Development of Spinal Cord
&
Vertebral Column

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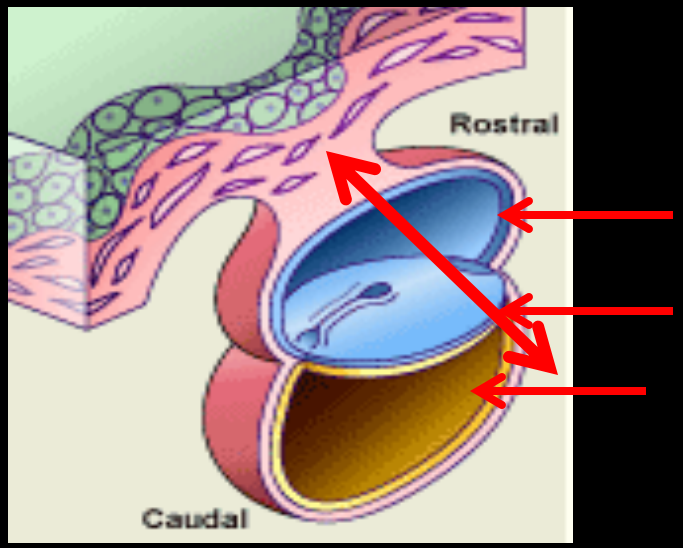
OBJECTIVES

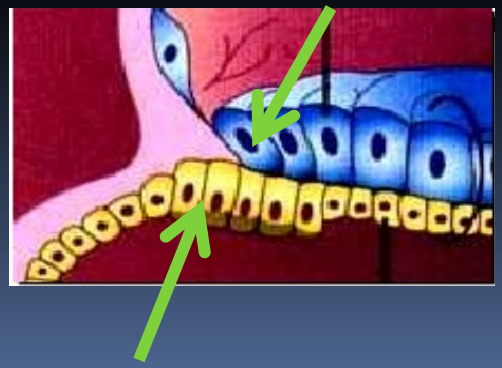
At the end of the lecture, students should be able to:

- Describe the development of the spinal cord from the neural tube.
- List the layers of the spinal cord and its contents.
- List subdivisions of mantle & marginal zones.
- List meningeal layers and describe positional changes of spinal cord.
- Describe development of vertebral column from sclerotomic portion of paraxial mesoderm.
- Describe chondrification & ossification stages in vertebral development.
- Describe spina bifida and its types.

Second Week

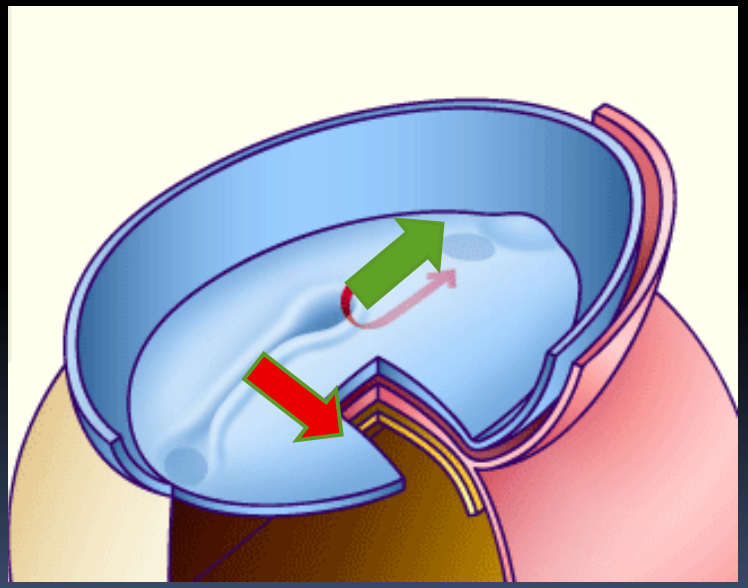
- Epiblast
- Hypoblast
- Amniotic cavity
- Yolk sac cavity





Third Week

- Primitive node
- Primitive streak
- Intra embryomic mesoderm
- Notochord

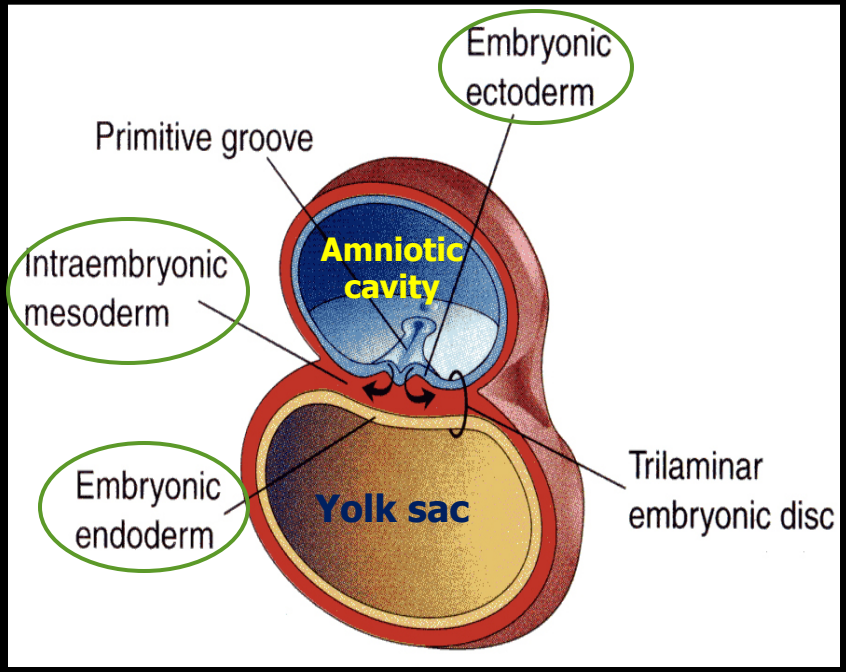


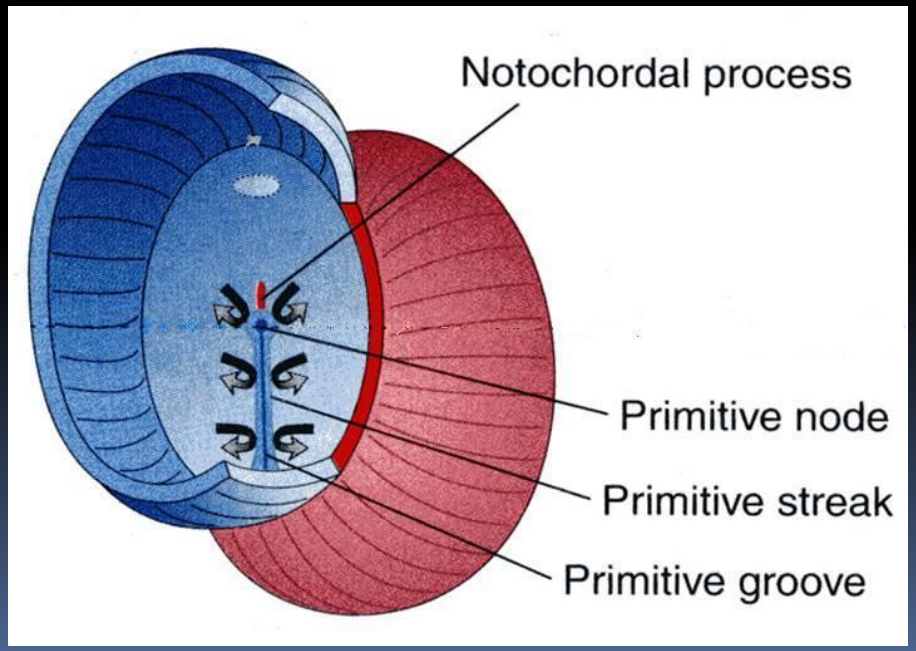
The Three Germ Layers

- Ectoderm
- Mesoderm
- Endoderm

Notochord stimulates neural tube formation which in turn stimulates development of the vertebral column.

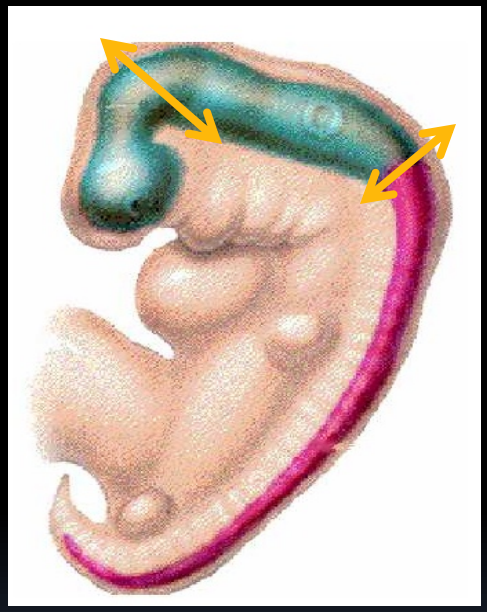
The Neural Tube is a derivative of the ectoderm





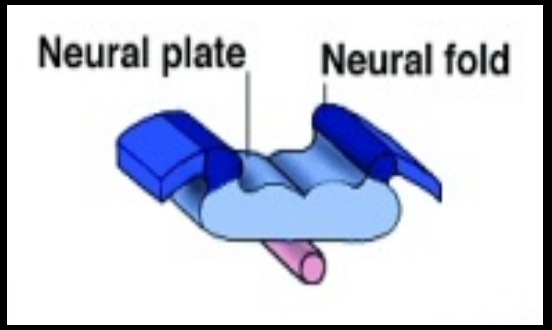
Neural Tube

- Arises from the ectoderm overlying the notochord
- Gives rise to the brain and the spinal cord
- Cervical flexure
- Cephalic flexure

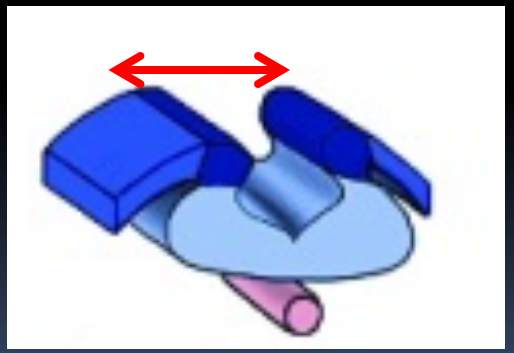


Neural Tube Formation

- The notochord induces the ectoderm above it which thickens to form the neural plate



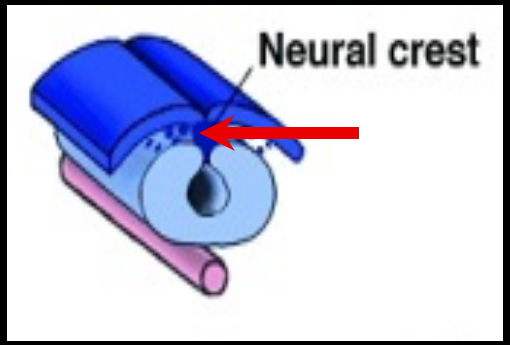
- The neural plate folds to form neural groove with prominent neural folds



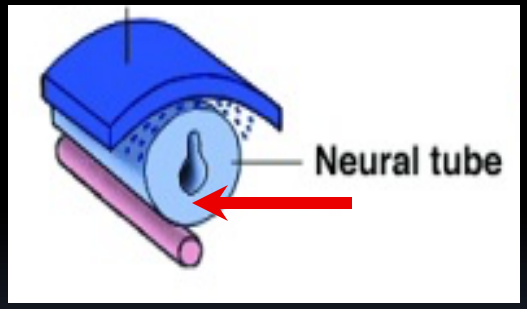
- The neural folds approaches each others with deepening of the neural groove

Neural Tube Formation

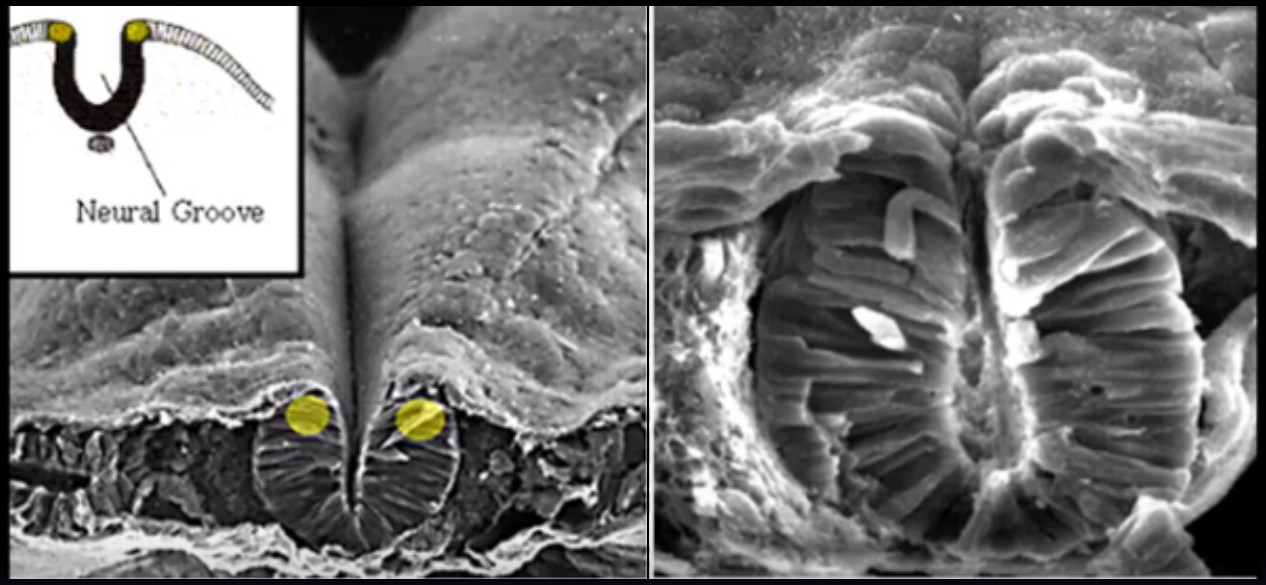
- The neural folds fuse and a neural tube is formed

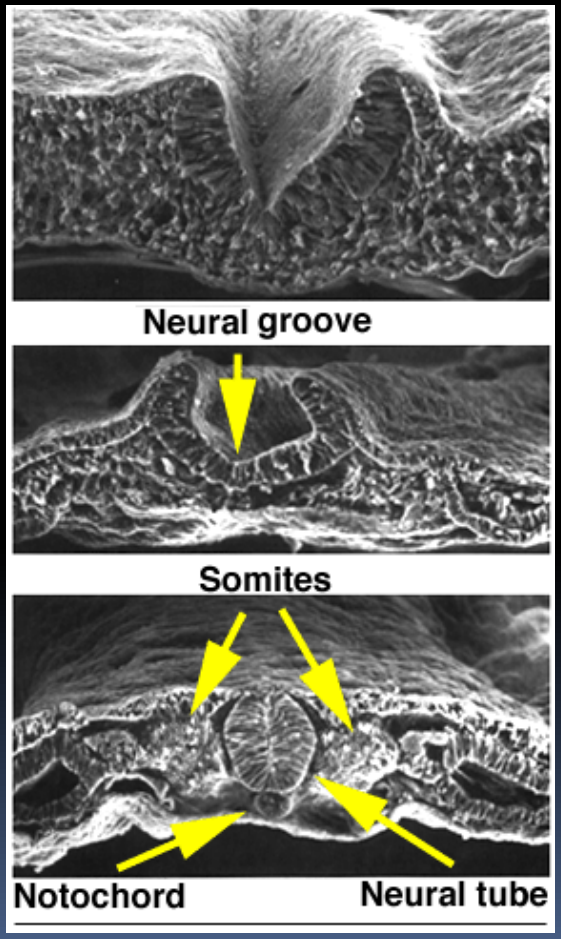


- The tube then separates from the overlying ectoderm



Neural Tube Formation





Neural Tube Closure

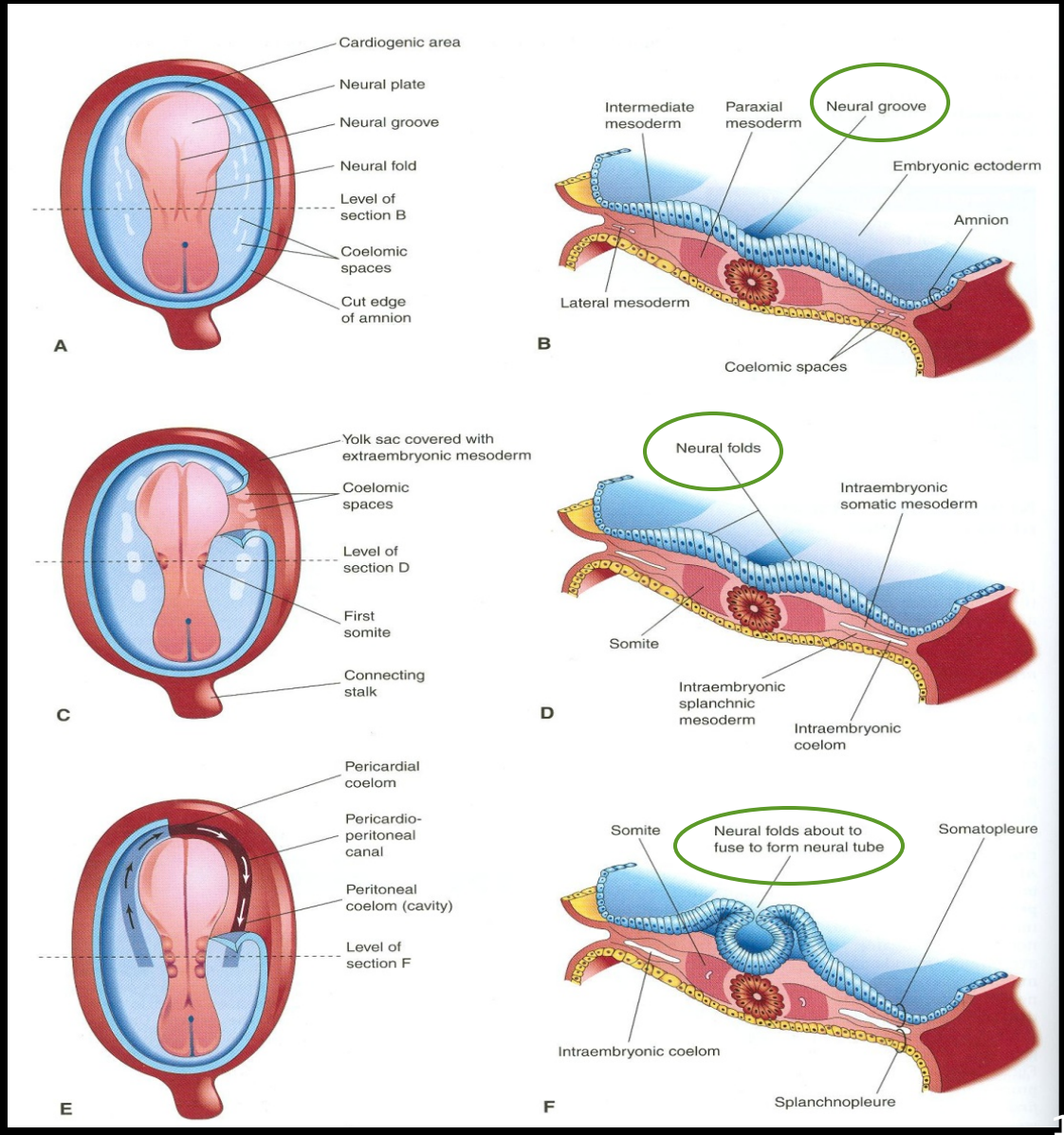
- Closer of the neural tube begins in the future neck region (4^{th} somite)
- Then proceeds cranially and caudally

Neural Tube Closure

- The most cranial and caudal ends of the tubes still open as
- Anterior neuropores
- Posterior neuropores
- The anterior pore will close at day 25 ⟶ lamina terminalis
- The posterior pore closes at day 27
- The lumen of the tube ⟶ ventricles of the brain and central canal of spinal cord

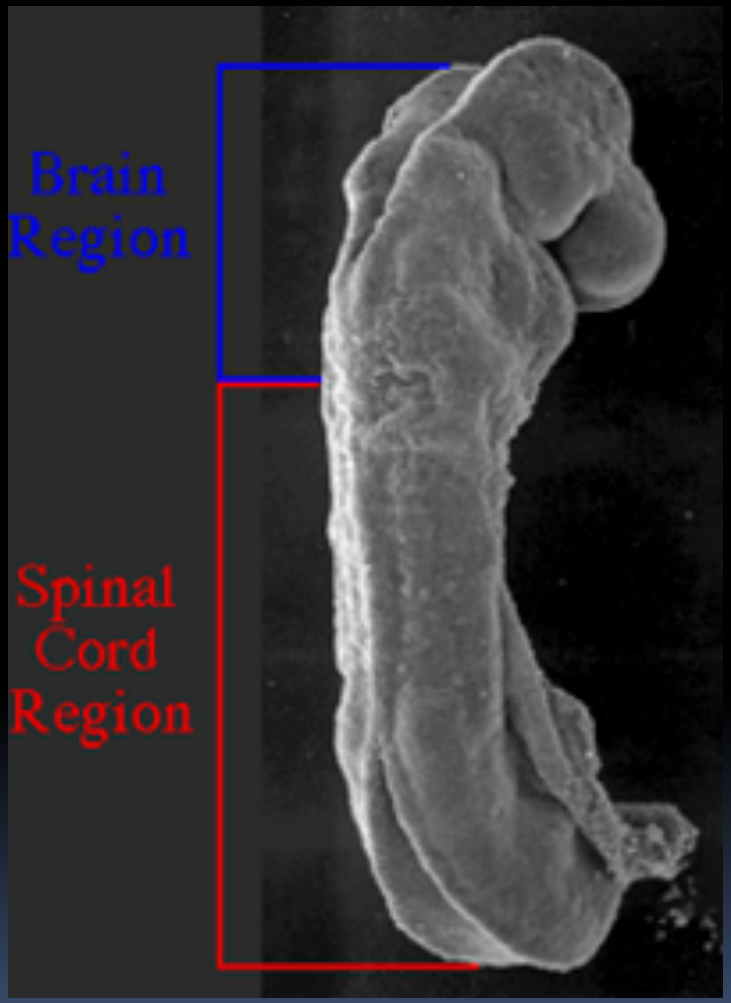
Development of Neural Tube

- Ectodermal cells dorsal to notochord thicken to form the **neural plate.**
- A longitudinal groove, **neural groove,** develops in the neural plate.
- The margins of the neural plate **(neural folds)** approach to each other and **fuse** to **form the neural tube.**



Development of the Spinal Cord

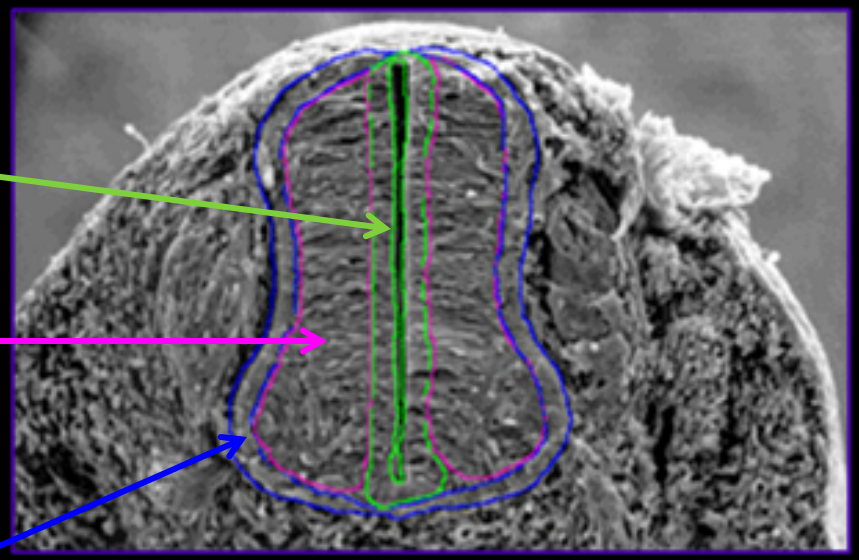
- The spinal cord develops from the caudal 2/3 of the neural tube



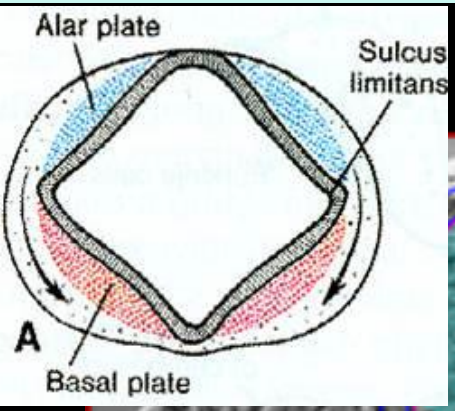
Layers of the spinal cord :

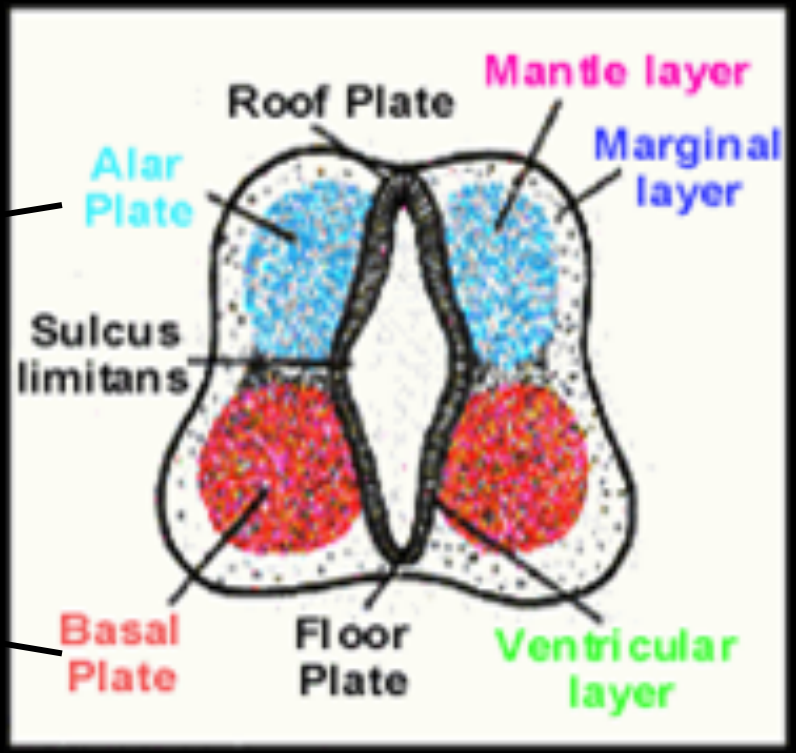
The cells of the neural tube are arranged in three layers :

- An inner ventricular zone of undifferentiated cells
- A middle mantle zone of **cell bodies** of **neurons** (future grey matter)
- An outer marginal zone of **nerve fibers** or **axons** of neurons (future white matter)



Development of the Spinal Cord (Mantle Layer)

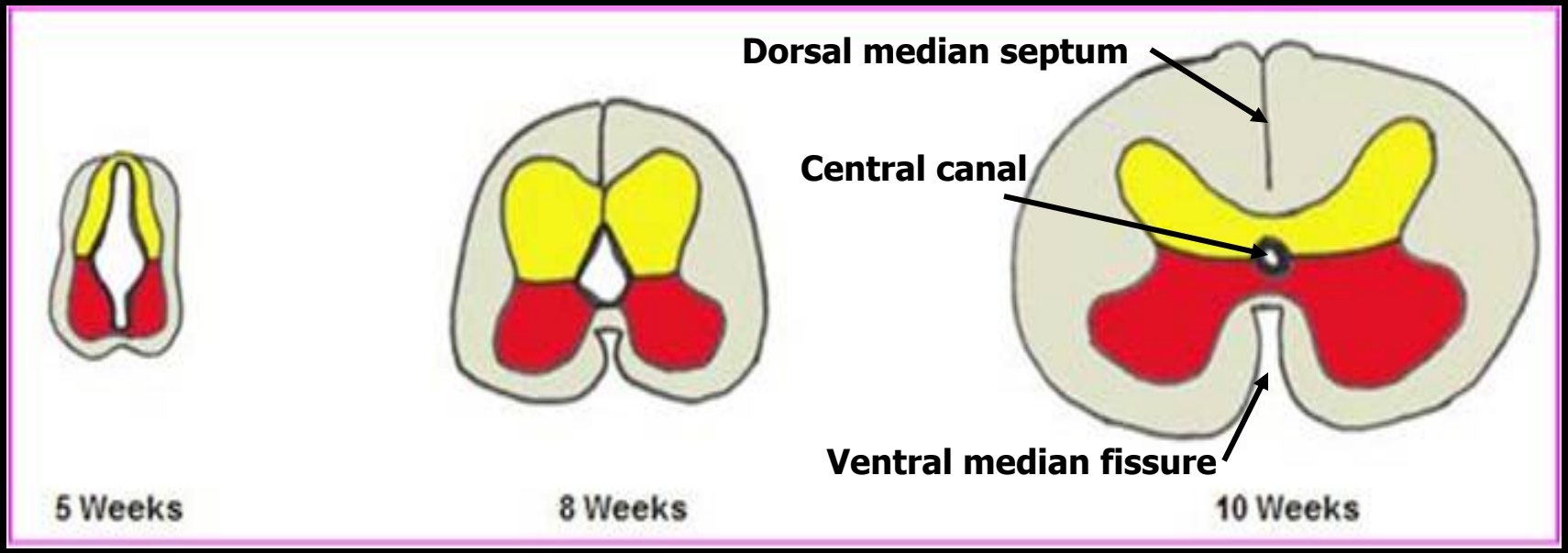




Neurons of mantle layer (future grey matter) differentiate into :

1. A dorsal alar plate (future dorsal horn): containing sensory neurons
2. A ventral basal plate (future ventral horn): containing motor neurons

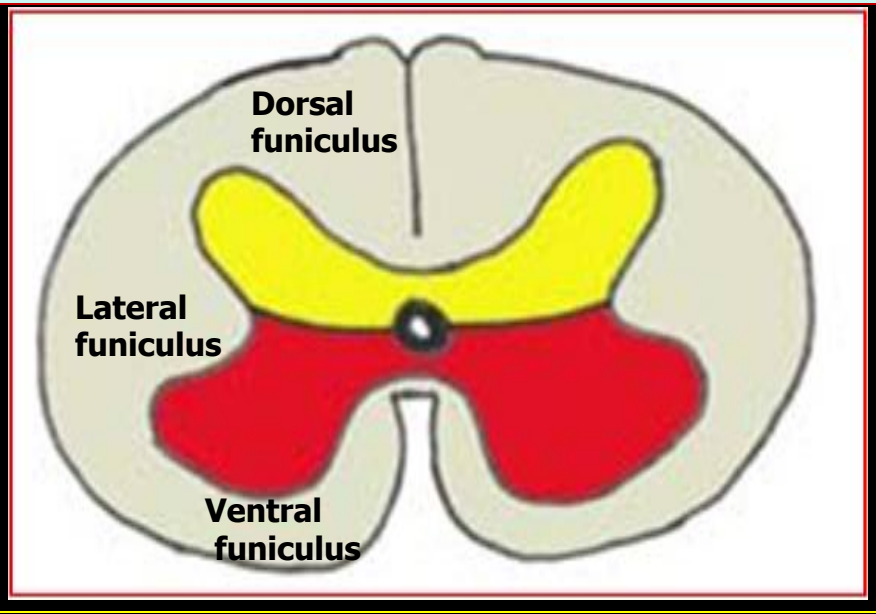
The 2 areas are separated by a (sulcus limitans).



Proliferation and bulging of both alar & basal plates result in:

- Formation of dorsal median septum
- Formation of ventral median fissure
- Narrowing of the lumen of the neural tube to form a small central canal

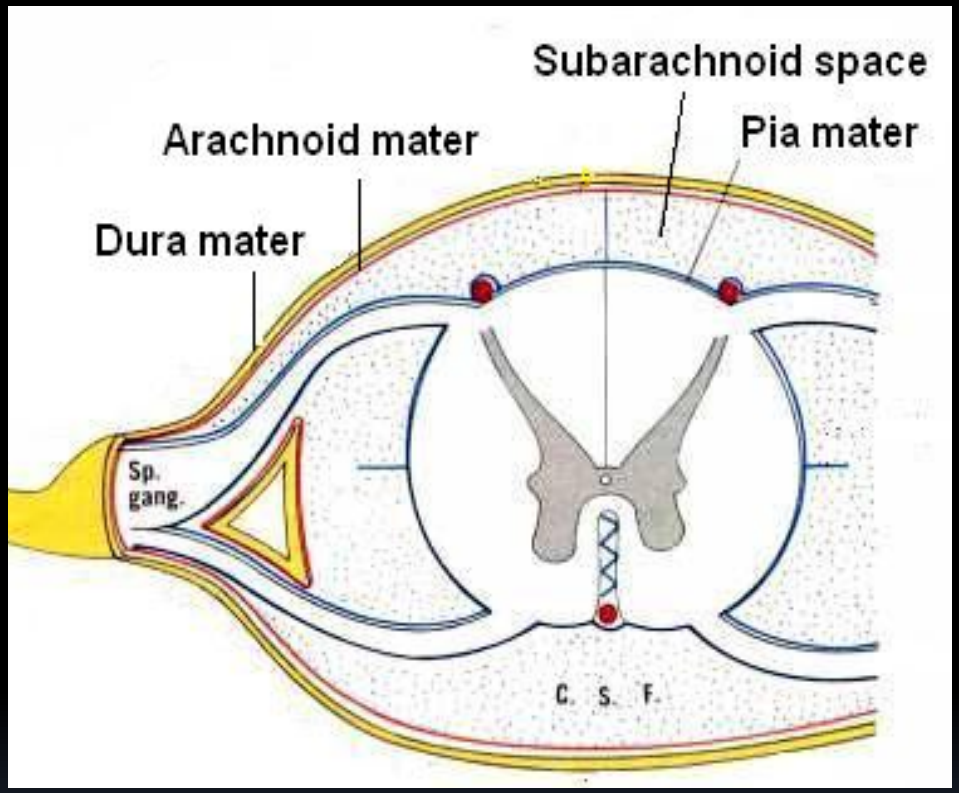
Development of the Spinal Cord (Marginal Layer)



- The marginal layer (future white matter) increases in size due to addition of ascending, descending & intersegmental nerve fibers & is divided into : dorsal, lateral and ventral funiculi
- Myelination of nerve fibers starts at 4th month & continues during the 1st postnatal year. Motor fibers myelinate before sensory fibers. So, After a nerve injury, both motor and sensory axons have the ability to regenerate and, given a proper pathway.

Meninges

- These are **3 membranes covering the neural tube:**
- Outer thick **dura mater: MESODERMAL in origin**
- Middle **arachnoid mater & Inner thin pia mater are ECTODERMAL in origin**

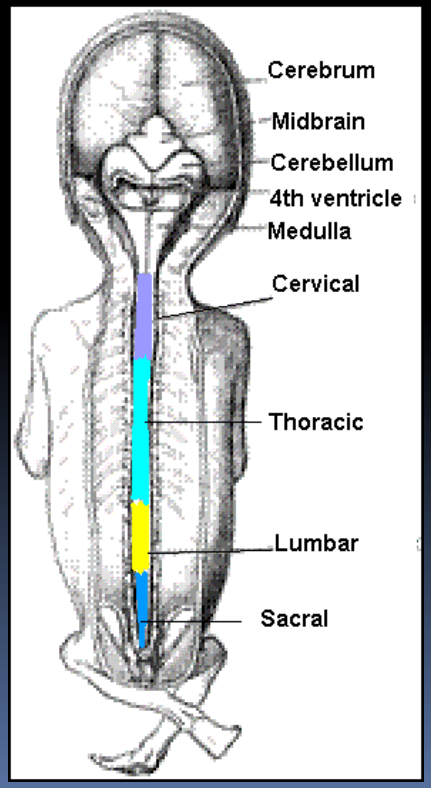


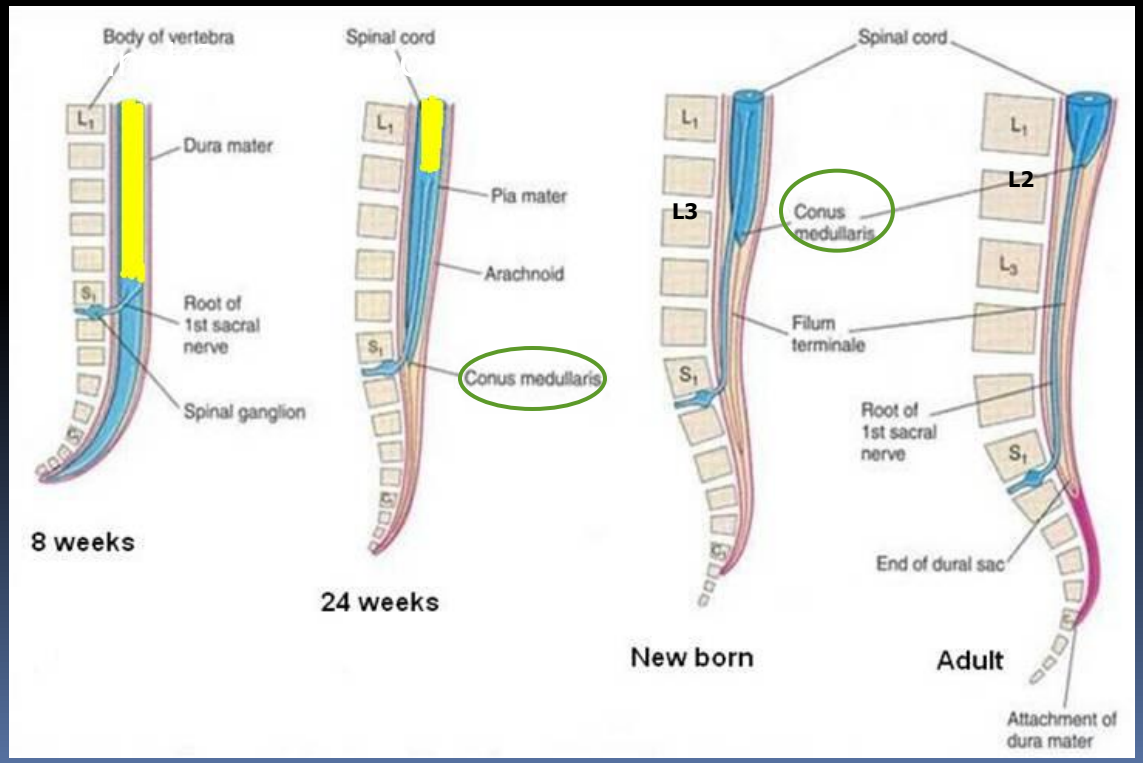
- A cavity appears between the arachnoid & the pia mater (subarachnoid space) & becomes filled with cerebrospinal fluid (CSF).

Positional Changes of Spinal Cord

- Initially, the spinal cord occupies the whole length of the vertebral canal.

- As a result a **faster growth** of **vertebral column**, the caudal end of spinal cord (conus medullaris) shifts gradually to a higher level.



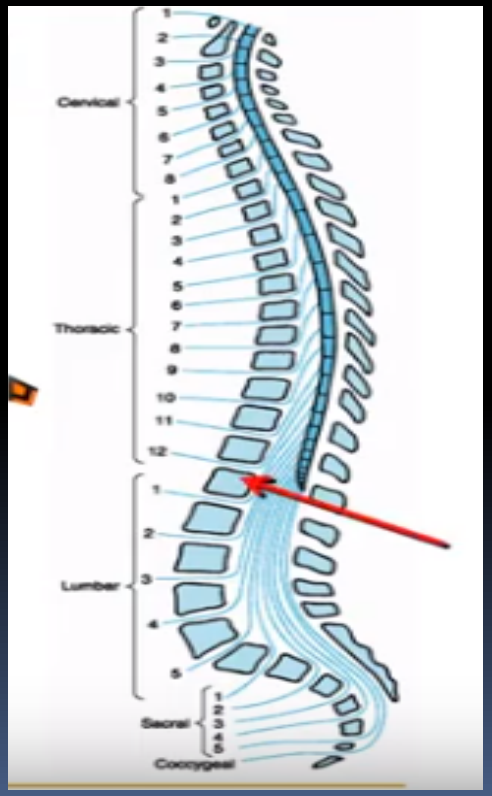


Spinal Cord Positioning

@ 3rd month → same length as vertebral canal

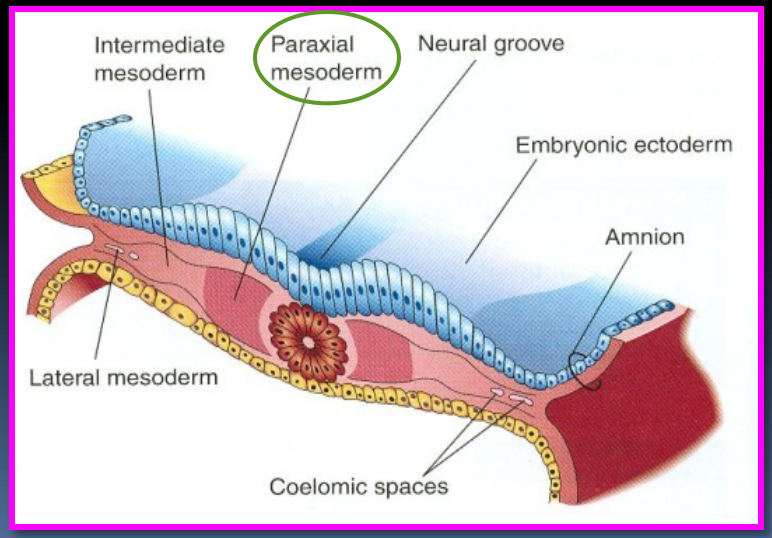
@ birth → spinal cord terminates at 3rd lumbar vertebra

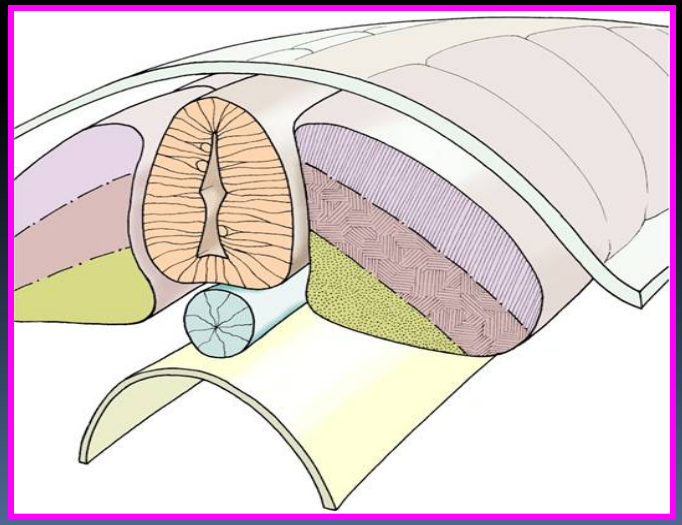
@ adult → spinal cord terminates at L1



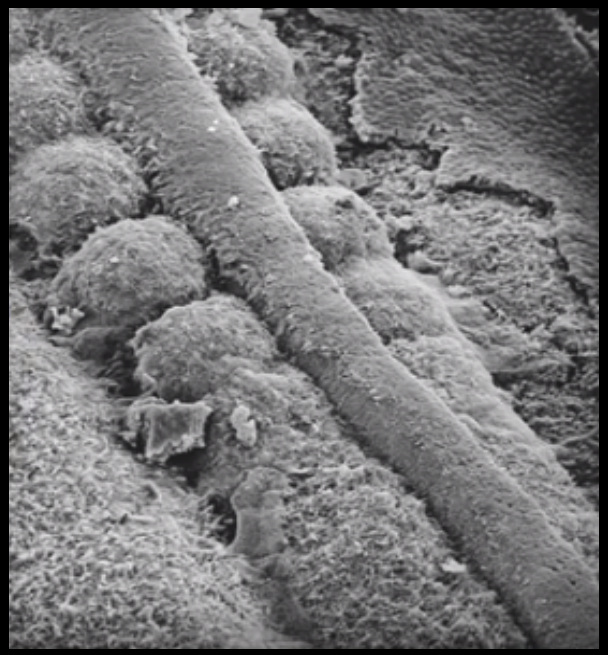
Development of the Vertebral Column

- The vertebral column develops from the ventromedial parts (sclerotomes) of the somites
- The somites develop from the para-axial mesoderm.





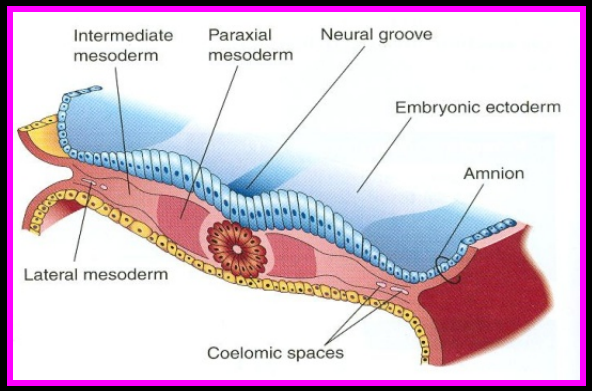
Specialization of Mesoderm



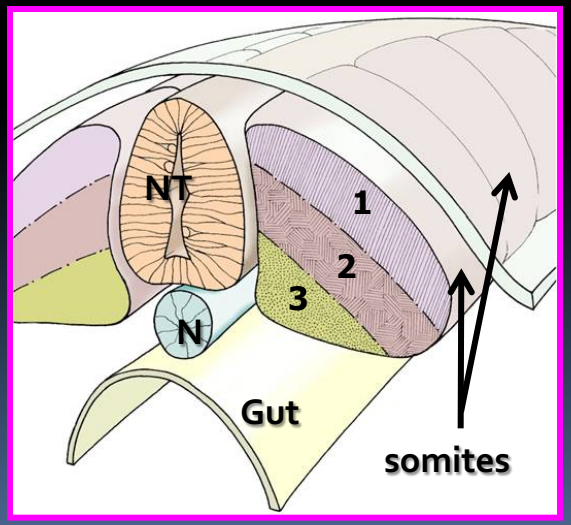
- Appearance of the notochord (first sign)
- Three collections of the mesoderm appear lateral to the notochord
- Somites
- Intermediate mesoderm
- Double sheets of lateral plate mesoderm

Intraembryonic Mesoderm

- Located between Ectoderm & Endoderm EXCEPT in the central axis of embryo where NOTOCHORD is found.
- Differentiates into 3 parts:
  1. Paraxial mesoderm
  2. Intermediate mesoderm
  3. Lateral mesoderm

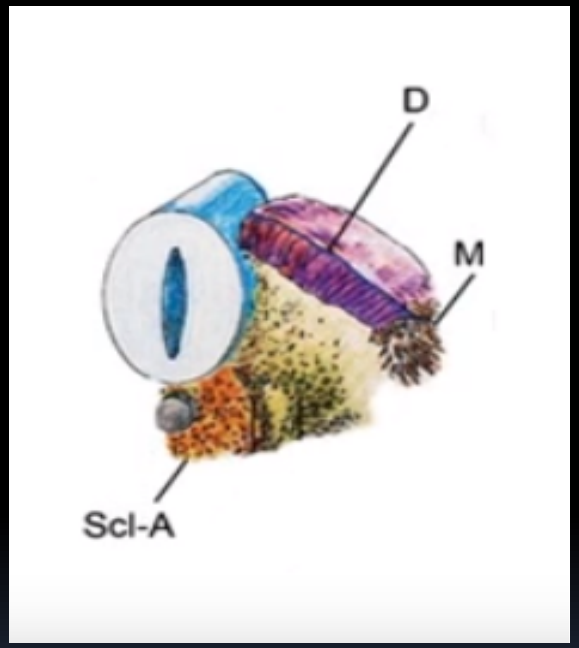


- Paraxial mesoderm divides into segments called 'somites'.
- Each somite divides into 3 parts:
  1. Dermatome
  2. Myotome
  3. Sclerotome



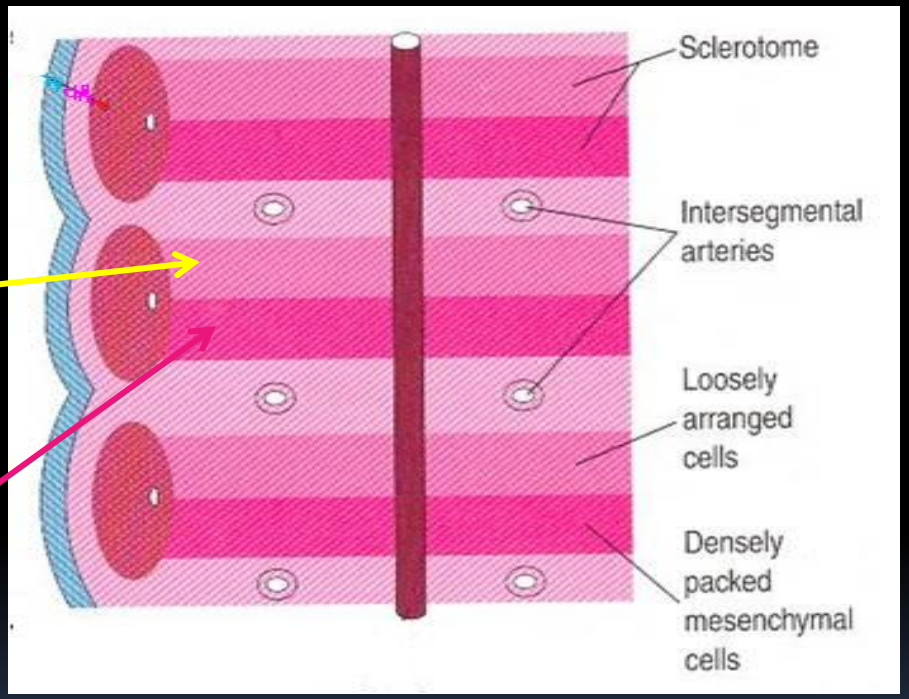
Specialization of Mesoderm

- Each one of somites divide into 3 parts:
- Sclerotome: form the vertebrae & ribs
- Dermatome: forms the dermis of the skin on the dorsal part of the body
- Myotome: forms the skeletal muscles of the neck, trunk & limbs



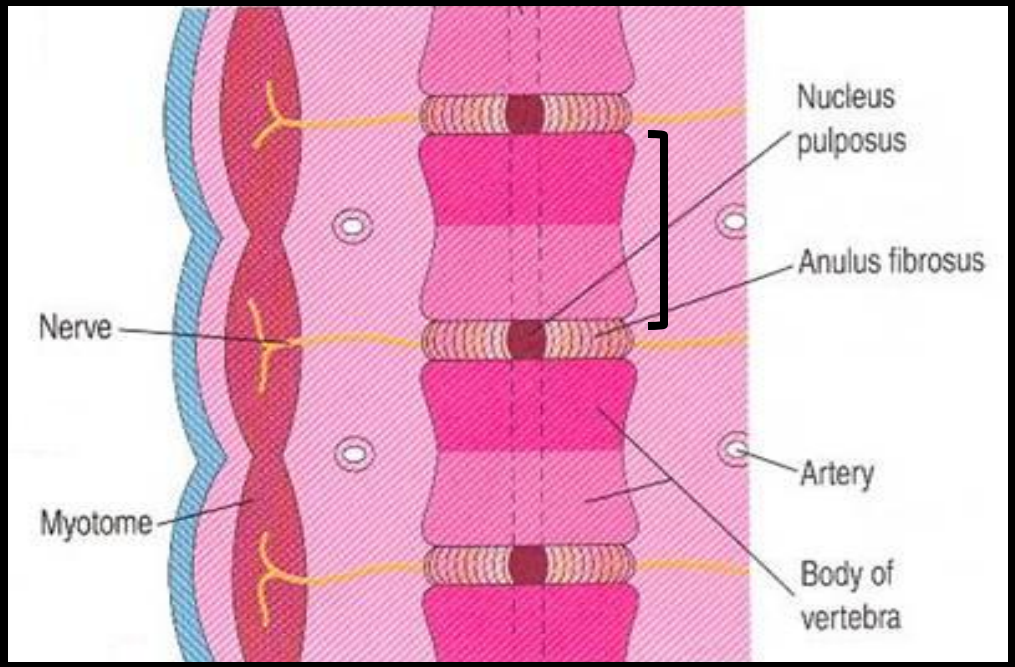
Formation of Body of Vertebra

- At 4th week, **each sclerotome** becomes **subvidided** into two parts :
  - an cranial part, consisting of loosely arranged cells
  - a caudal part, of more condensed tissue.



Formation of Body of Vertebra

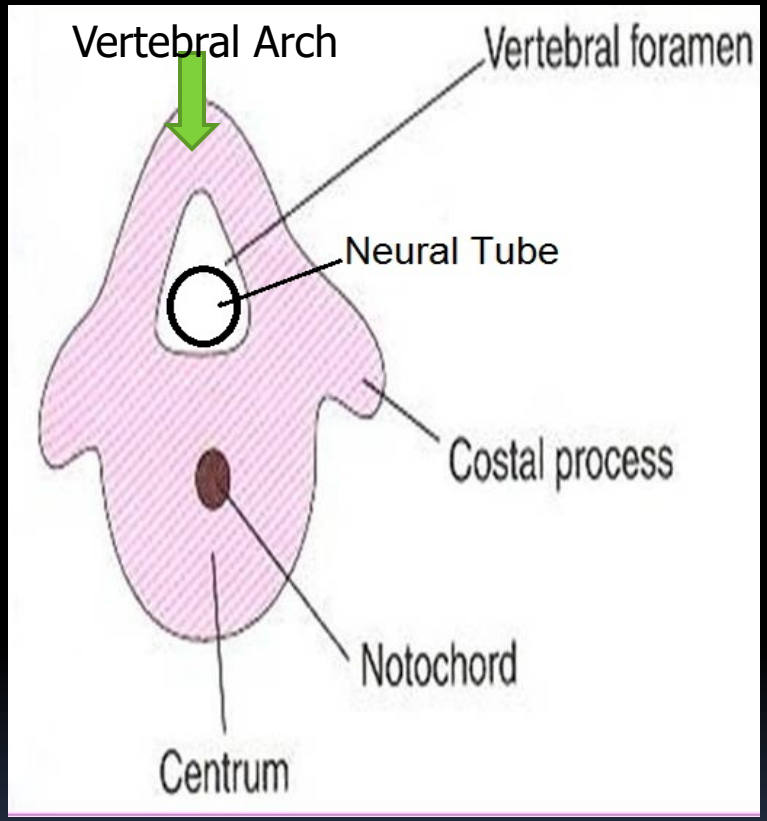
- The caudal part of each somite fuses with the cranial part of the consecutive somite, around the notochord to form the body of the vertebra, called **the centrum.**



Thus each centrum develops from 2 adjacent sclerotomes

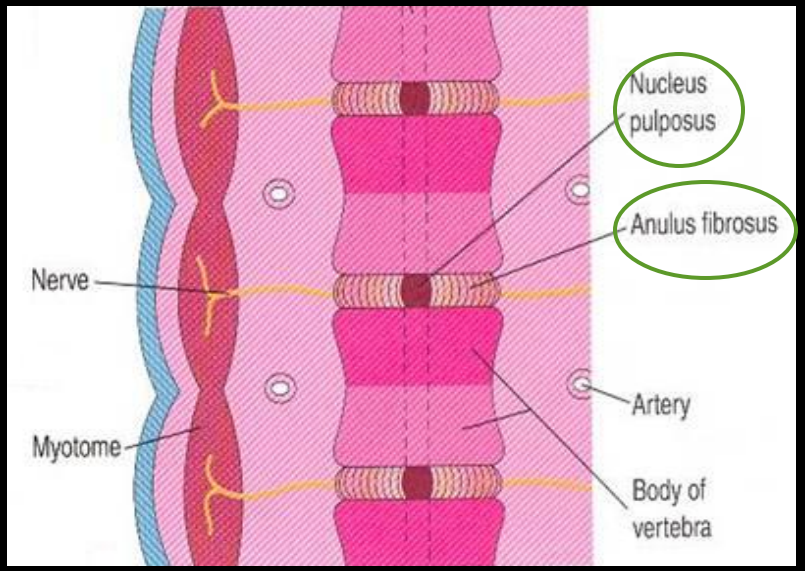
Thus the bodies of the vertebrae are intersegmental in origion

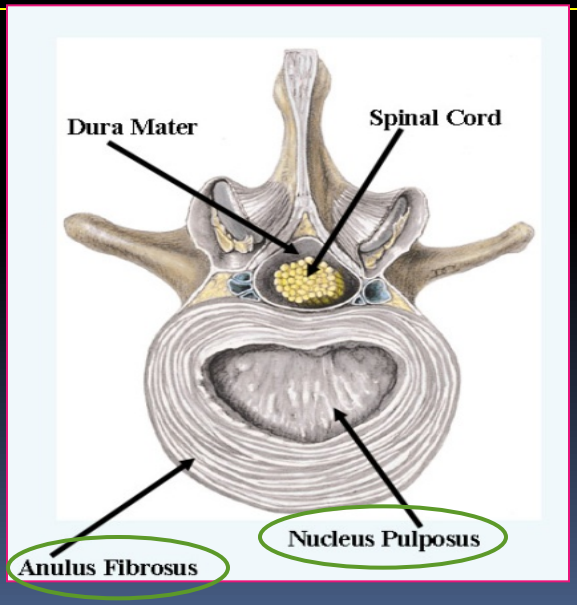
- The fused sclerotomes grow dorsally around the neural tube and form the vertebral (neural) arch.
- Ventrolaterally, costal processes develop that give rise to ribs in thoracic region.



Fate of Notochord

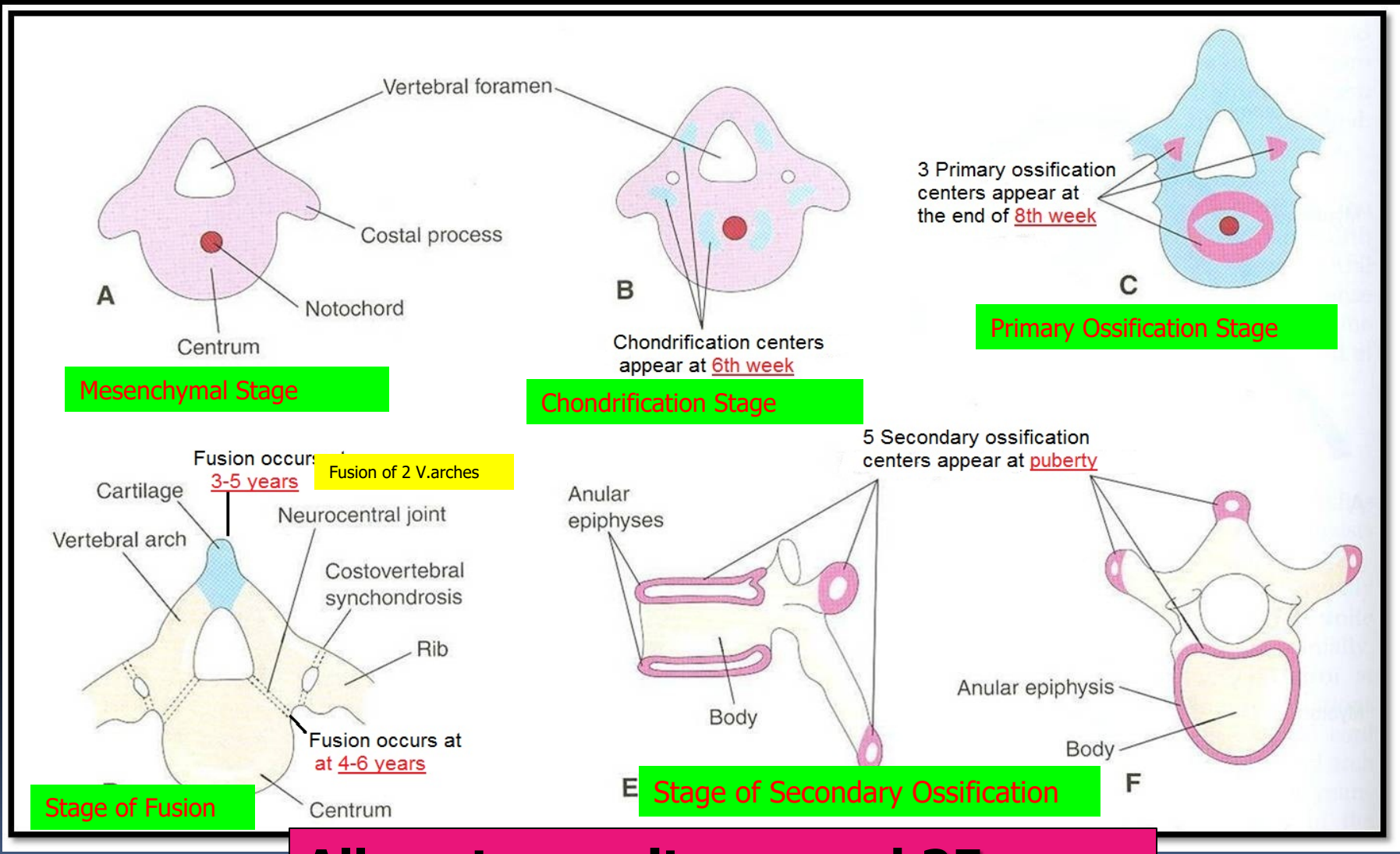
- **In the region of the bodies of vertebrae:** It degenerates
- **Between bodies of vertebrae:** It forms the central part, **'nucleus pulposus'** of the intervertebral discs





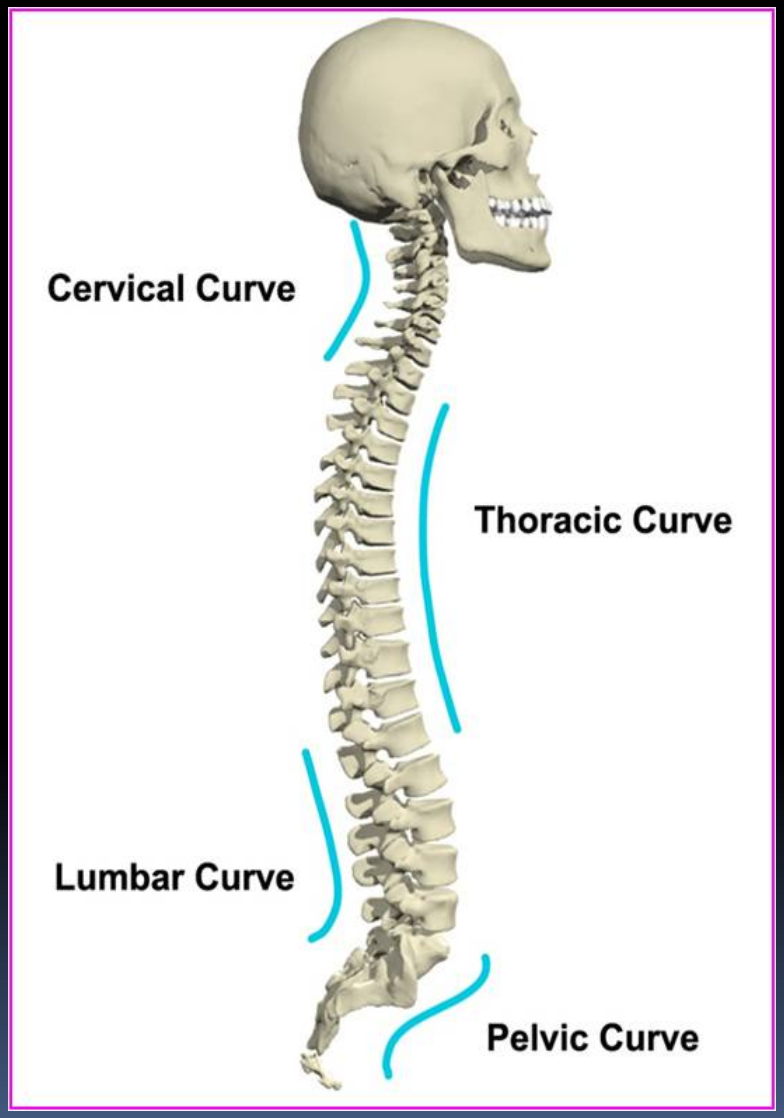
- **Annulus fibrosus** of the intervertebral discs is **formed by the mesoderm** surrounding the notochord.

Vertebral Development



All centers unite around 25 years

Curvatures of Vertebral Column



- **Primary curvatures (concave anterior) : develop prenatally**
  - Thoracic
  - Pelvic or Sacral

- **Secondary curvatures (convex anterior) : develop postnatally**
  - Cervical: concave posteriorly
    -as a result of lifting the head
  - Lumbar: concave posteriorly
    -as a result of walking
    -Help support trunk, upper body

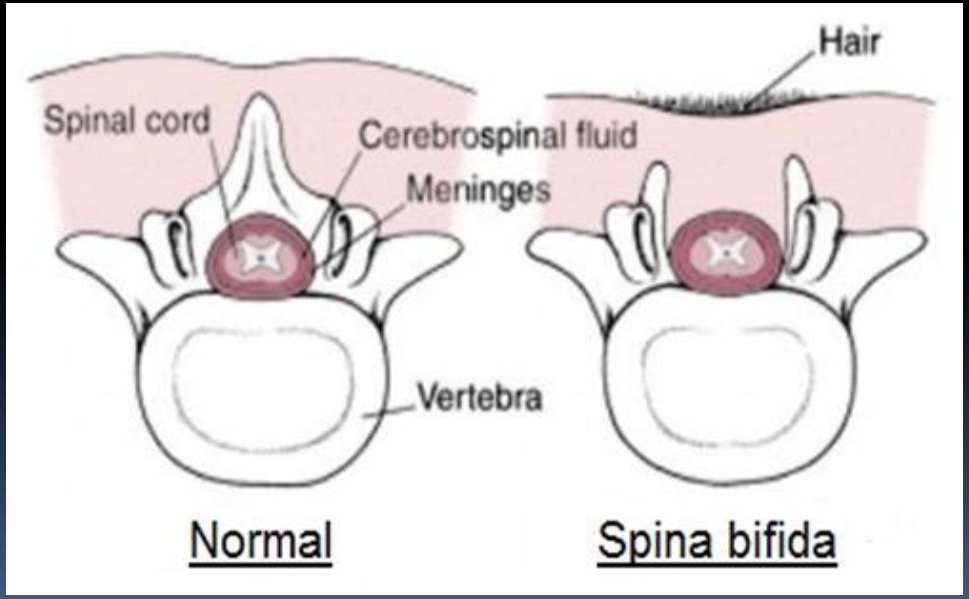
Spinal Cord Anomalies

- Spina Bifida

Failure of fusion of the halves of vertebral arches

Incidence: 0.04 - 0.15% **Sex**: more frequent in females

- *Occulta*
  - Spinal dermal sinus
  - Tethered cord
- *Manifesta*
  - Meningocele
  - Meningomyelocele
  - Myelochisis



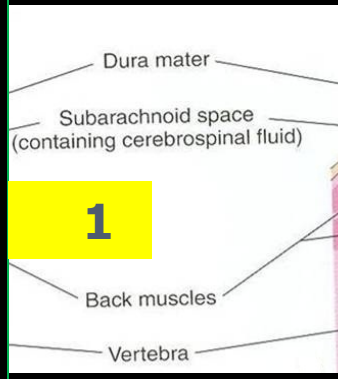
Spina Bifida Occulta

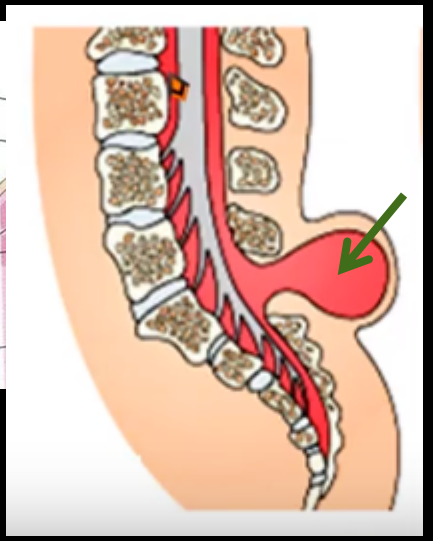
- The closed type
- Only one vertebra is affected
- No clinical symptoms
- Skin overlying it is intact
- Sometimes covered by a tuft of hair
- Usually does not involve underlying neural tissue

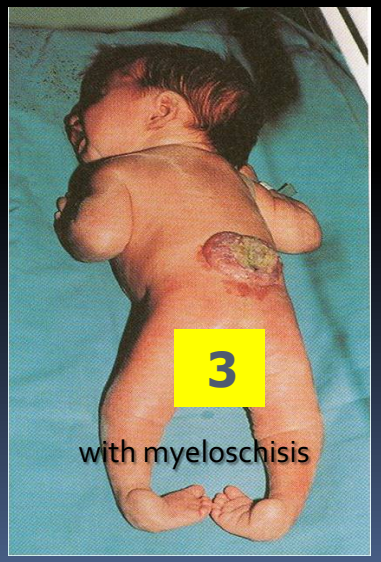
Spina Bifida Cystica

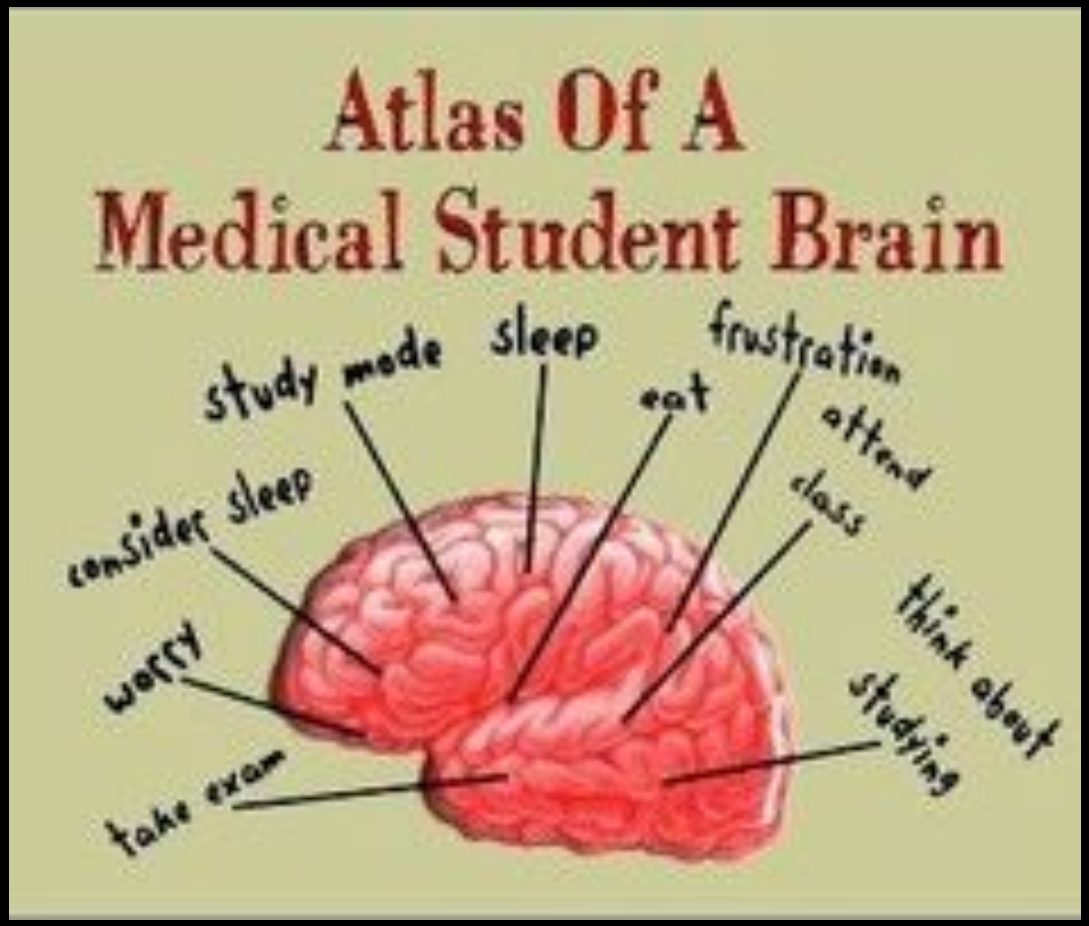
- **The open type**
  - Cystica is the most severe and complex form of spina bifida. It usually involves serious neurological problems. A portion of the nerves and the spinal cord are exposed outside the body
  - Neurological symptoms are present
  - **Subdivided into:**

1. Spina bifida with meningocoele: protrusion of sac containing meninges & cerebrospinal fluid
2. Spina bifida with meningomyelocoele: protrusion of sac containing meninges with spinal cord and/or nerve roots
3. Spina bifida with myeloschisis : spinal cord is open due to failure of neural folds to develop









Welcome back