•DEVELOPMENT OF VERTEBRAL COLUMN & SPINAL CORD

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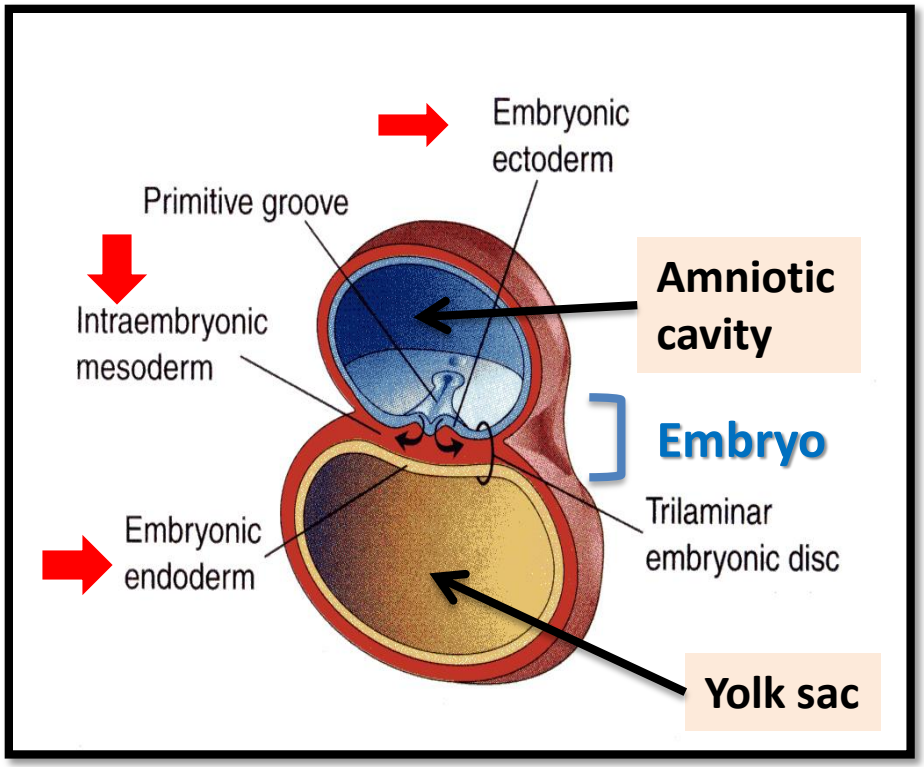
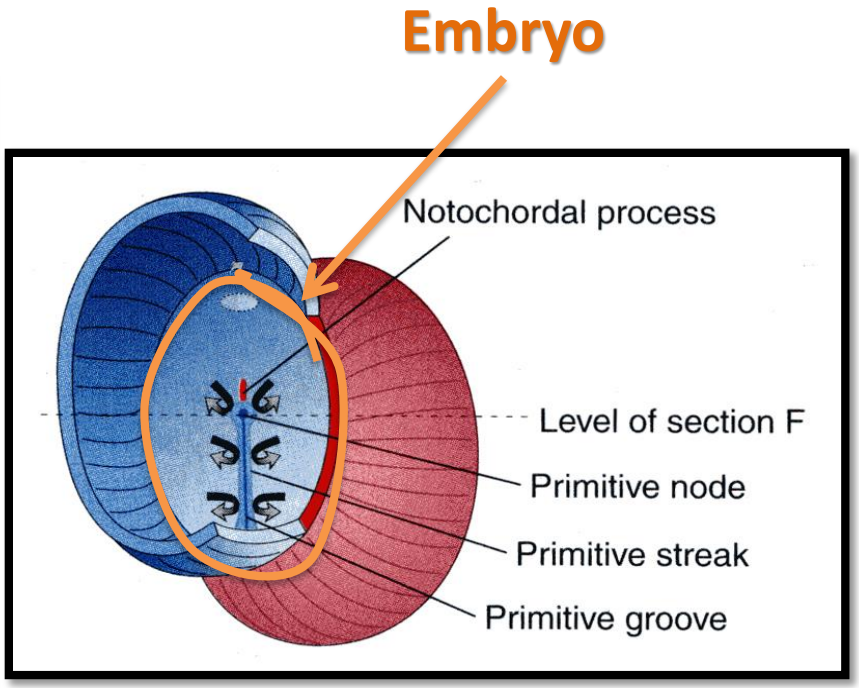
OBJECTIVES

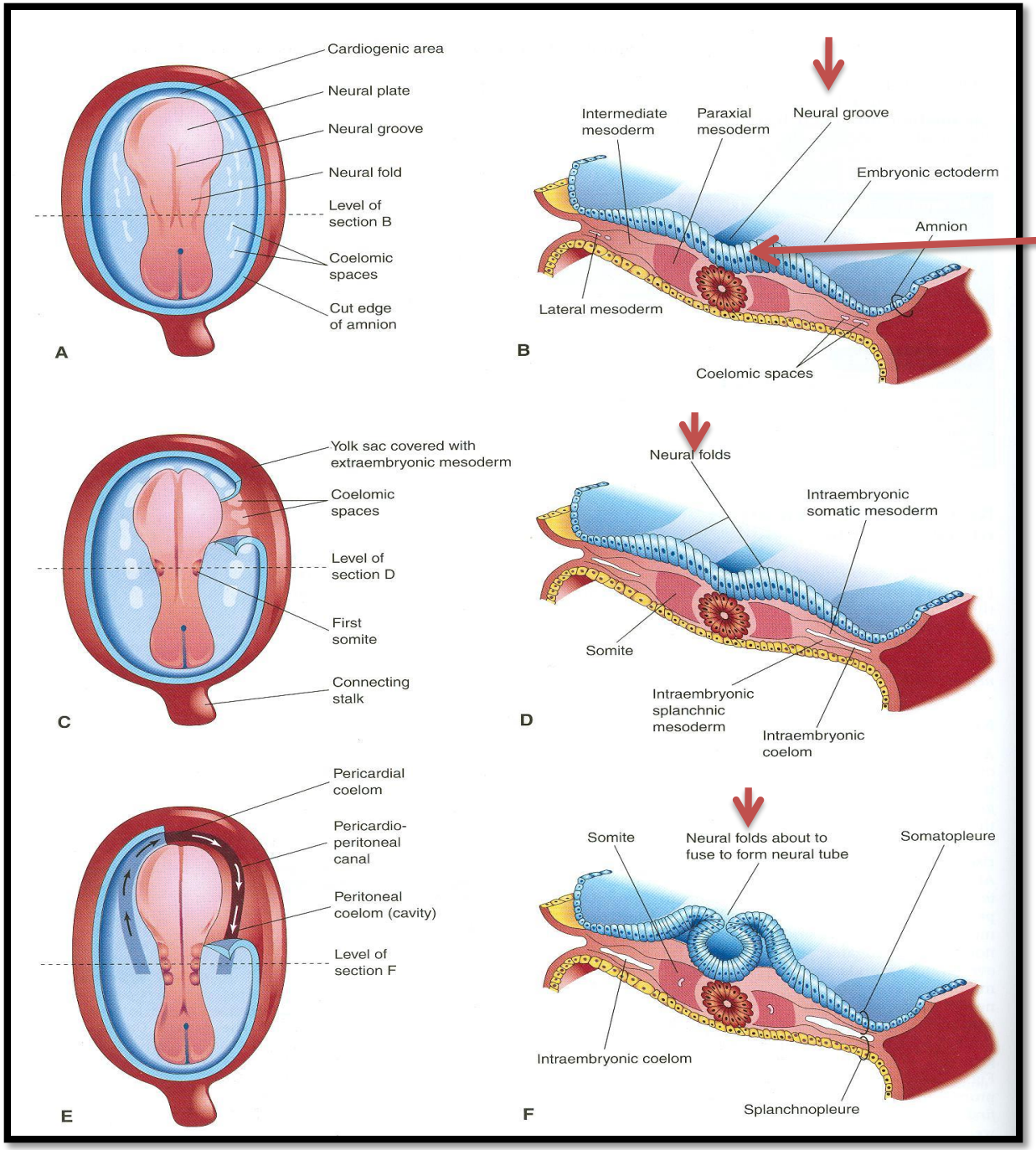
At the end of the lecture, students should be able to:

- 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.


Embryonic ectoderm
Primitive groove
Intraembryonic mesoderm
Amniotic cavity
Embryo
Trilaminar embryonic disc
Embryonic endoderm
Yolk sac


Embryo
Notochordal process
Level of section F
Primitive node
Primitive streak
Primitive groove

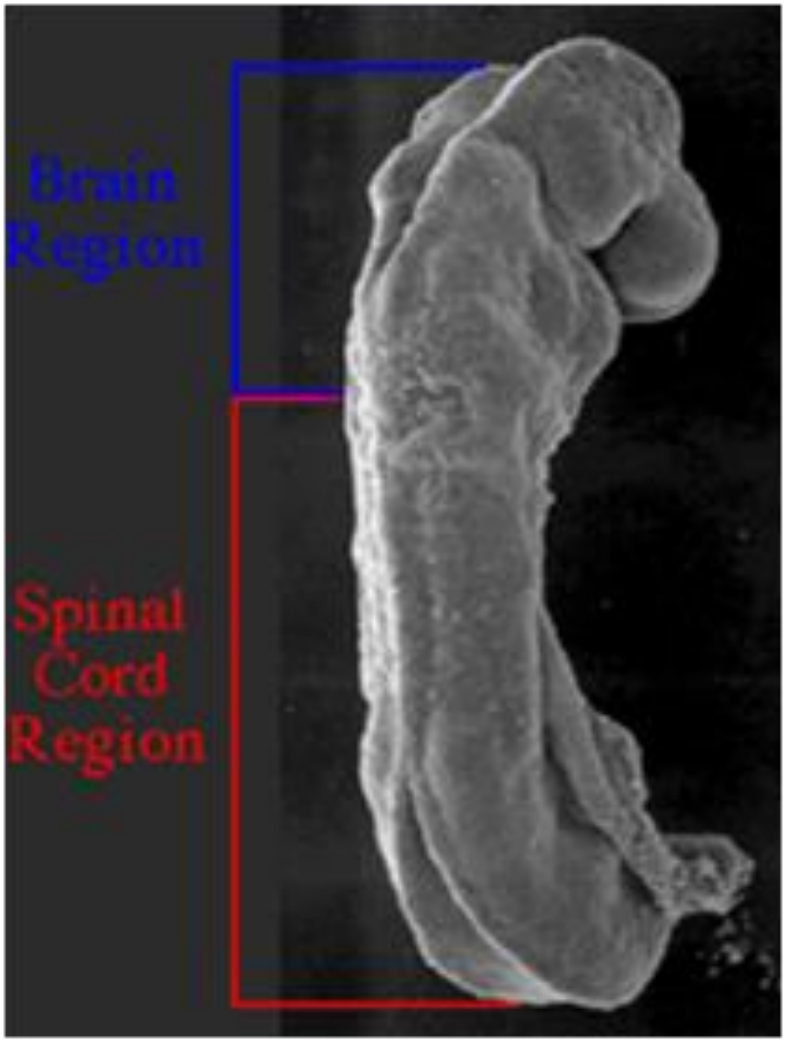
DEVELOPMENT OF SPINAL CORD



DEVELOPMENT OF NEURAL TUBE

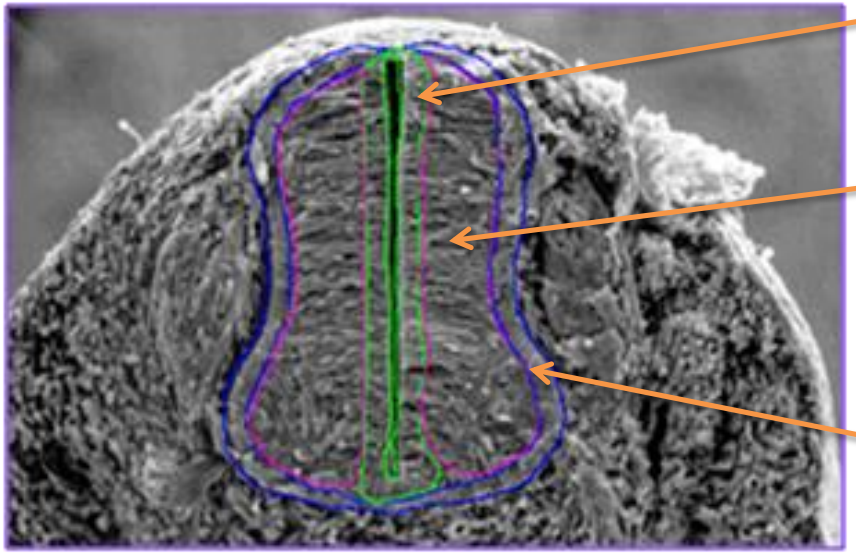
- Ectodermal cells dorsal to notochord thickens to form the neural plate.
- A longitudinal groove develops in the neural plate (neural groove).
- The margins of the neural plate (neural folds) approach to each other and fuse to form the neural tube.

DEVELOPMENT OF SPINAL CORD



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

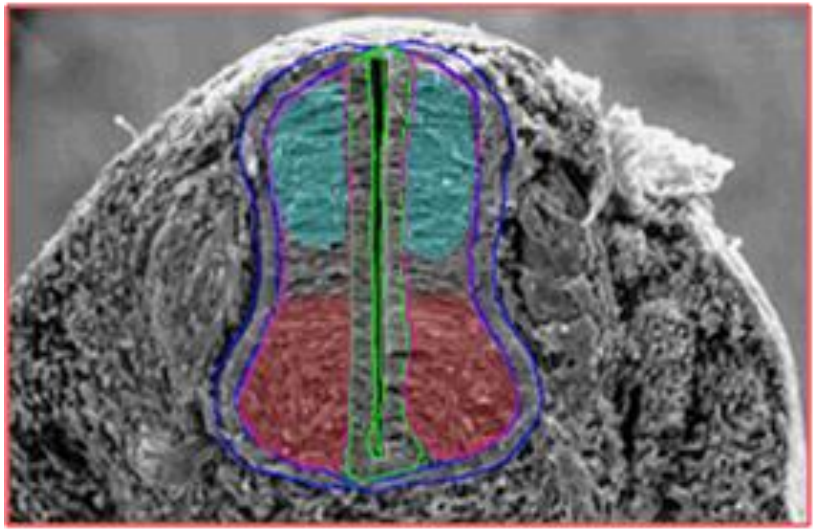
DEVELOPMENT OF SPINAL CORD

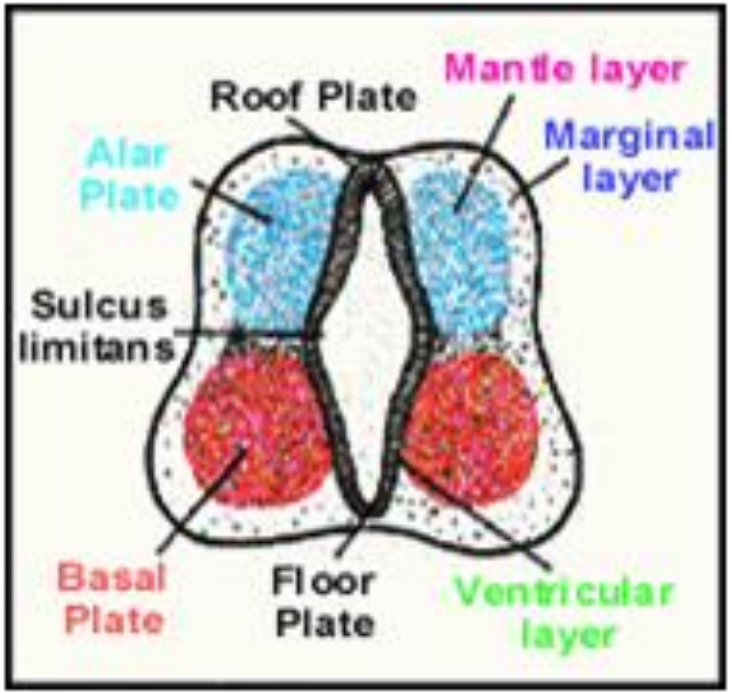


The cells of neural tube form:

- 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)

MANTLE LAYER OF SPINAL CORD



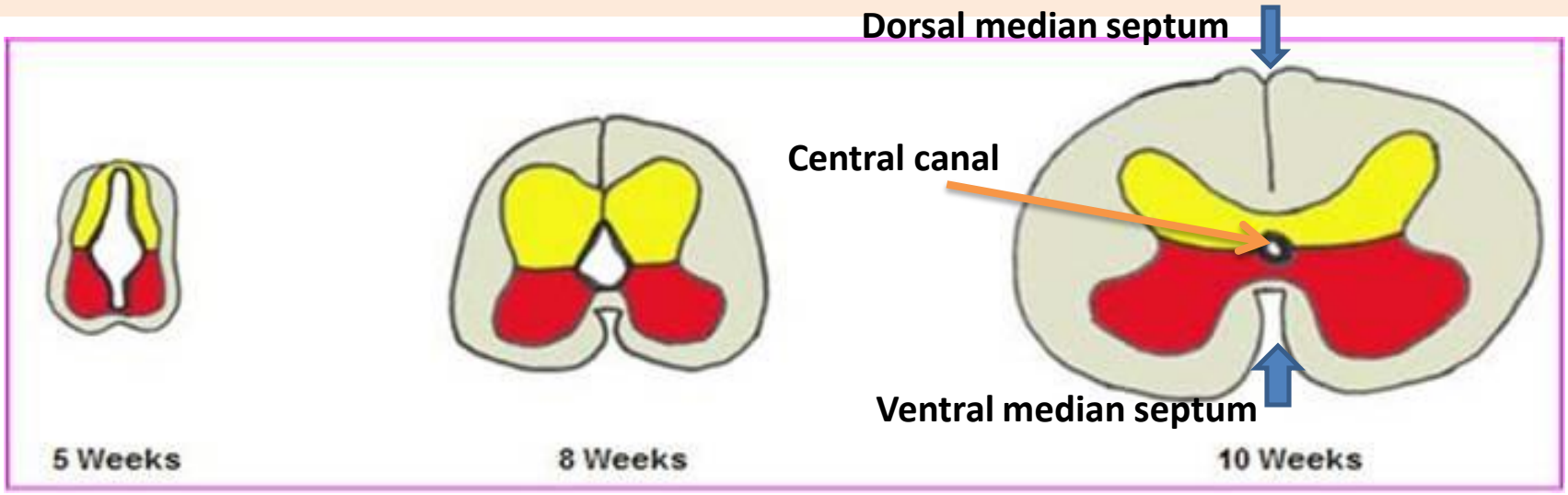


- Neurons of mantle layer (future grey matter) differentiate into:

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 longitudinal groove (sulcus limitans).

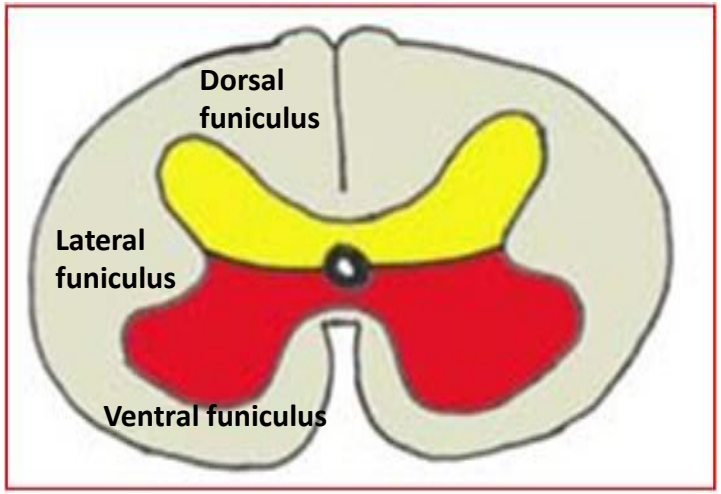
MANTLE LAYER OF SPINAL CORD



Proliferation and bulging of both alar & basal plates cause:

- ❑ **Formation of longitudinal dorsal & ventral median septa**
- ❑ **Narrowing of the lumen to form a small central canal**

MARGINAL LAYER OF SPINAL CORD



- Marginal layer **increases in size** due to addition of ascending, descending & intersegmental nerve fibers.
- **Myelination** of nerve fibers starts at **4th month** & continues **during the 1st postnatal period. Motor fibers myelinate before sensory fibers.**
- Marginal layer (future white matter) is divided into: **dorsal, lateral and ventral funiculus (white column)**

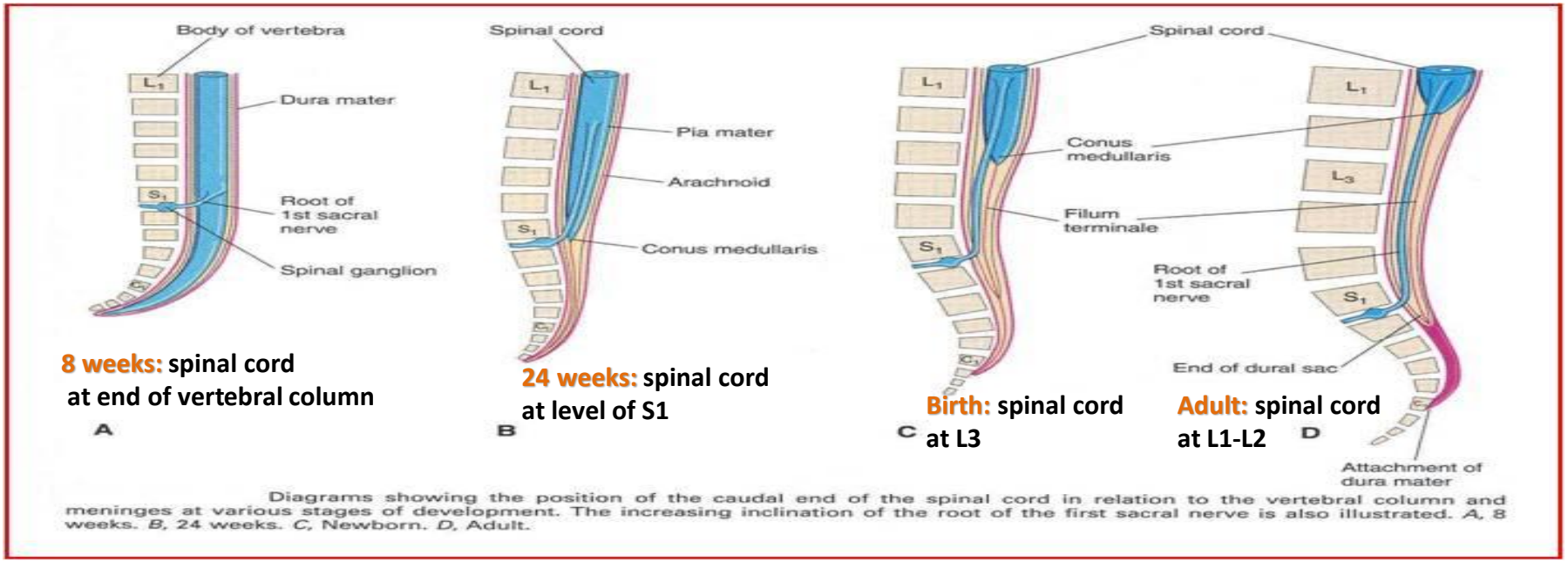
MENINGES

- They are 3 membranes covering the neural tube:

1. Outer thick **dura** matter: **mesodermal** in origin
2. Middle **arachnoid** matter: **ectodermal** in origin
3. Inner thin **pia** matter: **ectodermal** in origin

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

POSITIONAL CHANGES OF SPINAL CORD



8 weeks: spinal cord at end of vertebral column

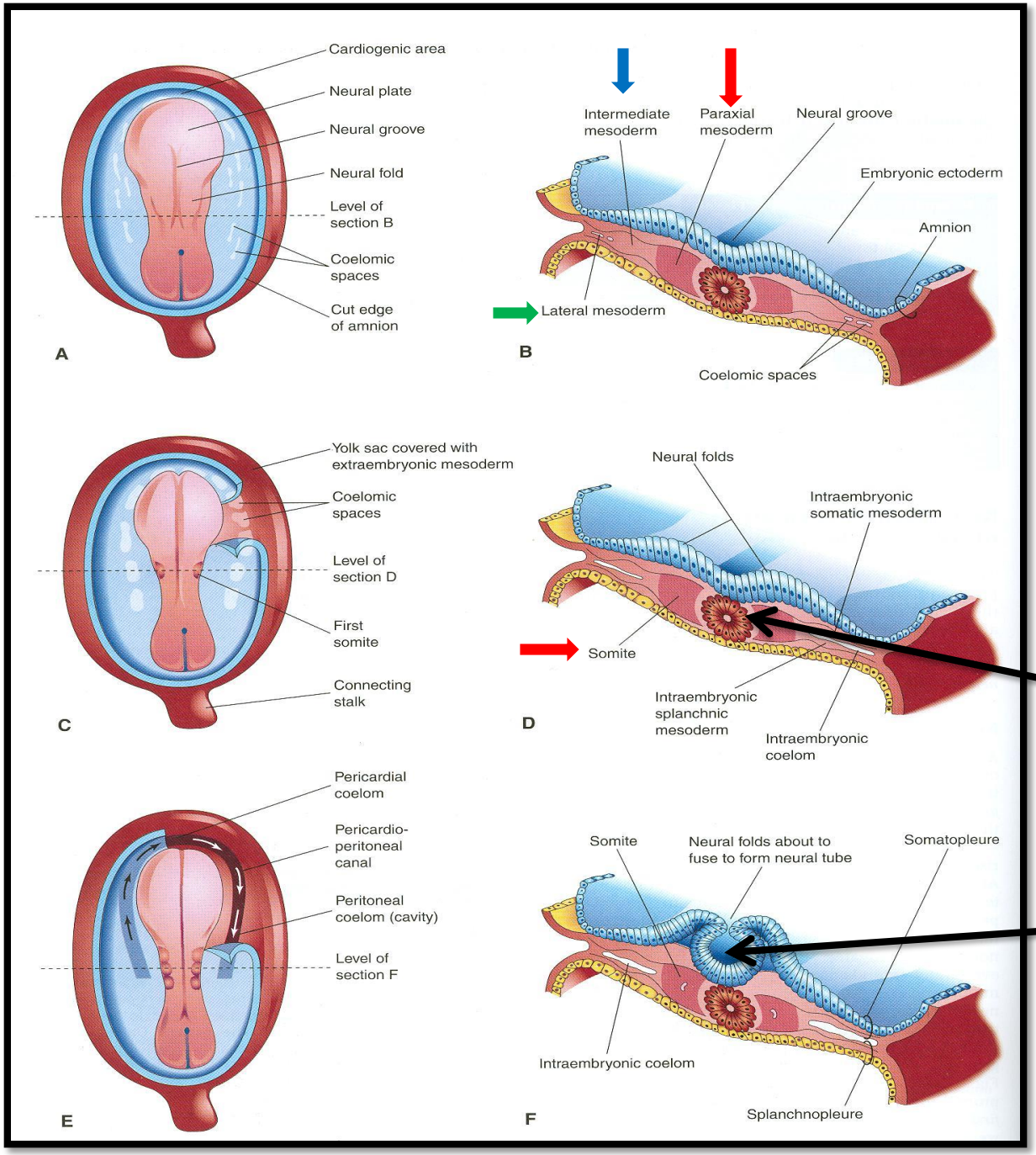
24 weeks: spinal cord at level of S1

Birth: spinal cord at L3

Adult: spinal cord at L1-L2

Diagrams showing the position of the caudal end of the spinal cord in relation to the vertebral column and meninges at various stages of development. The increasing inclination of the root of the first sacral nerve is also illustrated. *A*, 8 weeks. *B*, 24 weeks. *C*, Newborn. *D*, Adult.

- 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) shift gradually to a higher level.



Notochord

stimulates :

- **Neural tube formation**
- **Vertebral column formation**

Neural tube

INTRAEMBRYONIC MESODERM

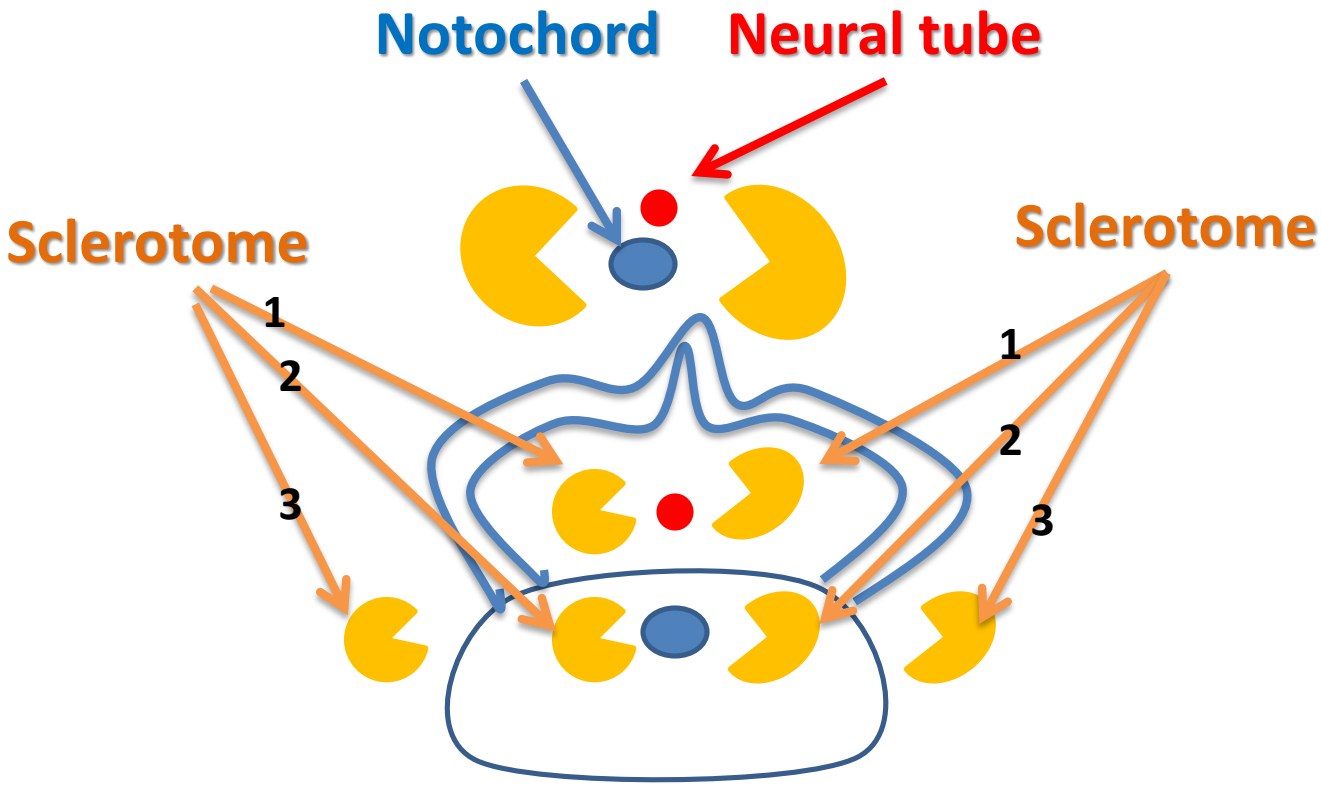
- Proliferates between Ectoderm & Endoderm EXCEPT in the central axis of embryo where NOTOCHORD is found.
- Differentiates into 3 parts:

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

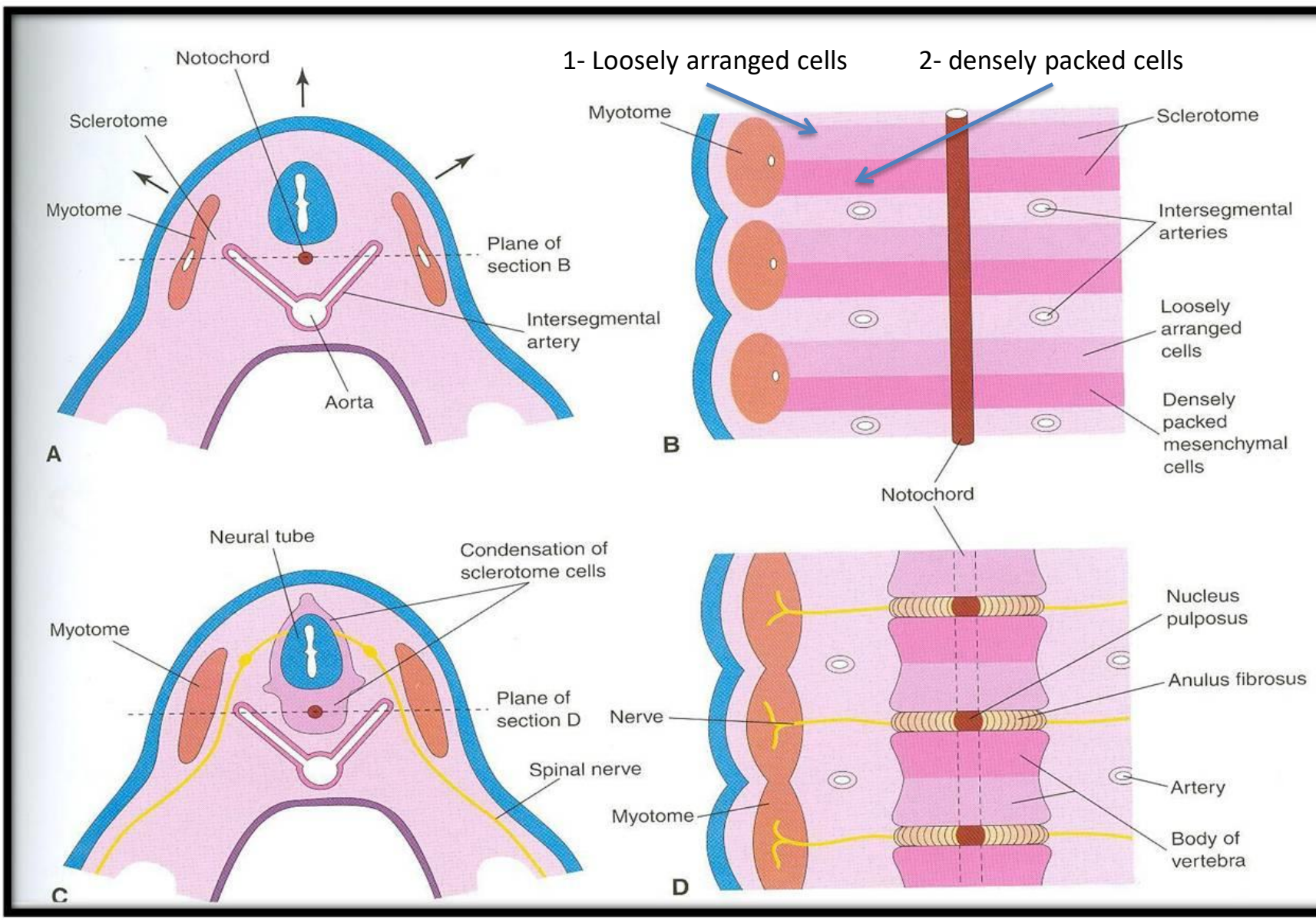
- Paraxial mesoderm divides into units (somites).
- Each somite divides into 3 parts:

1. Sclerotome
2. Myotome
3. Dermatome

DEVELOPMENT OF VERTEBRA



1- Sclerotome around neural tube: forms vertebral (neural) arch
2- Sclerotome around notochord: forms body of vertebra
3-Sclerotome in body wall near to neural tube & notochord : forms costal process (gives ribs in thoracic region)


Notochord
Sclerotome
Myotome
Plane of section B
Intersegmental artery
Aorta
A
1- Loosely arranged cells
2- densely packed cells
Myotome
Sclerotome
Intersegmental arteries
Loosely arranged cells
Densely packed mesenchymal cells
B
Notochord
Neural tube
Condensation of sclerotome cells
Myotome
Plane of section D
Spinal nerve
C
Nucleus pulposus
Anulus fibrosus
Nerve
Artery
Myotome
Body of vertebra
D

FORMATION OF BODY OF VERTEBRA

- **At 4th week, each sclerotome is formed of:**

1. **A cranial part of loosely arranged cells**
2. **A caudal part of densely packed cells**

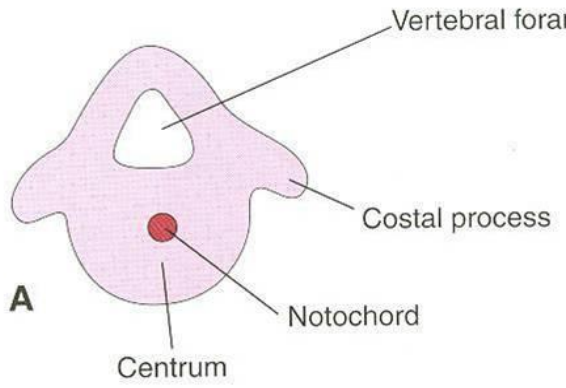
- **The caudal part** of each sclerotome fuses with **the cranial part of succeeding sclerotome to form the centrum (body primordium)**
- **Each centrum develops from 2 adjacent sclerotomes.**

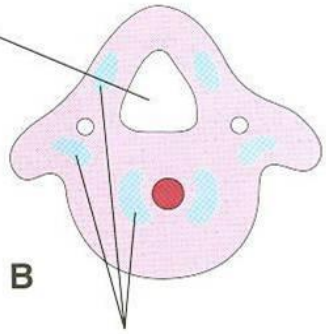
FATE OF NOTOCHORD

- **In the region of the bodies of vertebrae:** It degenerates .
- **Between bodies of vertebrae:** It forms the intervertebral discs (nucleus pulposus).

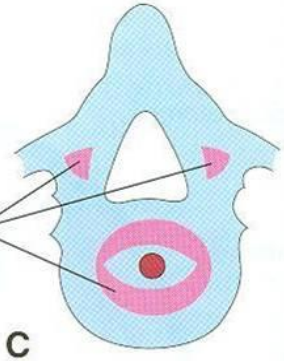
N.B.: Annulus fibrosus part of the intervertebral discs are formed by the mesoderm surrounding the notochord.

VERTEBRAL DEVELOPMENT



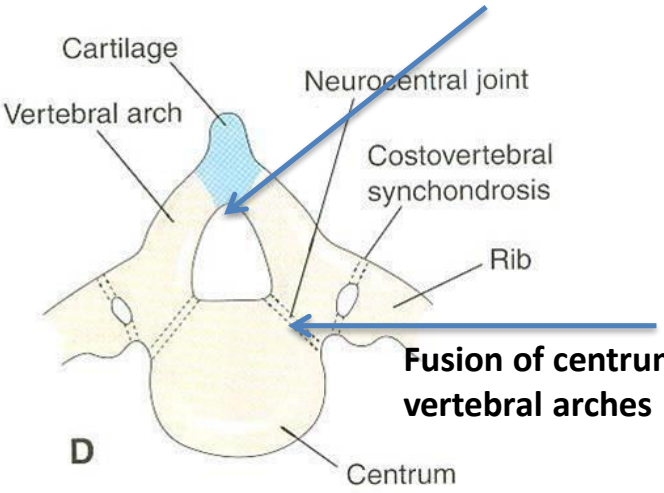


appear at 6th week

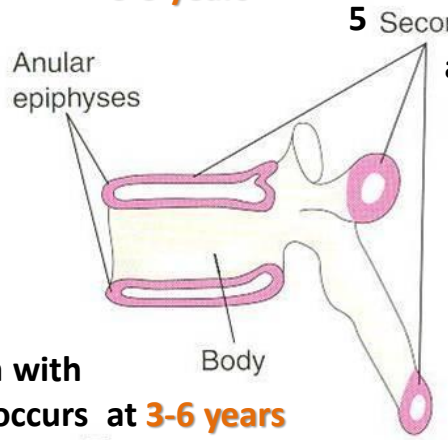


appear at end of 8th week

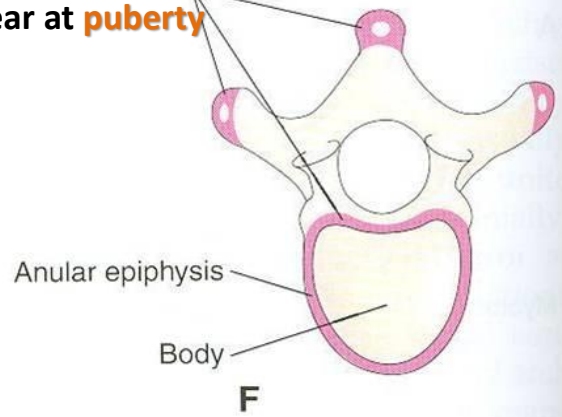
Fusion of bony halves of vertebral arch occurs at 3-5 years



Fusion of centrum with vertebral arches occurs at 3-6 years

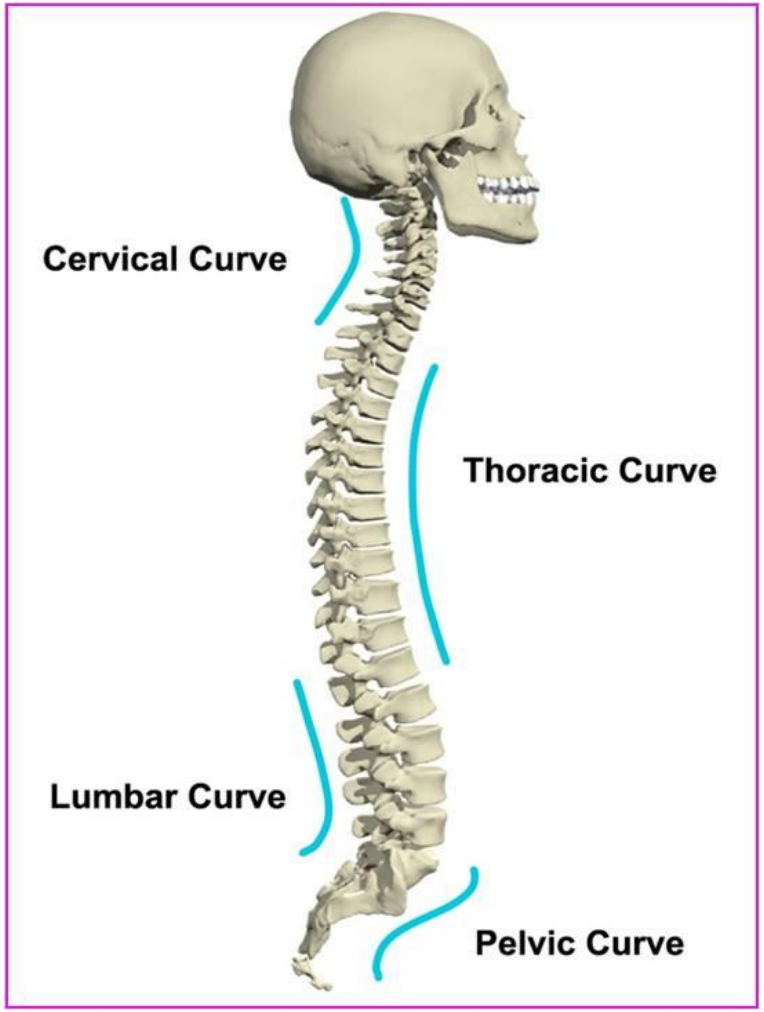


appear at puberty



All centers unite around 25 years

CURVATURES OF VERTEBRAL COLUMN



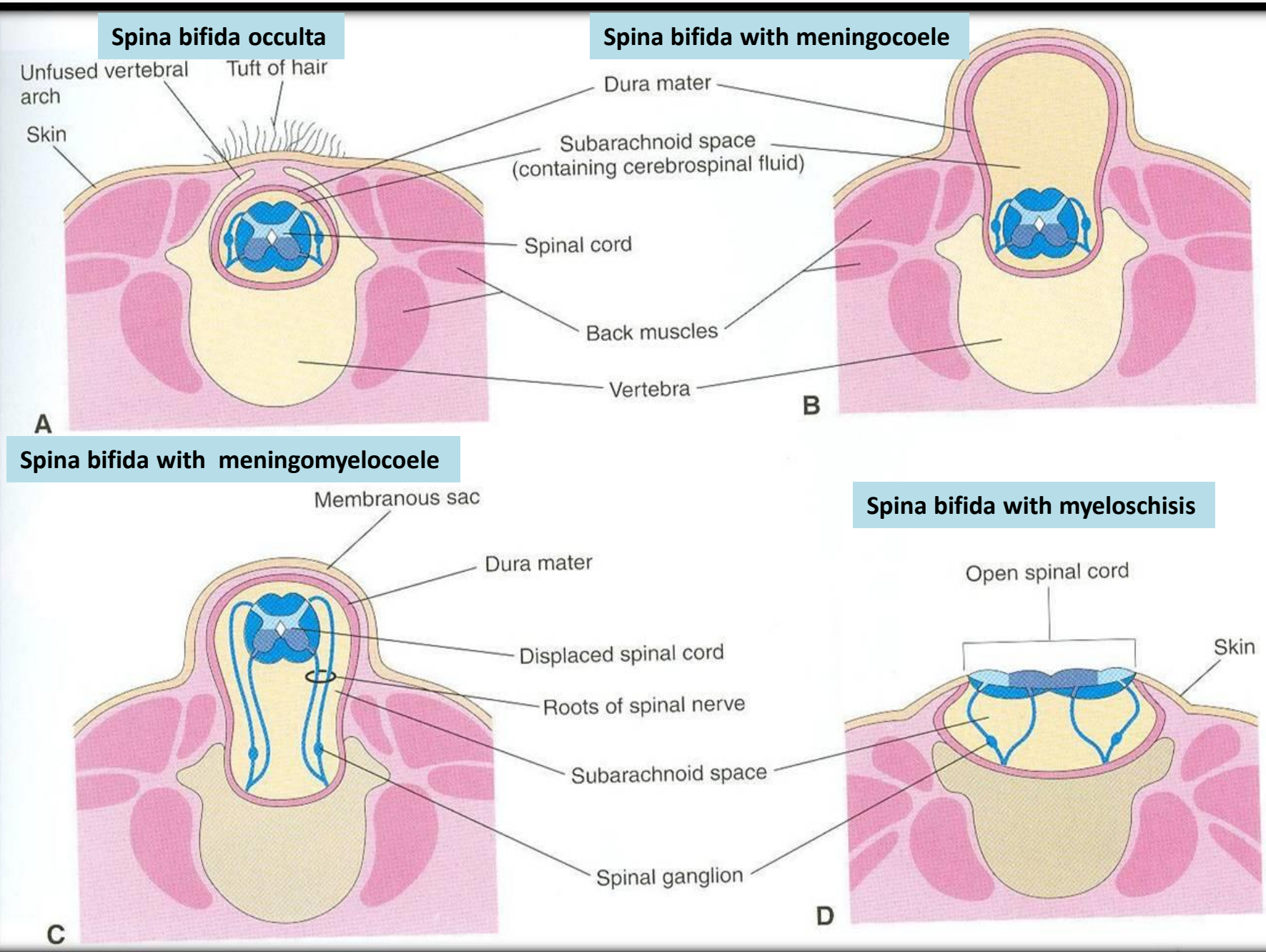
- **Primary curves (thoracic & pelvic or sacral):** develop prenatally
- **Secondary curves:** develop postnatally

1. **Cervical:** as a result of lifting the head
2. **Lumbar:** as a result of walking

SPINA BIFIDA

- **Cause:** Failure of fusion of the halves of vertebral arches
- **Incidence:** 0.04-0.15%
- **Sex:** more frequent in females
- **Types:**

1. Spina bifida occulta (20%)
2. Spina bifida cystica (80%)

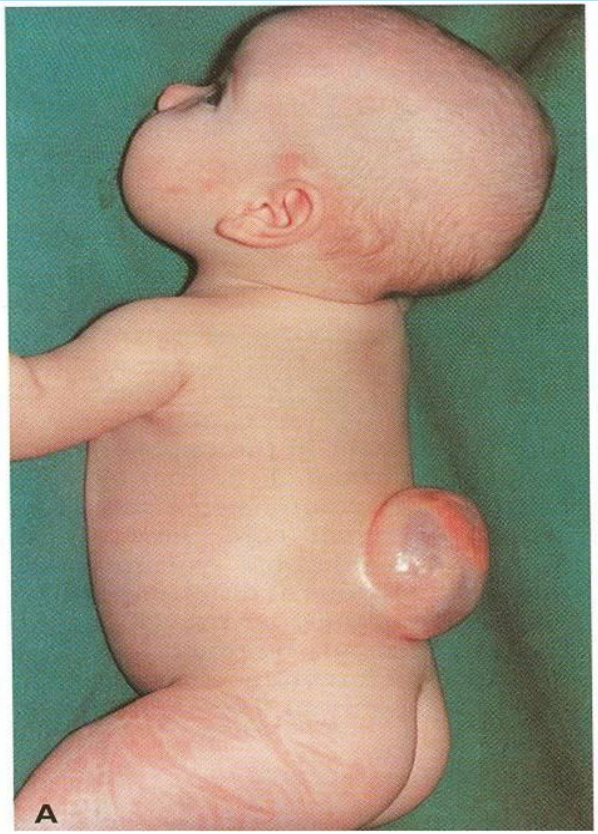

Spina bifida occulta
Unfused vertebral arch
Tuft of hair
Skin
Spinal cord
Back muscles
Vertebra
A
Spina bifida with meningocoele
Dura mater
Subarachnoid space (containing cerebrospinal fluid)
B
Spina bifida with meningomyelocoele
Membranous sac
Dura mater
Displaced spinal cord
Roots of spinal nerve
Subarachnoid space
Spinal ganglion
C
Spina bifida with myeloschisis
Open spinal cord
Skin
D

SPINA BIFIDA OCCULTA

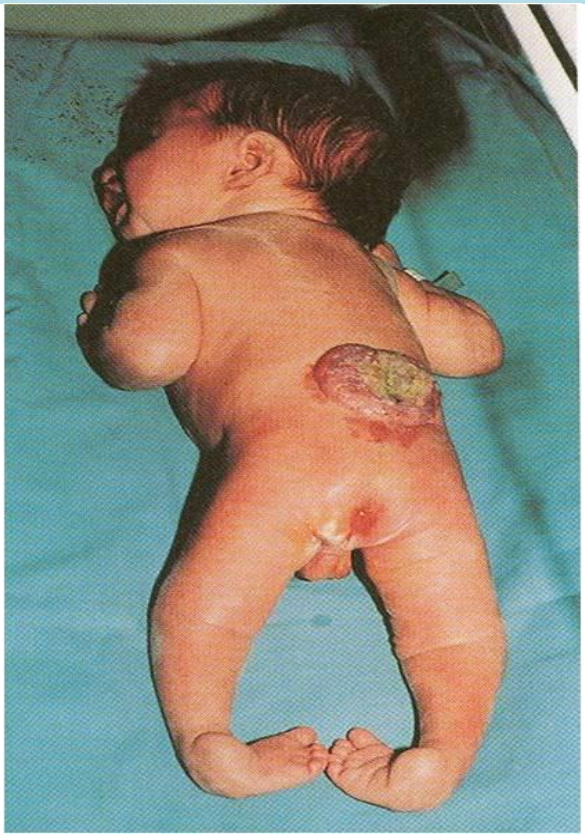
- The closed type
- Only one vertebra is affected
- No clinical symptoms
- Skin overlying it is intact
- Sometimes covered by a tuft of hair

SPINA BIFIDA CYSTICA

With meningomyelocoele



With myeloschisis



SPINA BIFIDA CYSTICA

- The open type
- 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 fusion of neural folds

SUMMARY OF DEVELOPMENT OF SPINAL CORD

- The spinal cord develops from the caudal 2/3 of the ectodermal neural tube.
- Layers of spinal cord are (from inside outward): ventricular, mantle (future grey matter) and marginal (future white matter).
- Mantle layer differentiates into dorsal alar plate (with sensory neurons) & ventral basal plate (with motor neurons) separated by sulcus limitans.
- Marginal layer is divided into dorsal, lateral & ventral funiculus.

SUMMARY OF DEVELOPMENT OF SPINAL CORD

- Myelination of nerve fibers starts at 4th month & continues during the 1st postnatal period. Motor fibers myelinate before sensory fibers.
- Meninges are 3 membranous sac covering the neural tube (from outside inward): dura (mesodermal in origin), arachnoid and pia (both are ectodermal in origin).
- A cavity between arachnoid & pia matters (subarachnoid space) contains cerebrospinal fluid.
- During development the end of spinal cord shifts its position: at 24 weeks (level of S1), at birth (level of L3), adult position (level of L1-L2).

SUMMARY OF DEVELOPMENT OF VERTEBRAL COLUMN

- Vertebral column develops from sclerotomic portion of paraxial mesoderm.
- Sclerotome around neural tube forms vertebral (neural) arch.
- Sclerotome around notochord forms body of vertebra. Each body develops from 2 adjacent sclerotomes.
- Notochord forms nucleus pulposus portion of the intervertebral discs.
- Chondrification centers appear at 6^{th} week.
- Three primary ossification centers appear at 8^{th} week.

SUMMARY OF DEVELOPMENT OF VERTEBRAL COLUMN

- Fusion between halves of neural arch occurs at 3-5 years, between neural arch & body at 3-6 years.
- Five secondary ossification centers appear at puberty and fuse around 25 years.
- Spina bifida is due to failure of fusion of the halves of the neural (vertebral) arch. It may be occulta (20%, closed type, no symptoms) or cystica (80%, open type, with symptoms).

QUESTION 1

- Which one of the following regions of spinal cord contains **cell bodies of sensory neurons?**

1. Alar plate ⟵
2. Ventricular zone
3. Basal plate
4. Dorsal funiculus

QUESTION 2

- At which one of the following periods of life fusion between vertebral arch & body of vertebra occurs?

1. 8^{th} week
2. Puberty
3. 3-6 years ⬅
4. Around 25 years

QUESTION 3

- Regarding spina bifida which one of the following statements is correct?

1. The closed type is more frequent than the open type.
2. The closed type presents with clinical symptoms.
3. Spina bifida is due to failure of fusion between the halves of vertebral arch.
4. In cases of spina bifida with meningocoele, the spinal cord is open.


THANK YOU