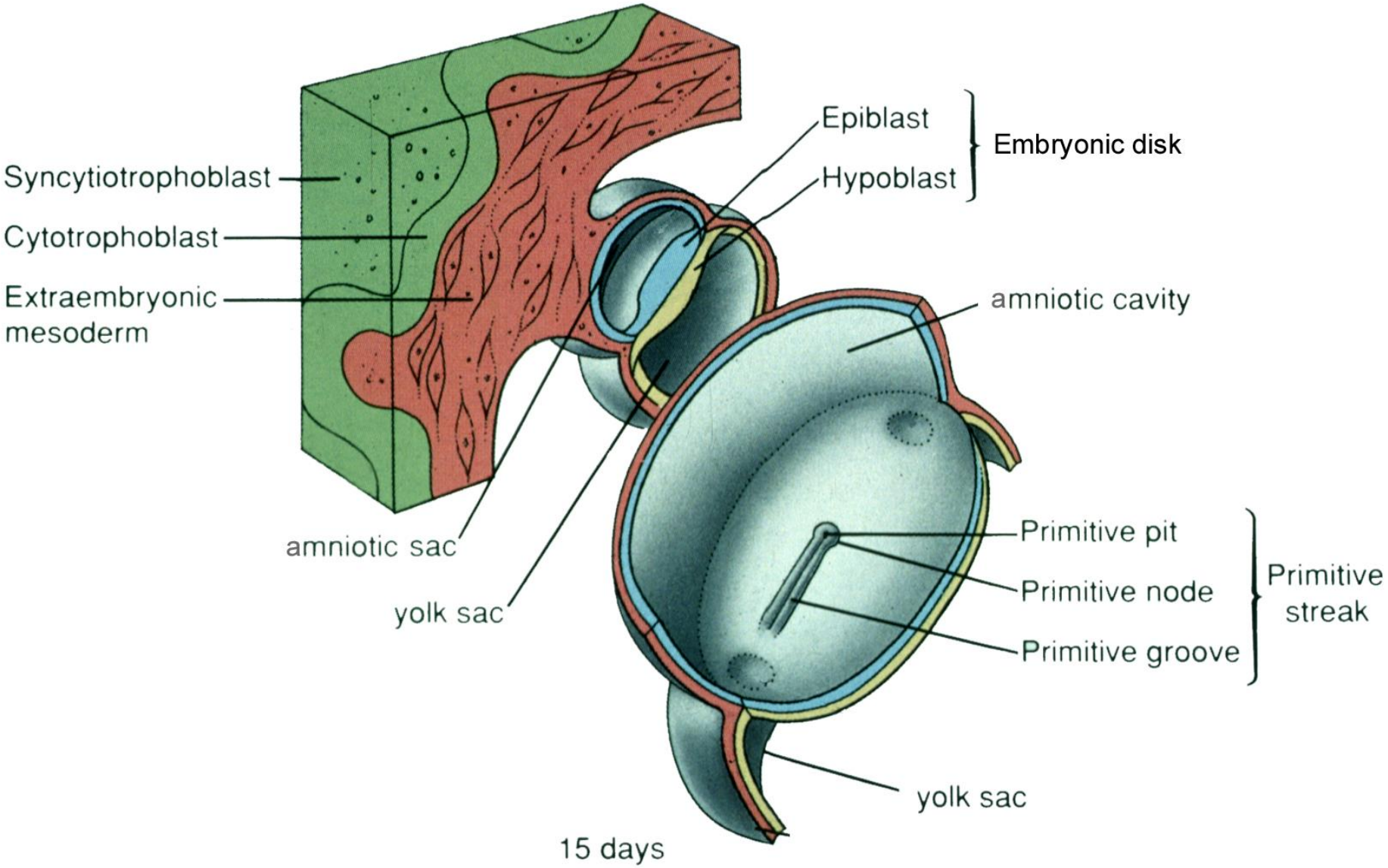
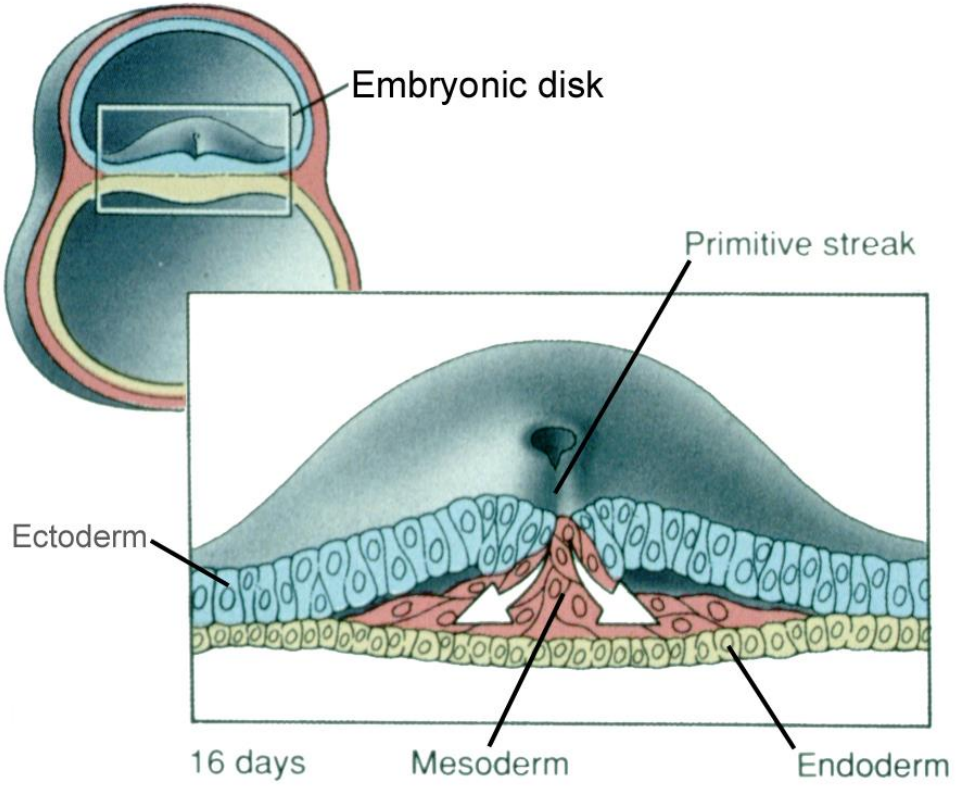
Embryology of the Nervous System

Steven McLoon
Department of Neuroscience
University of Minnesota

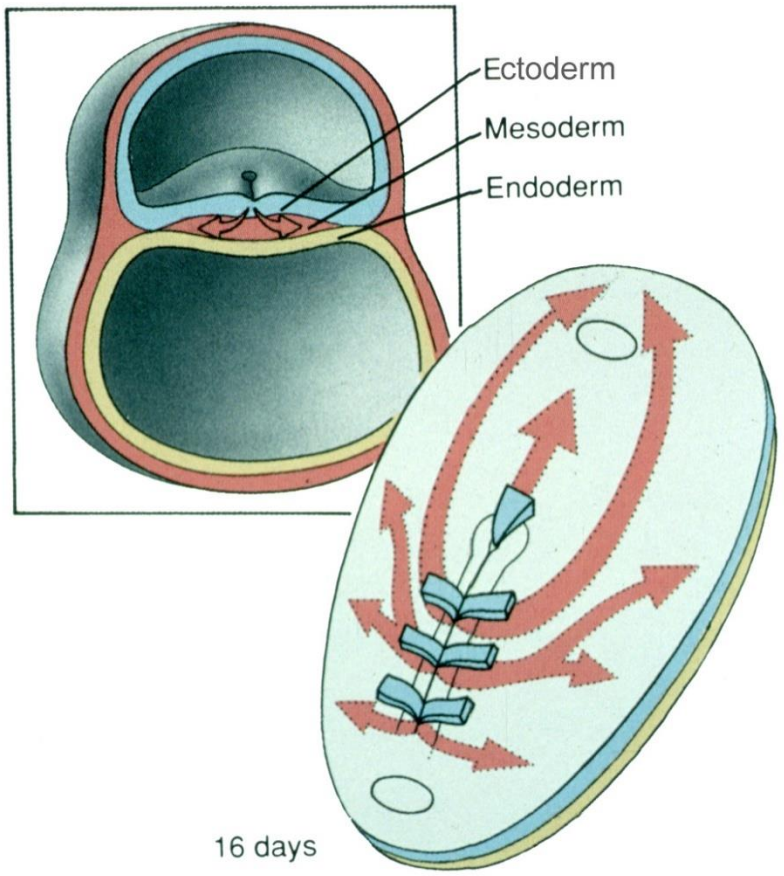
In the blastula stage embryo, the embryonic disk has two layers.



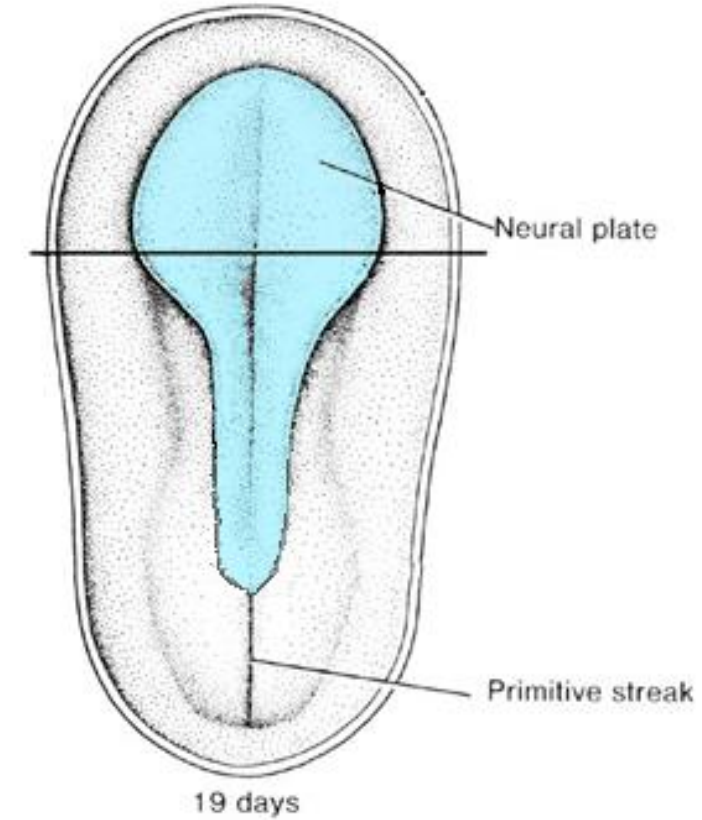
During gastrulation, epiblast cells migrate through the primitive streak to form a three layered embryo.



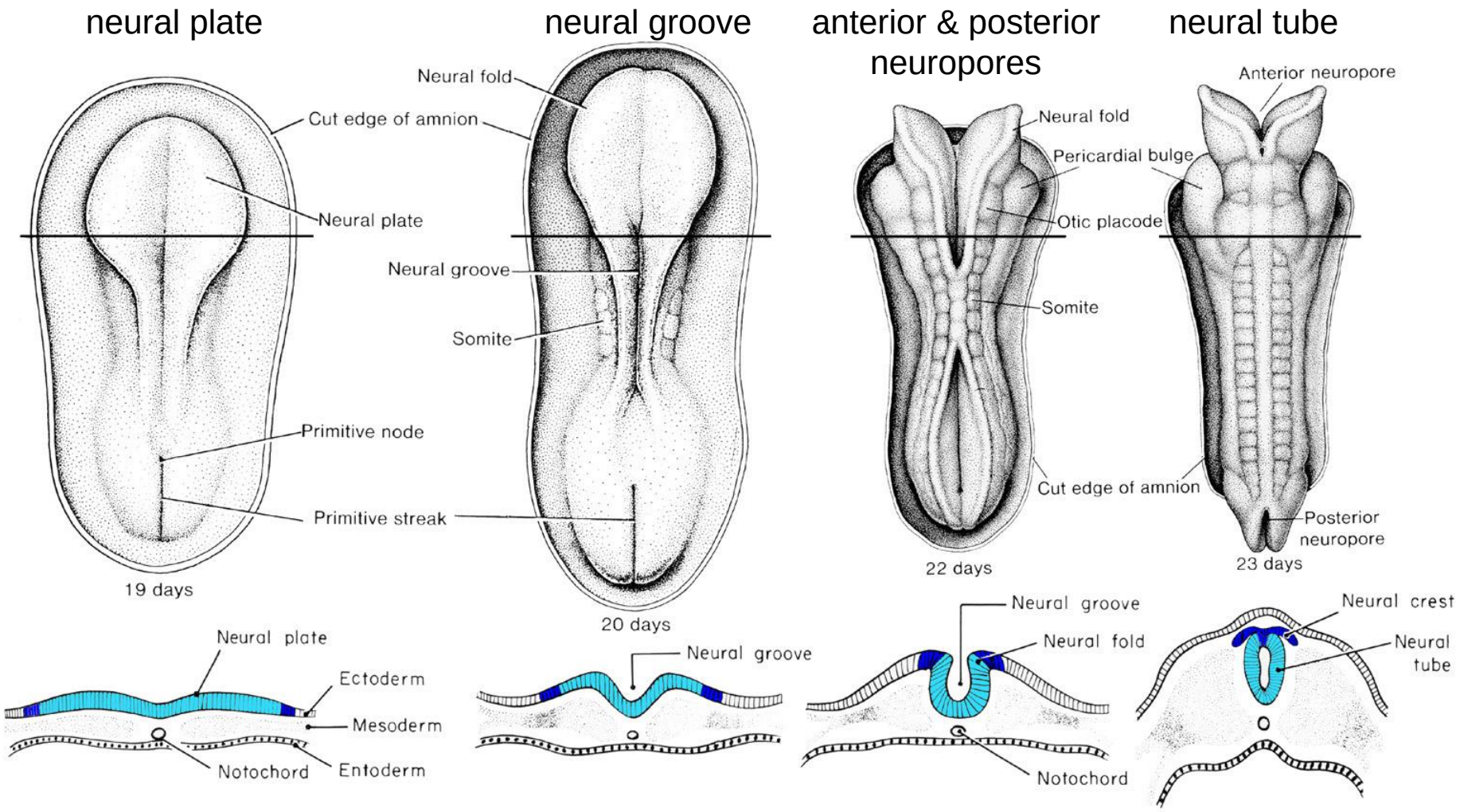
During gastrulation, epiblast cells migrate through the primitive streak to form a three layered embryo.



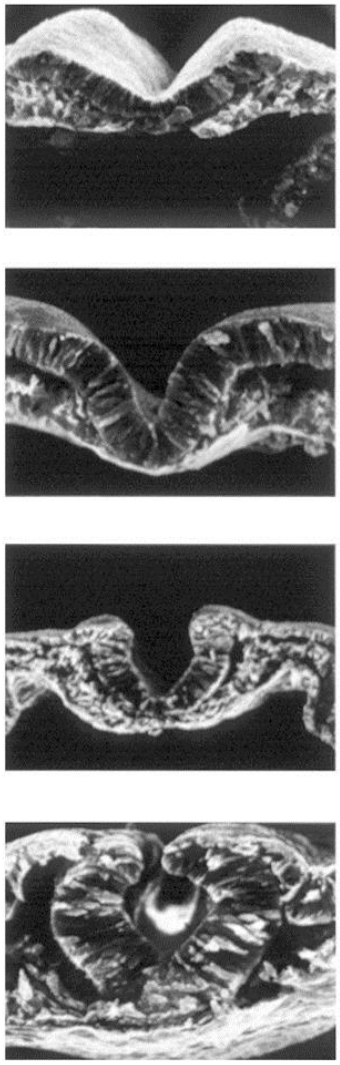
Factors from the midline mesoderm induce nervous system in the overlying ectoderm, and the neural plate forms from ectoderm.

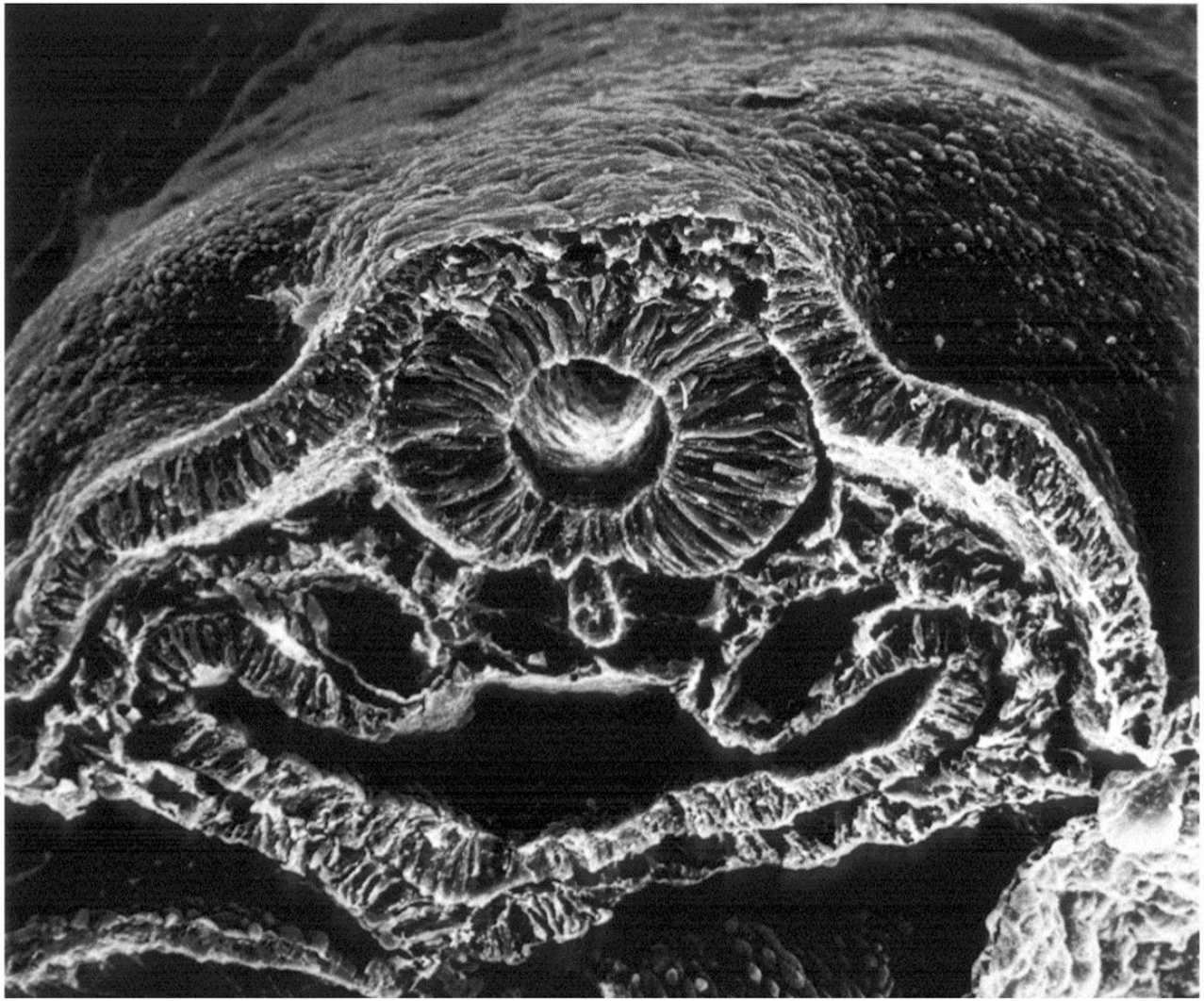


During neurulation, the neural tube develops from the neural plate.



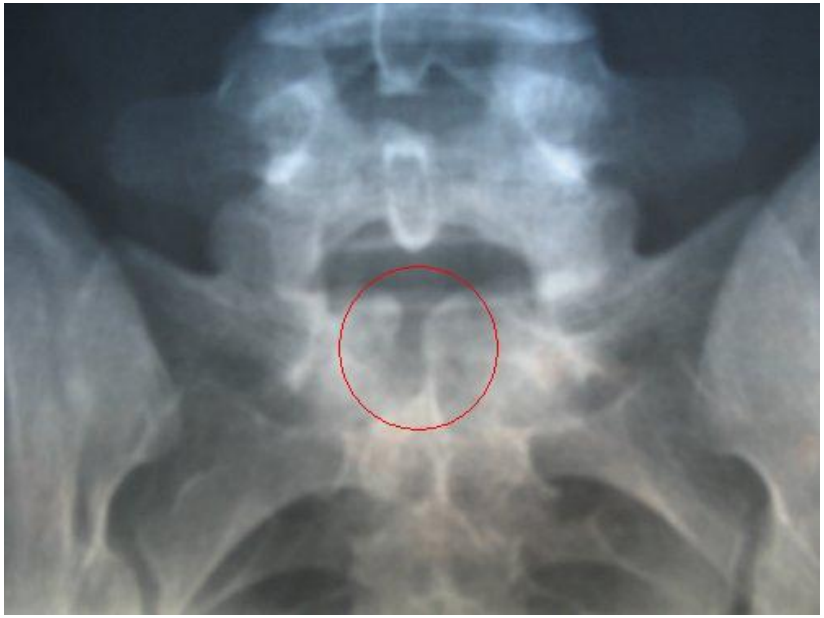
During neurulation, the neural tube develops from the neural plate.

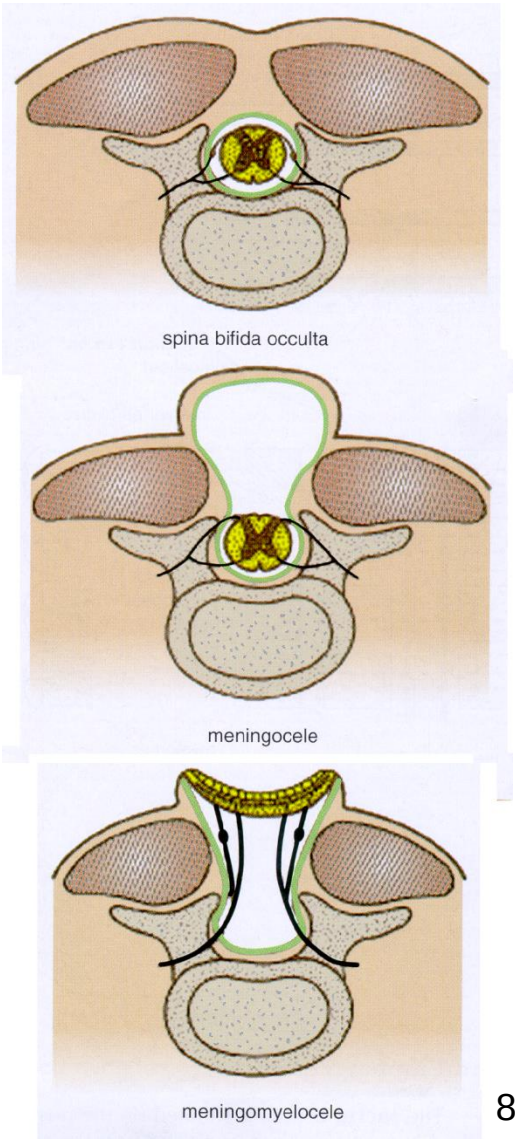




Incomplete closure of the neural tube is a common birth defect.

- Spina bifida:
- Incomplete closure of the spinal neural tube and/or the spine.
- The severity of the defect is variable and most often is of no consequence.
- ~1 in 50 live births exhibit spina bifida occulta, making this one of the most common birth defects.





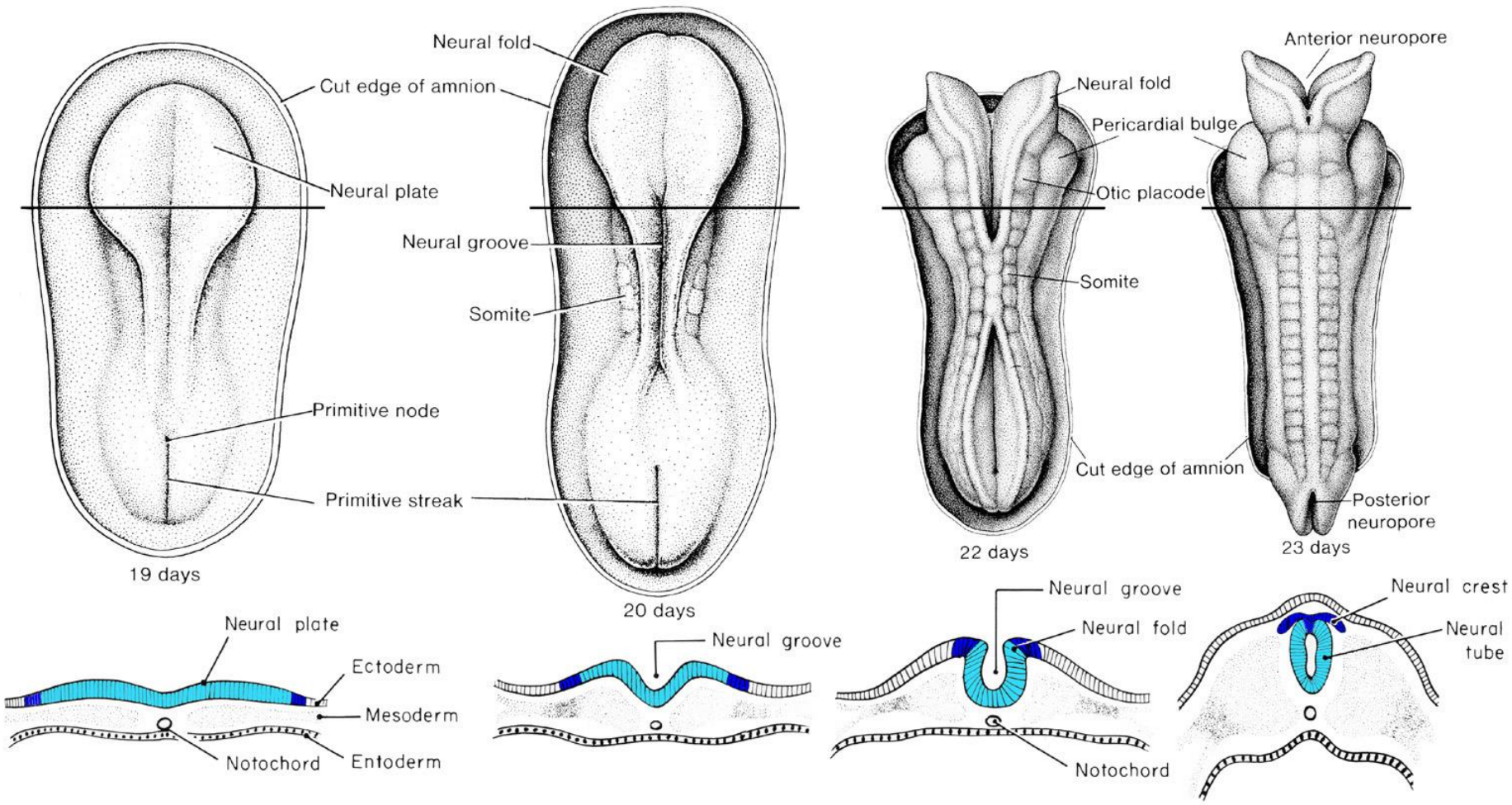
Incomplete closure of the neural tube is a common birth defect.

- Spina bifida (continued):
  - A daily supplement of folic acid (vitamin B9) in the diet of pregnant mothers reduces the incidence of spina bifida by over 70%.
  - Folic acid is converted to dihydrofolic acid in the liver, which is essential for DNA replication and repair.

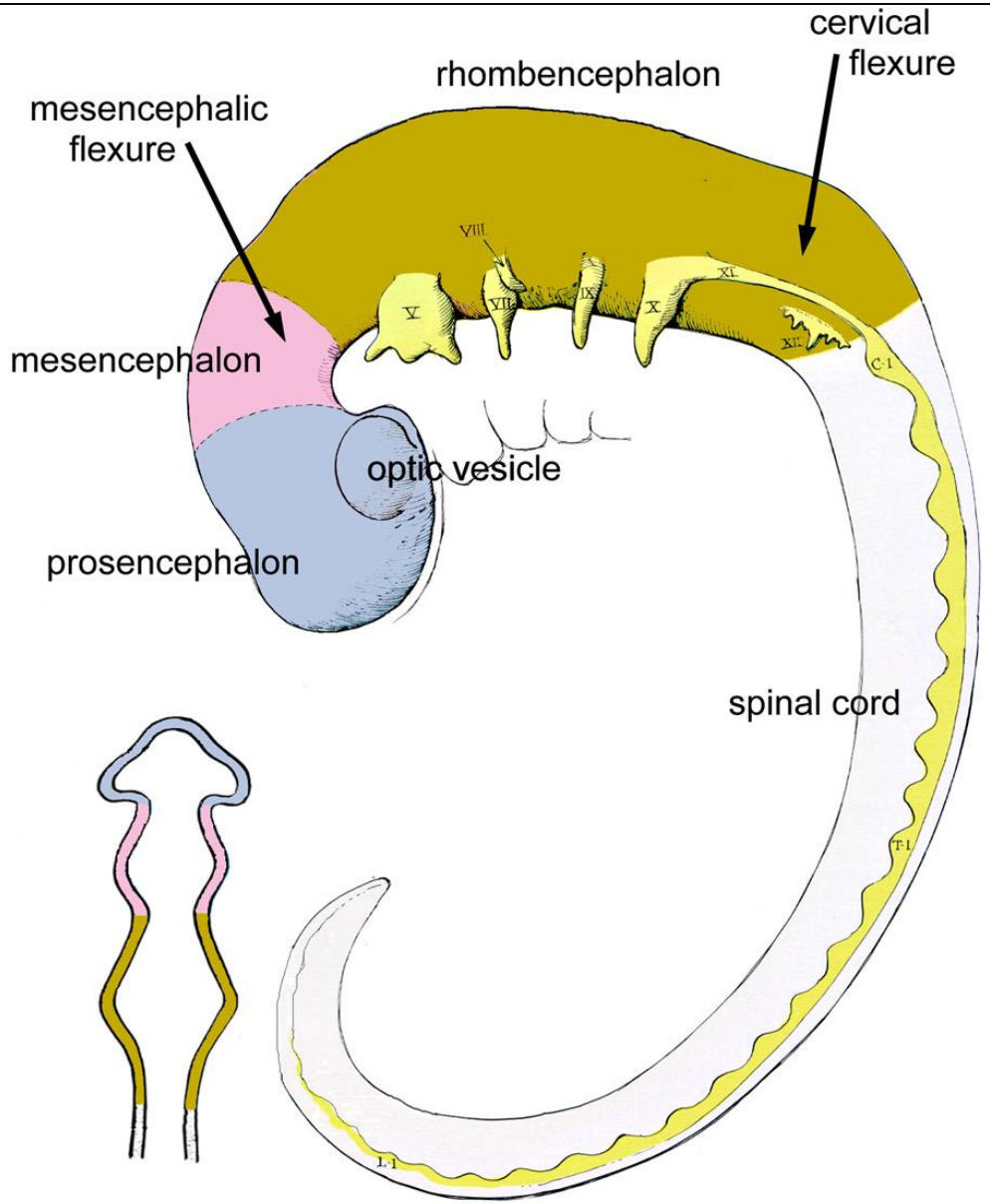
Incomplete closure of the neural tube is a common birth defect.

- Anencephaly = incomplete closure of the brain end of the neural tube
- Rare and lethal.

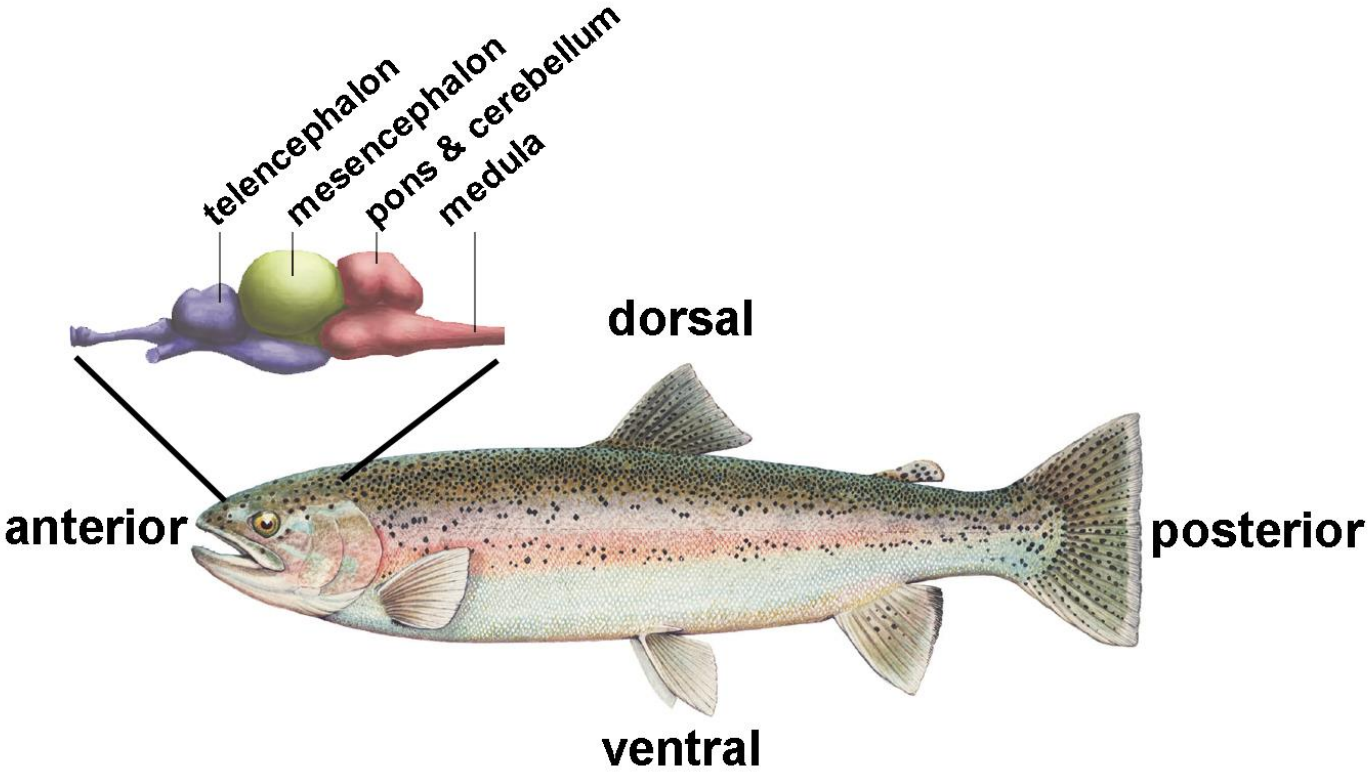
Three swellings at the rostral end of the early neural tube are the primary brain vesicles.



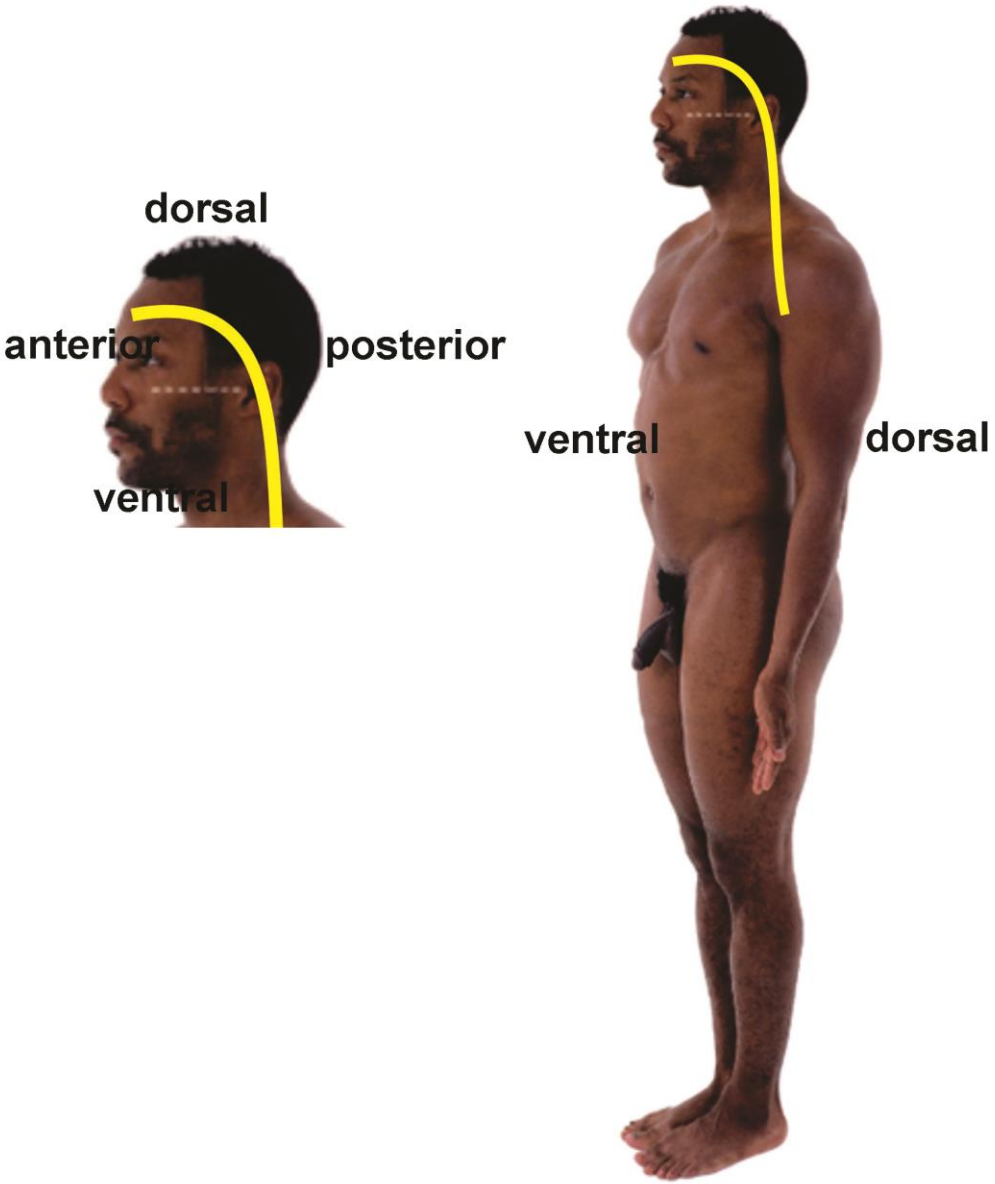
Three swellings at the rostral end of the early neural tube are the primary brain vesicles.



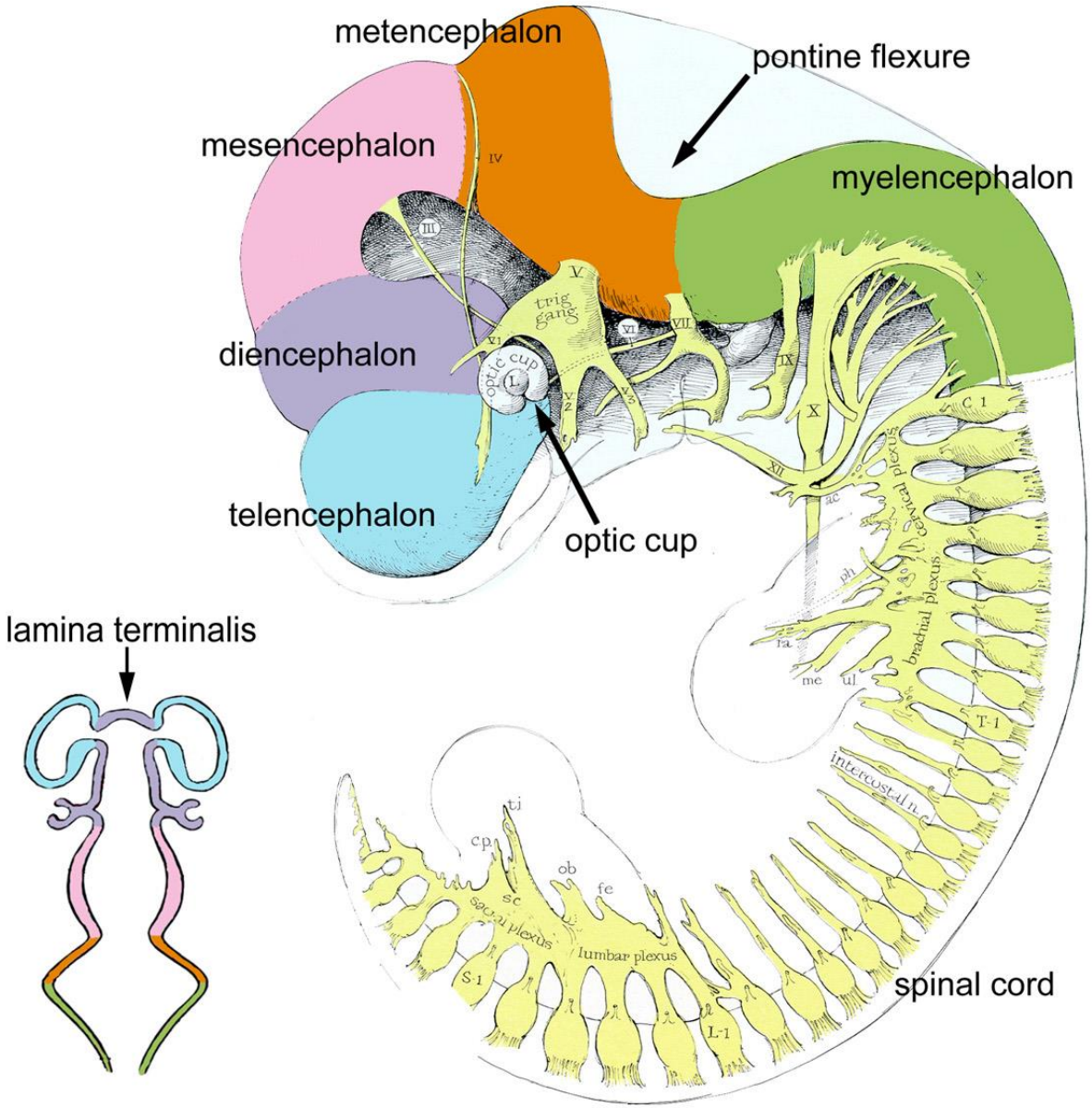
Flexures allow us to stand upright.



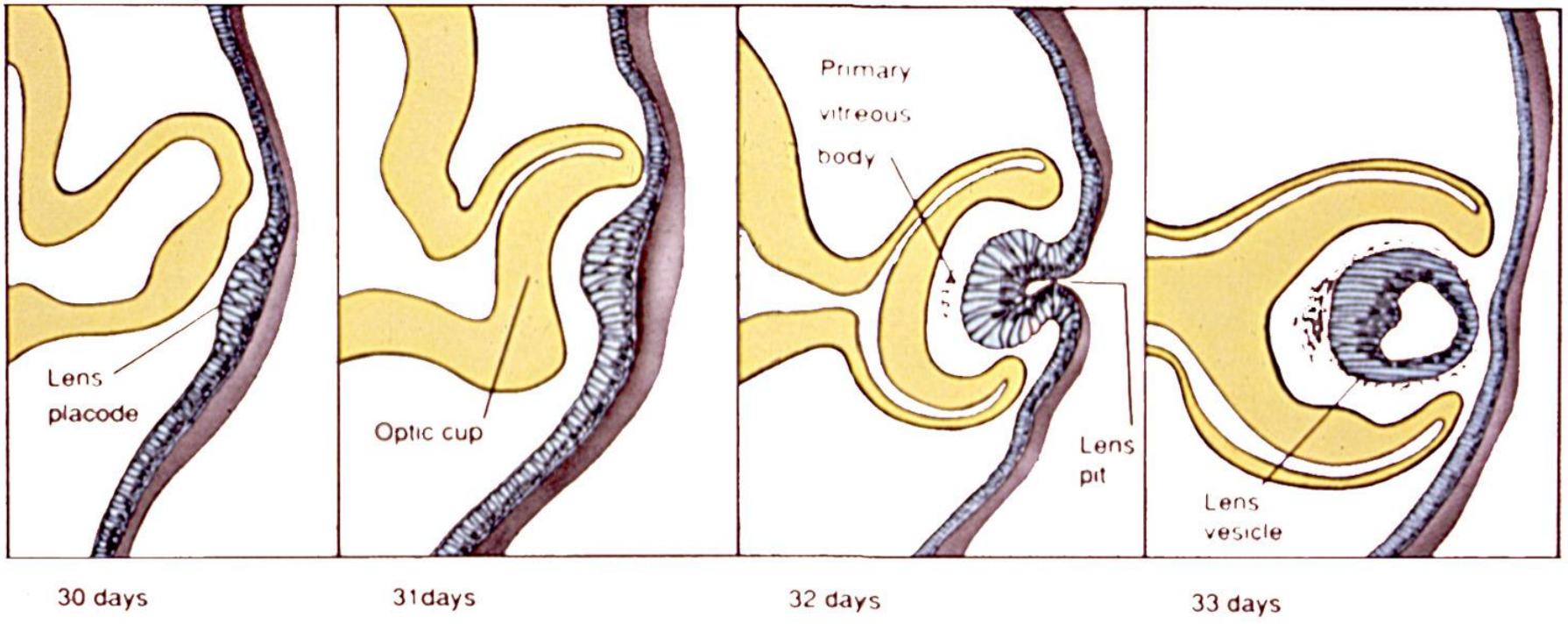
Flexures allow us to stand upright.



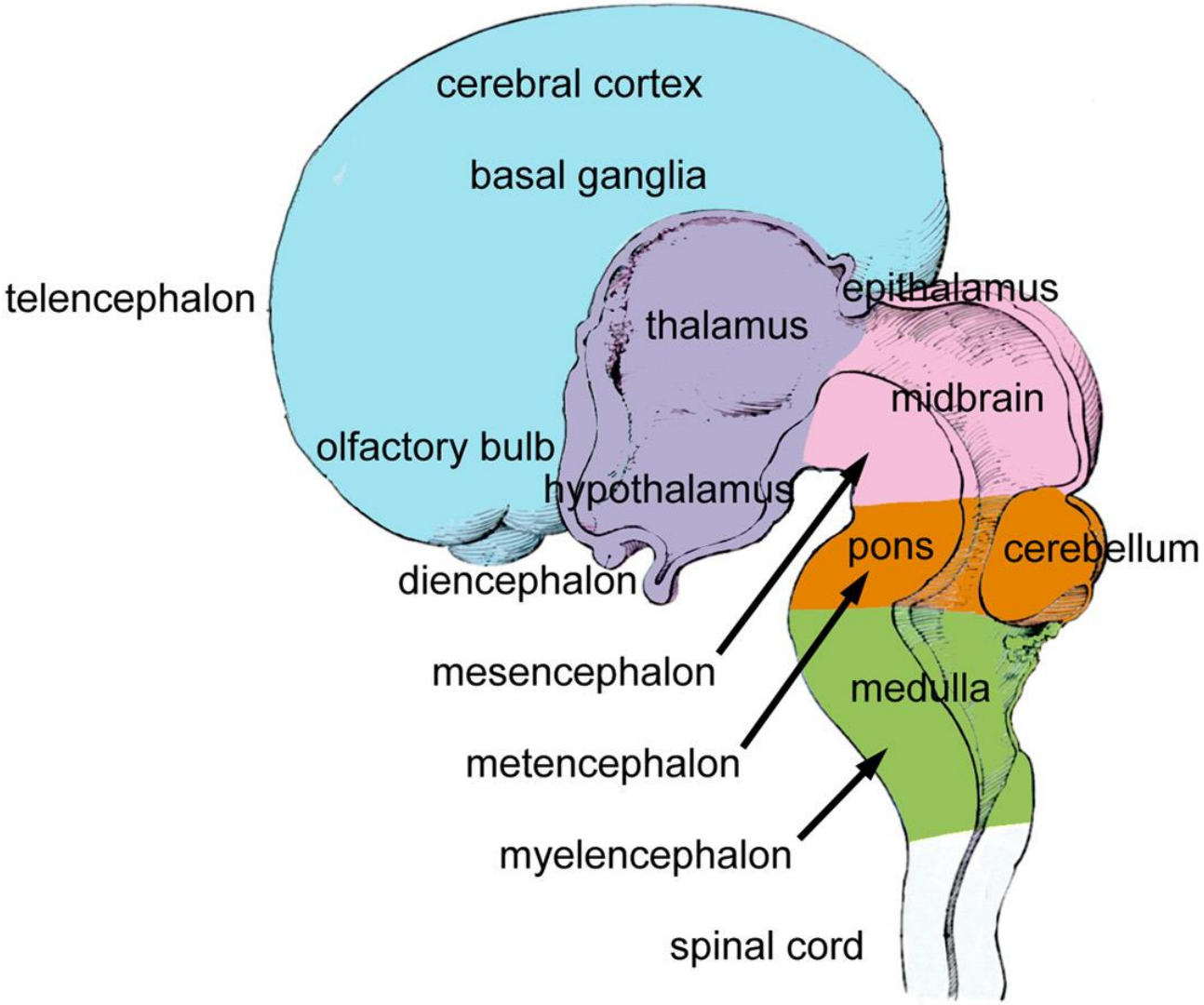
Additional changes form the secondary brain vesicles and optic vesicles.

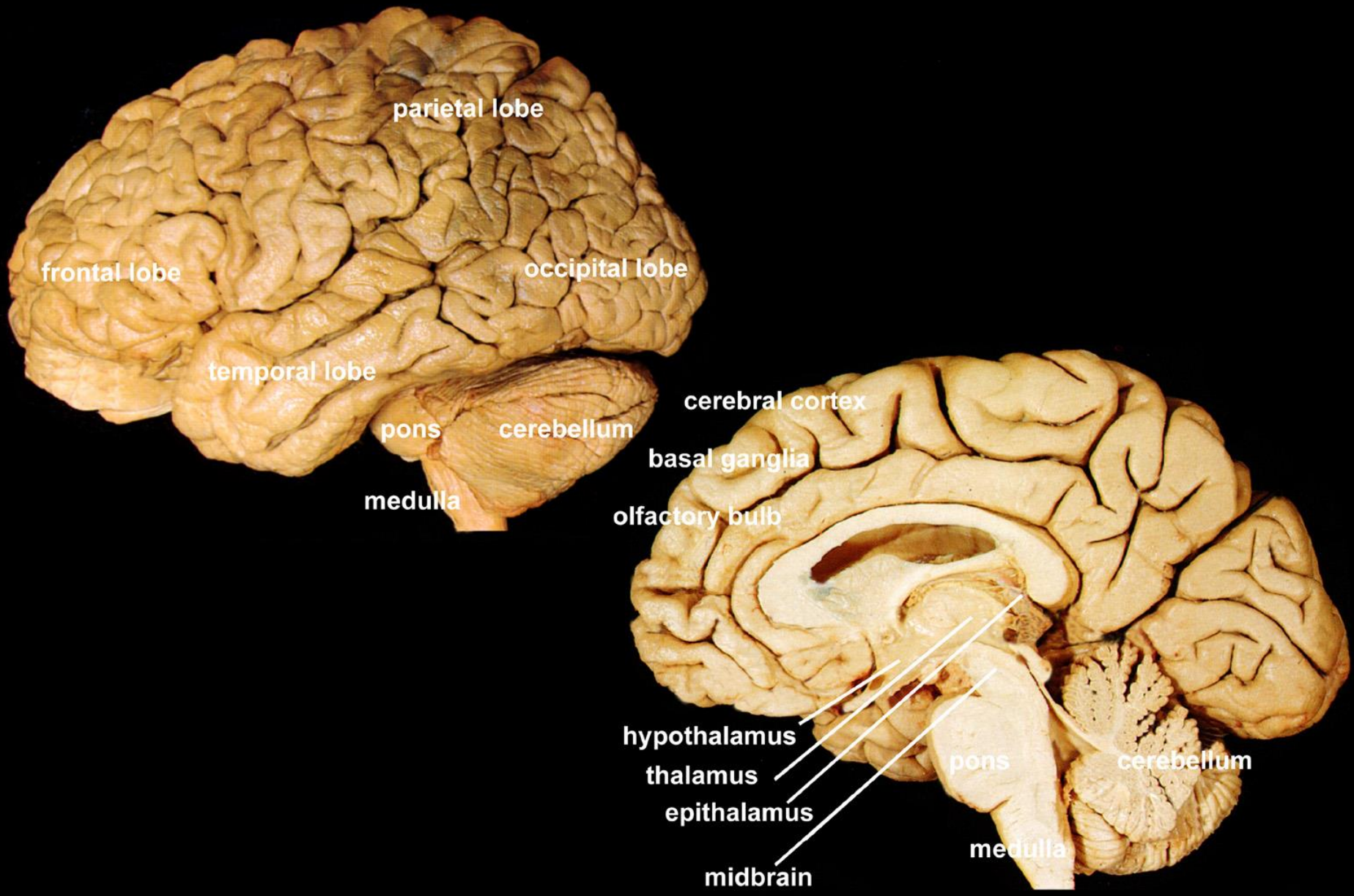


Optic vesicles give rise to neural retina & pigment epithelium.

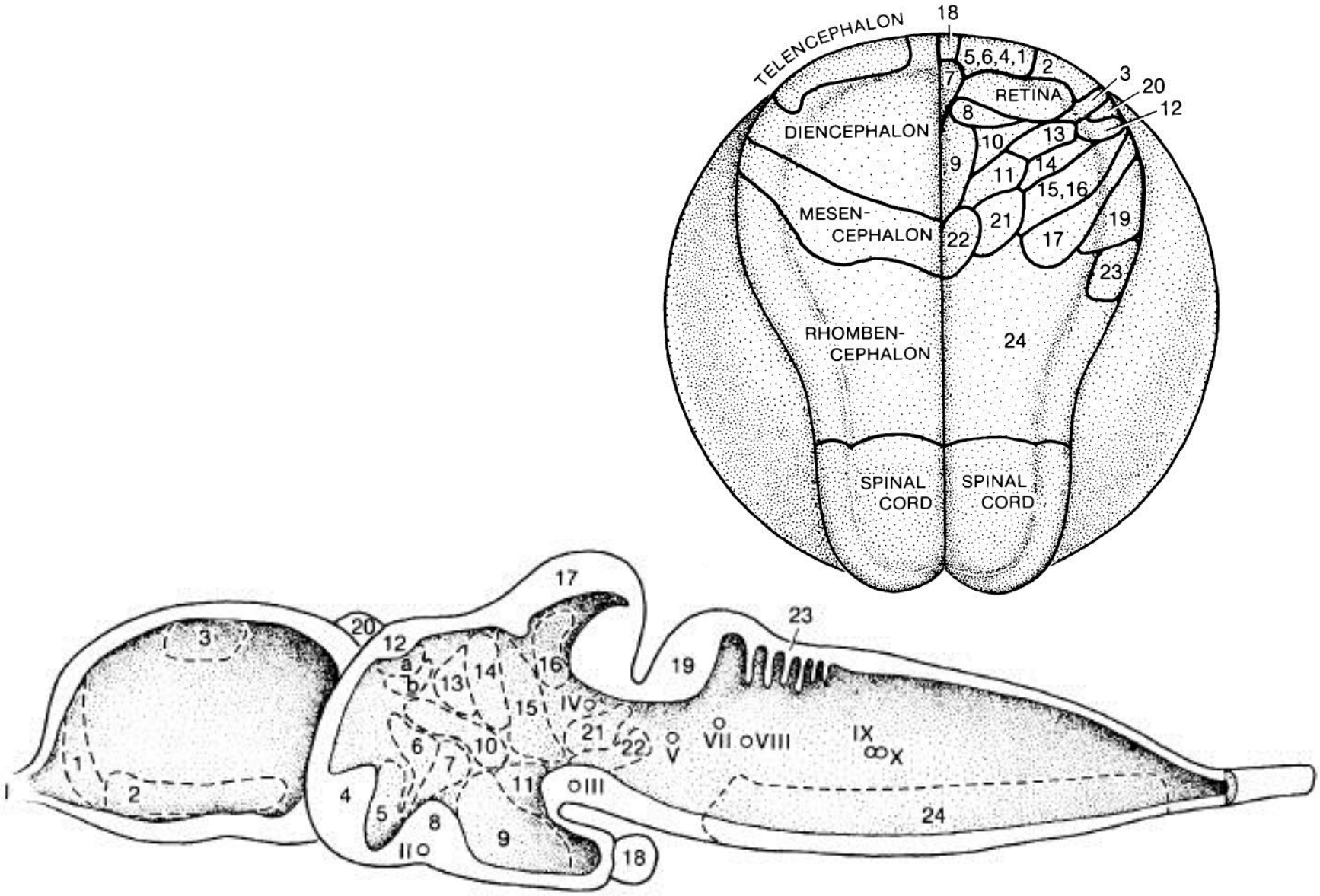


Each major adult brain region develops from one of the secondary brain vesicles.



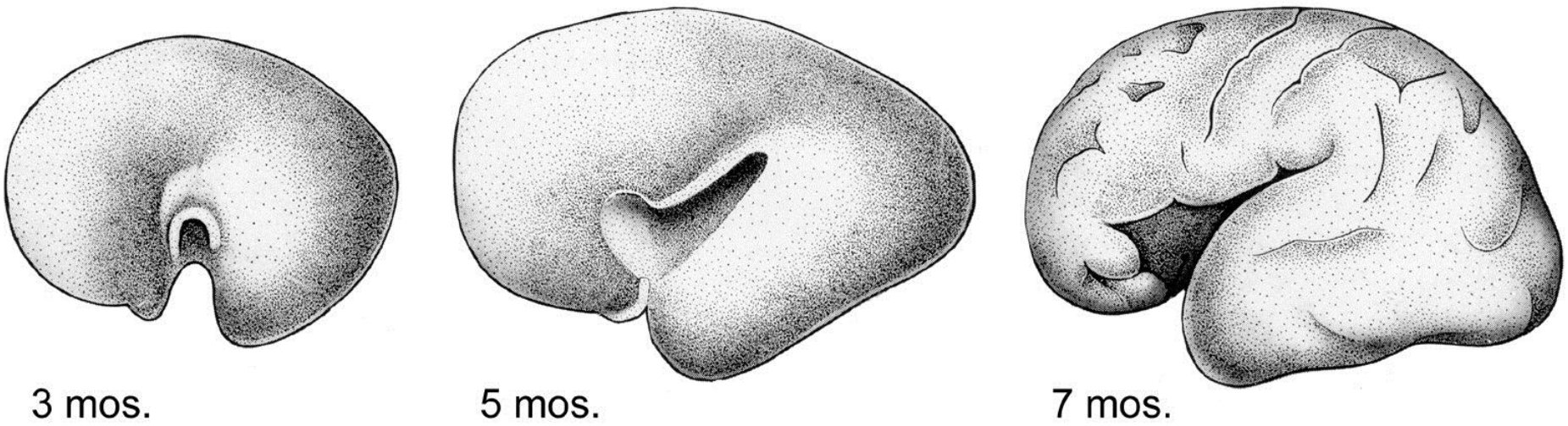

parietal lobe
frontal lobe
occipital lobe
temporal lobe
pons
cerebellum
medulla
cerebral cortex
basal ganglia
olfactory bulb
hypothalamus
thalamus
epithalamus
midbrain
pons
cerebellum
medulla

The entire nervous system develops from the neural plate.



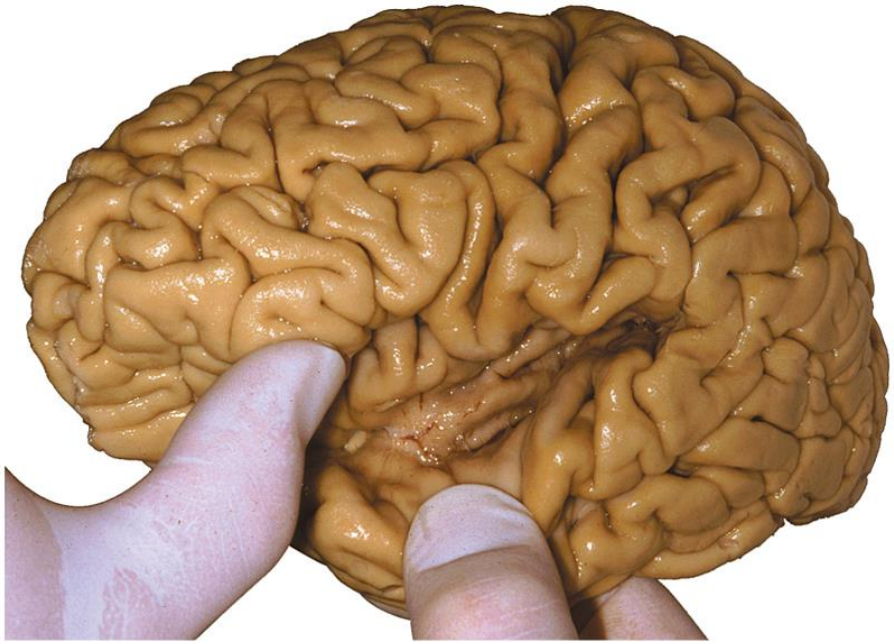
The telencephalon grows posterior then anterior.

- The “ram’s horn” pattern of growth of the telencephalic vesicle creates the temporal lobe.



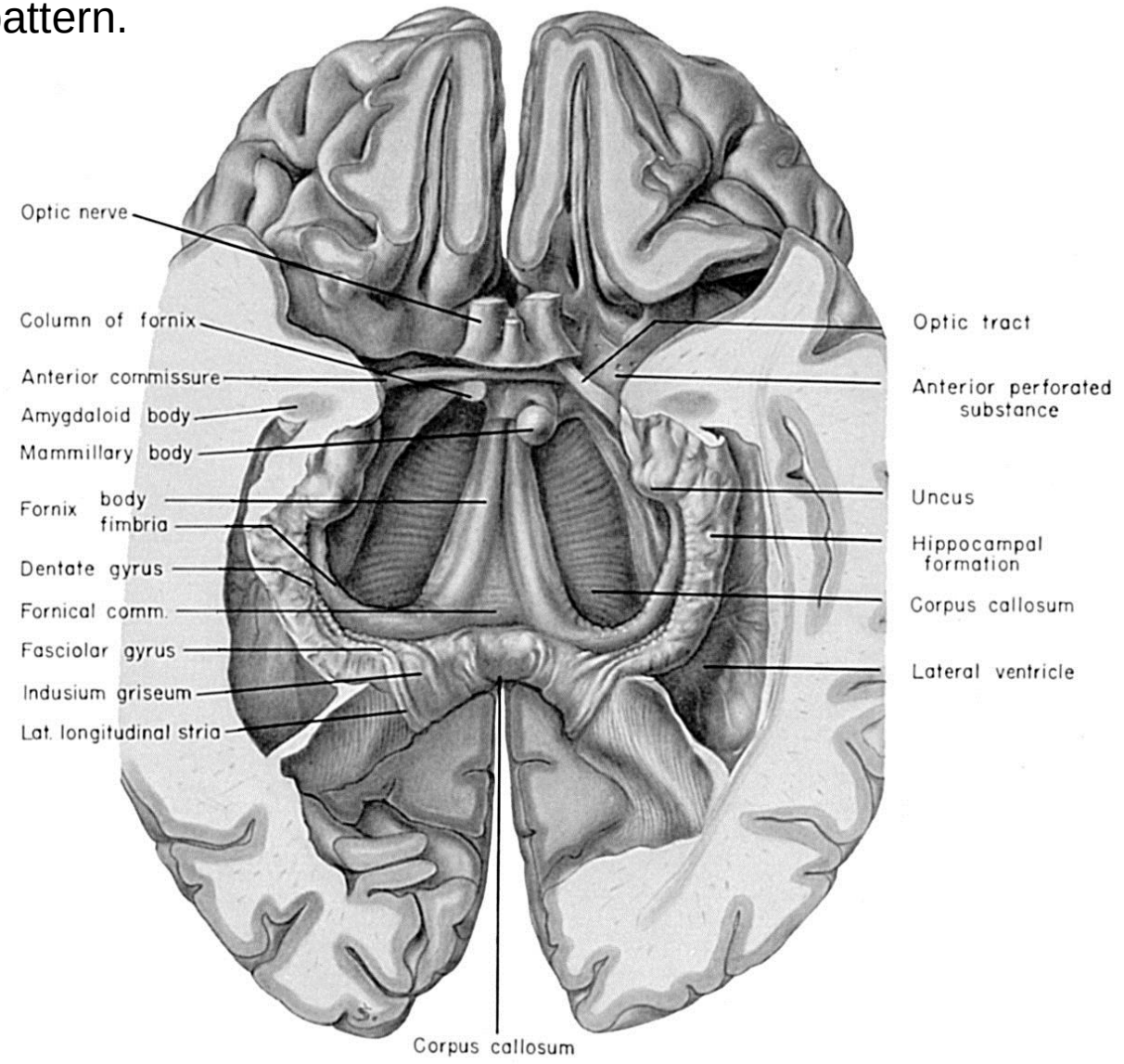
The telencephalon grows posterior then anterior.

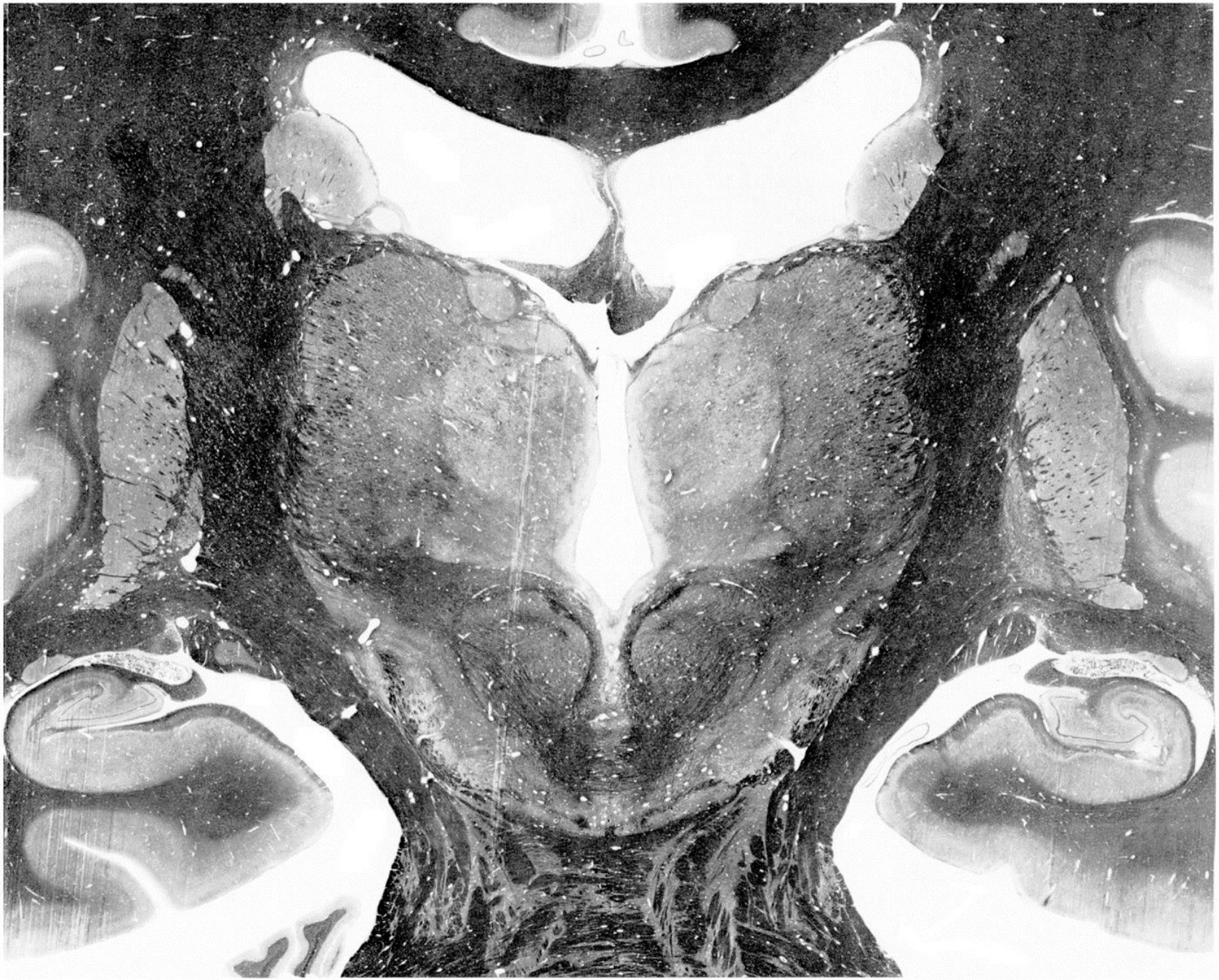
- The temporal lobe covers the insula.



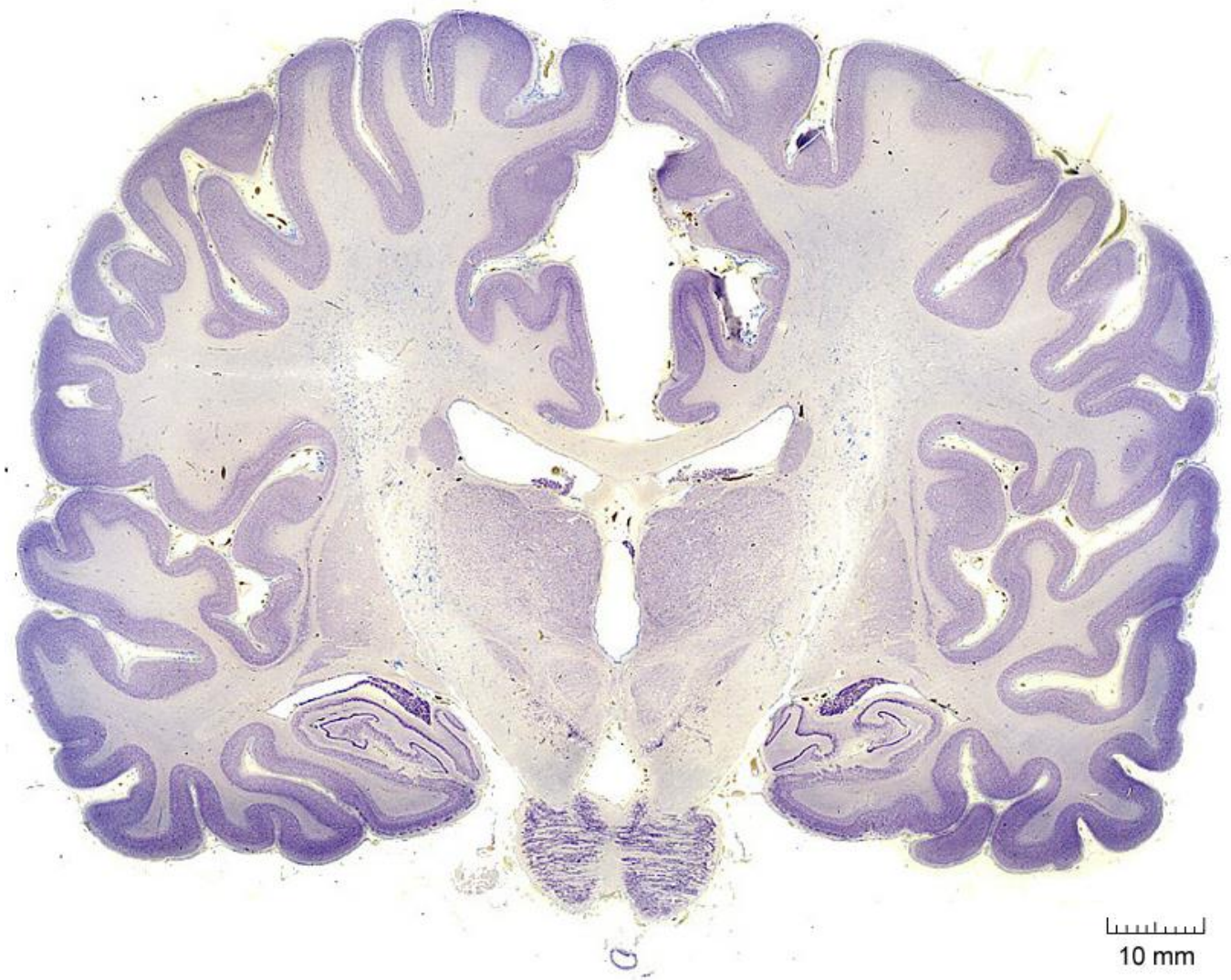
The telencephalon grows posterior then anterior.

- Other adult brain structures exhibit the “ram’s horn” pattern.

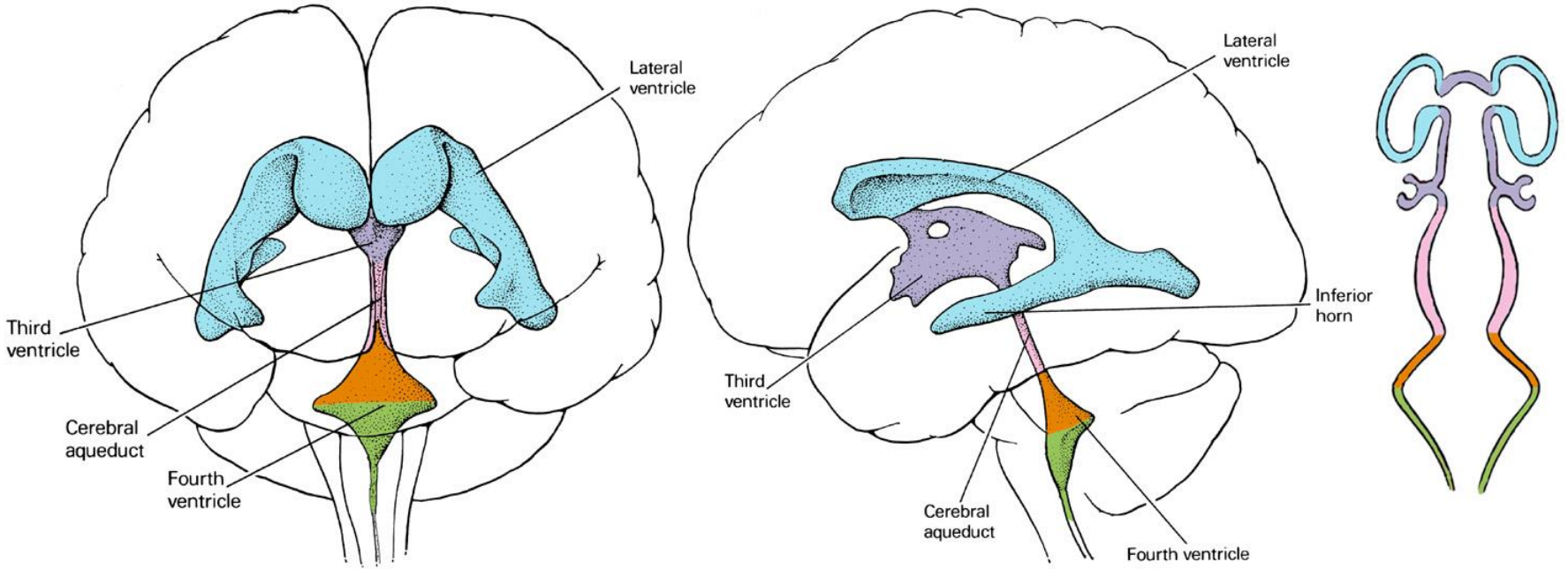




The lumen of the neural tube persists as the ventricular system of the adult brain.

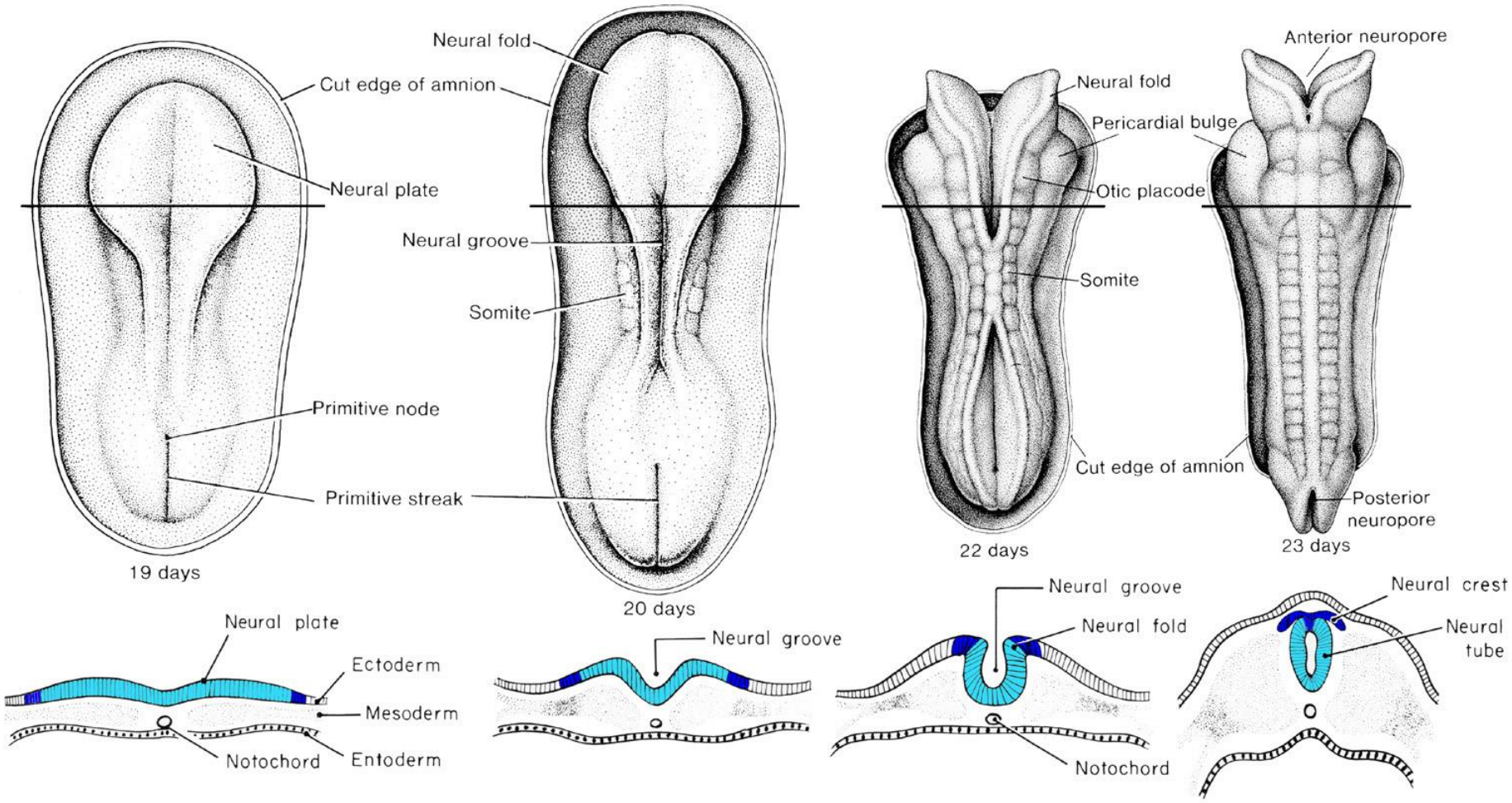


The lumen of the neural tube persists as the ventricular system of the adult brain.



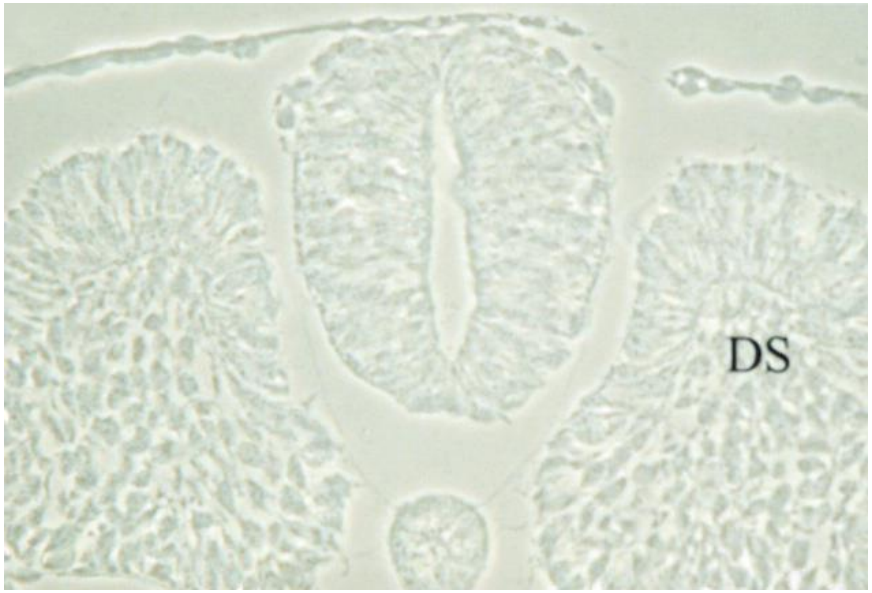
Neural Crest

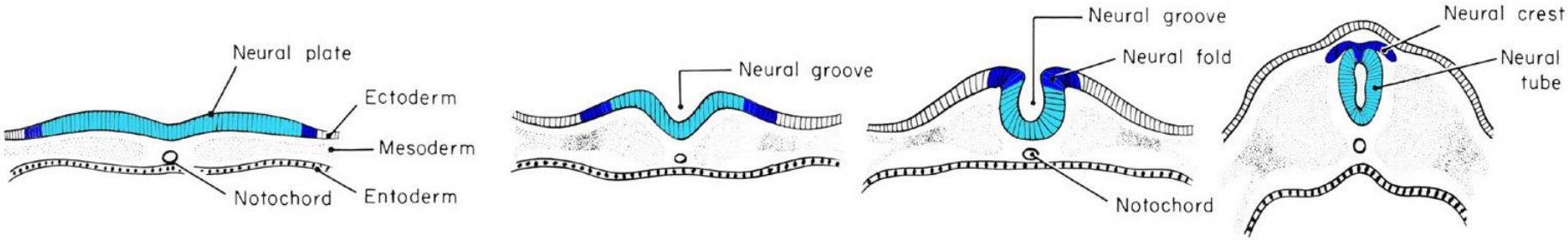
- The neural crest develops from cells at the margin of the neural plate.



Neural Crest

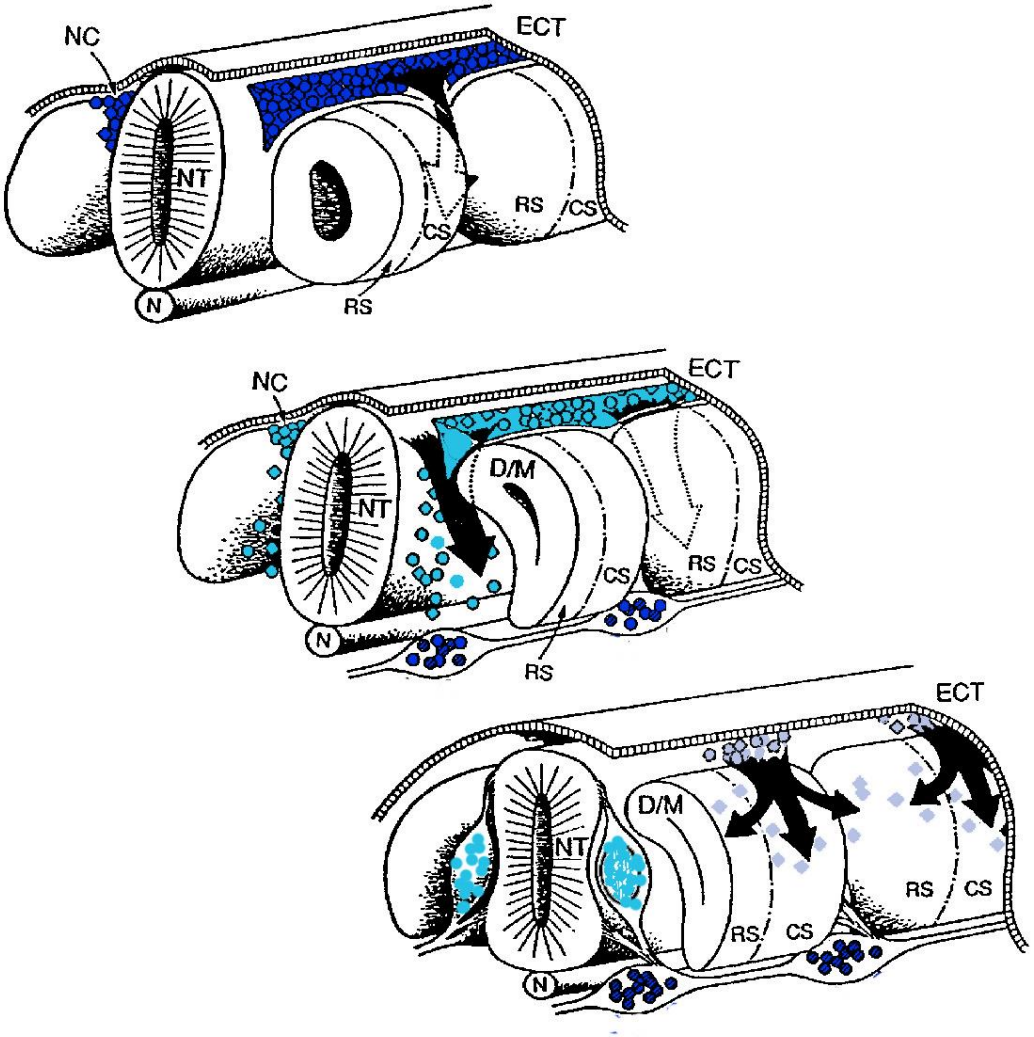
- Cells delaminate from the dorsal neural tube to form the neural crests.





Neural Crest

• Neural crest cells migrate throughout the body and develop into most of the cells of the peripheral nervous system, as well as other cell types.



Neural Crest

- Crest derivatives:

neurons
- most cranial nerve sensory ganglia
- dorsal root ganglia
- sympathetic ganglia
- parasympathetic ganglia
- enteric neurons

glia
- schwann cells of nerves
- satellite cells of ganglia

neurosecretory cells
- thyroid calcitonin (C) cells
- adrenal medulla cells

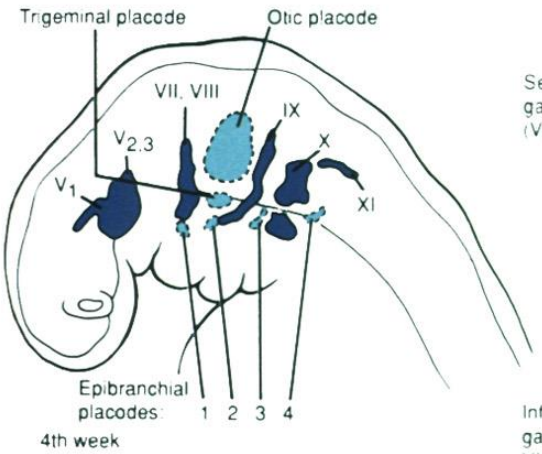
melanocytes

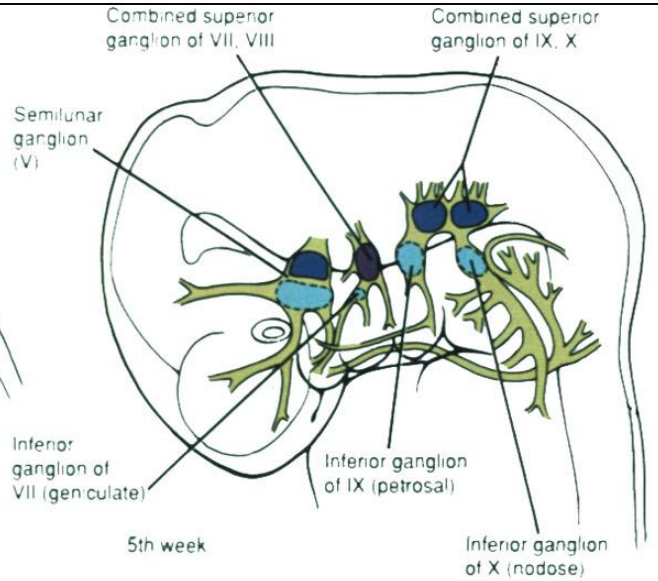
some skeletal and connective tissue of head and face

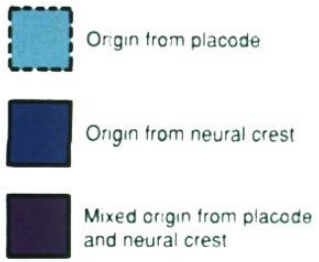
muscles
- ciliary muscle of eye
- muscle of cranial blood vessels and dermis

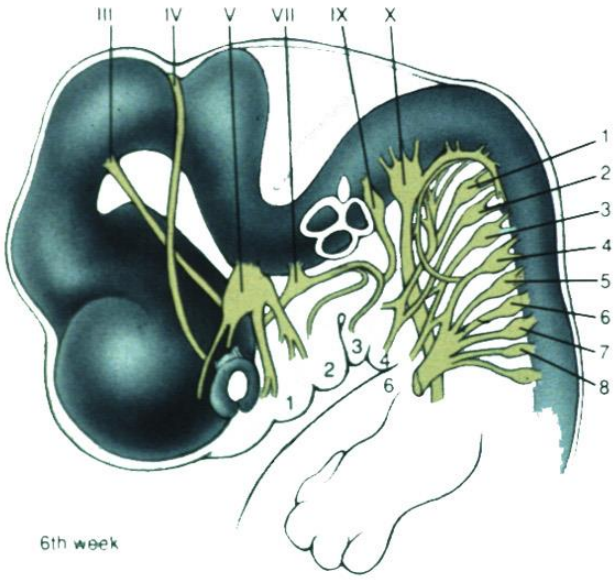
mesenchyme of thyroid, parathyroid & salivary glands

Neural placodes give rise to some neurons of cranial nerve sensory ganglia.





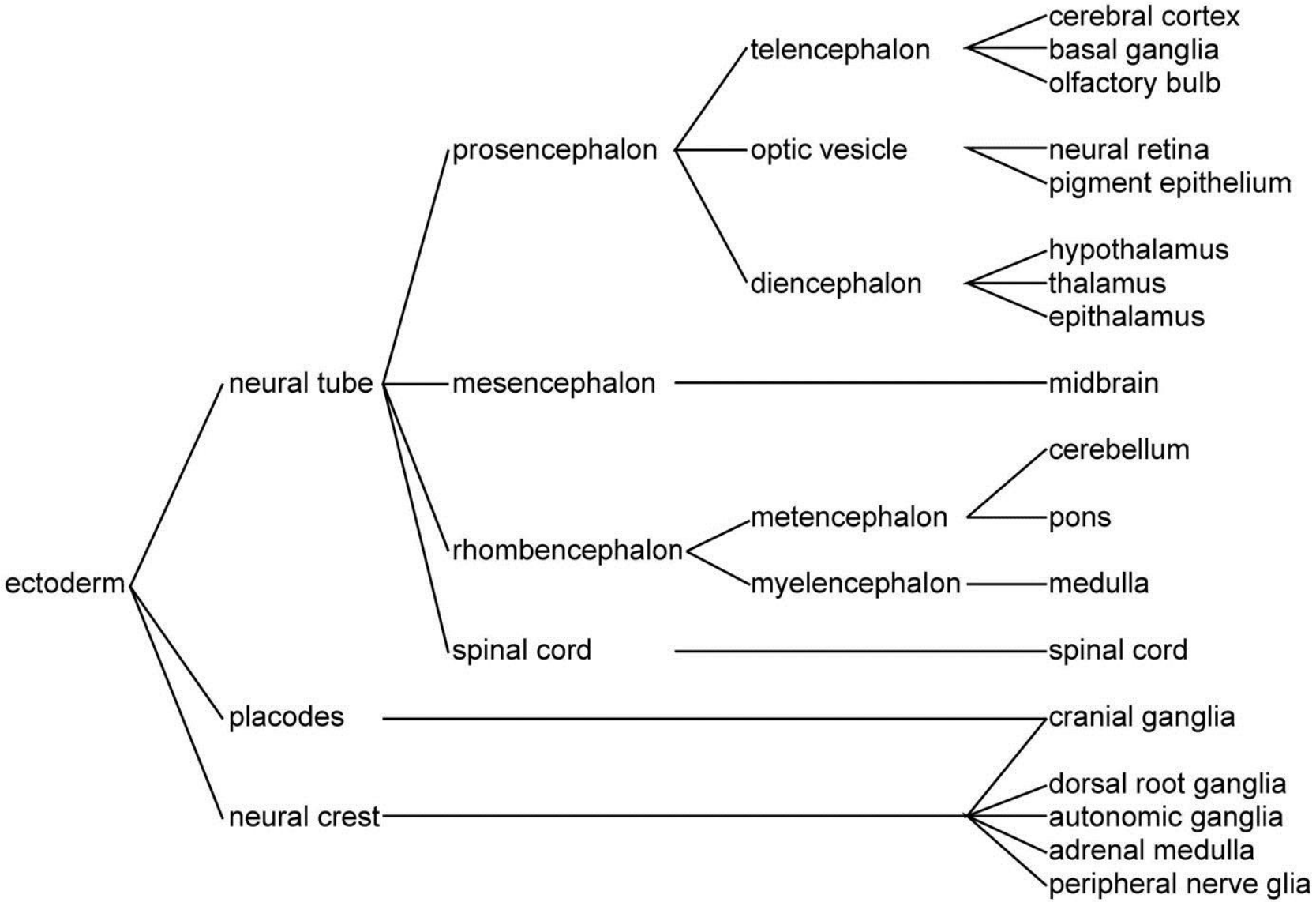




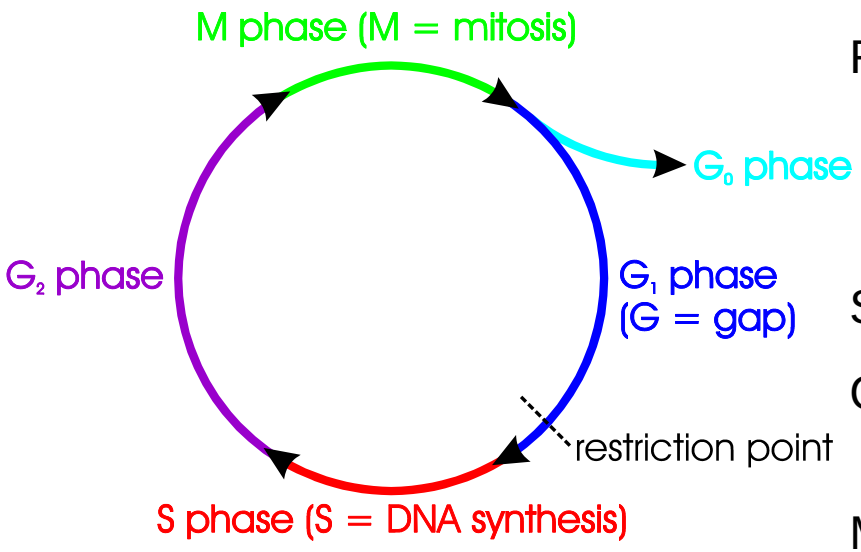
Origin of the Neurons of the Peripheral Nervous System

Neuron Group	Origin
olfactory receptors	nasal placode
ciliary ganglion	neural crest
trigeminal ganglior	neural crest & trigeminal placode
geniculate ganglion	neural crest & 1st epibranchial placode
sphenopalatine ganglion	neural crest
submandibular ganglion	neural crest
cochlear ganglion	otic placode
vestibular ganglion	otic placode & neural crest (minor)
superior glossopharyngeal g.	neural crest
inferior glossopharyngeal g.	2nd epibranchial placode
otic ganglion	neural crest
superior vagal ganglion	neural crest
inferior (nodose) vagal g.	3rc & ۷th epibranchial placodes
dorsal root ganglia	neural crest
sympathetic ganglia	neural crest
sacral parasympathetic g.	neural crest

Origin of the Nervous System



Review of the Cell Cycle
(steps involved in cell division)



G_1 period during which proteins that initiate or block division are expressed

Restriction point - a condition during which a cell is destined to progress through mitosis regardless of any changes in the environment of the cell

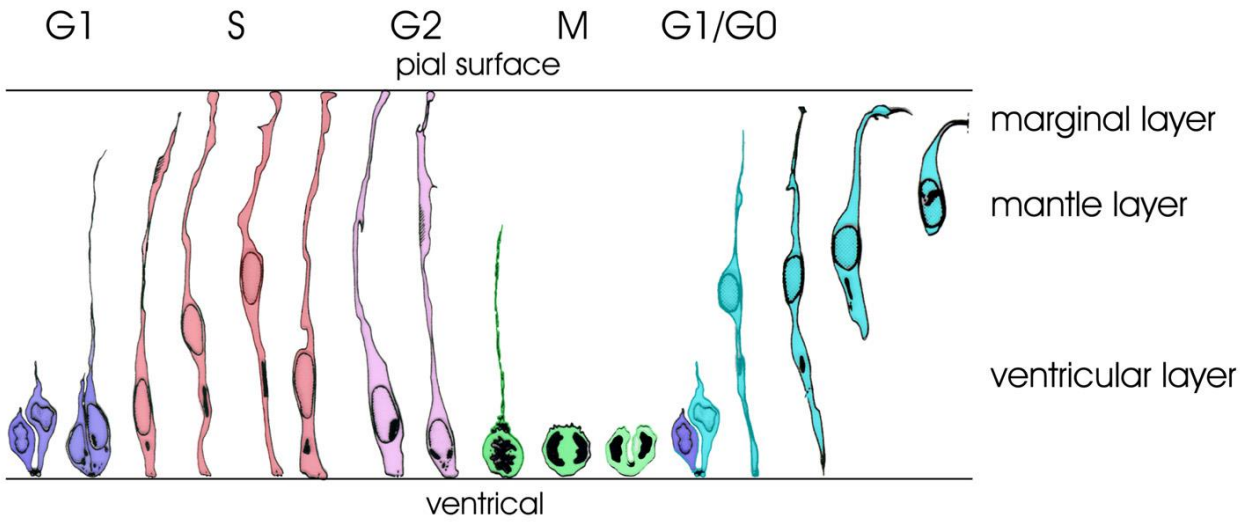
S period during which DNA is replicated

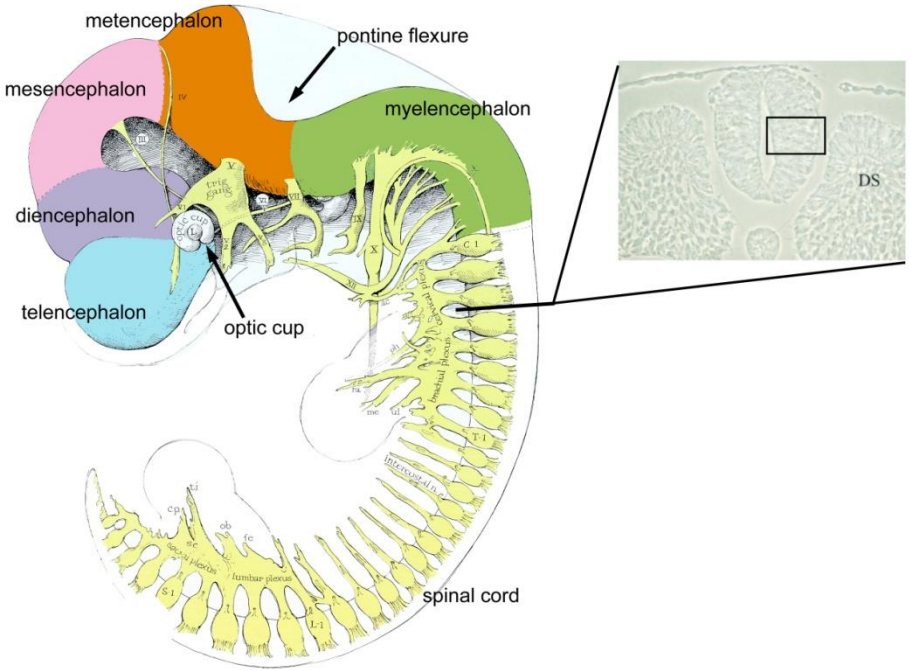
G_2 period during which proteins needed for mitosis are expressed

M period during which cell divides into two; steps are: prophase, metaphase, anaphase, telophase and cytokinesis

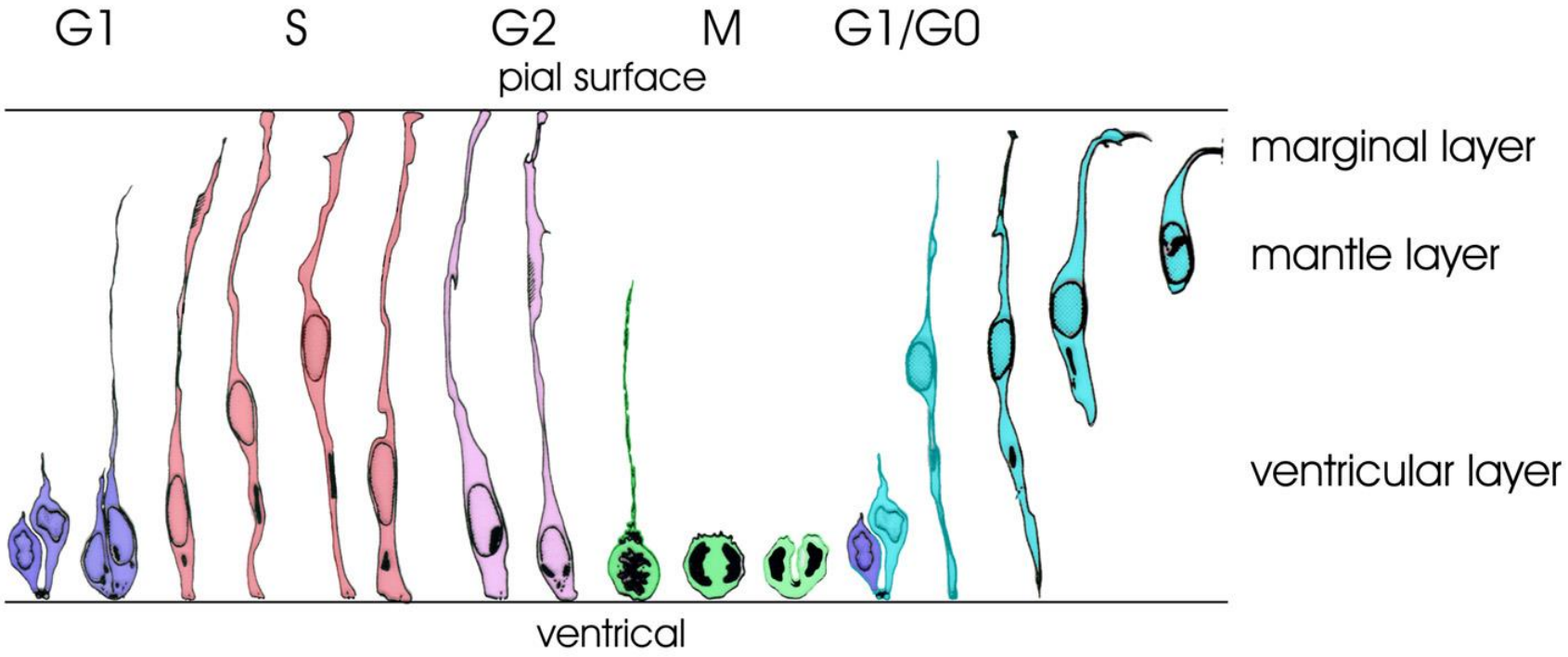
G_0 permanent arrest in G_1; period during which neurons differentiate and function

Initially, all cells of the neural tube undergo cell division.

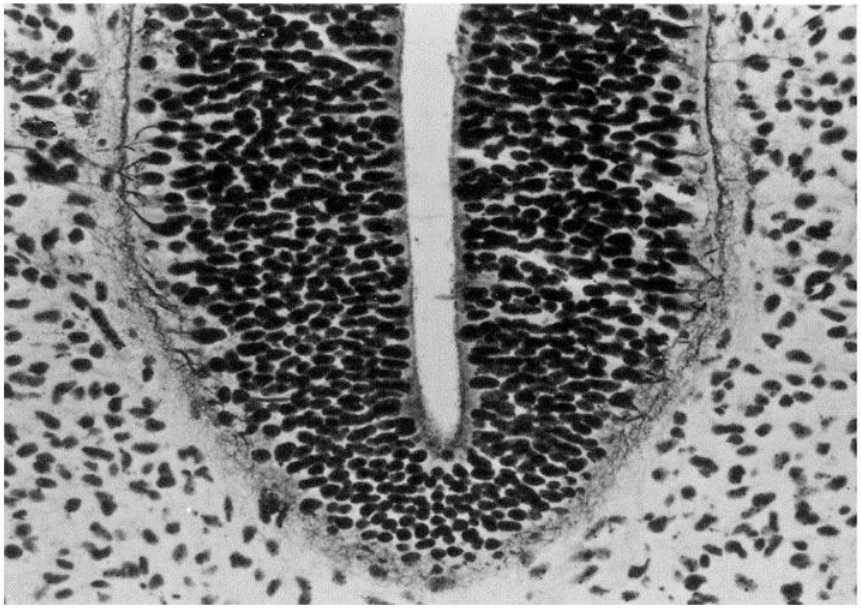


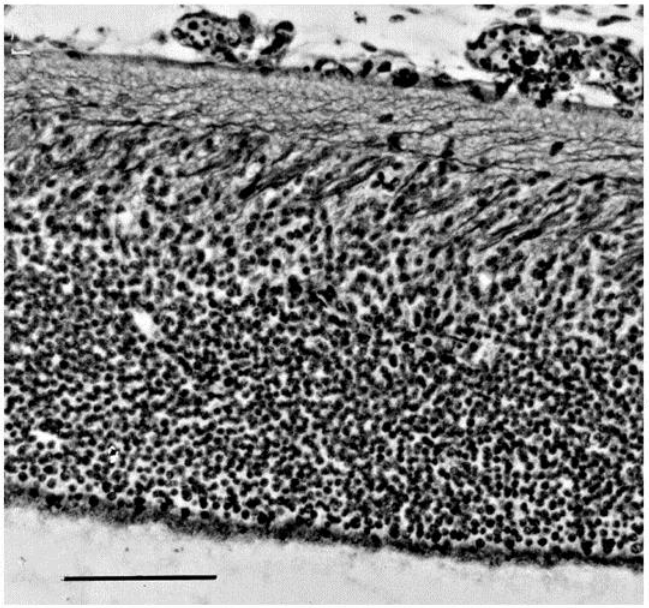


As development progresses, some cells cease to divide and begin to differentiate. This forms three layers.

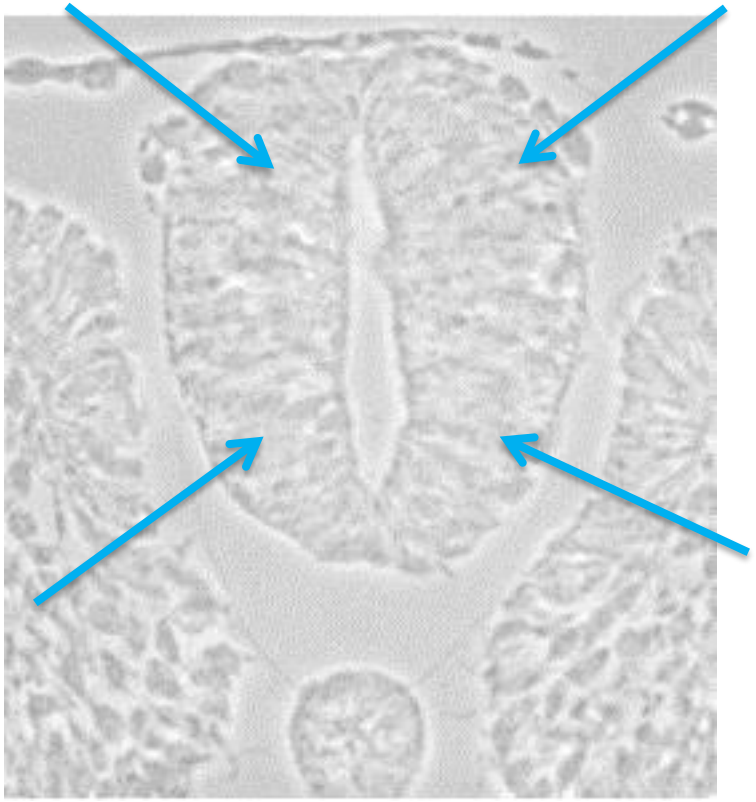


As development progresses, some cells cease to divide and begin to differentiate. This forms three layers.



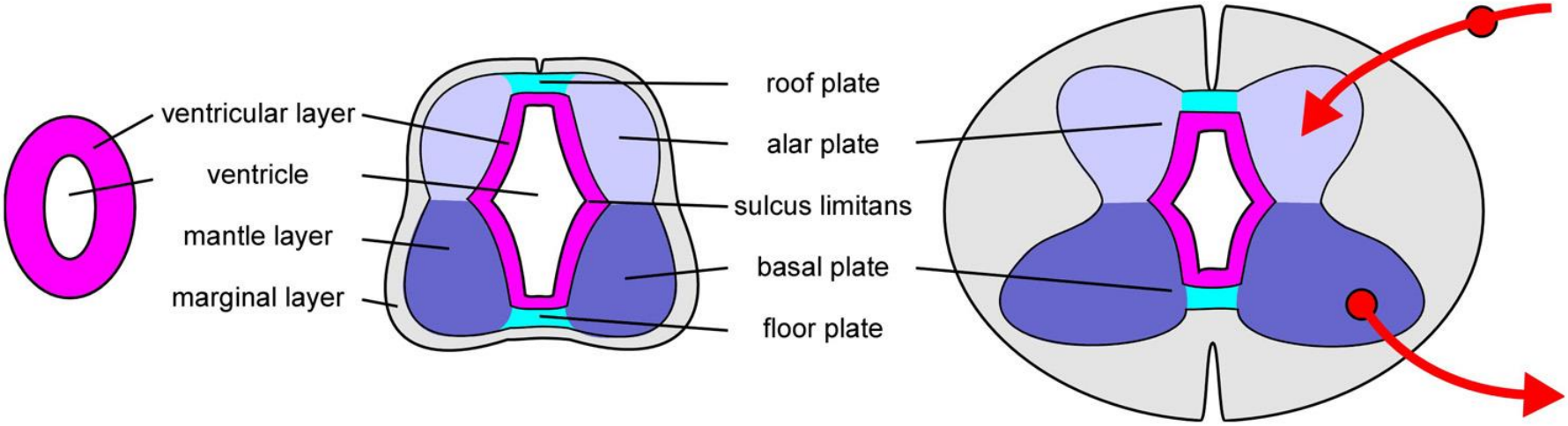


Cell division is not uniform around the neural tube.

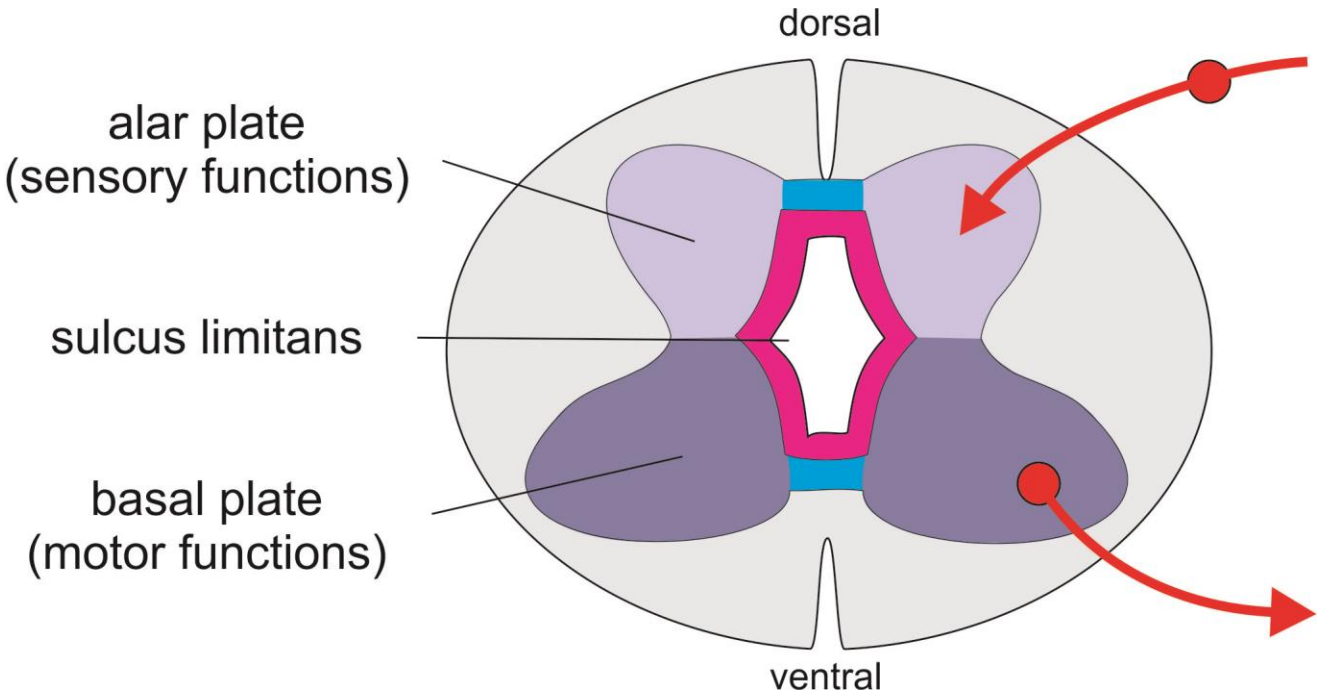


Arrows indicate areas of more cell division.

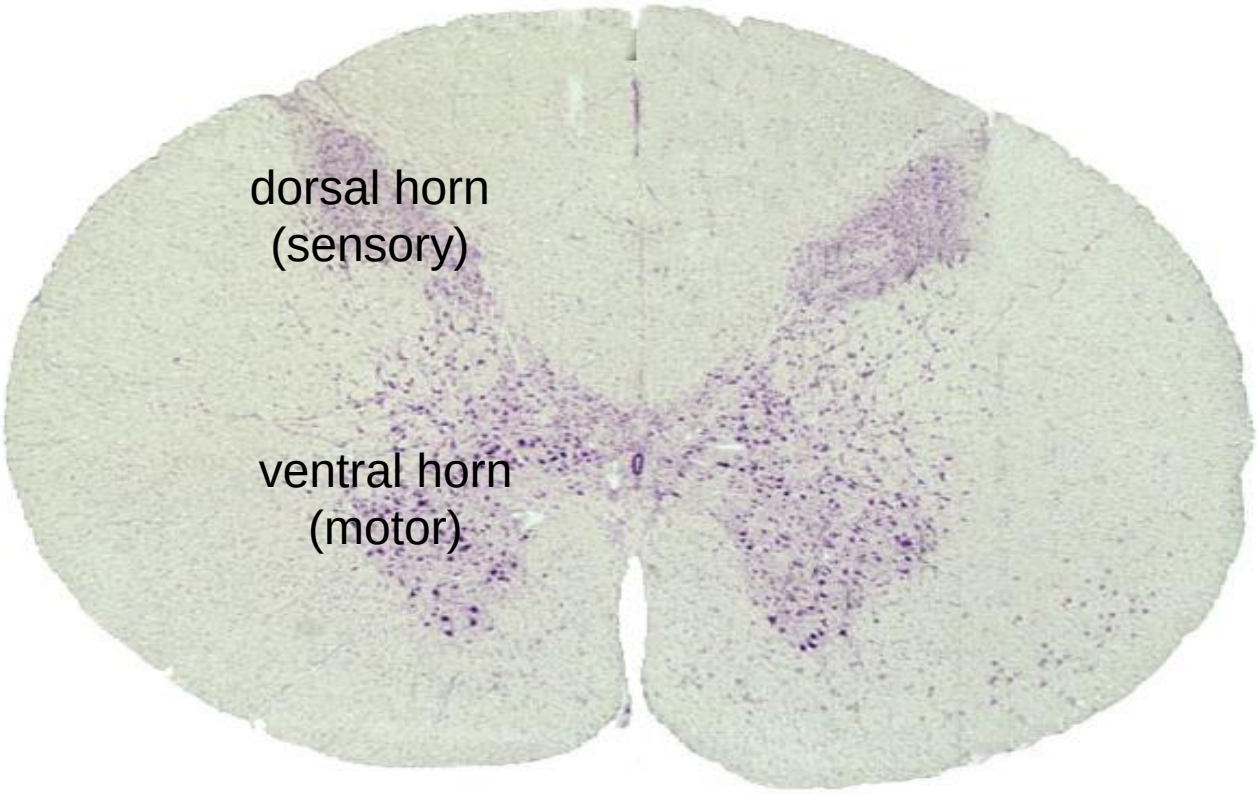
Uneven cell division results in uneven accumulation of postmitotic cells around the circumference of the tube.



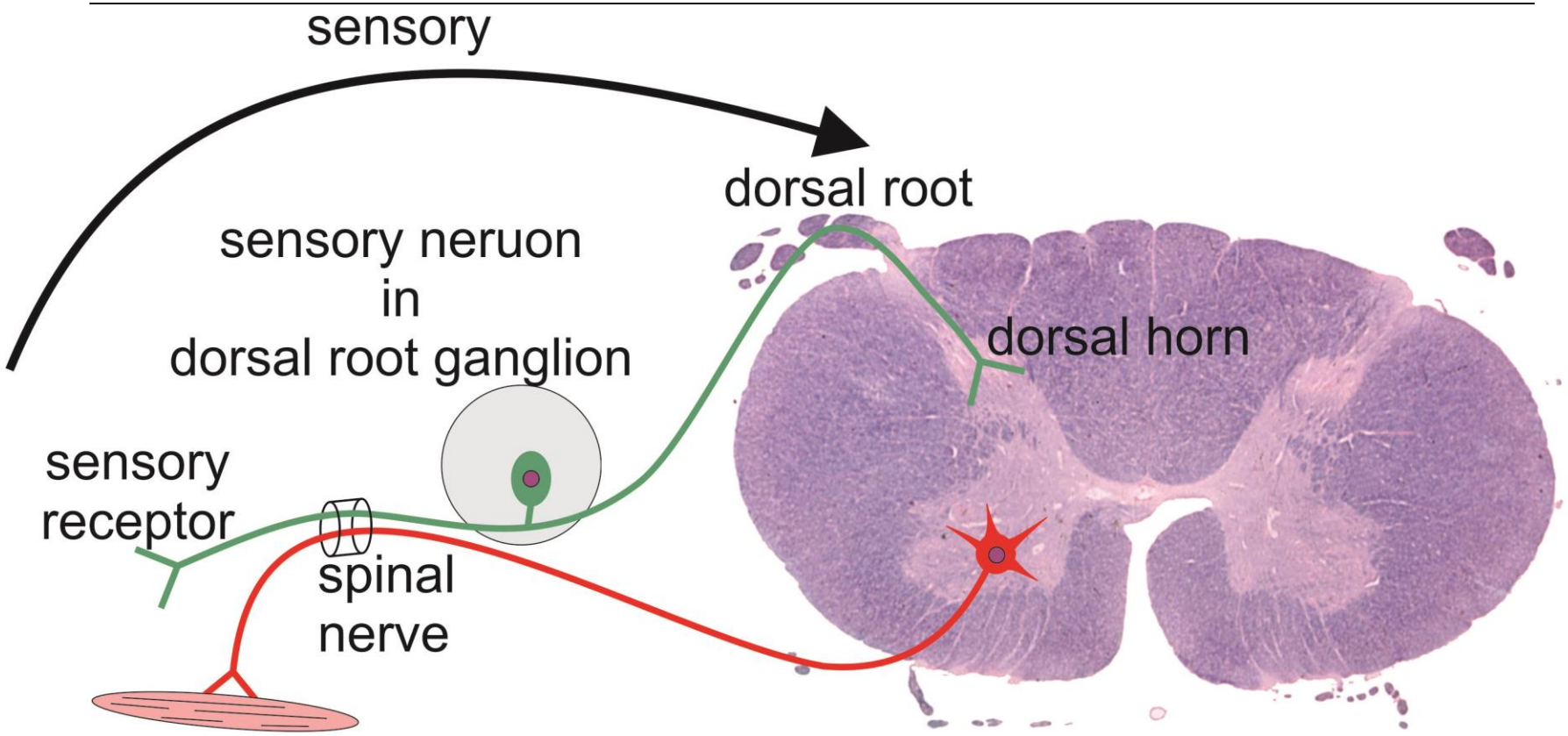
Alar and basal plates represent functional domains.



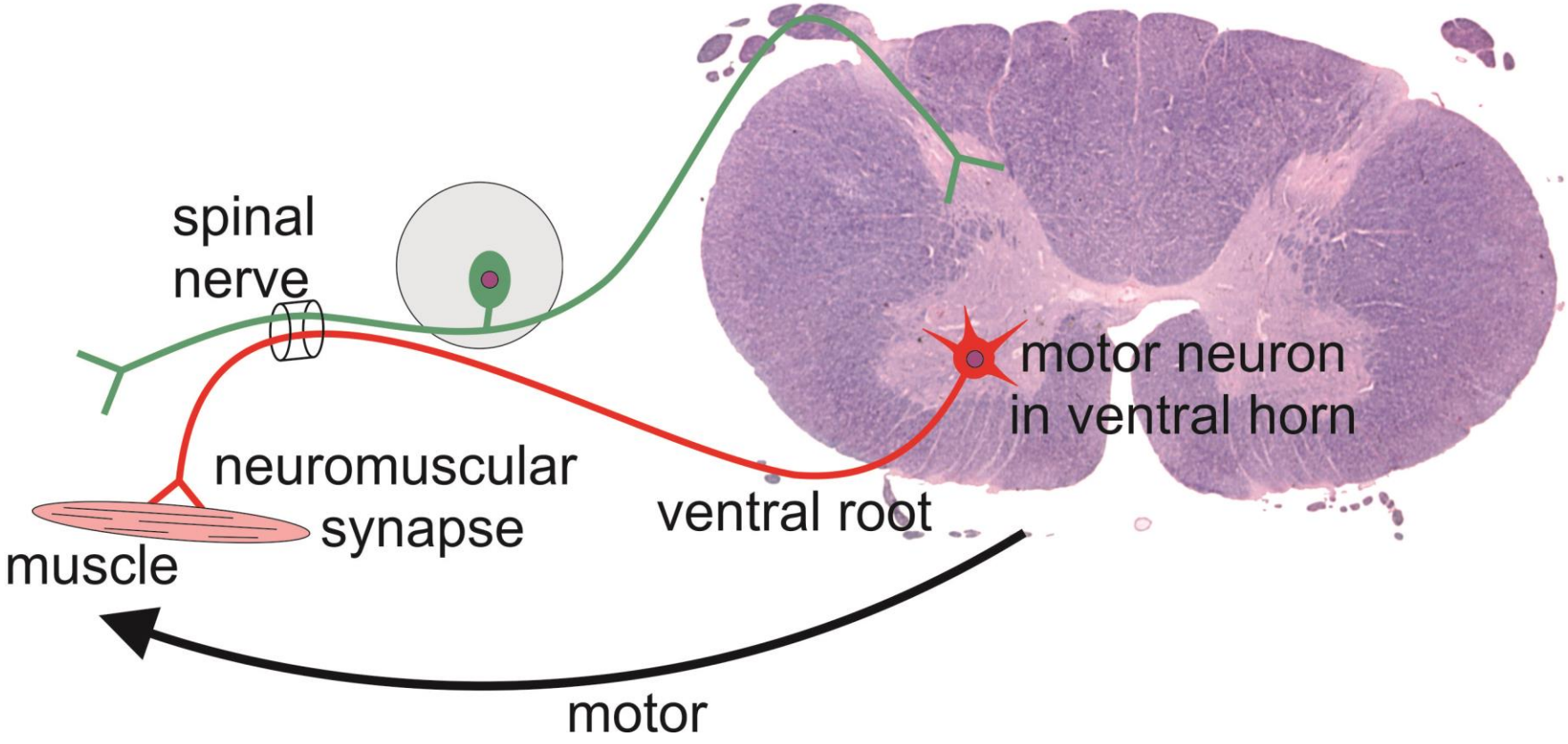
Alar and basal plates represent functional domains.



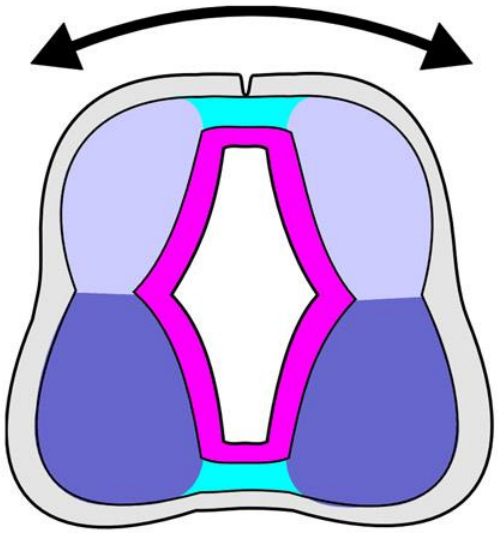
Sensory Input from the Body into the Spinal Cord

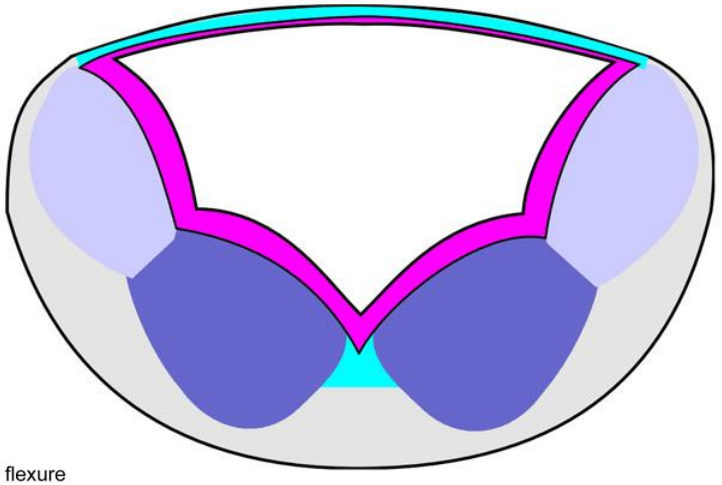


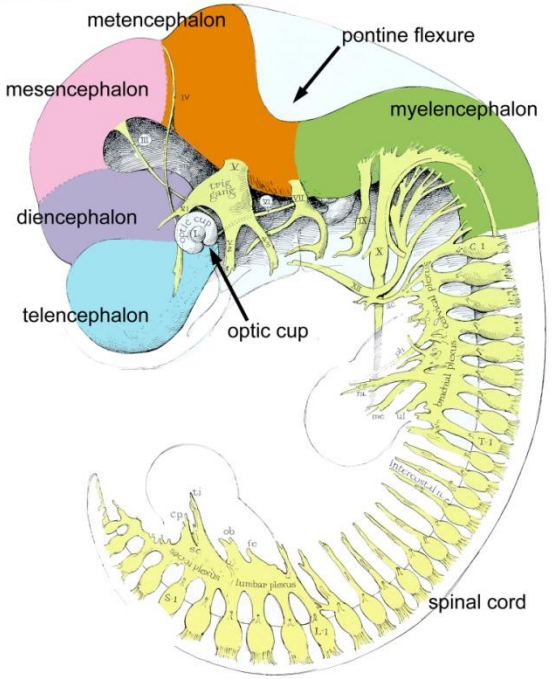
Motor Output from the Spinal Cord to the Body



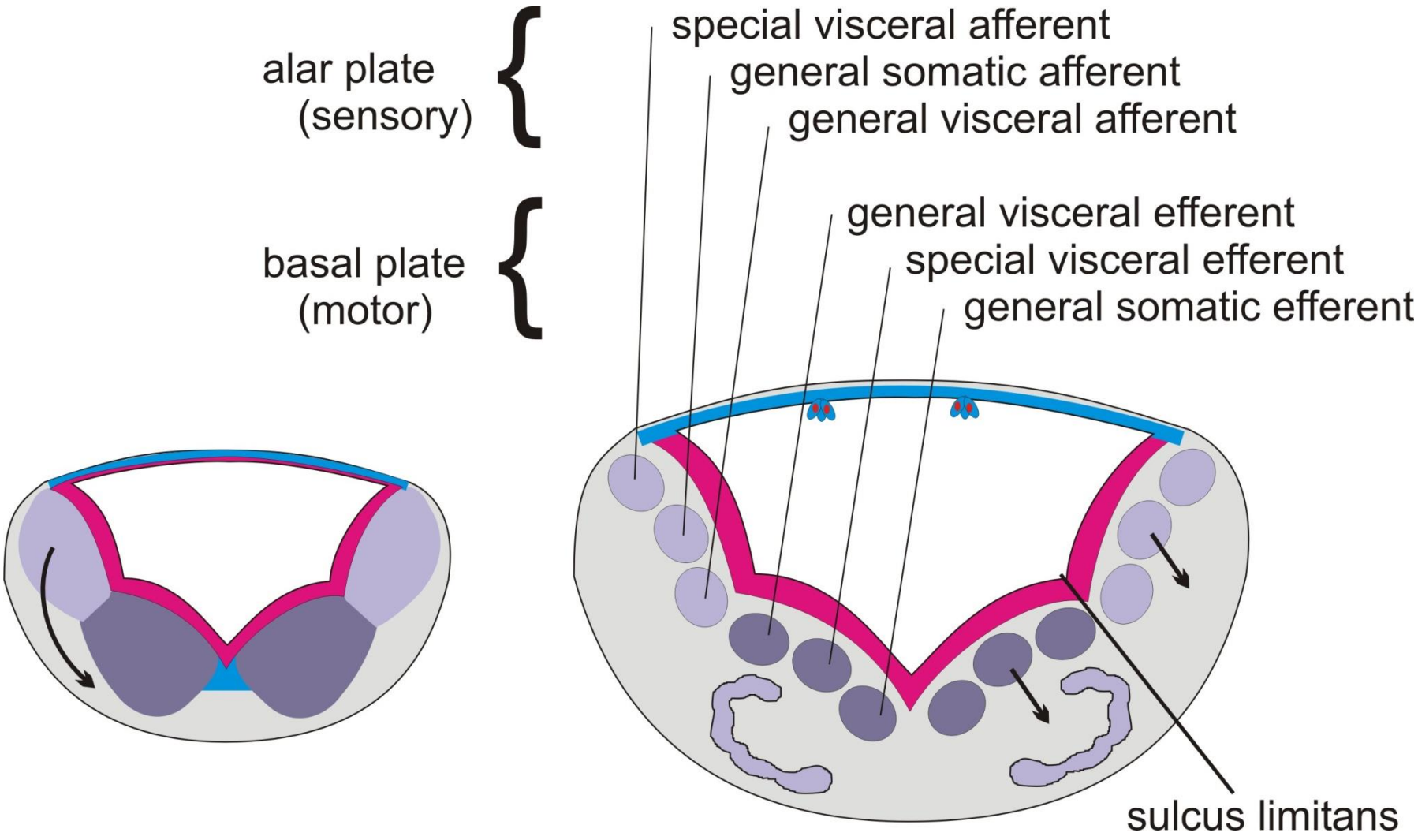
As the pontine flexure forms, the roof plate spreads forming the IV ventricle.



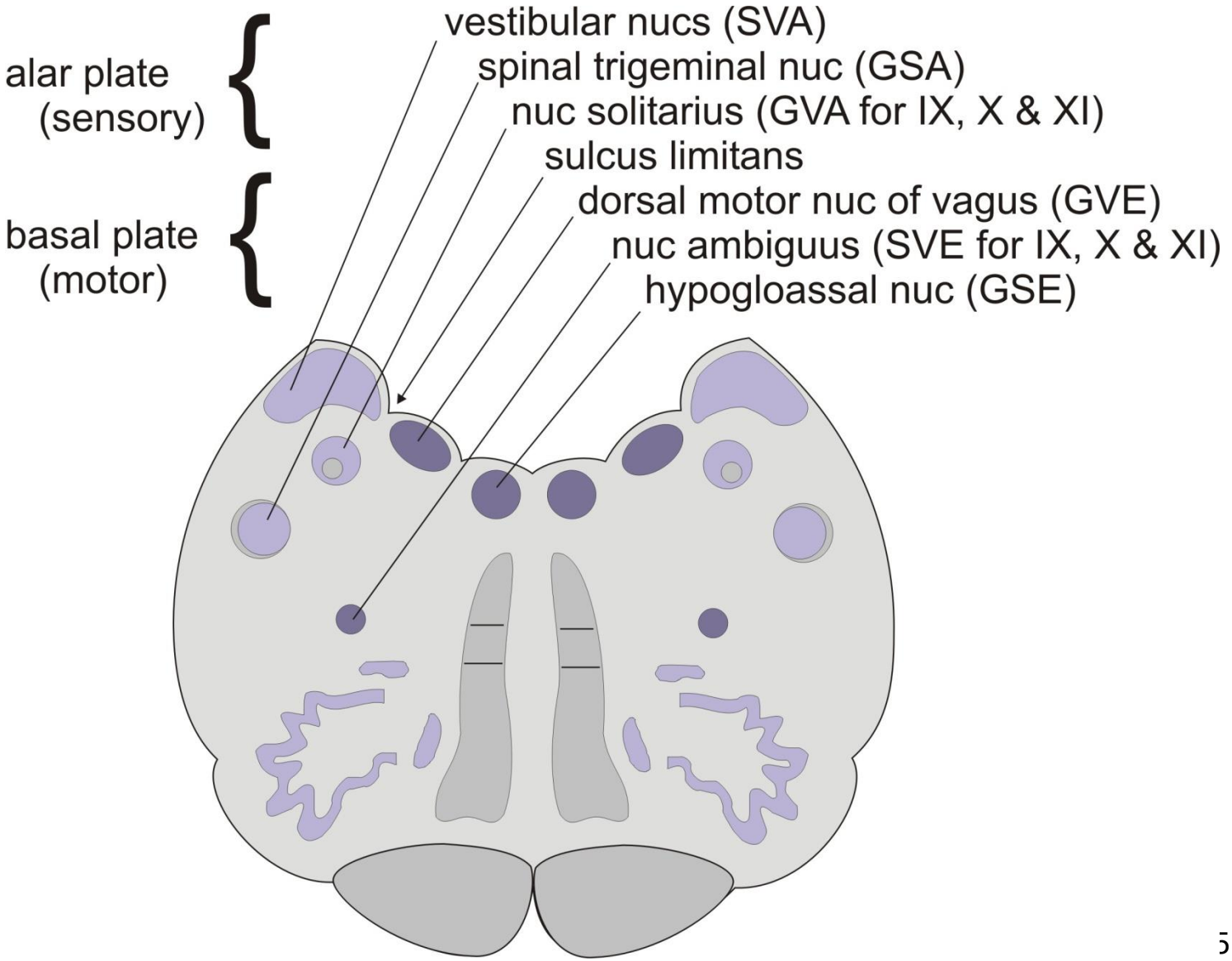




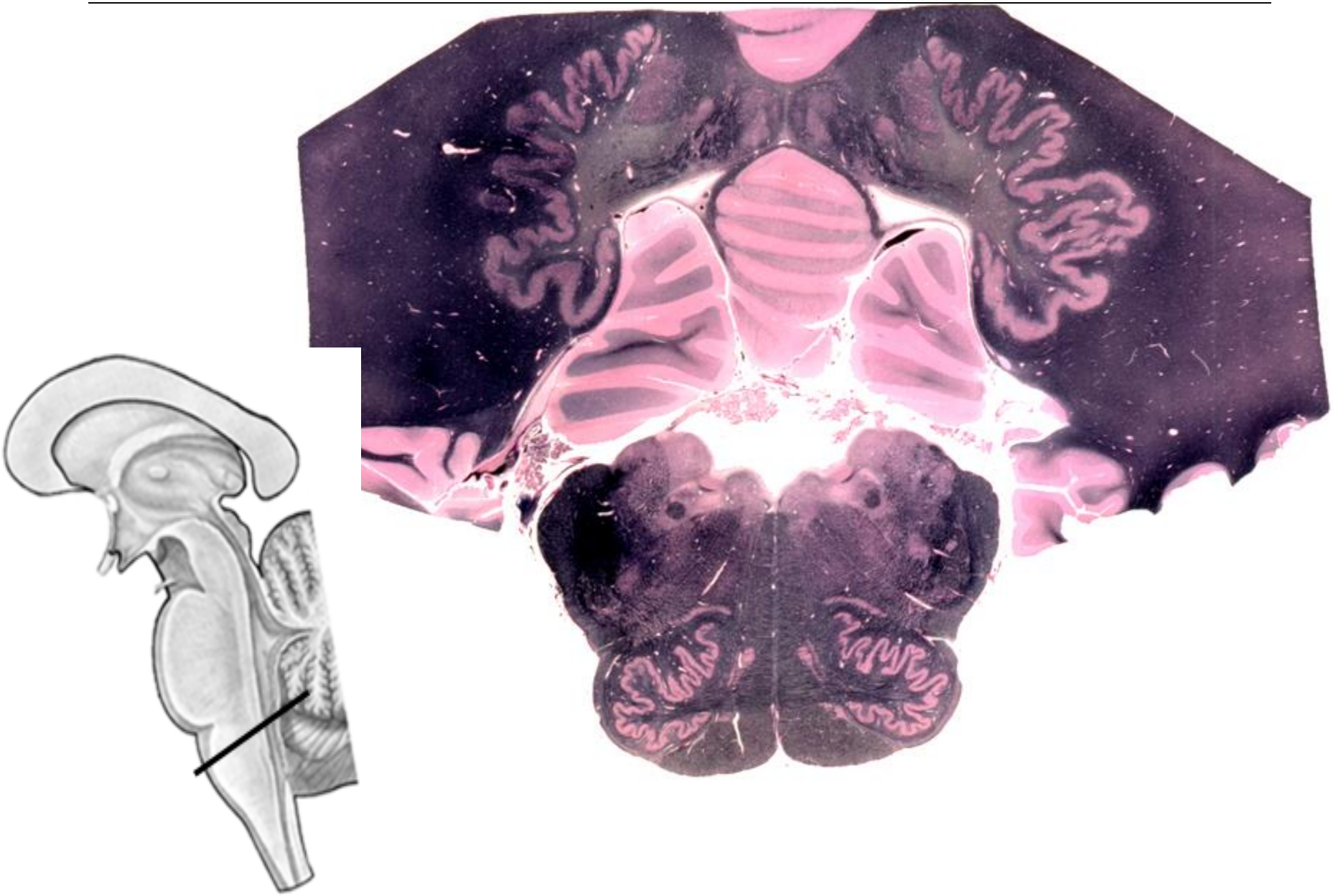
Alar and basal plates on both sides of the tube each subdivide into three distinct columns of cells with different functions.



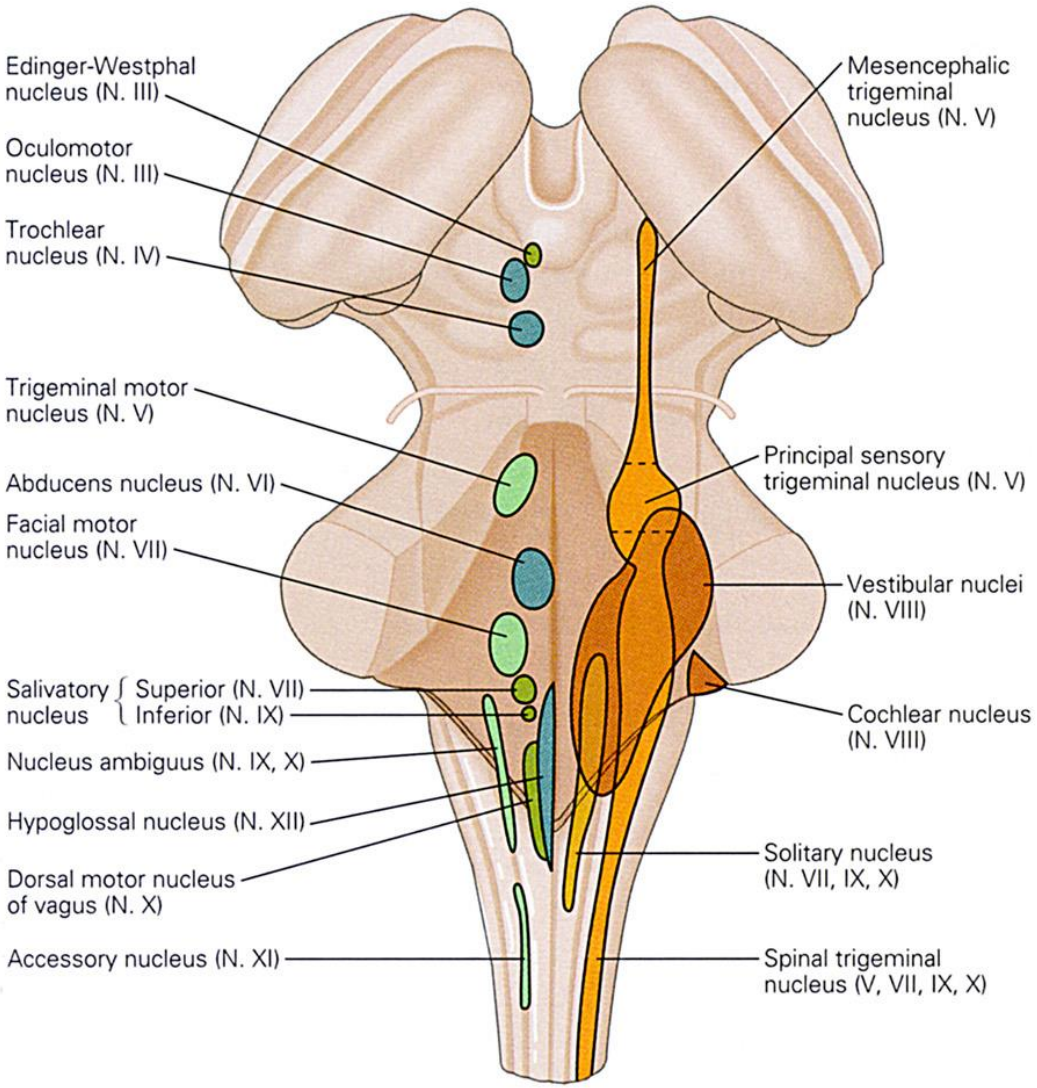
Each cranial nerve nucleus is derived from a single functional cell column.

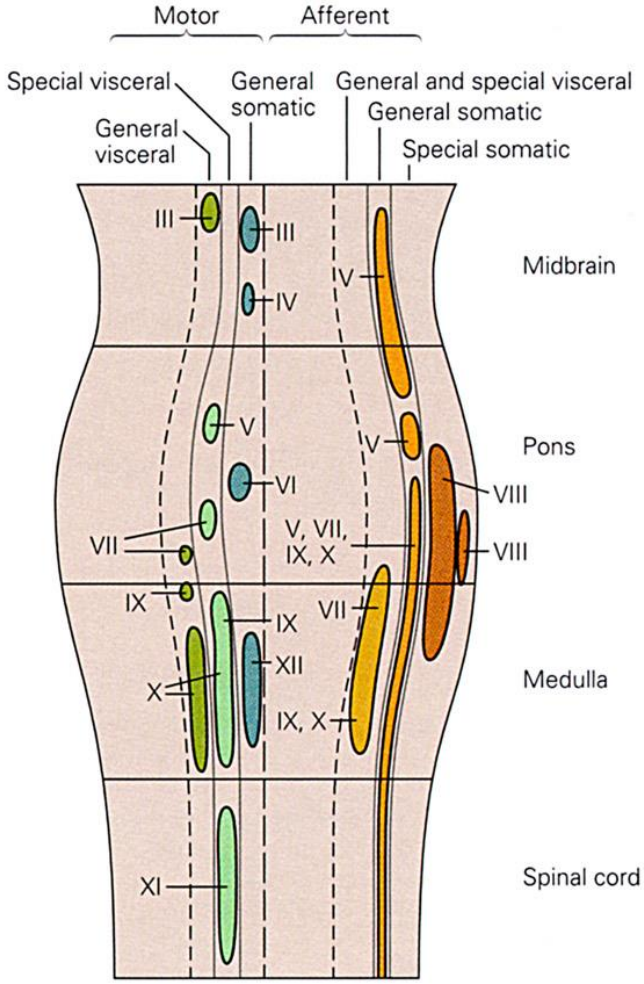


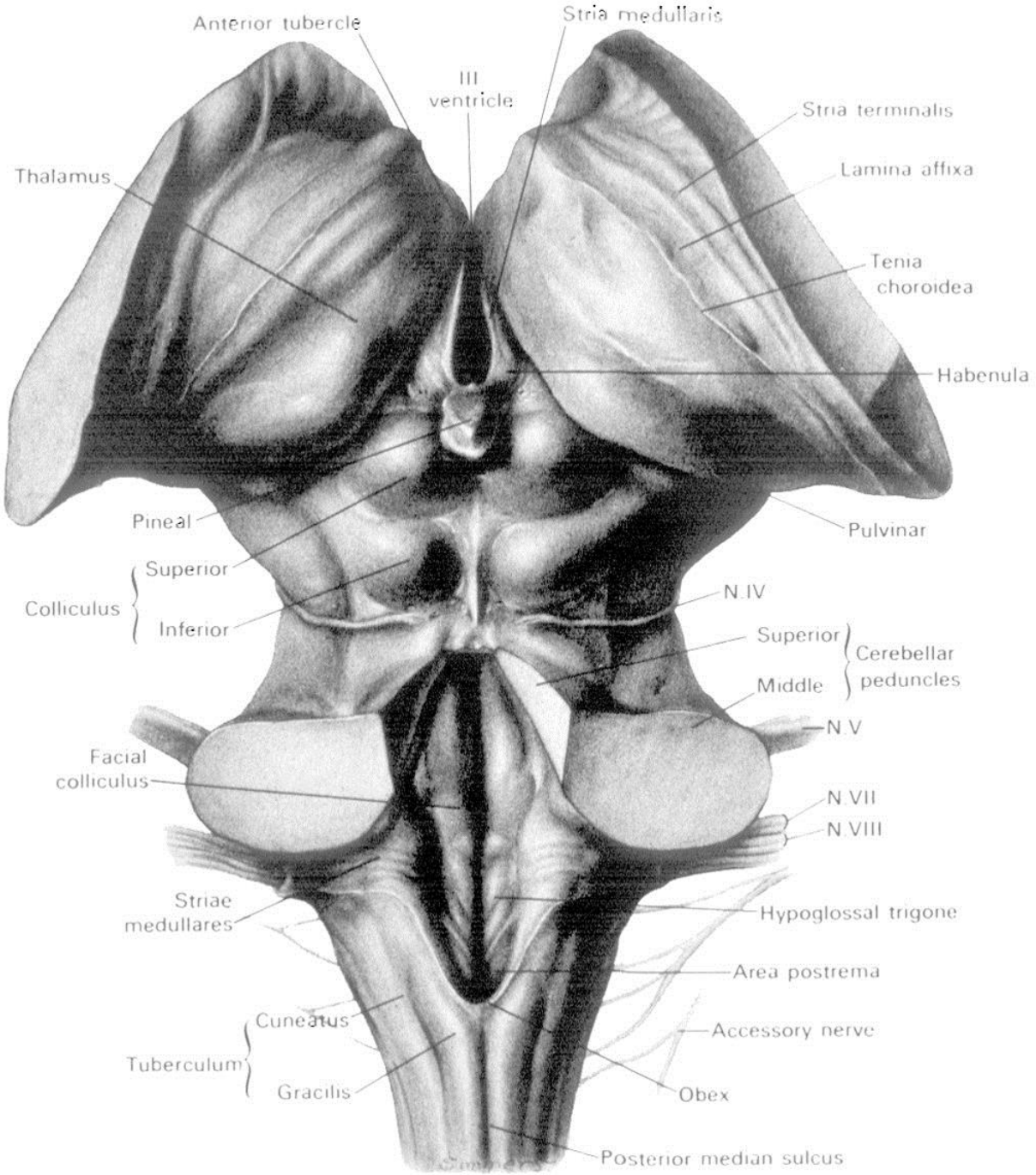
Adult (upper) Medulla



Along the length of the adult brainstem, nuclei are discontinuous columns of functionally related cells.

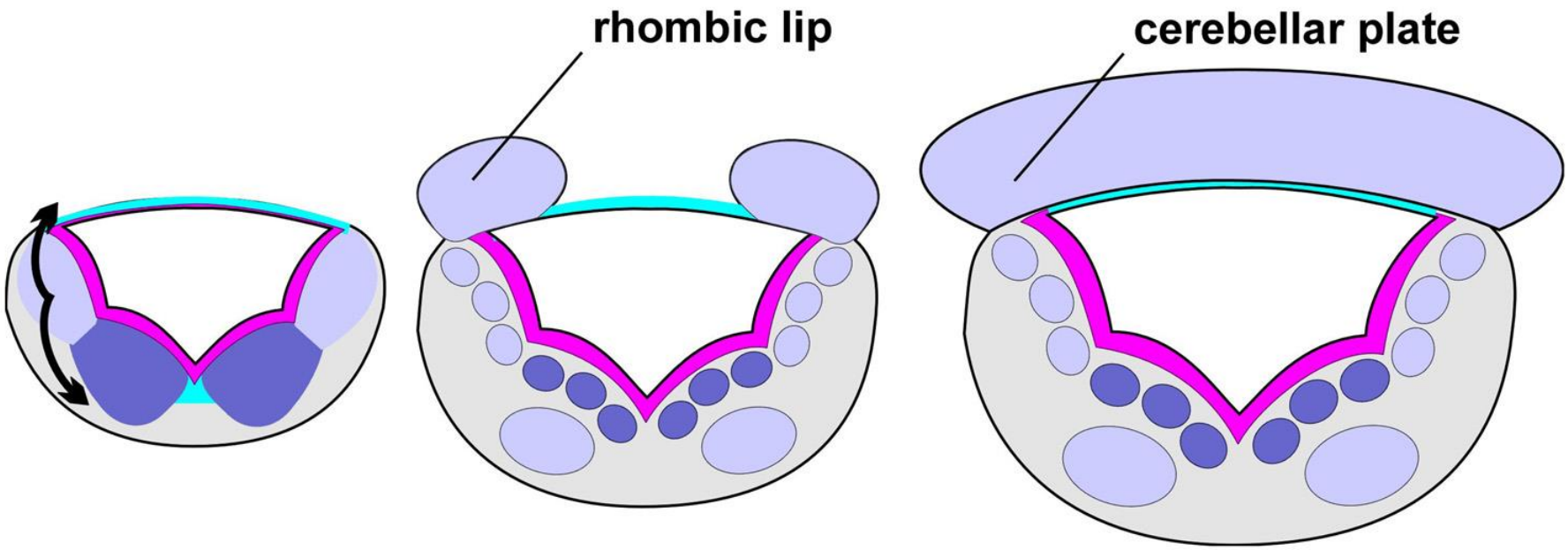




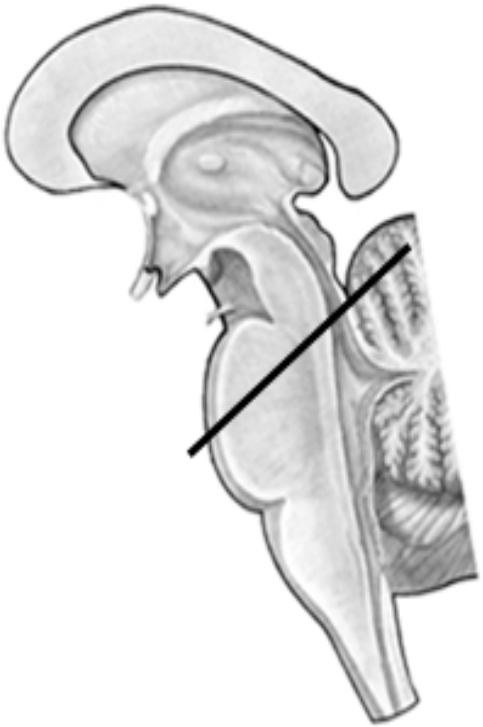

Anterior tubercle
Stria medullaris
III ventricle
Stria terminalis
Thalamus
Lamina affixa
Tenia choroidea
Habenula
Pineal
Pulvinar
Superior
Colliculus
Inferior
N.IV
Superior
Cerebellar peduncles
Middle
N.V
Facial colliculus
N.VII
N.VIII
Striae medullares
Hypoglossal trigone
Area postrema
Cuneatus
Tuberculum
Gracilis
Accessory nerve
Obex
Posterior median sulcus

Metencephalon (Pons and Cerebellum)

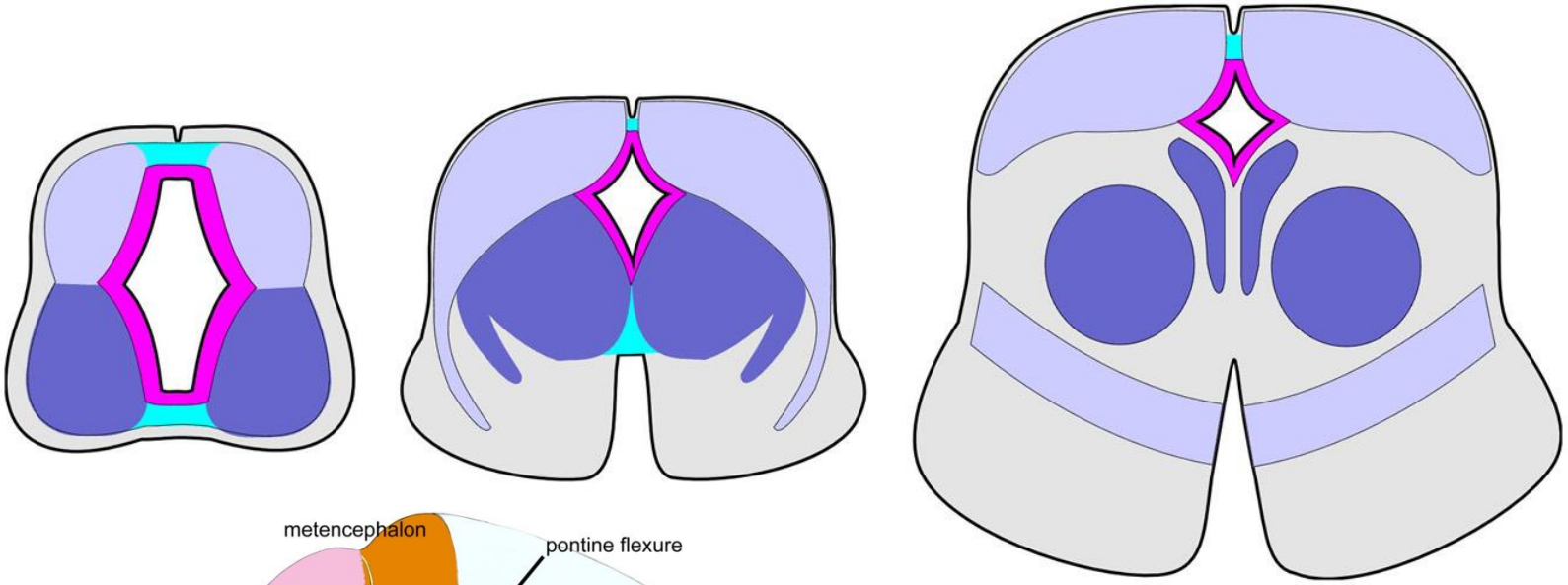
Some cells migrate from the alar and basal plates and undergo further cell division.

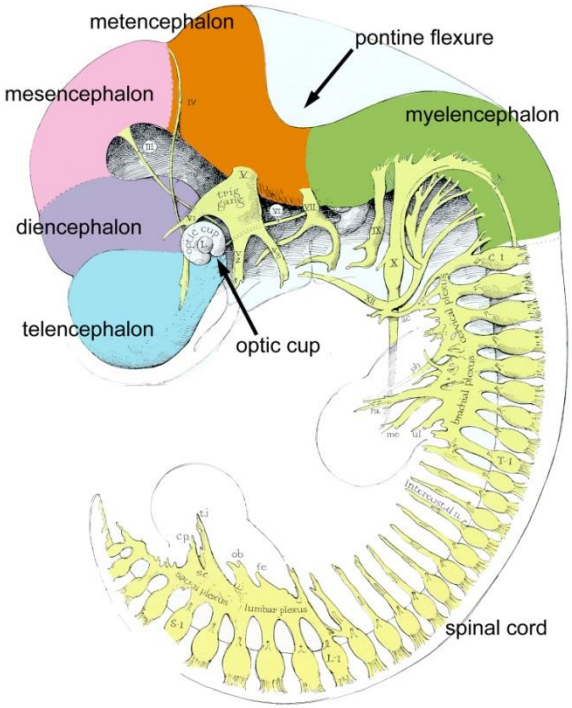


Adult Pons and Cerebellum



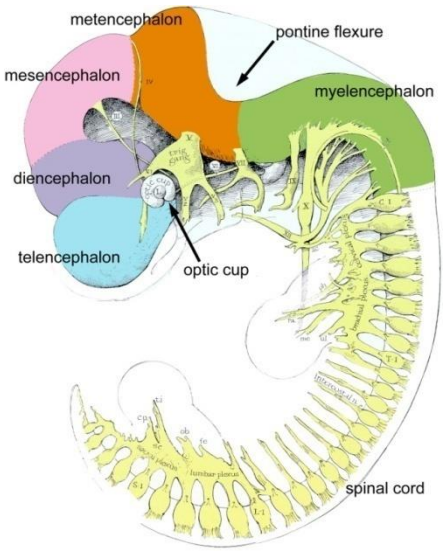
Mesencephalon

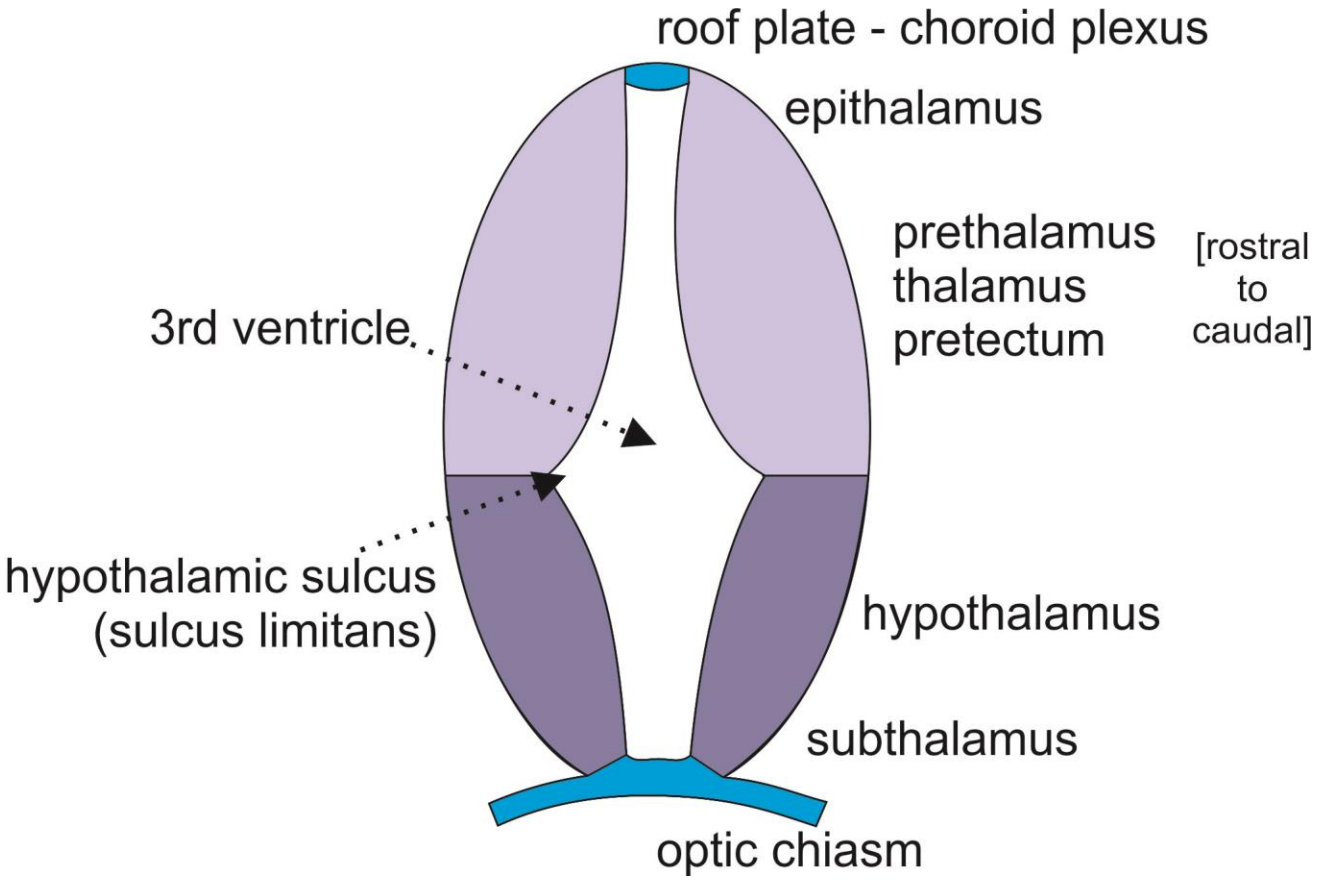




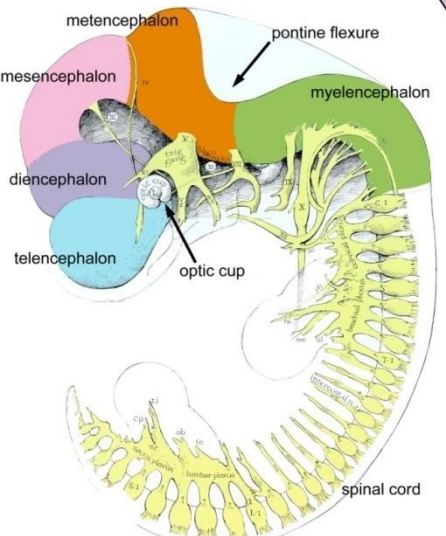
Adult Mesencephalon

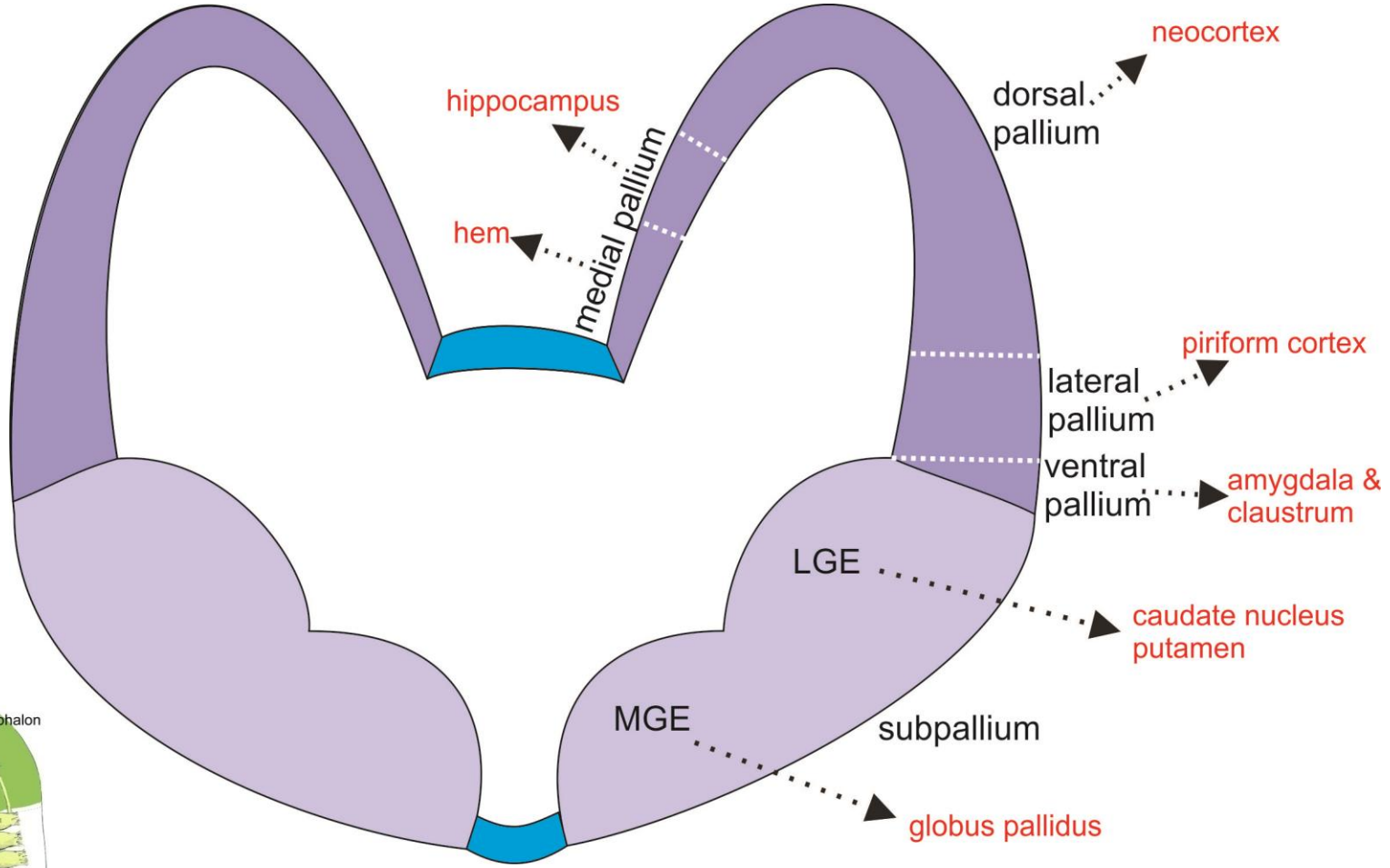
Diencephalon





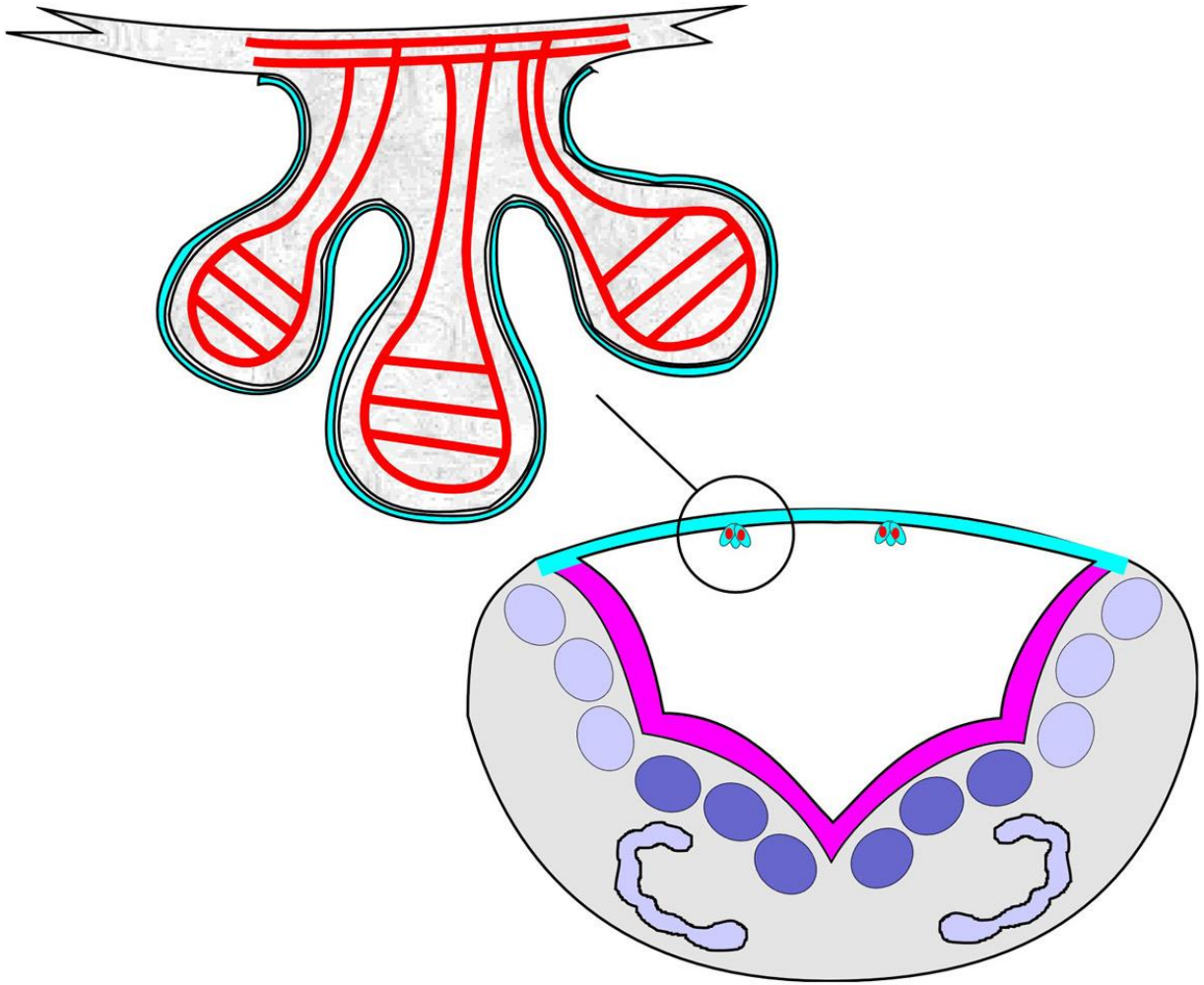
Telencephalon





Adult Diencephalon & Telencephalon

Choriod plexus develops from invagination of roof plate and pia into the ventricle.



Summary of the Origin of Cell Types in the Nervous System

ectoderm			mesoderm
PNS		CNS	
Neural Placodes	Neural Crest	Neural Tube	
some sensory neurons	most sensory neurons	all neurons	microglia
	autonomic neurons	astrocytes	vasculature
	schwann cells	oligodendrocytes	
	satellite cells	ependymal cells	