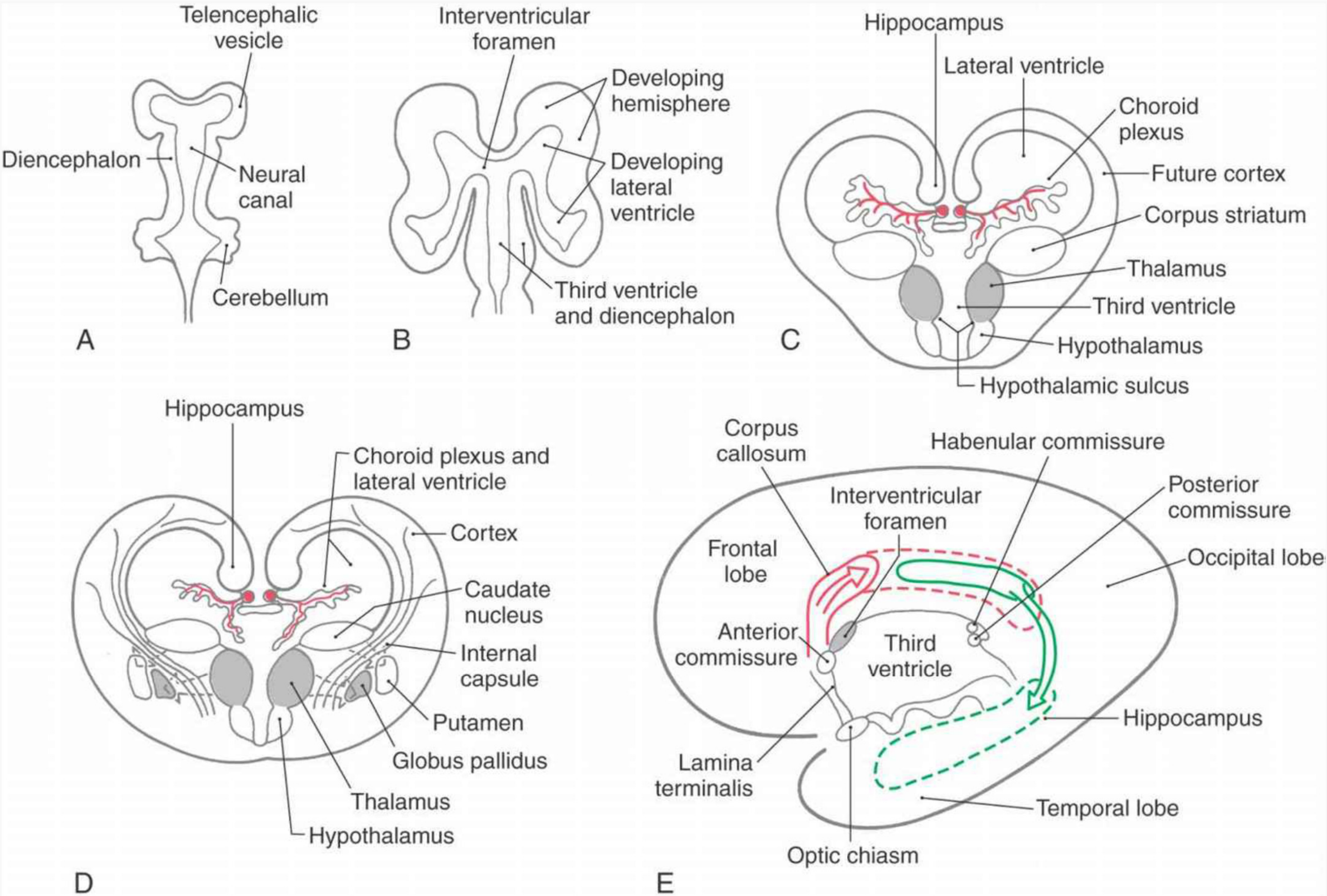


- **Development of the diencephalon**. Lateral (A) and midsagittal (B) views of the forebrain at about 8 to 9 weeks of gestational age. The cross-sectional views (C, D) are taken from the planes shown in B and emphasize diencephalic structures.

Development of the telencephalon



- The 2 cerebral hemispheres arise as 2 evaginations from the lateral wall of the forebrain.
- The cavity of each of them expands to form the lateral ventricle.
- The wall of the hemisphere consists of 3 layers: ependymal, mantle & marginal.
- The mantle layer at the base of the hemisphere forms the basal ganglia.
- The hemispheres enlarge & overlaps the brain stem & cerebellum.



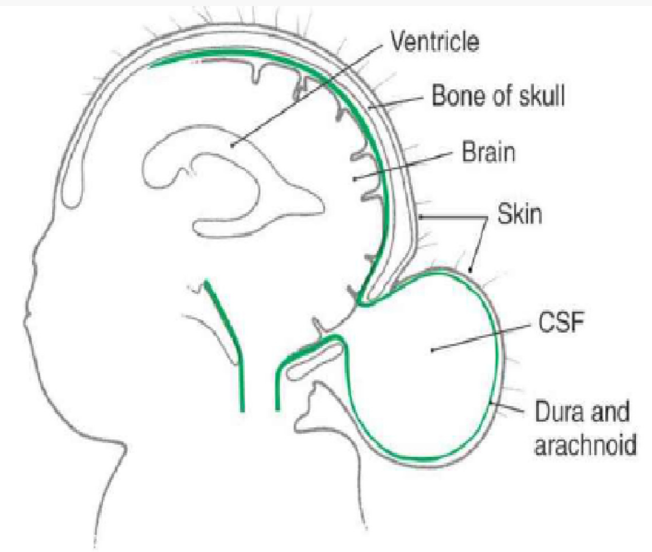
- **Development of the telencephalon**. Enlargement of the ventricles is shown in longitudinal view (A, B), differentiation of the basal nuclei and internal capsule in cross section (C, D), and growth of the corpus callosum (in red) and hippocampus (in green) in the sagittal plane (E).

Congenital Malformations of brain development

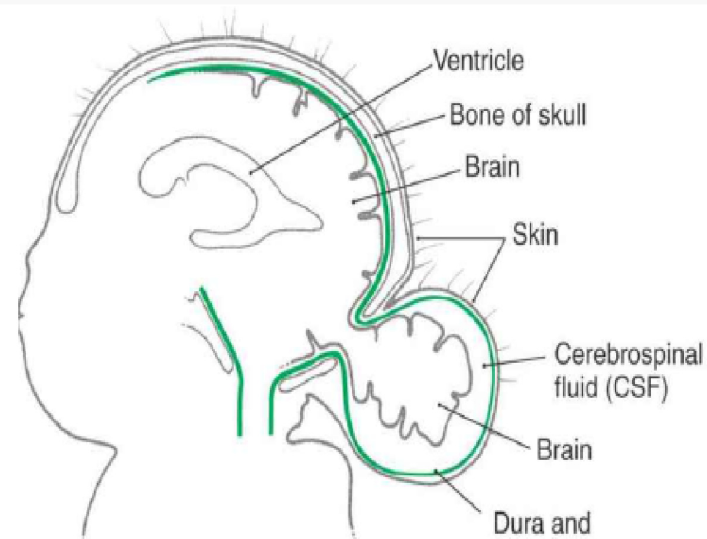
- **Hydrocephalus:**
  - **Internal hydrocephalus**: Excessive accumulation of CSF within the ventricles of the brain.
  - **External hydrocephalus**: Excessive accumulation of the CSF between the brain & arachnoid mater.
- **Exencephaly**: It is due to failure of closure of anterior neuropore. The vault of the skull is absent & the brain is exposed. When the brain is degenerated the anaomaly is known as Anencephaly.


Congenital Malformations of brain development

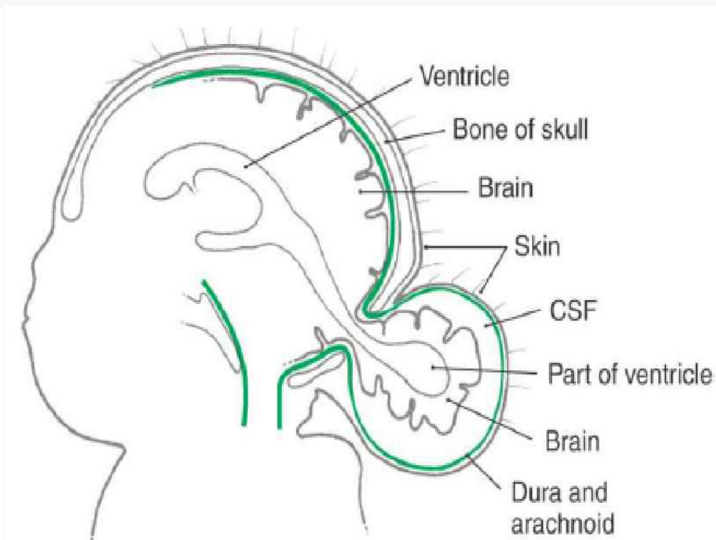
- **Menigocele**: the meninges herniated through a deficient part of the skull.
- **Meningoencephalocele**: part of the brain herniated through the meningocele.
- **Meningo-hydro-enecephalocele**: part of the ventricle is found within the brain tissue which herniated through the meningocele.



Meningocele



Meningoencephalocele



Meningohydroencephalocele

Congenital Malformations of brain development

- **Holoprosencephaly**: Results from degeneration of midline structures leading to fusion of lateral ventricles, orbital & nasal cavities.
- **Microcephaly**: due to poor growth of the brain, is frequently associated with mental retardation.