

Development of Spinal Cord & Vertebral Column

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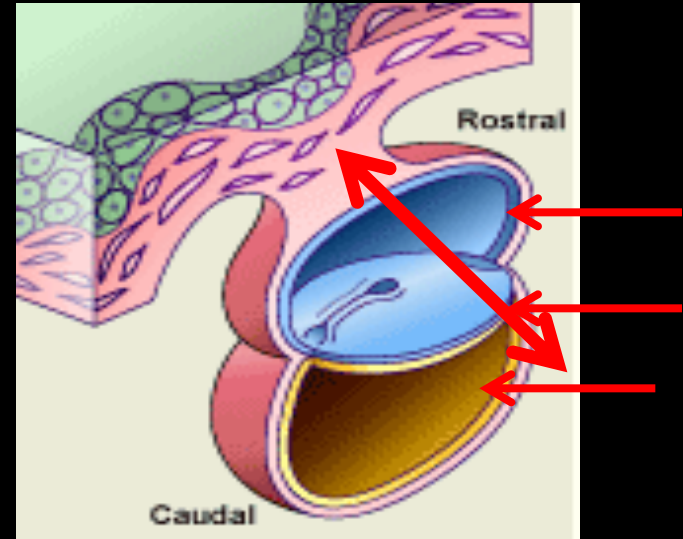
OBJECTIVES

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.

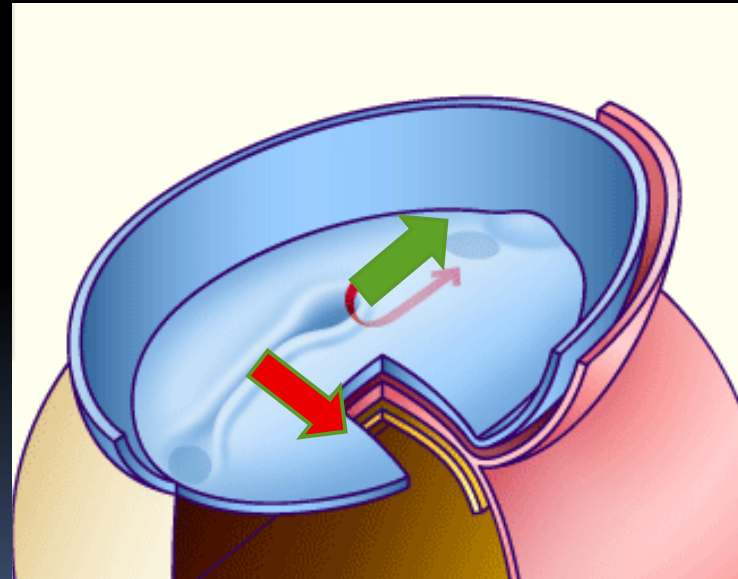
Second Week

- Epiblast
- Hypoblast
- Amniotic cavity
- Yolk sac cavity



Third Week

- Primitive node
- Primitive streak
- Intra embryonic mesoderm
- Notochord

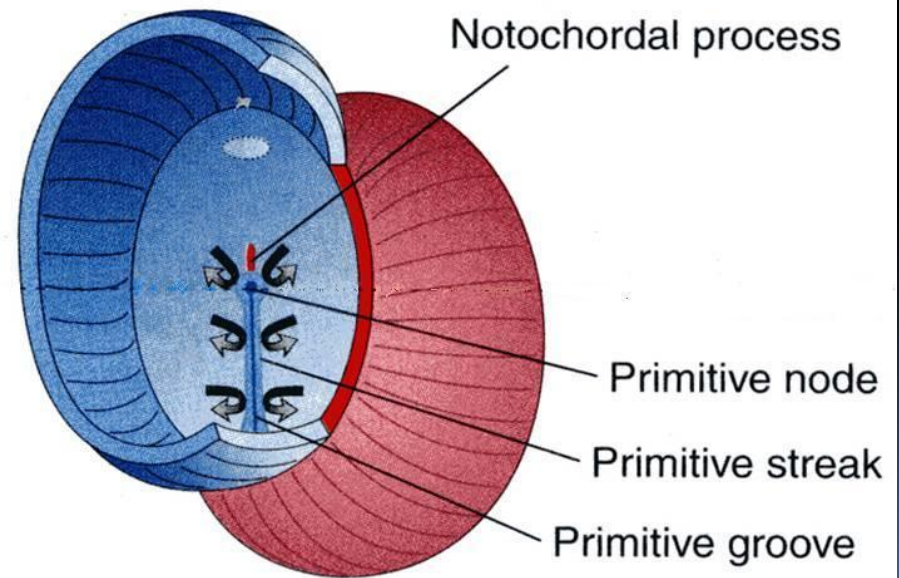
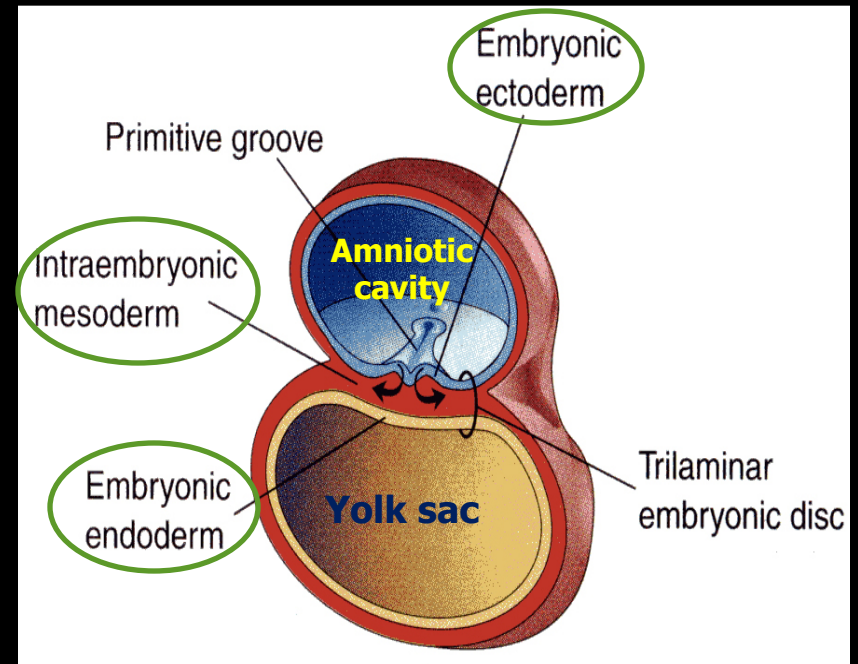


The Three Germ Layers

- Ectoderm
- Mesoderm
- Endoderm

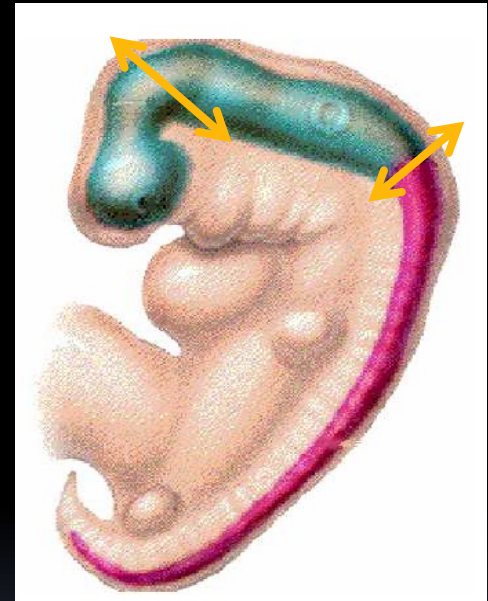
Notochord stimulates neural tube formation which in turn stimulates development of the vertebral column.

The Neural Tube is a derivative of the ectoderm



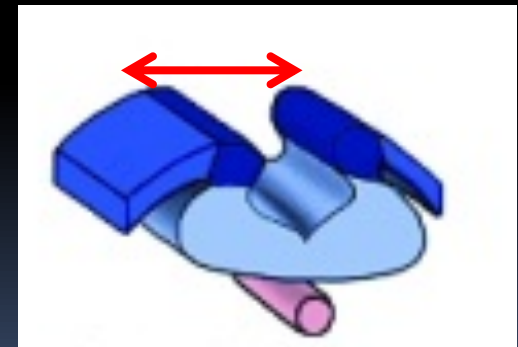
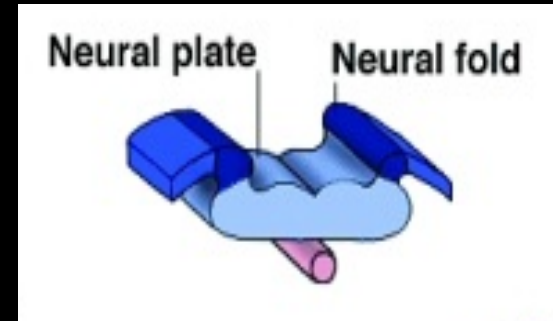
Neural Tube

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



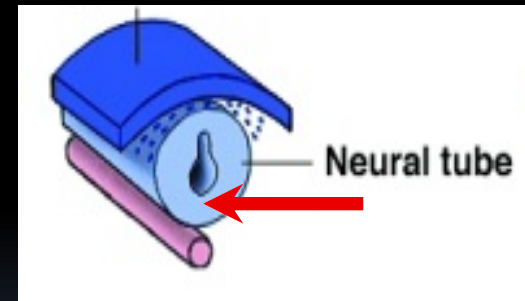
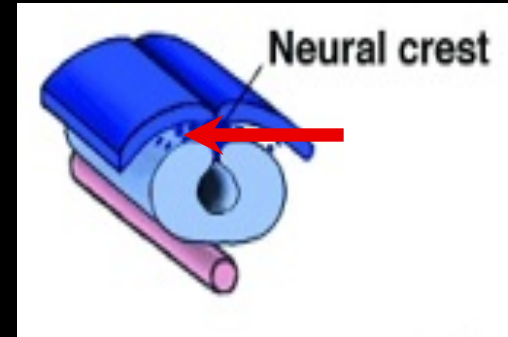
Neural Tube Formation

- 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

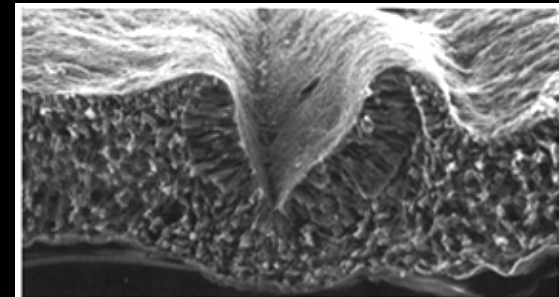
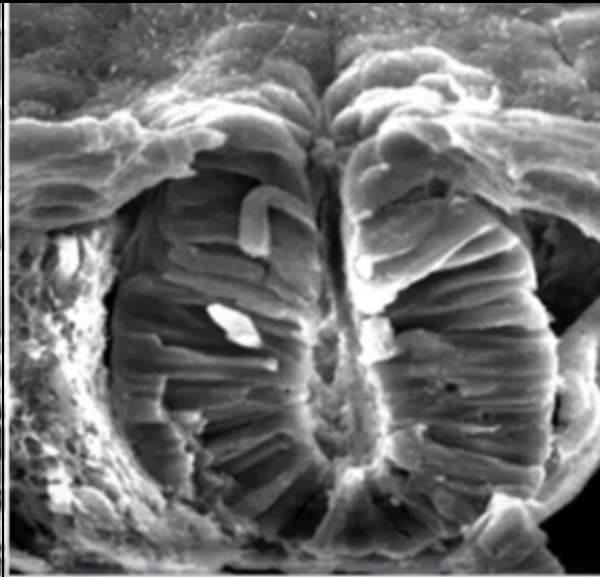
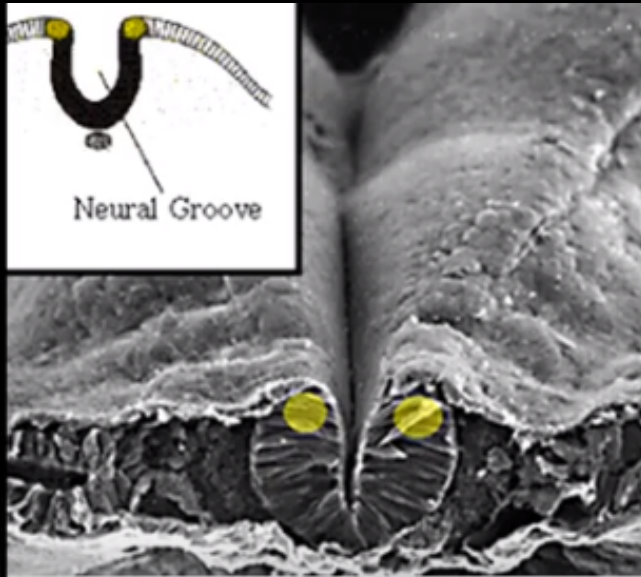
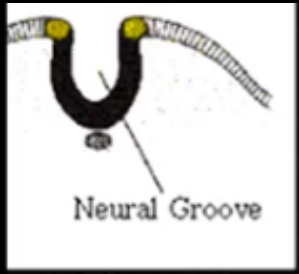


Neural Tube Formation

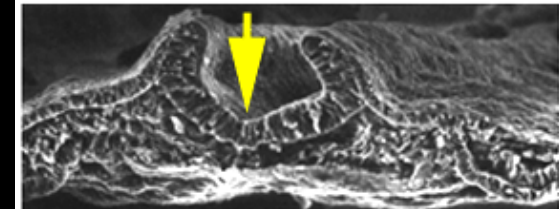
- The neural folds fuse and a **neural tube** is formed
- The tube then separates from the overlying ectoderm



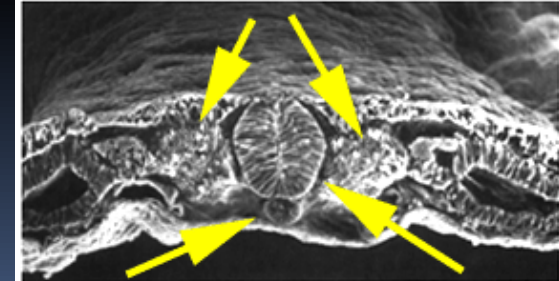
Neural Tube Formation



Neural groove



Somites



Notochord

Neural tube

Neural Tube Closure

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



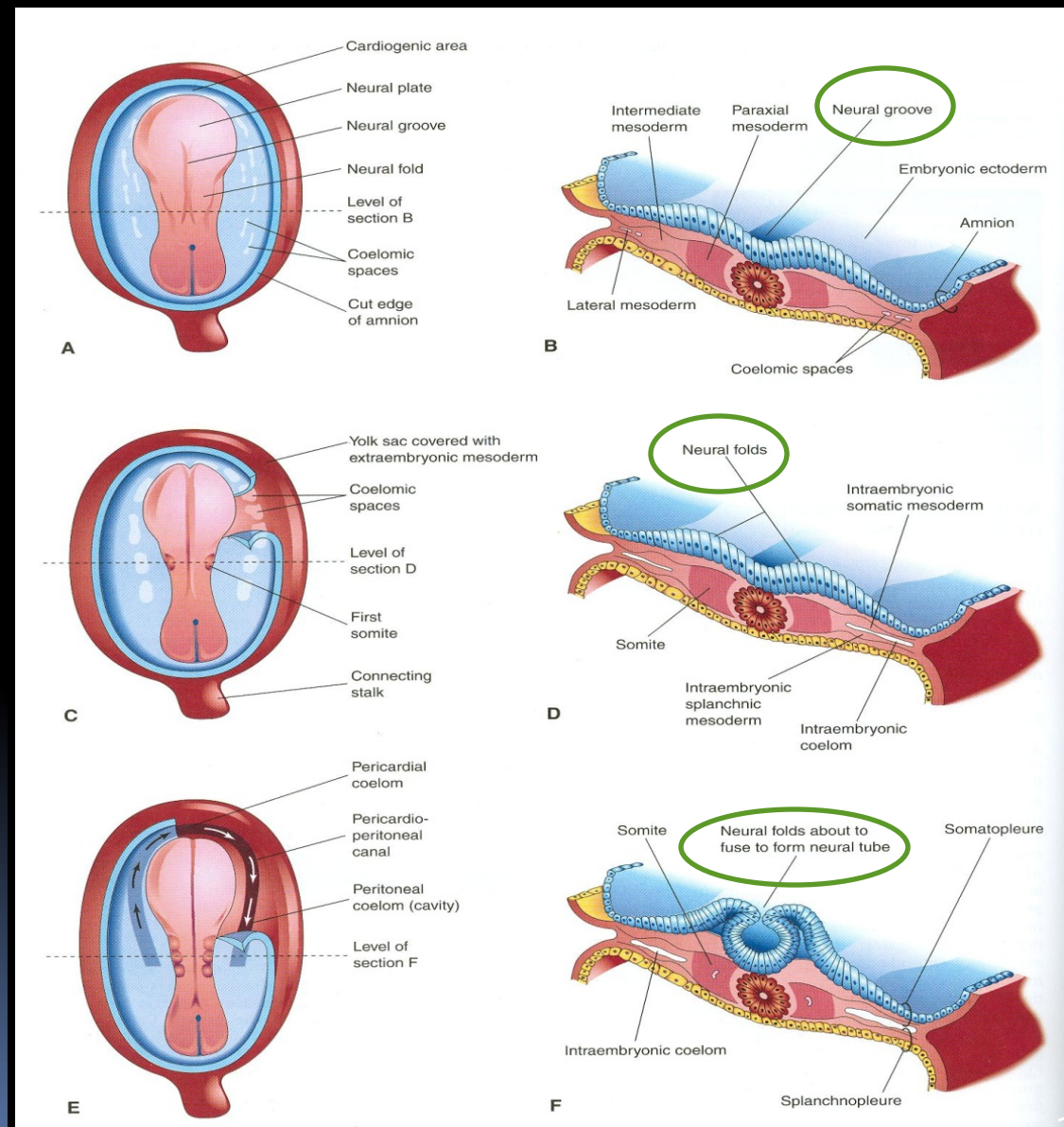
Neural Tube Closure

- 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



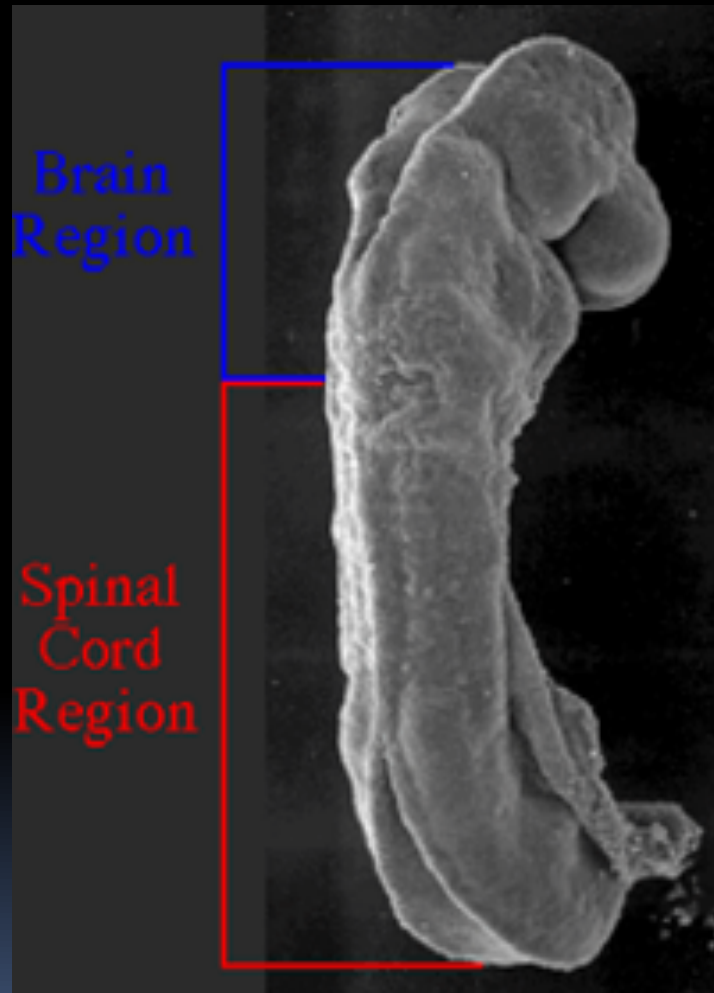
Development of Neural Tube

- 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

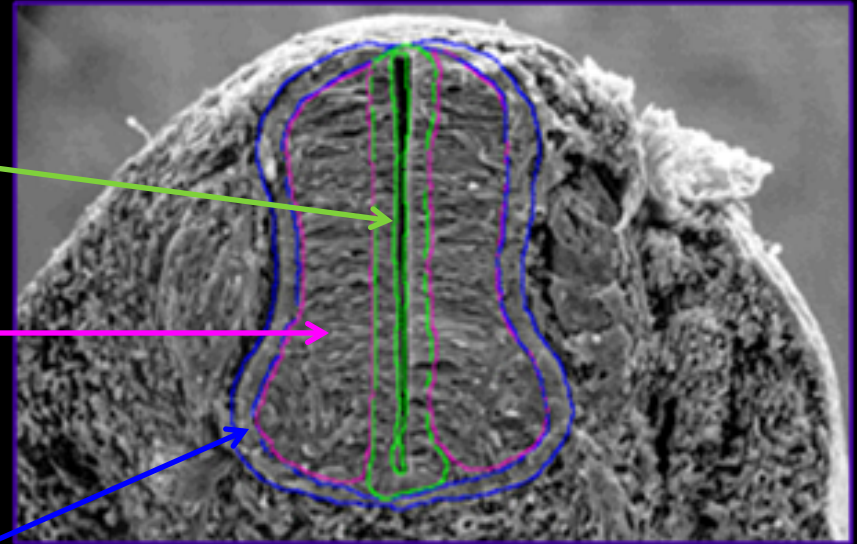
- The spinal cord develops from the caudal 2/3 of the neural tube



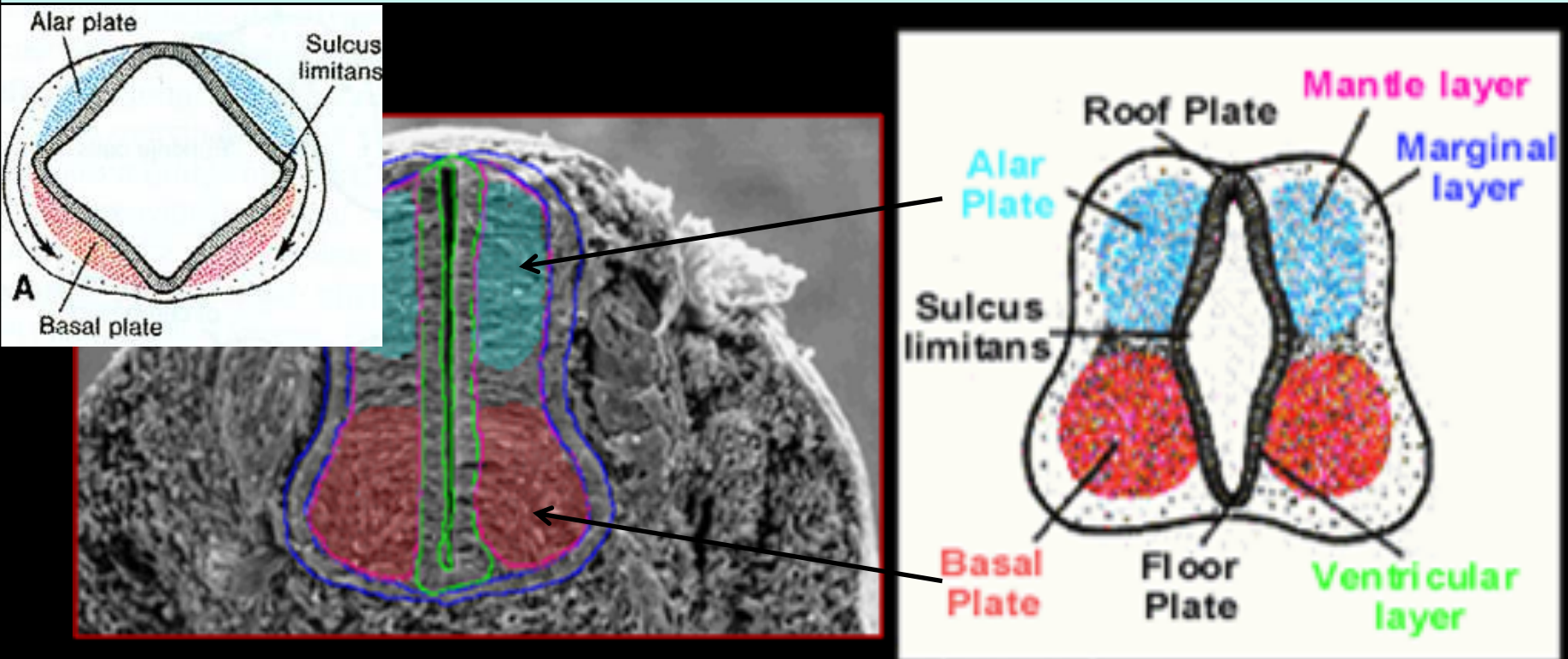
Layers of the spinal cord :

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)



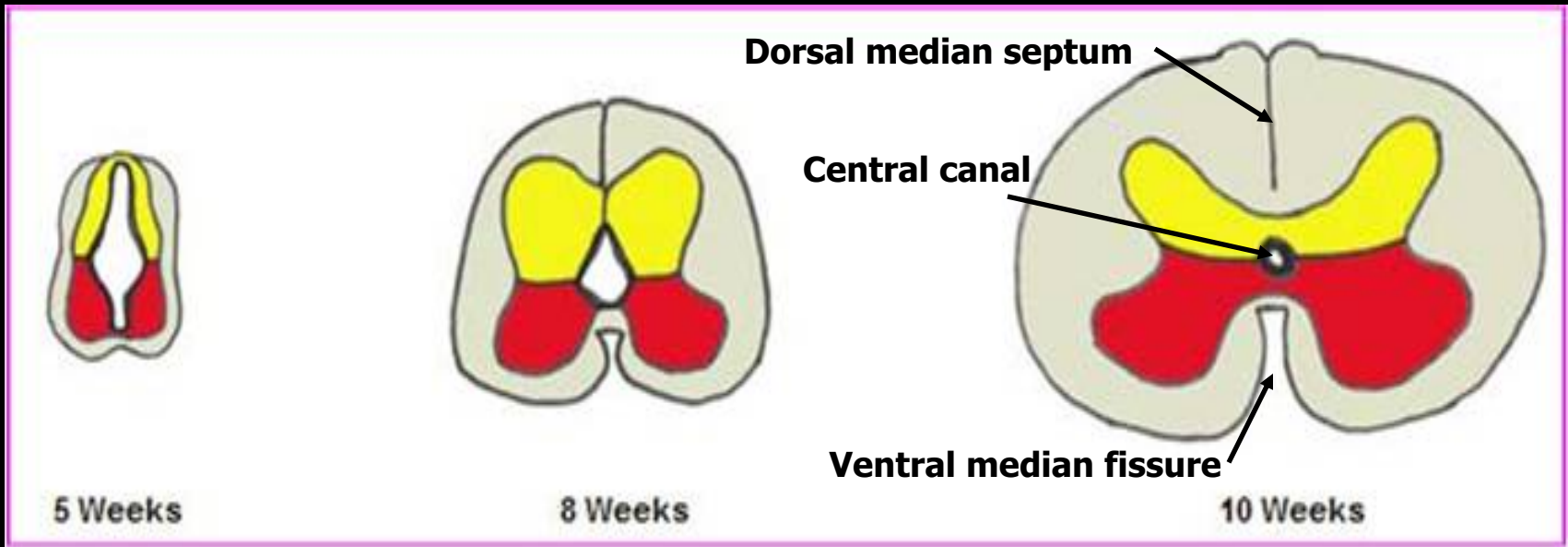
Development of the Spinal Cord (Mantle Layer)



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

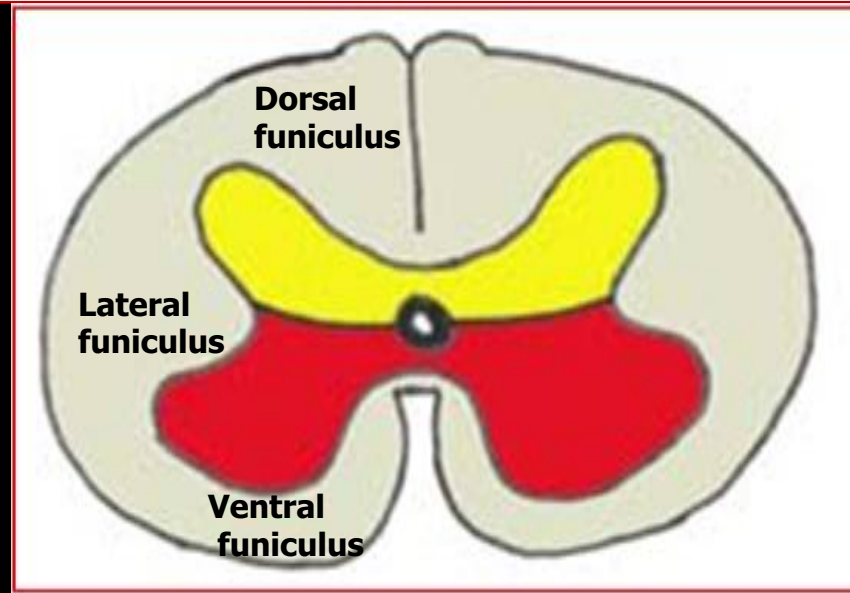
The 2 areas are separated by a (sulcus limitans).



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

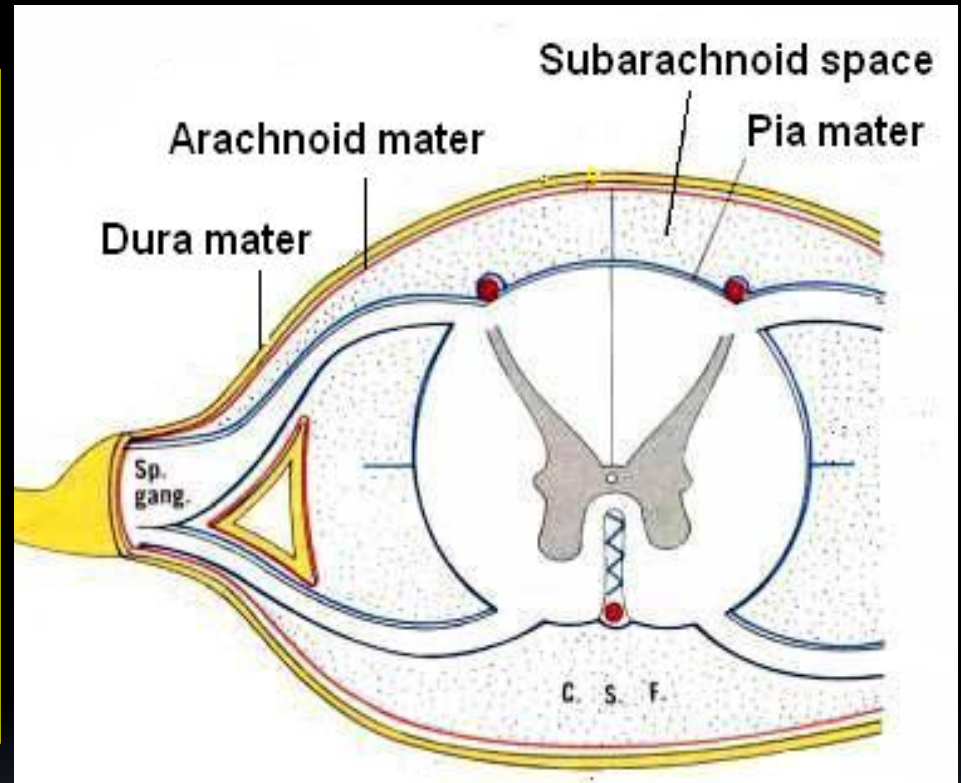
Development of the Spinal Cord (Marginal Layer)



- ❑ **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

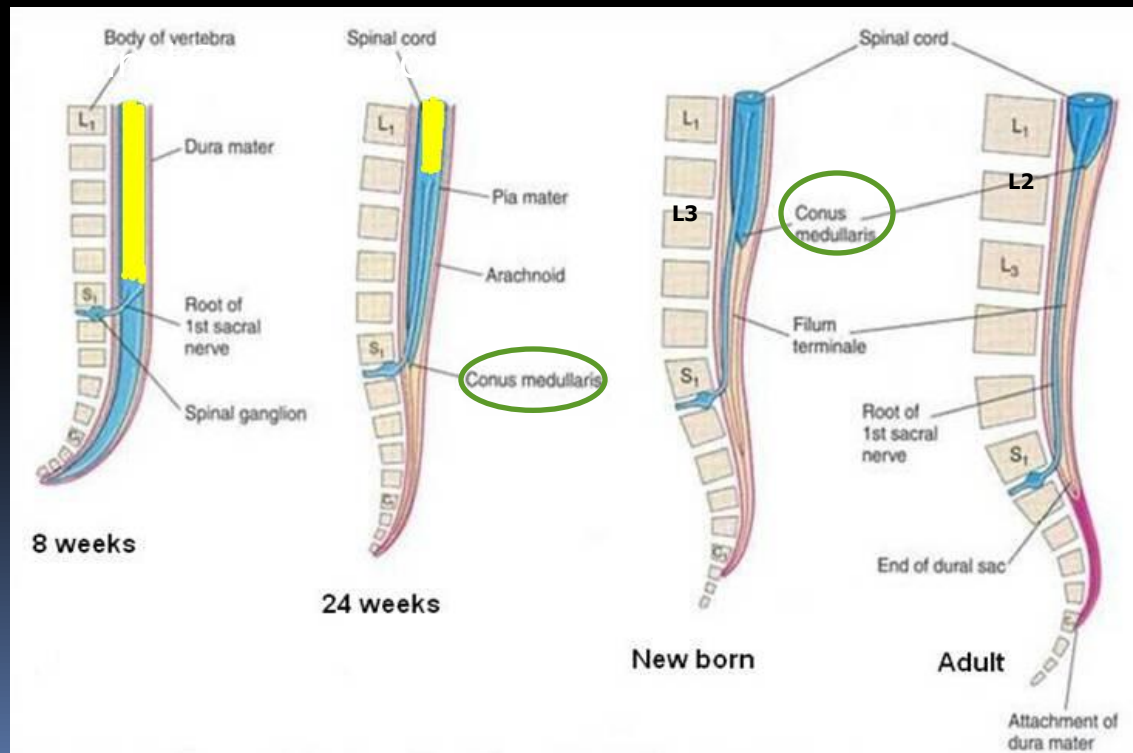
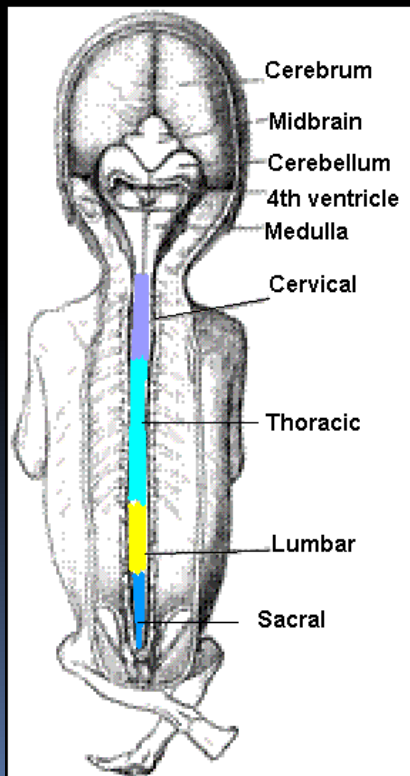


- A cavity appears between the arachnoid & the pia mater (subarachnoid space) & becomes filled with **cerebrospinal fluid (CSF)**.

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.

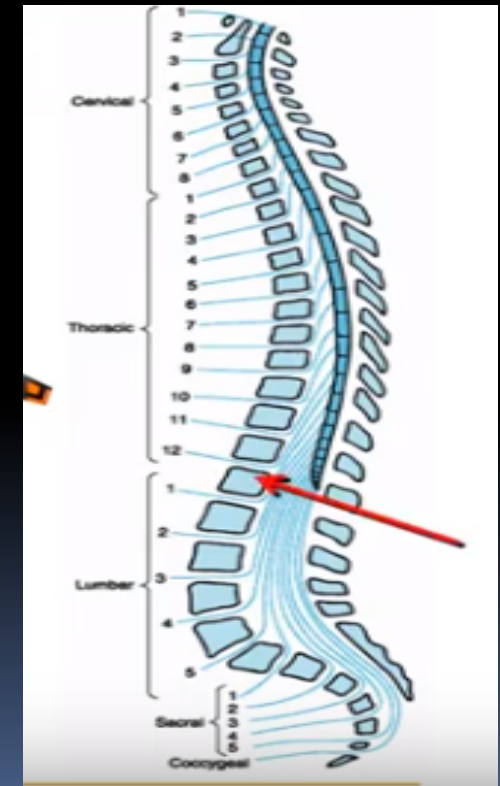


Spinal Cord Positioning

@ 3rd month → same length as vertebral canal

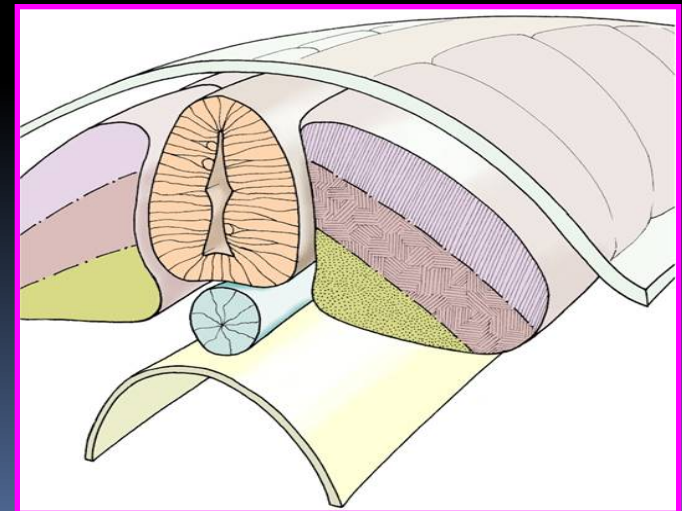
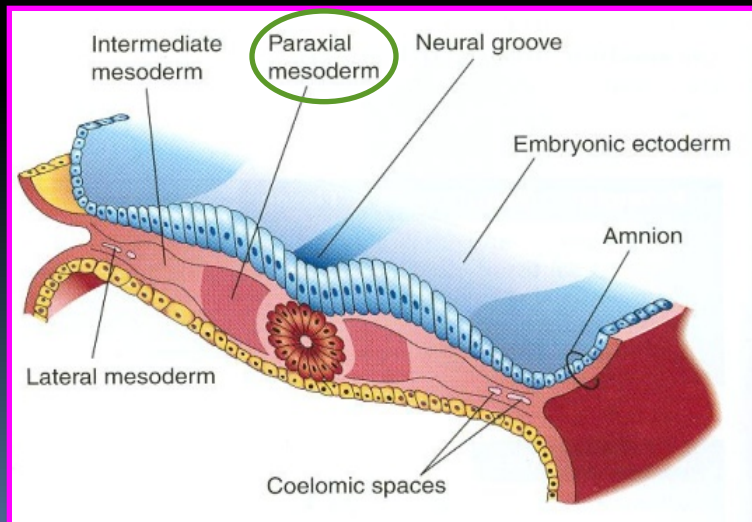
@ birth → spinal cord terminates at 3rd lumbar vertebra

@ adult → spinal cord terminates at L1



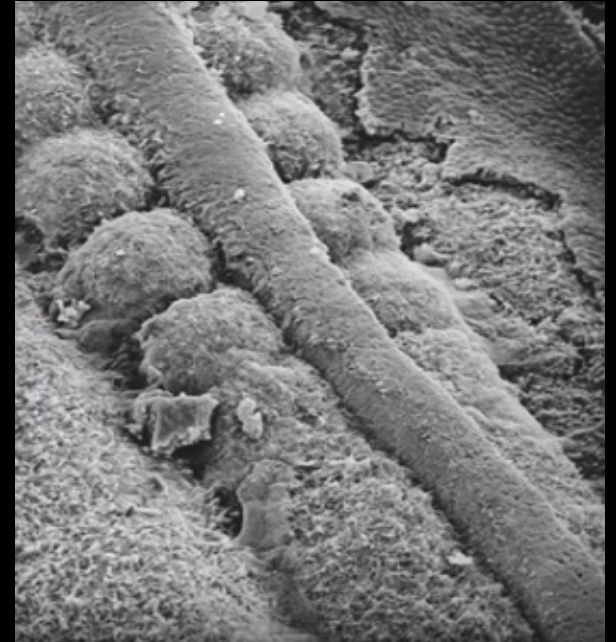
Development of the Vertebral Column

- 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

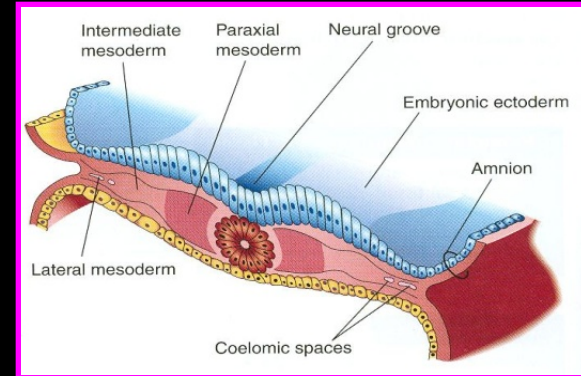


Intraembryonic Mesoderm

❑ Located between Ectoderm & Endoderm **EXCEPT** in the central axis of embryo where **NOTOCHORD** is found.

❑ Differentiates into 3 parts:

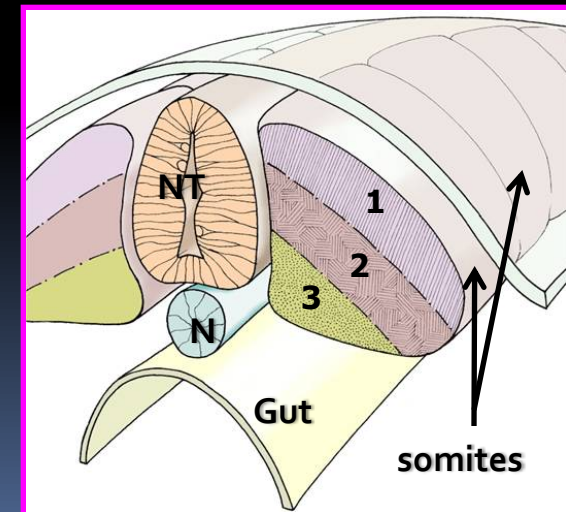
1. Paraxial mesoderm
2. Intermediate mesoderm
3. Lateral mesoderm



❑ Paraxial mesoderm divides into segments called 'somites'.

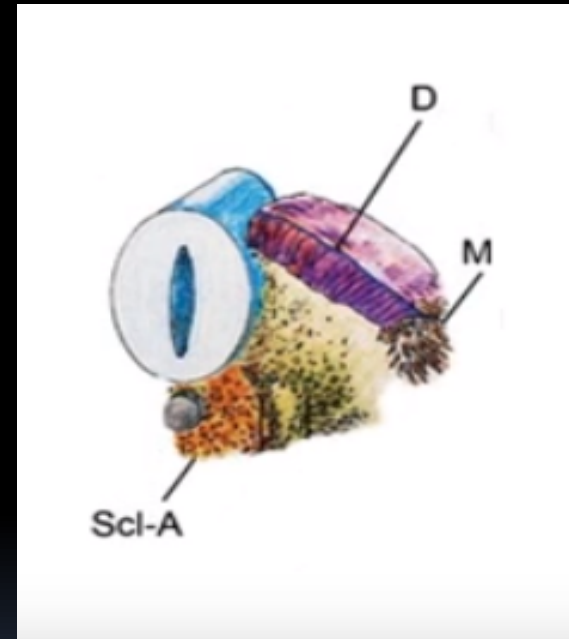
❑ Each somite divides into 3 parts:

1. Dermatome
2. Myotome
3. **Sclerotome**



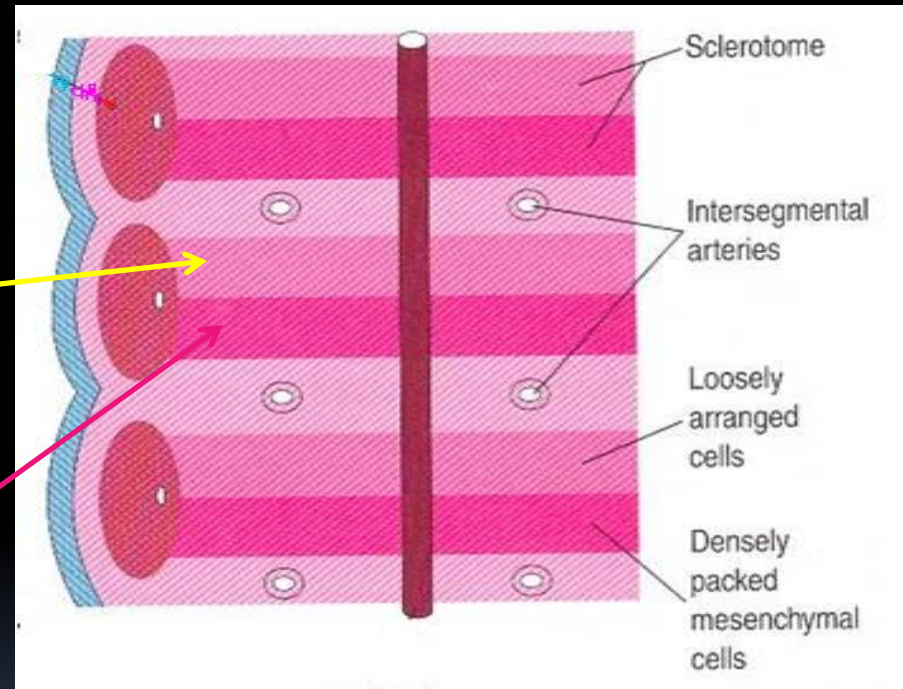
Specialization of Mesoderm

- 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



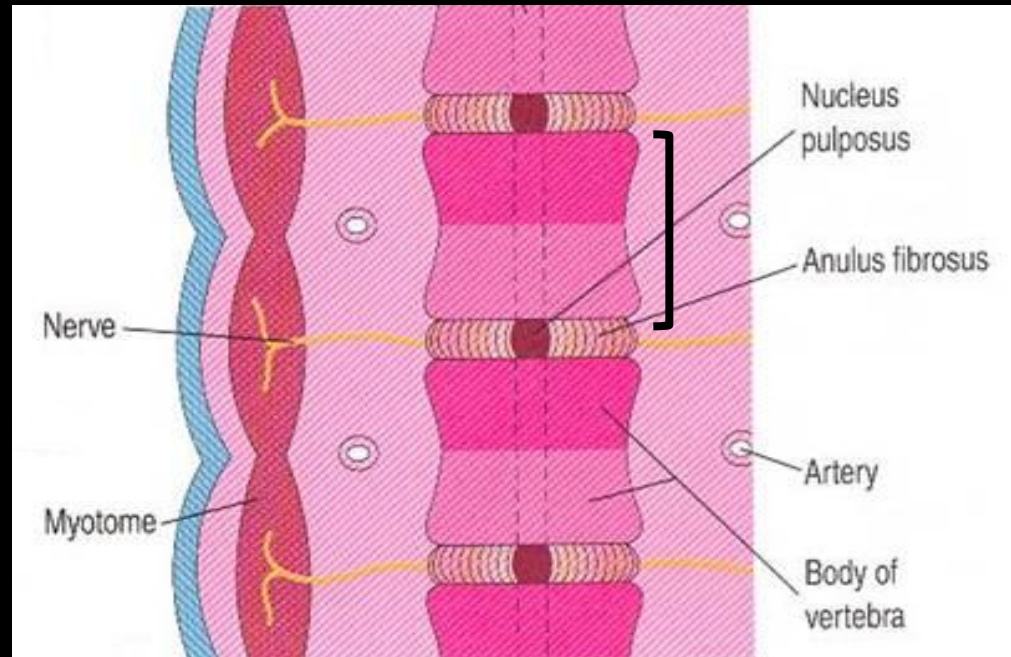
Formation of Body of Vertebra

- At 4th week, each **sclerotome** becomes subdivided 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**.

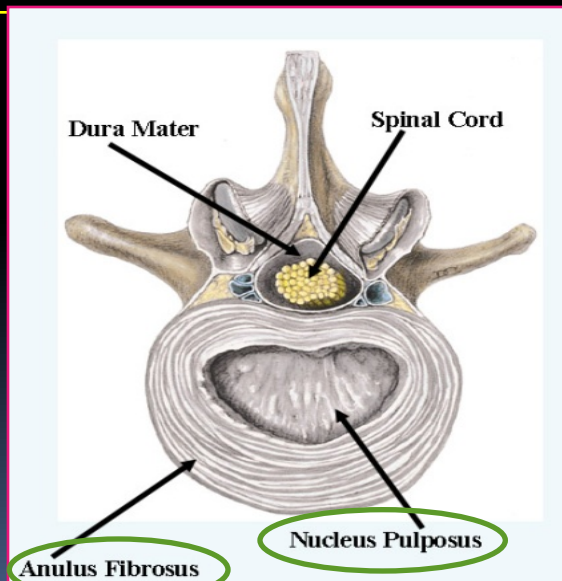
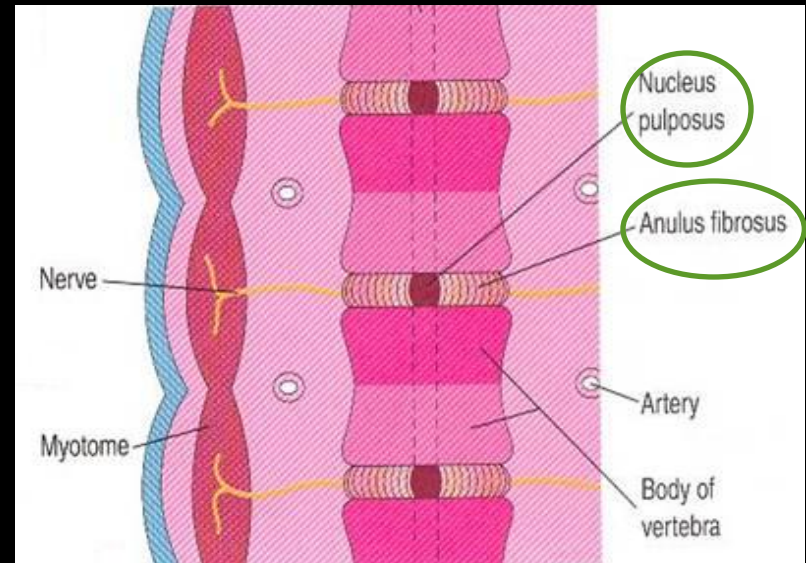


Thus each centrum develops from 2 adjacent sclerotomes

Thus the bodies of the vertebrae are intersegmental in origin

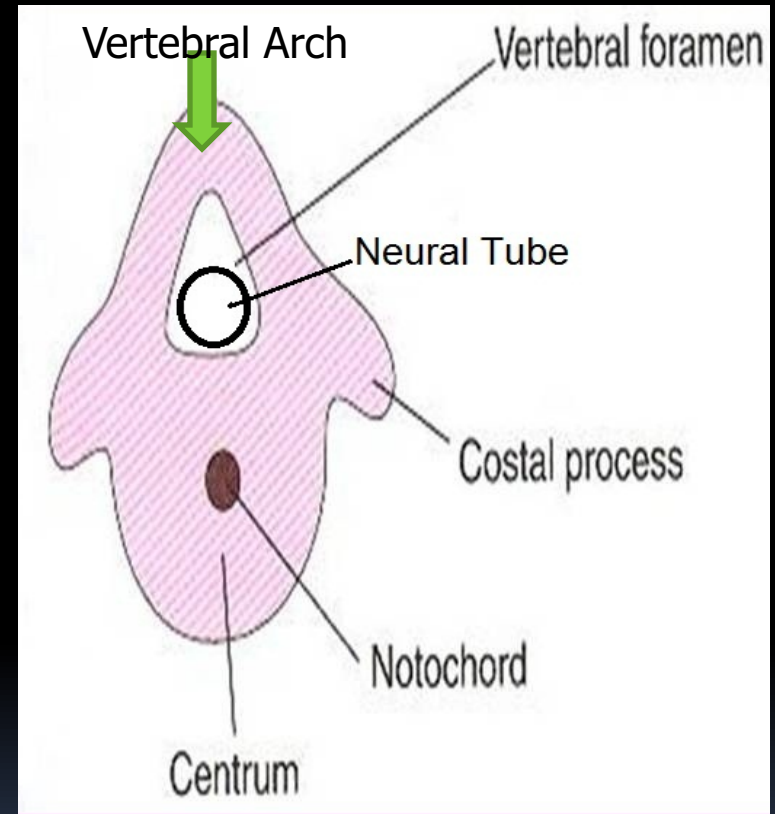
Fate of Notochord

- ❑ 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

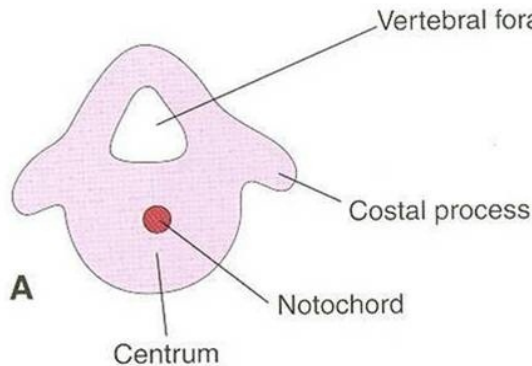


- ❑ Annulus fibrosus of the intervertebral discs is formed by the mesoderm surrounding the notochord.

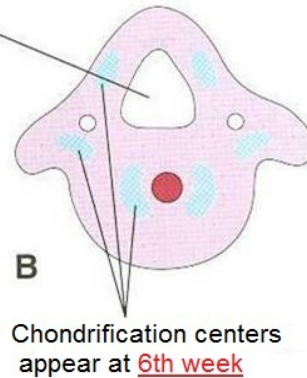
- The fused sclerotomes grow dorsally around the neural tube and form the vertebral (neural) arch.
- Ventrolaterally, costal processes develop that give rise to ribs in thoracic region.



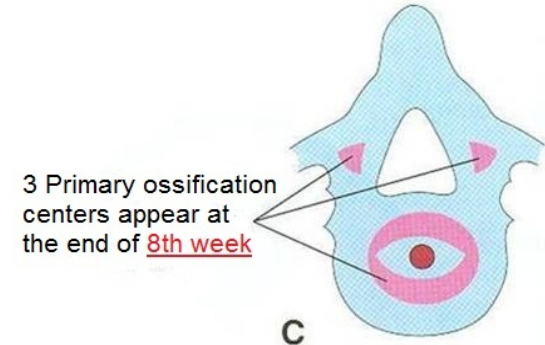
Vertebral Development



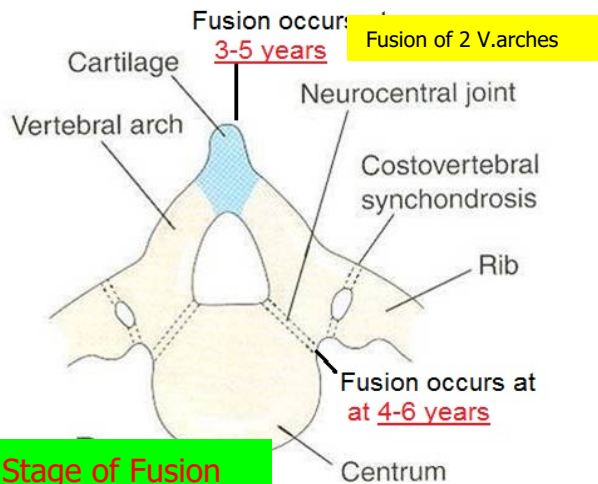
Mesenchymal Stage



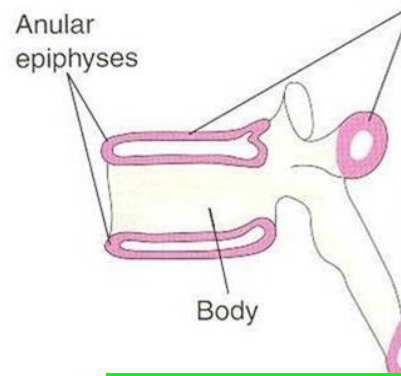
Chondrification Stage



Primary Ossification Stage

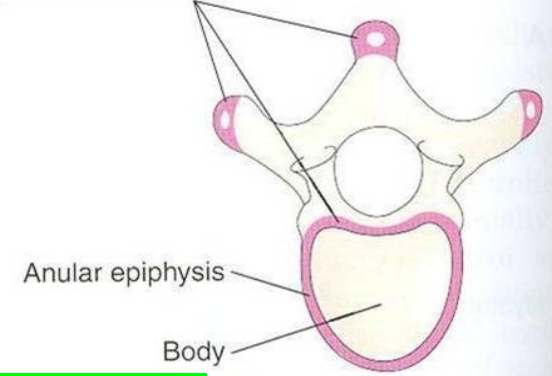


Stage of Fusion



Stage of Secondary Ossification

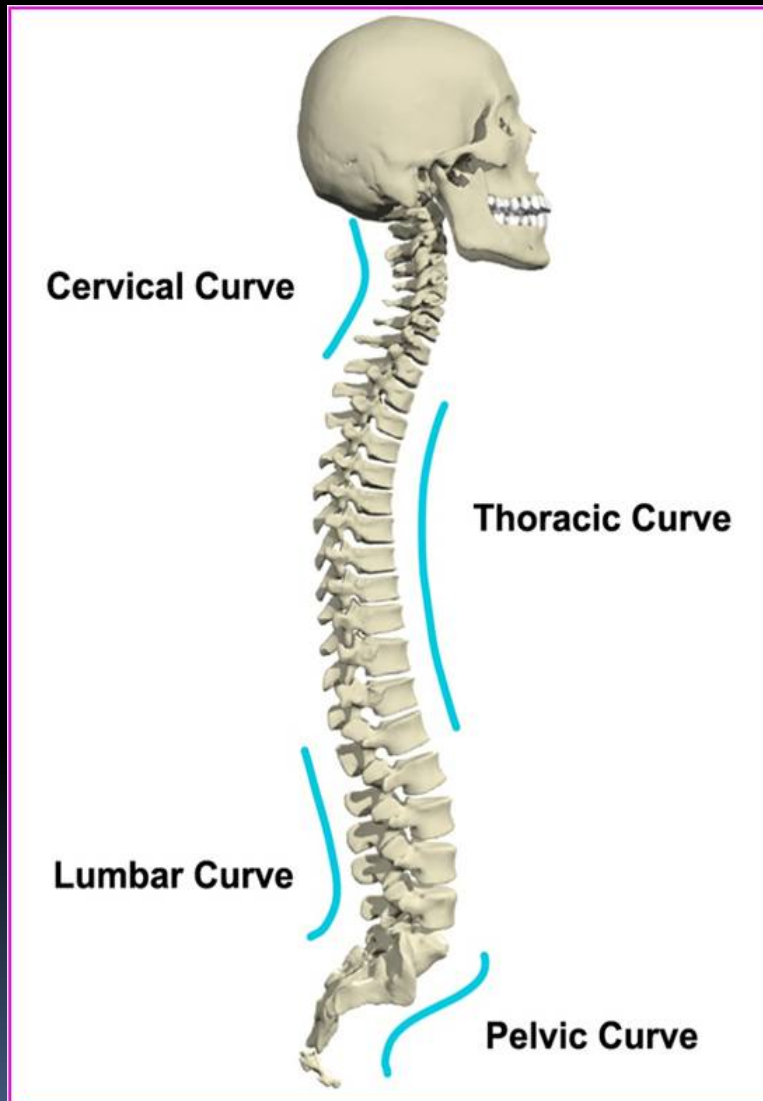
5 Secondary ossification centers appear at puberty



F

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

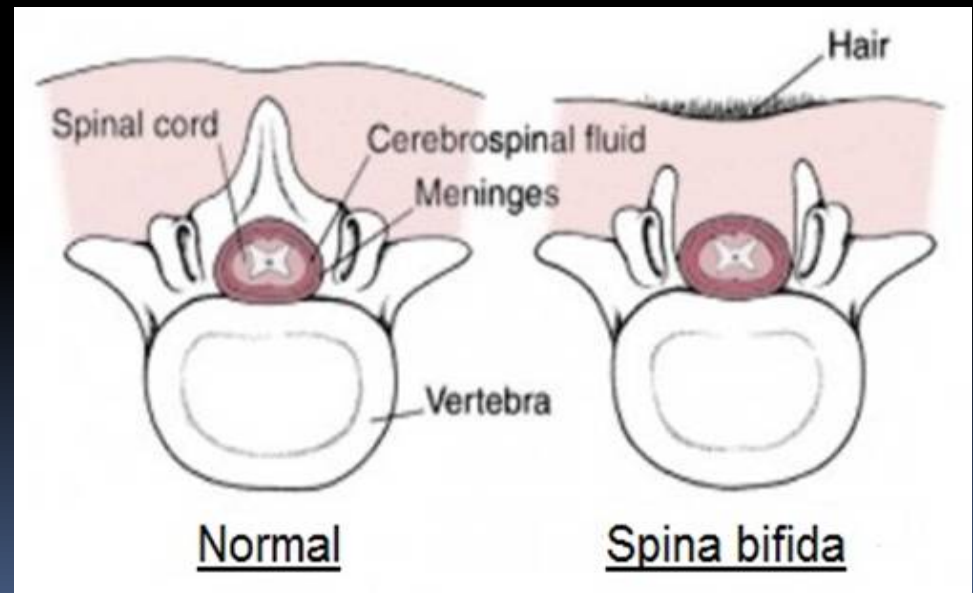
Tethered cord

■ 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

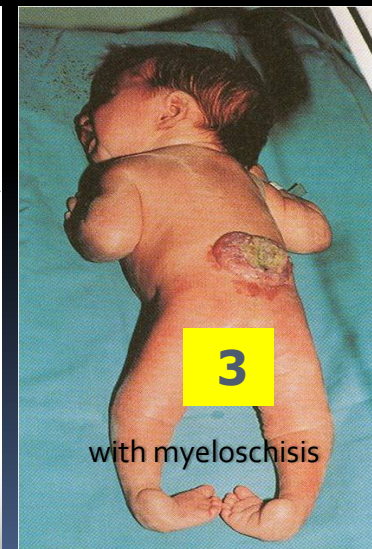
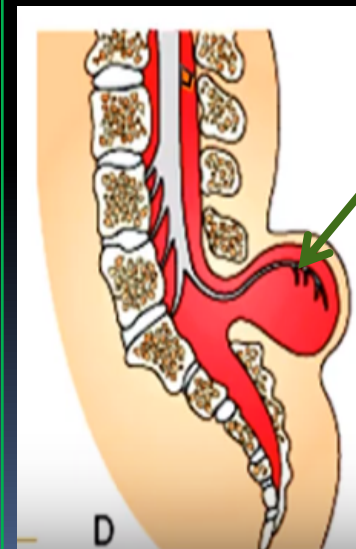
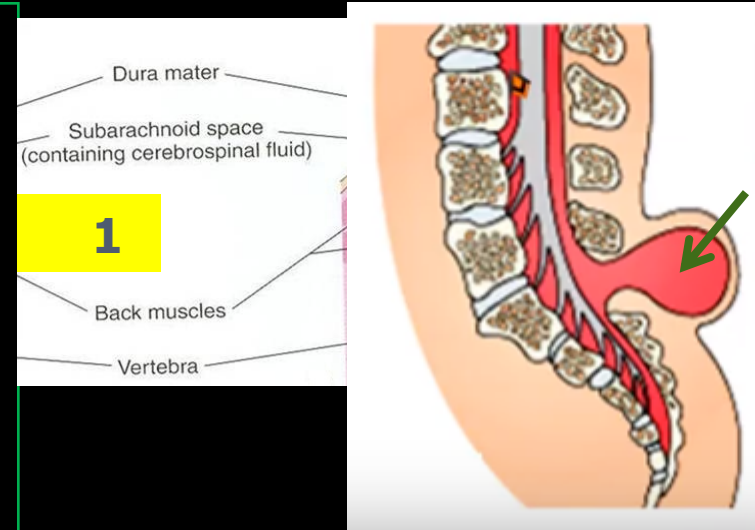
□ The open type

○ 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

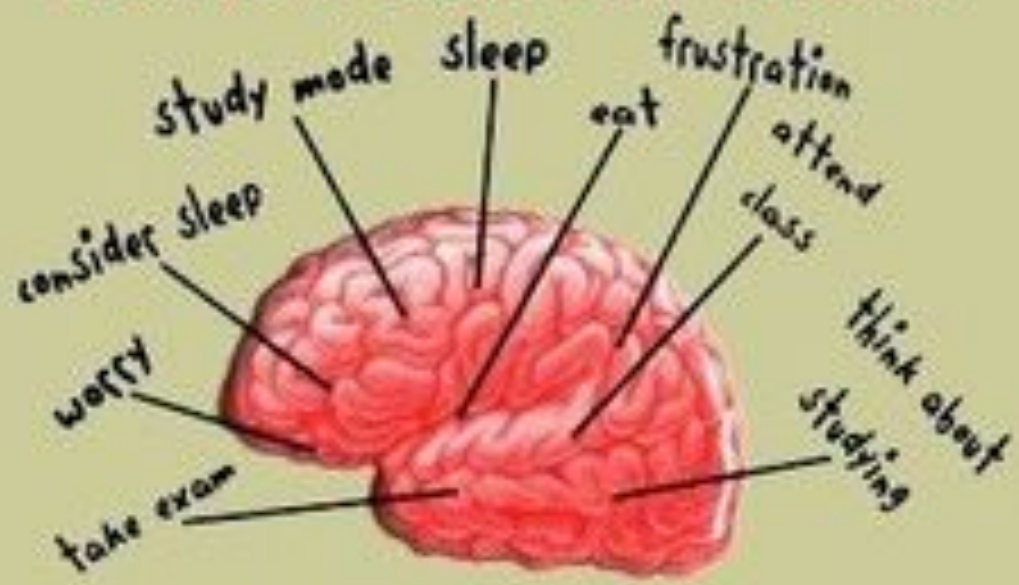
○ Neurological symptoms are present

○ Subdivided into:

1. Spina bifida with meningocele: protrusion of sac containing meninges & cerebrospinal fluid
2. Spina bifida with meningocele: 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



Atlas Of A Medical Student Brain



Welcome back

