

Lecture - Neural Development

From Embryology

Contents

Introduction

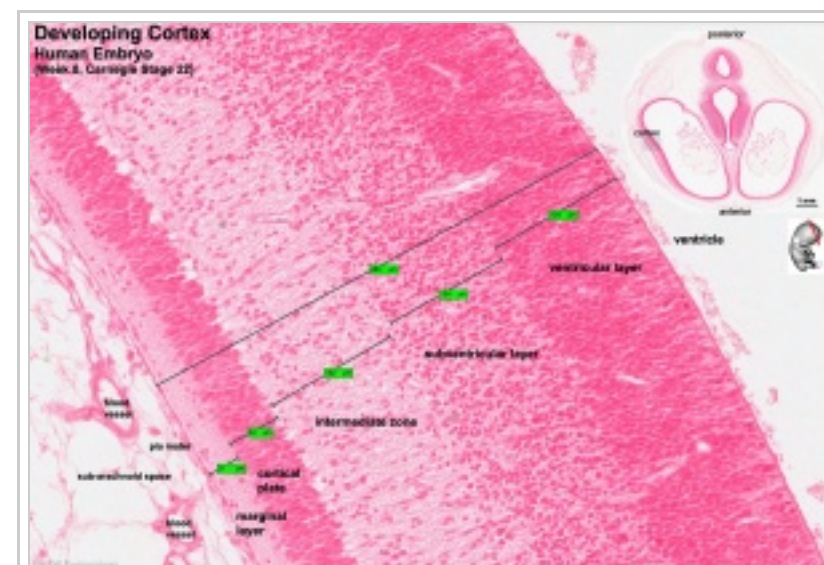
1. Understand early neural development.
2. Understand the formation of the brain; grey and white matter from the neural tube.
3. Understand the formation of spinal cord.
4. Understand the role of migration of neurons during neural development.

- Detailed structure of the adult nervous system is provided in other Anatomy courses.
- History - Santiago Ramón y Cajal

Lecture Resources

Movies [Expand]

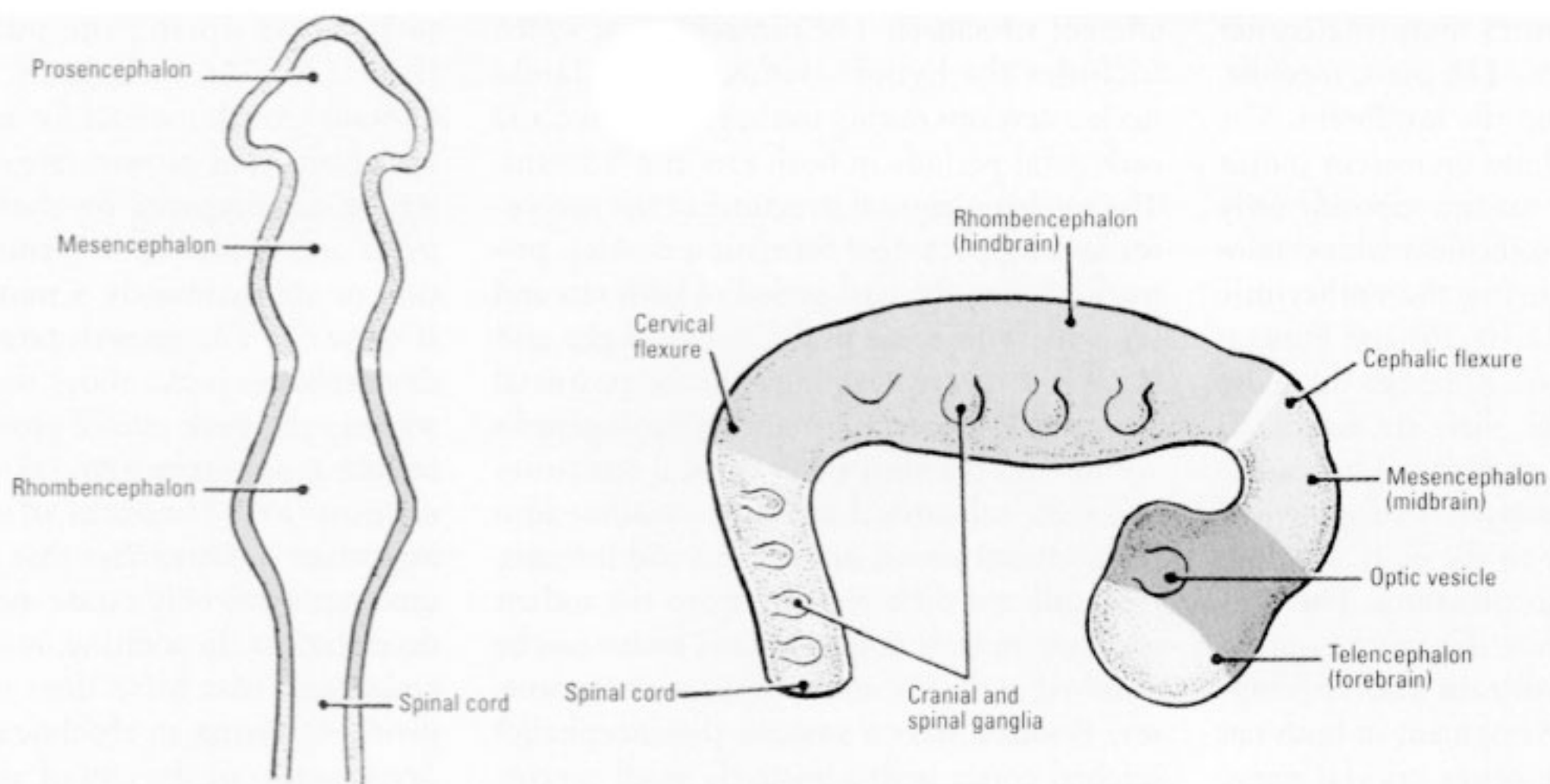
References [Expand]



Cerebrum development human embryo (week 8, Stage 22)

Early Brain Structure

Primary Vesicles



Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models. Rice D, Barone S Jr. Environ Health Perspect. 2000 Jun;108 Suppl 3:511-33. Review. PMID: 10852851

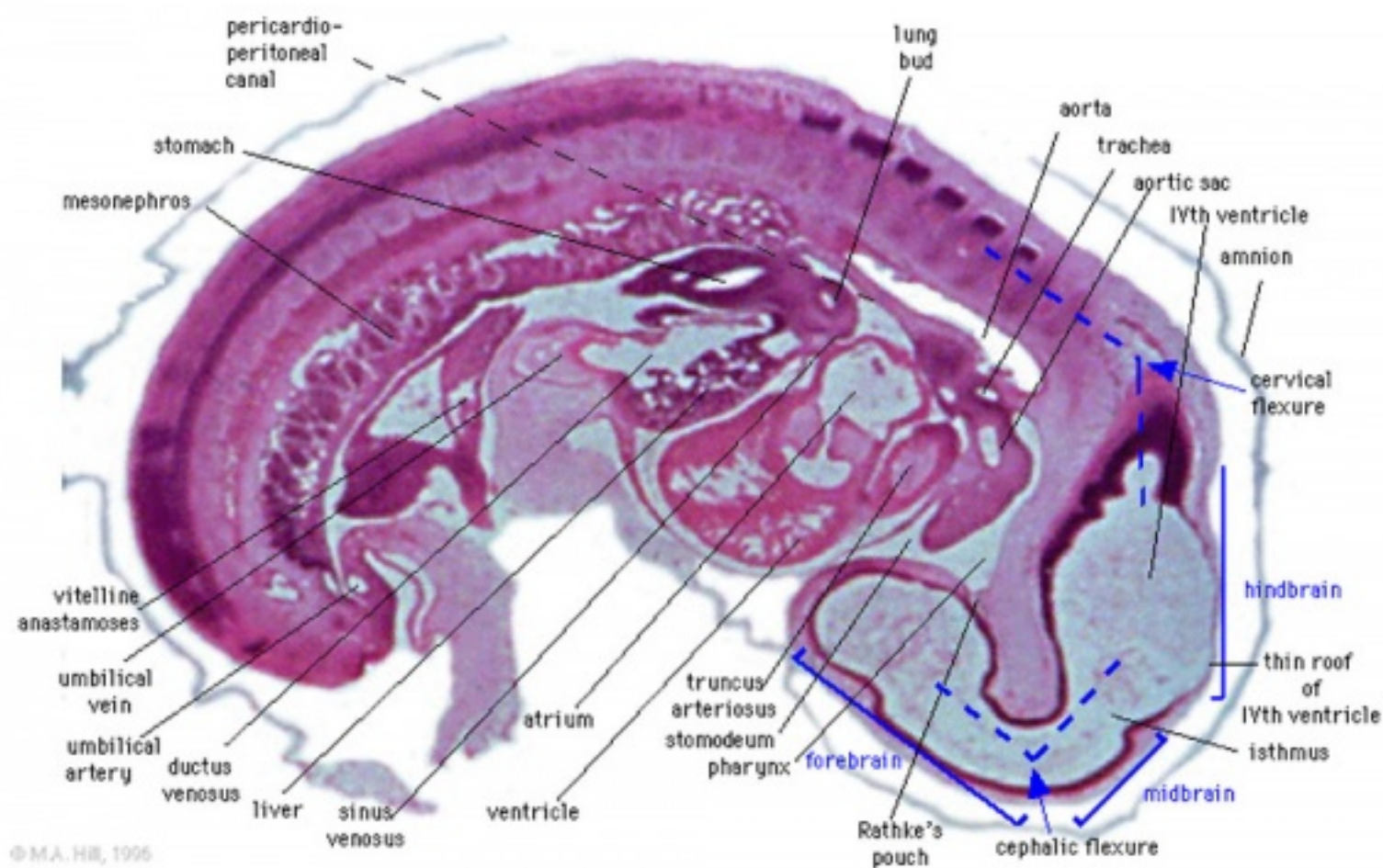
- rostral neural tube forms 3 primary brain vesicles (week 4)
- 3 primary vesicles: **prosencephalon** (forebrain), **mesencephalon** (midbrain), **rhombencephalon** (hindbrain)

Brain Flexures

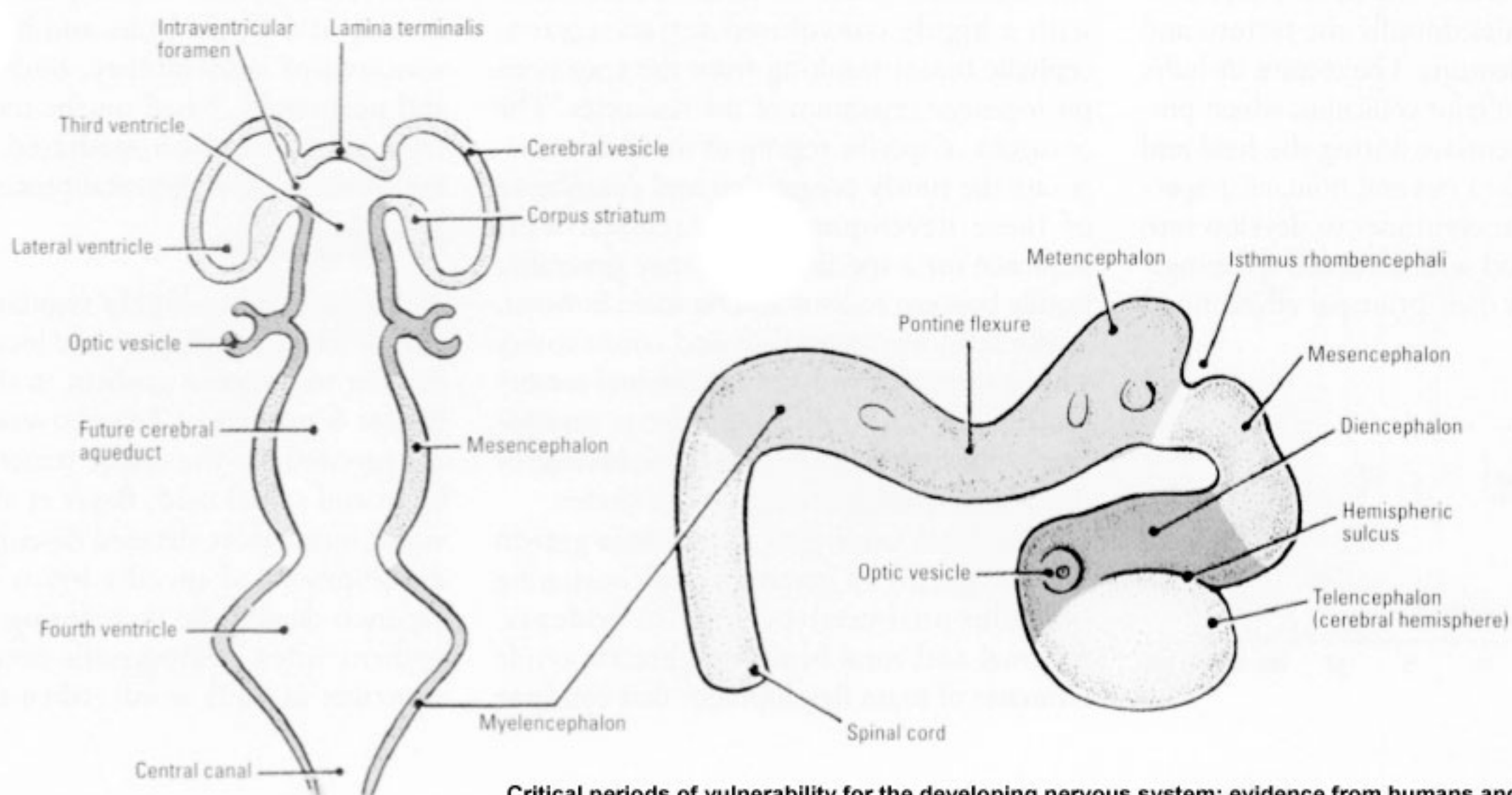
Rapid growth folds the neural tube forming 3 brain flexures

- **cephalic flexure** - pushes mesencephalon upwards
- **cervical flexure** - between brain stem and spinal cord

- **pontine flexure** - generates 4th ventricle



Secondary Vesicles



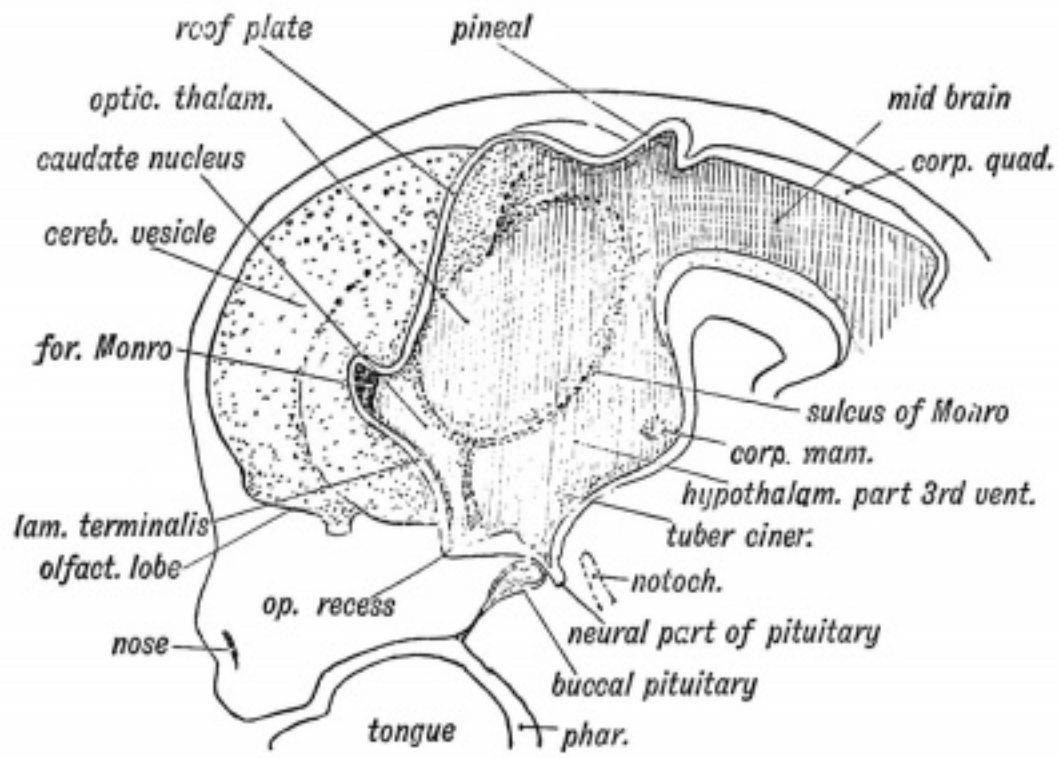
Critical periods of vulnerability for the developing nervous system: evidence from humans and animal models. Rice D, Barone S Jr. Environ Health Perspect. 2000 Jun;108 Suppl 3:511-33. Review. PMID: 10852851

From the 3 primary vesicles developing to form 5 secondary vesicles

- prosencephalon- **telencephalon** (endbrain, forms cerebral hemispheres), **diencephalon** (betweenbrain, forms optic outgrowth)
- **mesencephalon**
- rhombencephalon- **metencephalon** (hindbrain), **myelencephalon** (medullabrain)

Carnegie stage 13 Embryo showing neural tube and brain flexures.

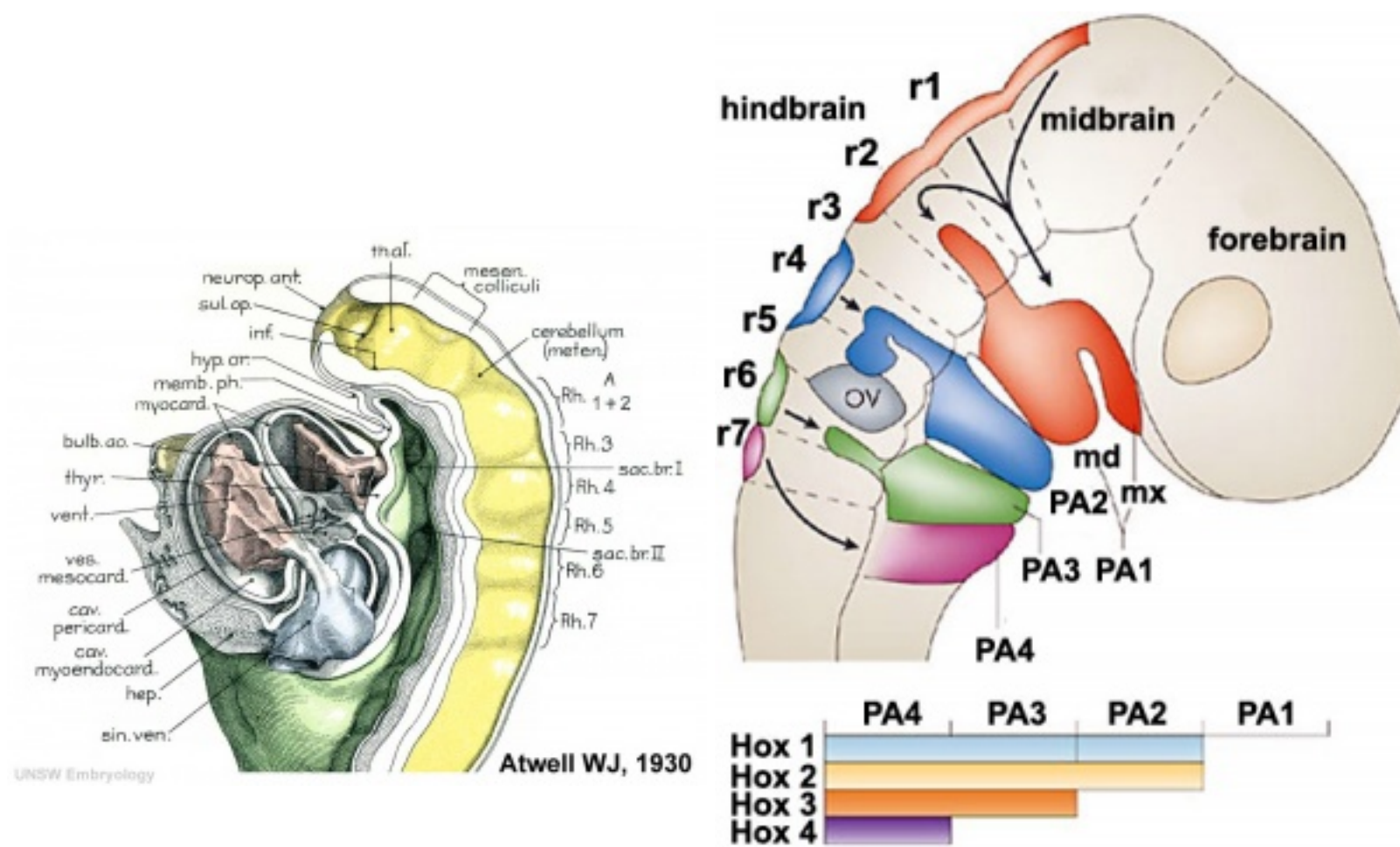
Neural Tube	Primary Vesicles	Secondary Vesicles	Adult Structures
Brain	Prosencephalon	Telencephalon	Rhinencephalon, Amygdala, Hippocampus, Cerebrum (Cortex), Basal Ganglia, lateral ventricles
		Diencephalon	Epithalamus, Thalamus, Hypothalamus, Subthalamus, Pituitary, Pineal, third ventricle
	Mesencephalon	Mesencephalon	Tectum, Cerebral peduncle, Pretectum, cerebral aqueduct
	Rhombencephalon	Metencephalon	Pons, Cerebellum
		Myelencephalon	Medulla Oblongata
Spinal Cord			



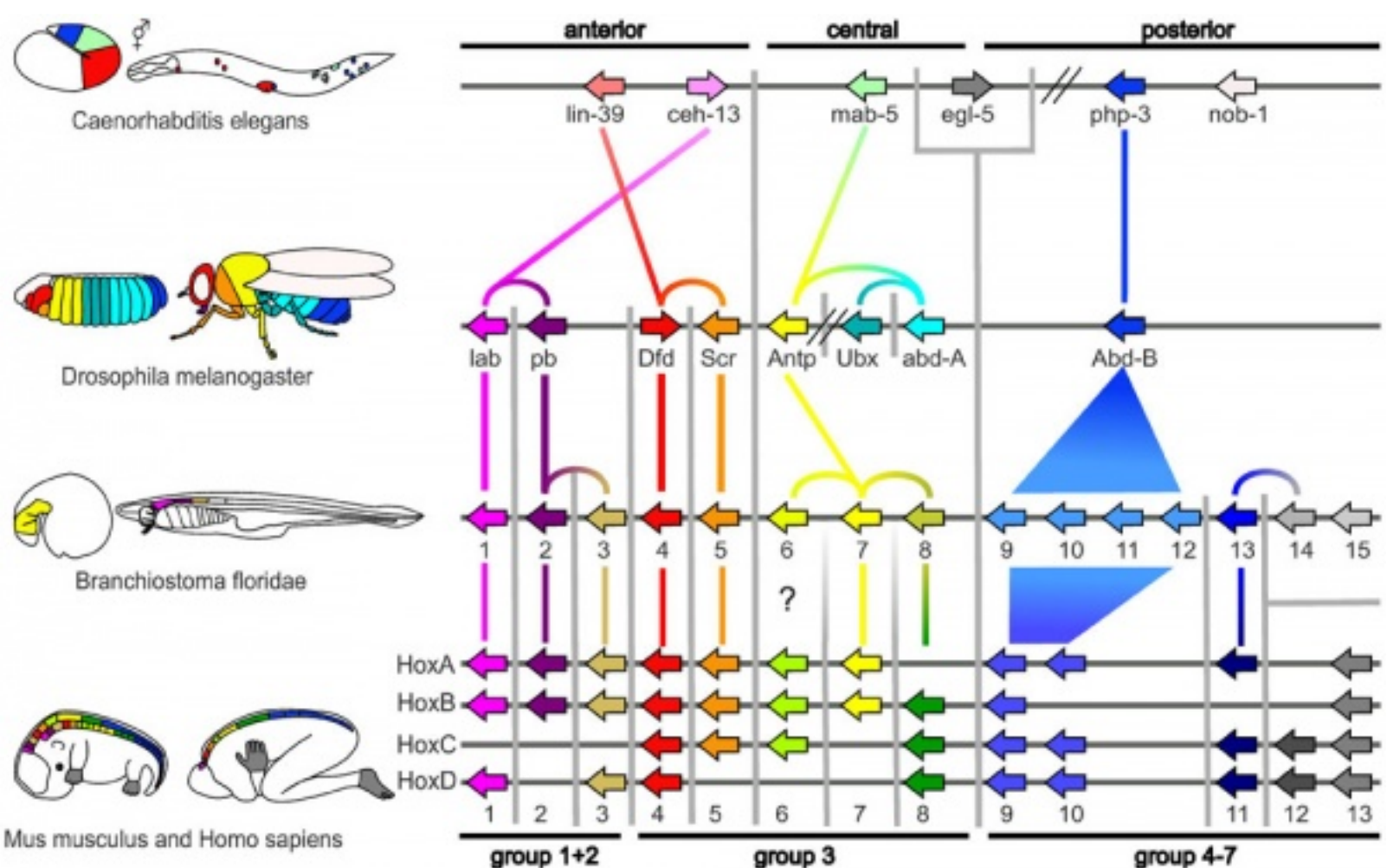
Historic figure showing the parts derived from the walls of the fore-brain. (After Wilhelm His (1831-1904))

Rhombomeres

- Hindbrain - Rhombomeres represent the crania-caudal segmentation of the neural tube at the level of the hindbrain.
- Historic - Identified morphologically as identifiable regions.
- Modern - Represent the different expression levels of Hox genes and levels of neural crest migration.



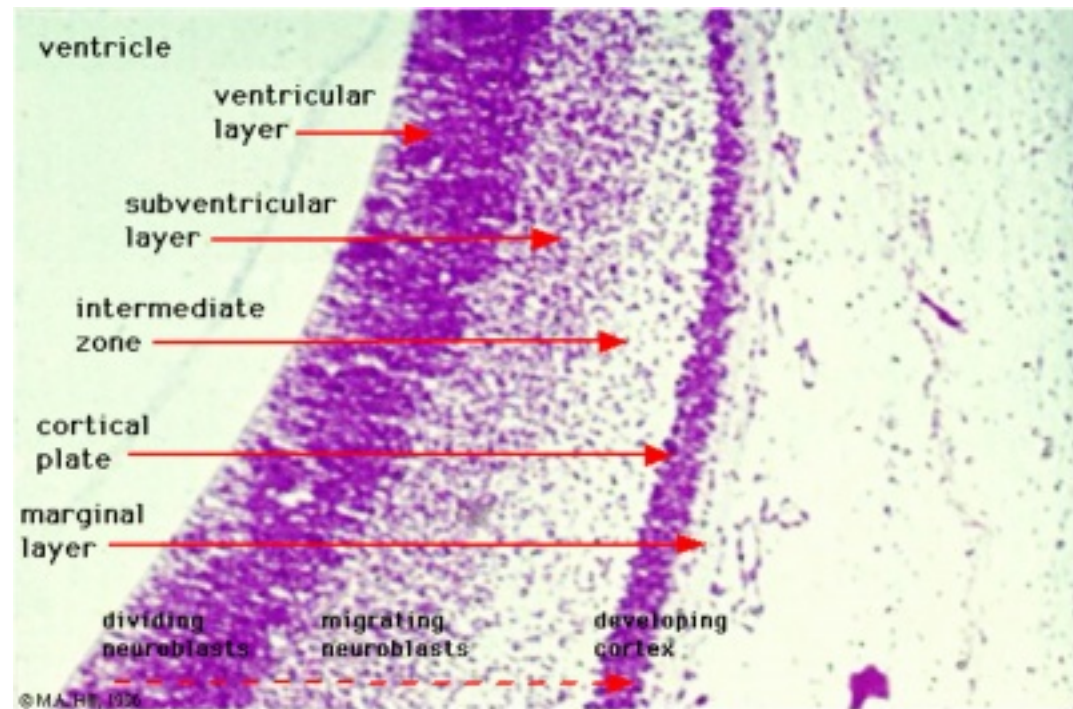
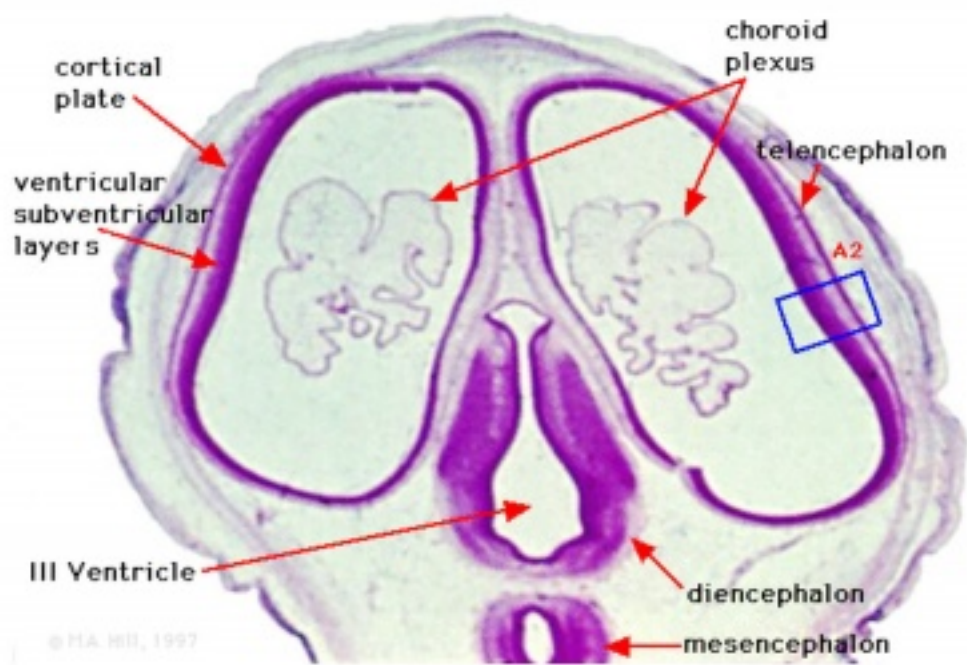
Historic image of embryonic rhombomeres Hindbrain neural crest migration



Neural Layers

- **Ventricular Germinal Zone (VGZ)** - mitosis at the ventricular luminal surface, produces early-generated macroneurons
- **Subventricular Zone (SVZ)** - mitosis away from the ventricular surface, produces later-generated microneurons and glia

Brain

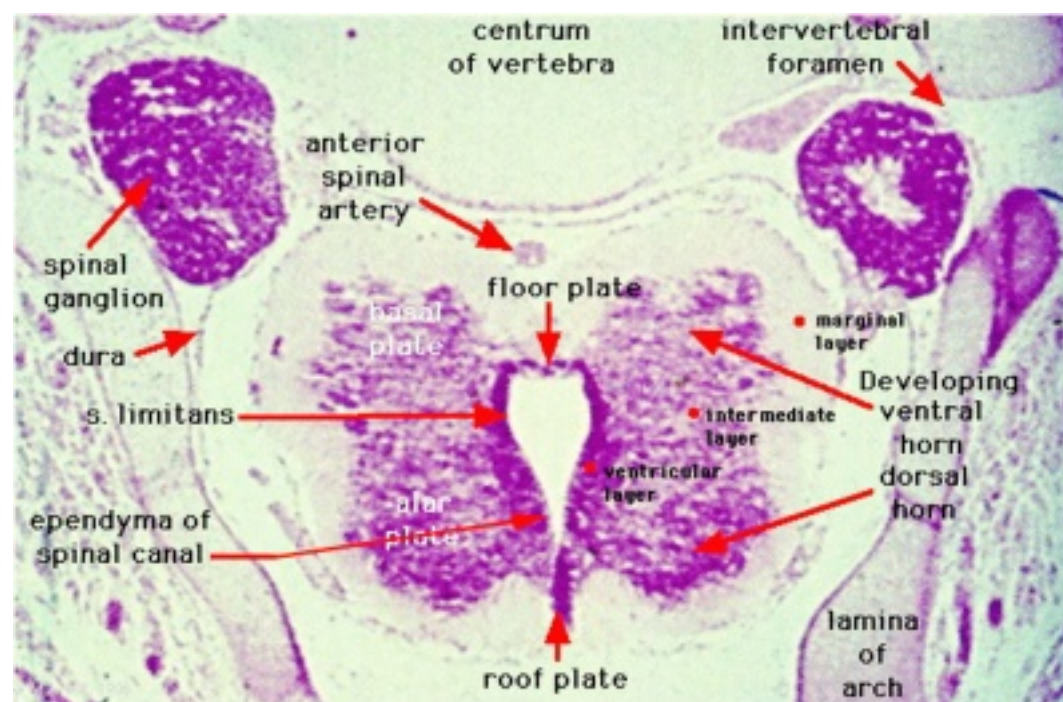
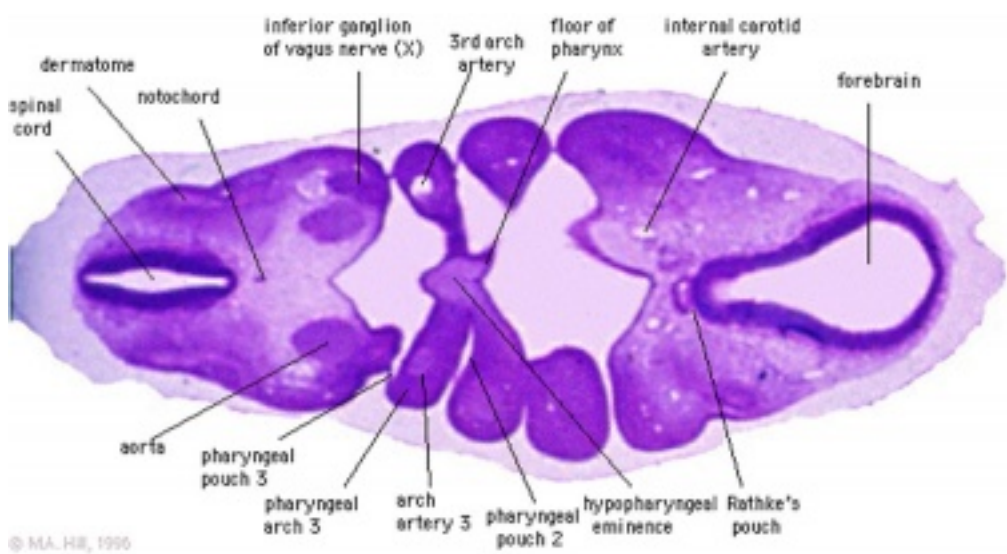


Human Embryo developing head cross section (Week 8, Stage 22) Detail of developing cortex (shown in blue box)

- Neural progenitor cells migrate from the ventricular layer along **radial glia**.
- Cortex layers develops inside (first) outside (last)
- Glial progenitor cells develop later from the same ventricular stem cells.

Spinal Cord

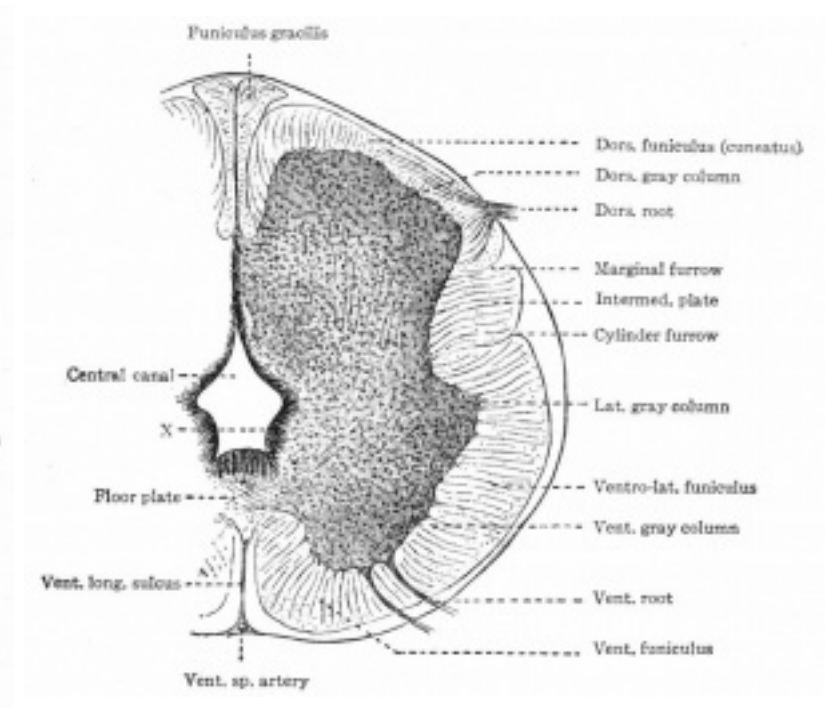
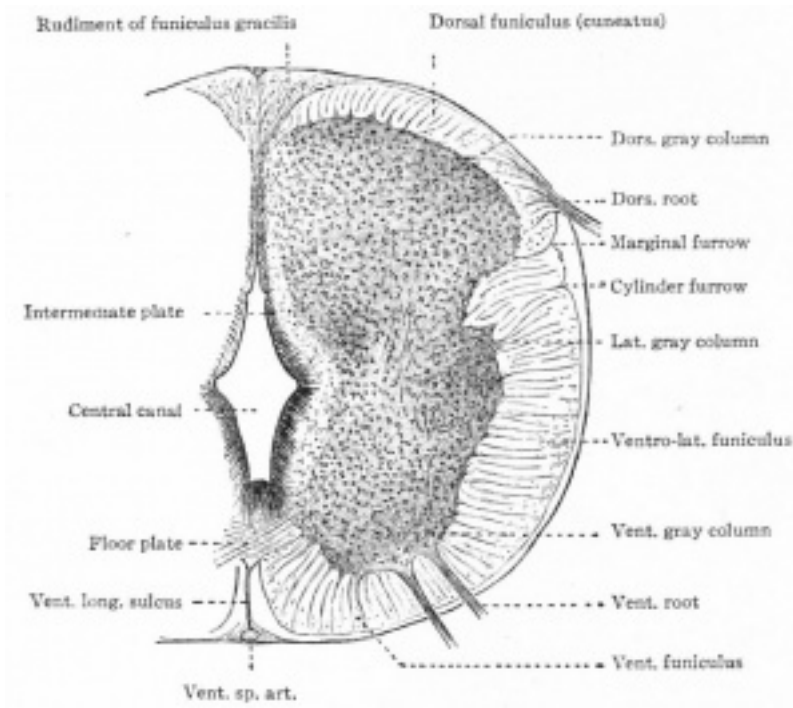
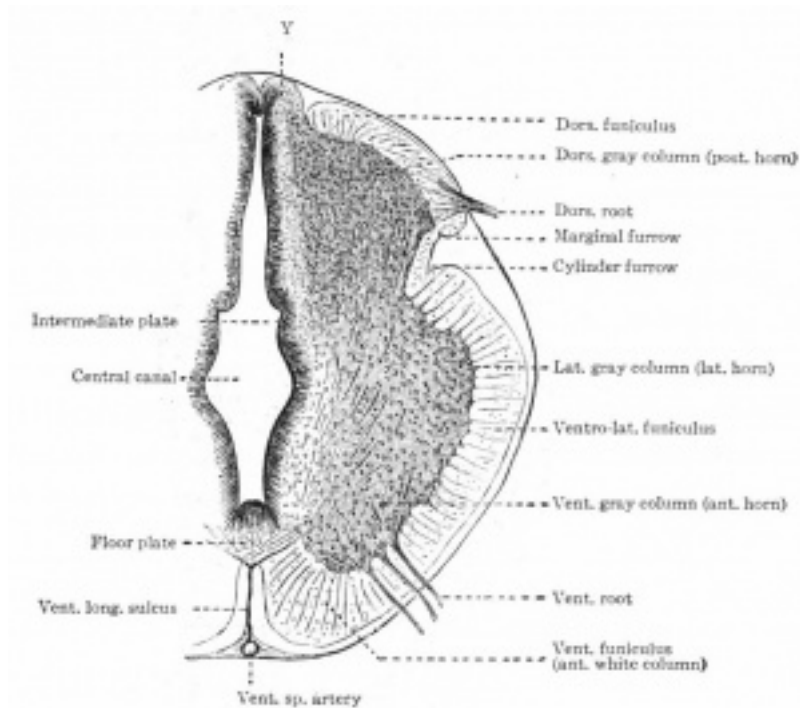
- Similar processes to those described for brain.
- Remember notochord ventral patterning by SHH and dorsal ectoderm (dorsalisation).
- Identify the different regions within the neural tube (floor plate, basal plate, alar plate, roof plate)



Stage 13

Stage 22

Half of a transverse section of the spinal cord



Human embryo of 18.5 mm (7.5 weeks).

Human embryo of 24 mm (8.5 weeks).

Human fetus of about 3 months.

Ventricular Development

- The ventricular system develops from the single cavity formed from the hollow neural tube.
- This fluid-filled space is separated from the amnion following fusion of the neural tube and closure of neuropores.
- At different regions sites within the wall (**floor of lateral ventricle and roof of the third and fourth ventricles**) differentiate to form **choroid plexus** a modified vascular structure which will produce Cerebrospinal fluid (CSF)
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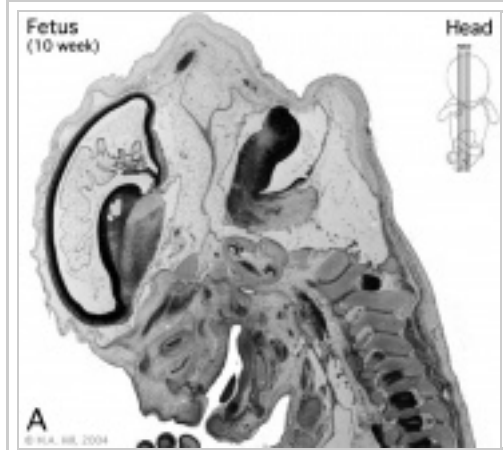
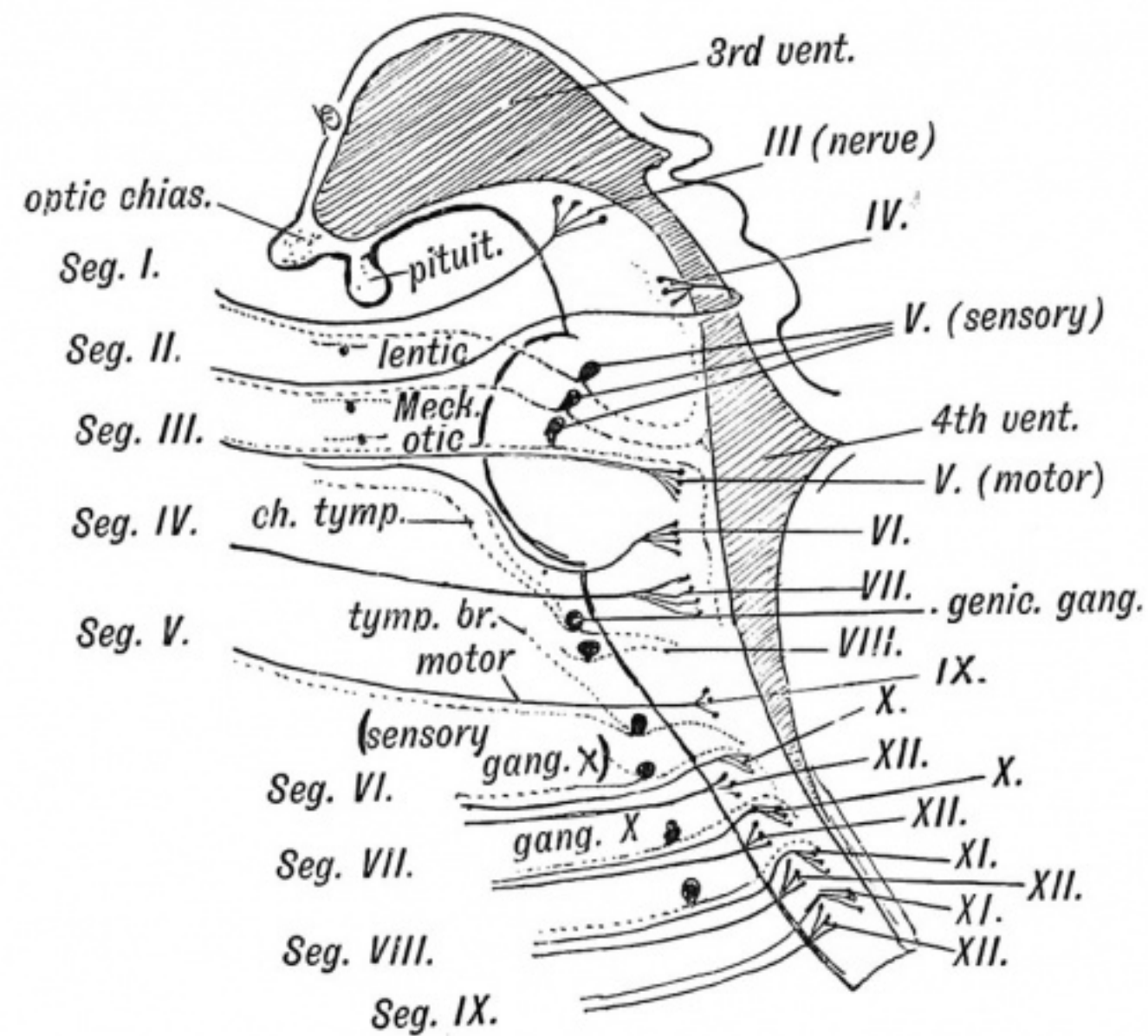
(FYI - you do not need to know detailed stage development)

Human Ventricular Development Timeline [Expand]



Human Embryo (week 8, Stage 22) ventricular system

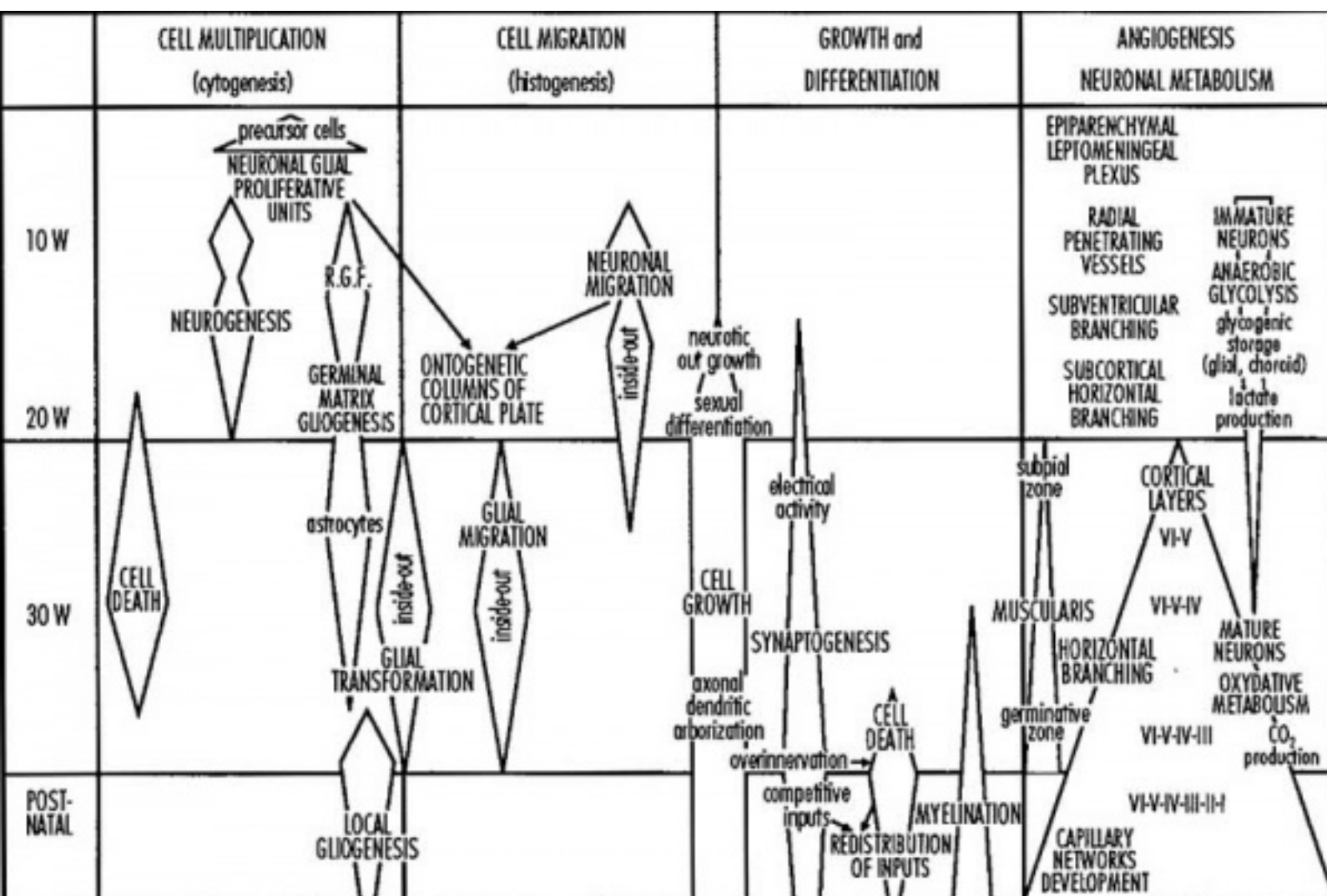
Cranial Nerves



Human Fetus (week 10) showing choroid plexus and early ventricular system

Historic diagram showing the relationship of the Cranial Nerves to the Primitive Segments of the Head.

Fetal Neural



Timeline of events in Human Neural Development

During the fetal period there is ongoing growth in size, weight and surface area of the brain and spinal cord. Microscopically there is ongoing: cell migration, extension of processes, cell death and glial cell development.

Cortical maturation (sulcation and gyration) and vascularization of the lateral surface of the brain starts with the insular cortex (insula, insular cortex or insular lobe) region during the fetal period. This cerebral cortex region in the adult brain lies deep within the lateral sulcus between the temporal lobe and the parietal lobe.

- **sulcation** - The process of brain growth in the second to third trimester which forms sulci, grooves or folds visible on fetal brain surface as gyri grow (gyration). Abnormalities of these processes can lead to a smooth brain (lissencephaly).
- **gyration** - The development of surface folds on the brain (singular, gyrus)

Insular Gyral and Sulcal Development

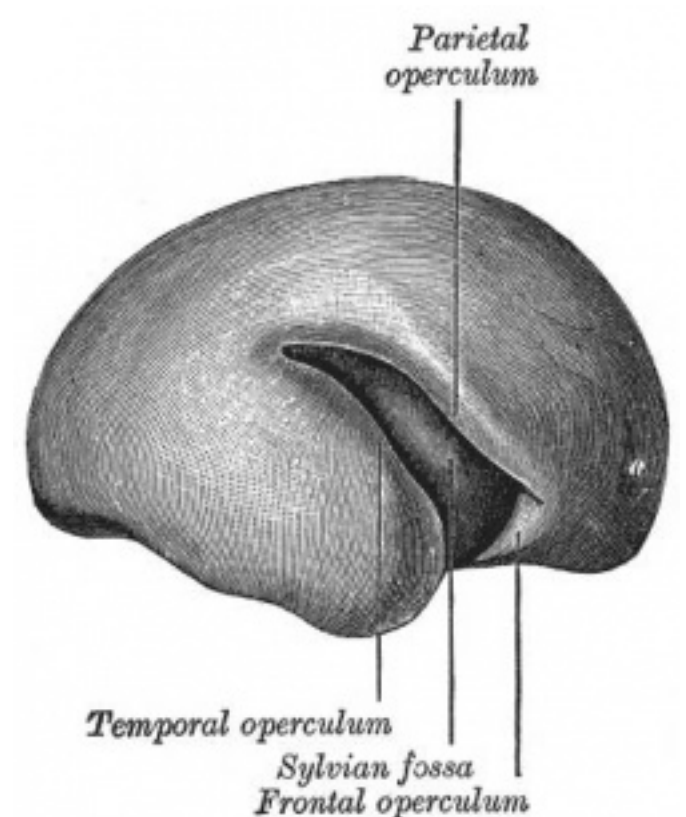
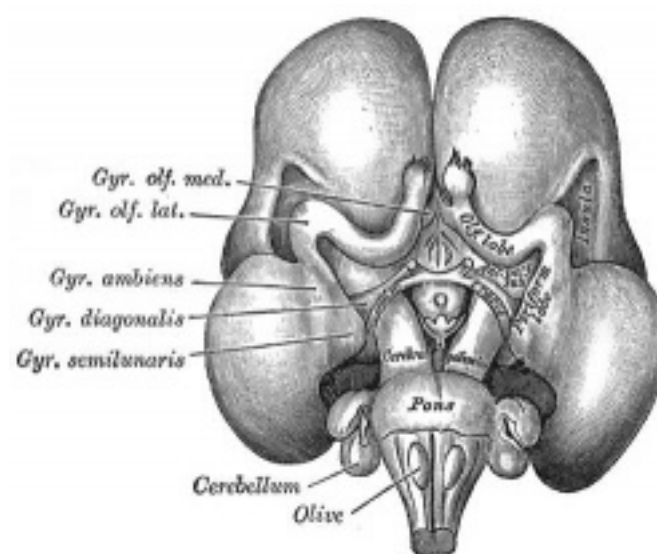
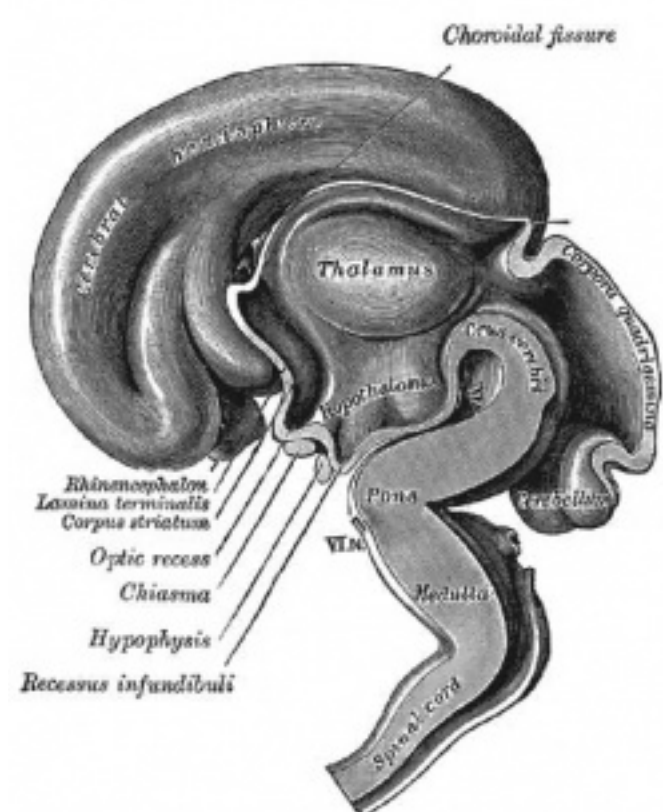
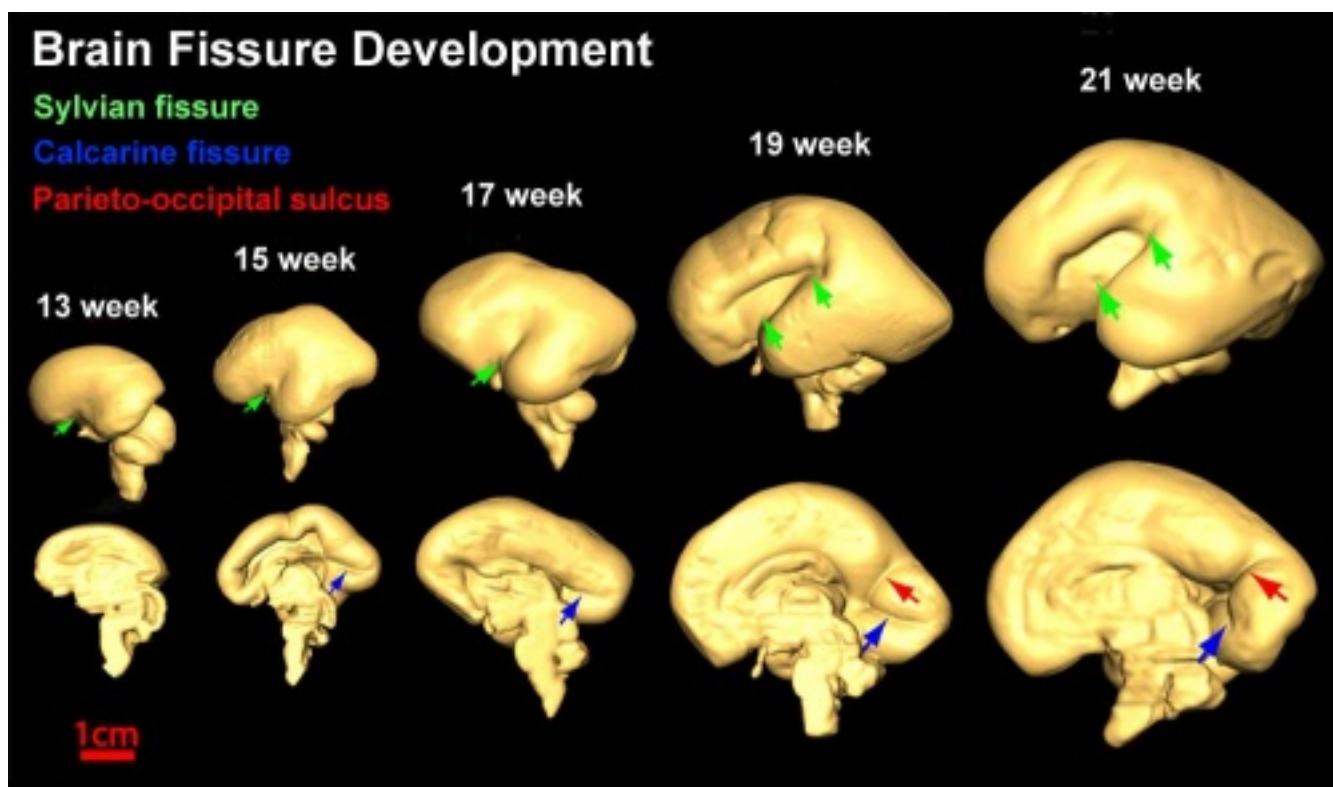
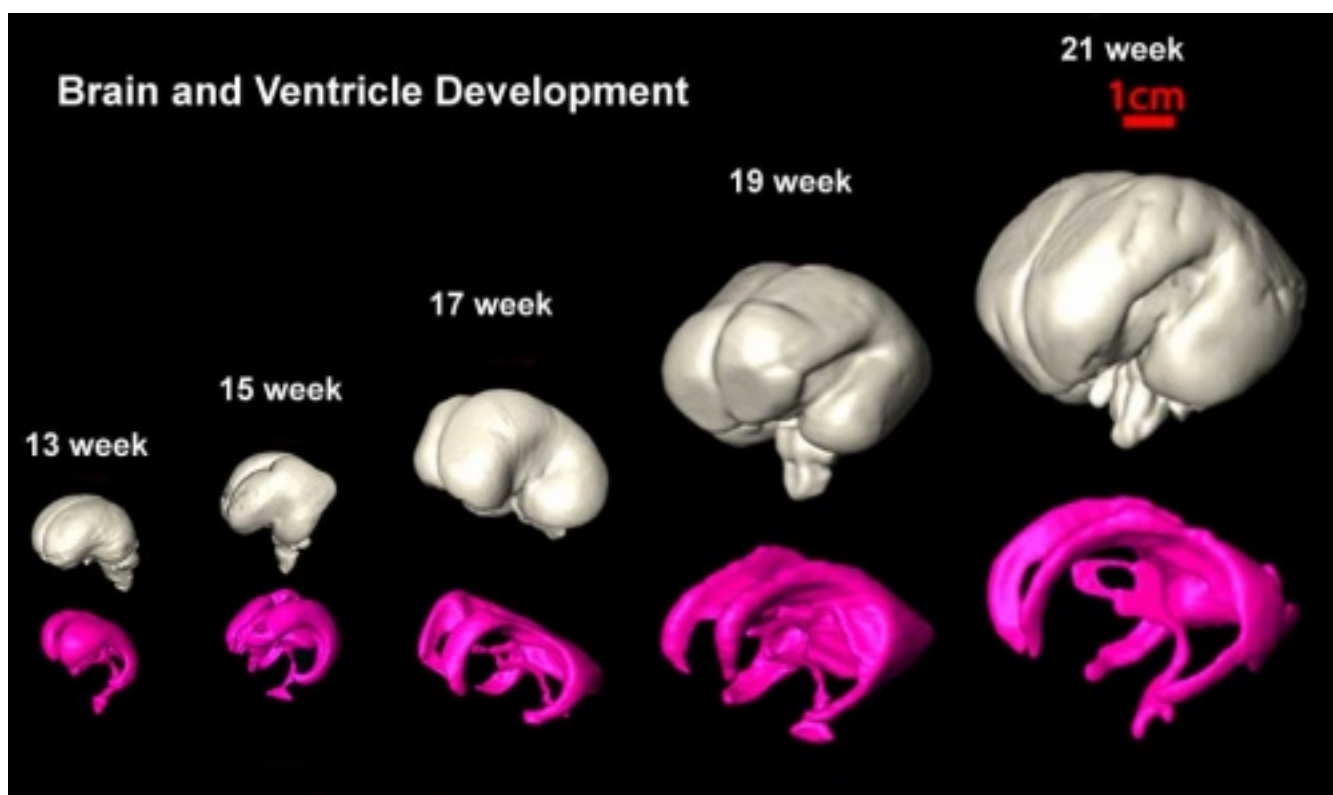
- 13-17 gestational weeks - appearance of the first sulcus
- 18-19 gestational weeks - development of the periinsular sulci
- 20-22 gestational weeks - central sulci and opercularization of the insula
- 24-26 gestational weeks - covering of the posterior insula
- 27-28 gestational weeks - closure of the lateral sulcus (Sylvian fissure or lateral fissure)

(Data from^[2])

- Between 29-41 weeks volumes of: total brain, cerebral gray matter, unmyelinated white matter, myelinated, and cerebrospinal fluid (from MRI)
 - grey matter- mainly neuronal cell bodies; white matter- mainly neural processes and glia.
- total brain tissue volume increased linearly over this period at a rate of 22 ml/week.
- Total grey matter also showed a linear increase in relative intracranial volume of approximately 1.4% or 15 ml/week.
- The rapid increase in total grey matter is mainly due to a fourfold increase in cortical grey matter.
- Quantification of extracerebral and intraventricular CSF was found to change only minimally.

(Text - modified from ^[3])

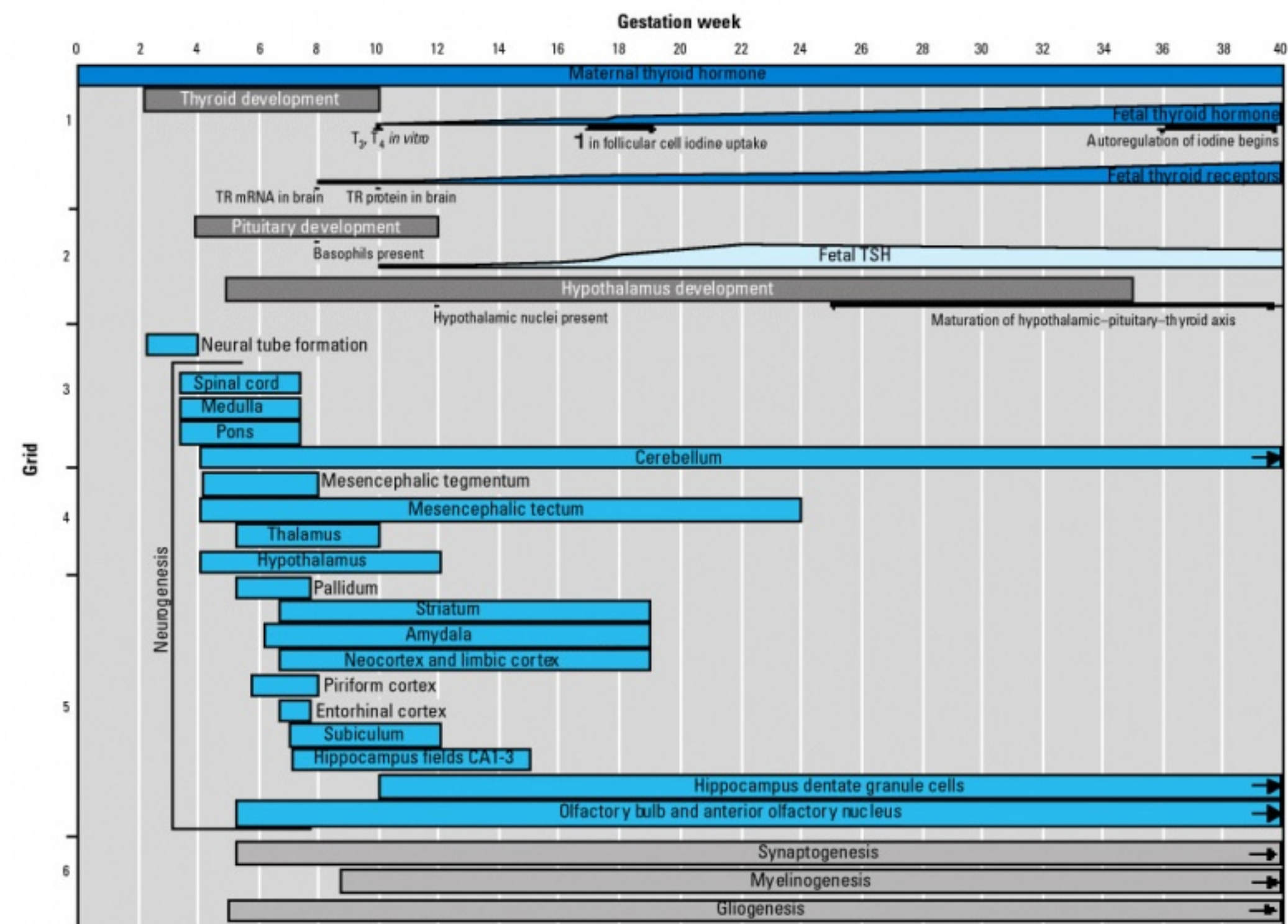
Neural development will continue after birth with substantial glial development, growth, death and reorganization occurring during the postnatally.



Human brain at three months (median sagittal section) Human brain at four months (inferior surface) Human brain at five months (outer surface)

Links: Neural System - Fetal | Neuroscience - Regional specification of the developing brain (<http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=neurosci&part=A1465&rendertype=figure&id=A1466>)

Thyroid System and Neural Development



Timeline of human thyroid system and brain development from conception to birth.^[4] (Estimation of neurogenesis adapted from Bayer et al.^[5])

Links: Endocrine - Thyroid Development

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Historic Embryology

Historic Disclaimer - information about historic embryology pages [Expand]

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- Contributions to Embryology Carnegie Institution No.59 Relative Weight and Volume of the Component Parts of the Brain of the Human Embryo at Different Stages of Development. Jenkins, G.B. (1921). pp5-54.

Images

Bailey, F.R. and Miller, A.M. (1921). Text-Book of Embryology. New York: William Wood and Co.

The nervous system

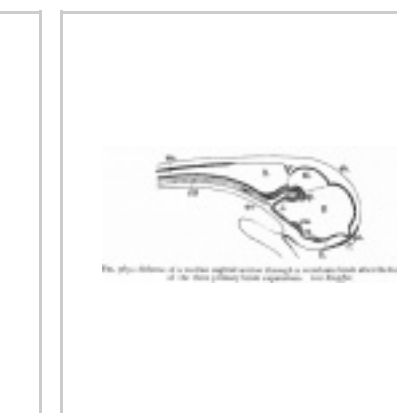
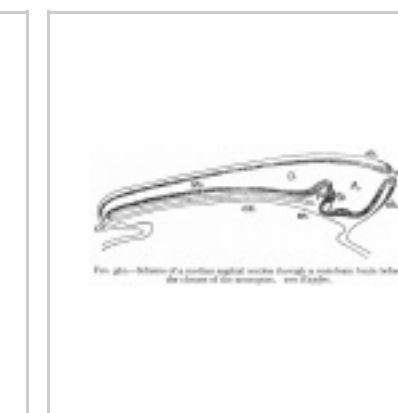
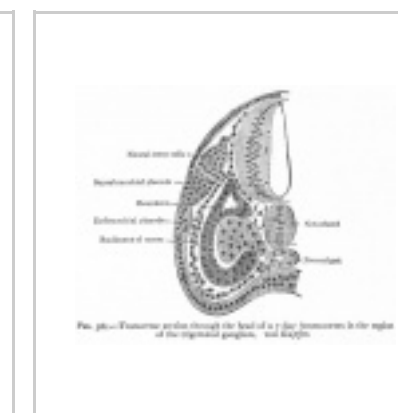
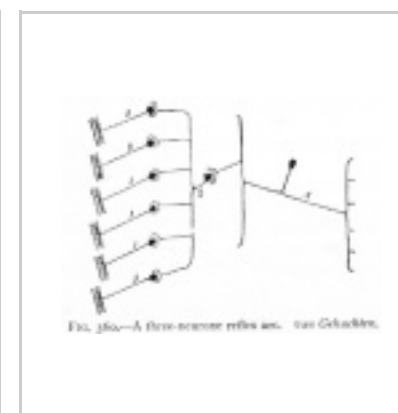
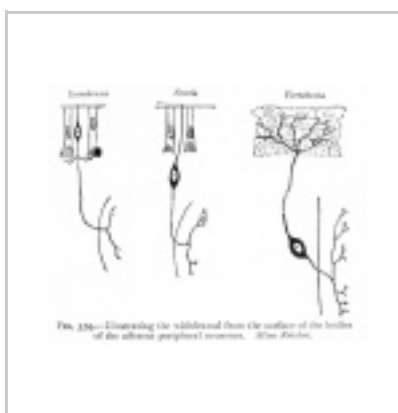
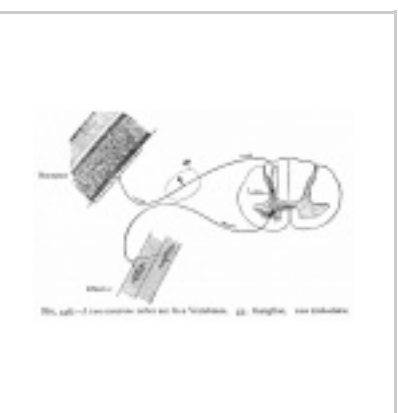


Fig. 358 A two-neuron reflex arc in a Vertebrate

Fig. 359

Fig. 360

Fig. 361

Fig. 362

Fig. 363

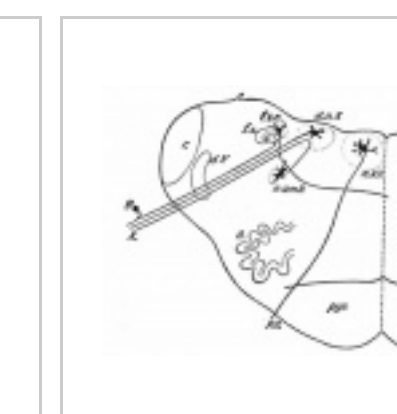
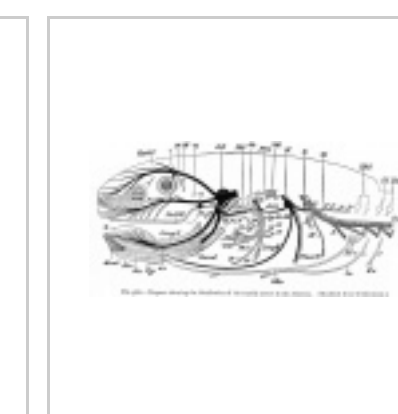
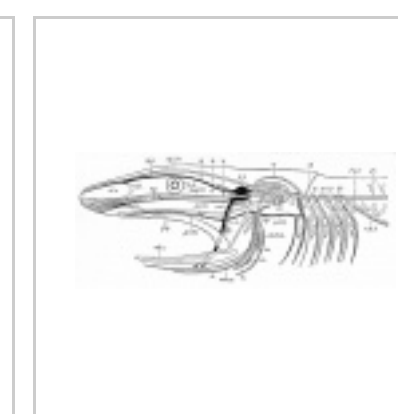
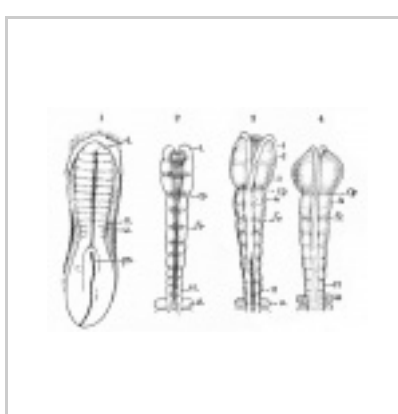


Fig. 364

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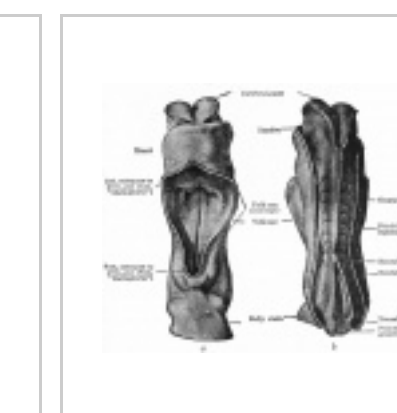
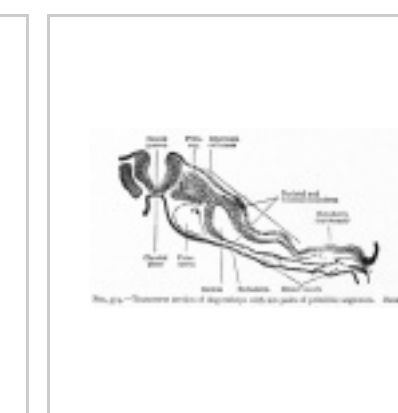
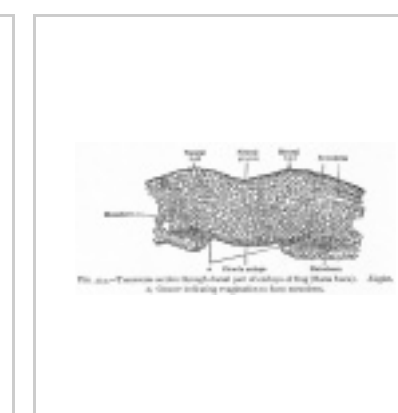
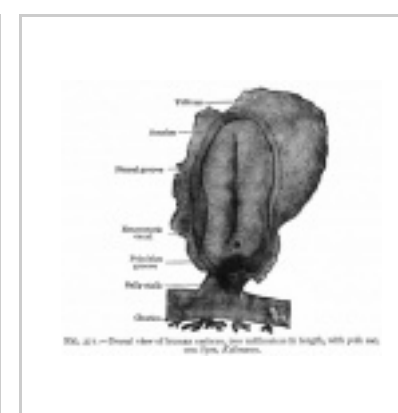
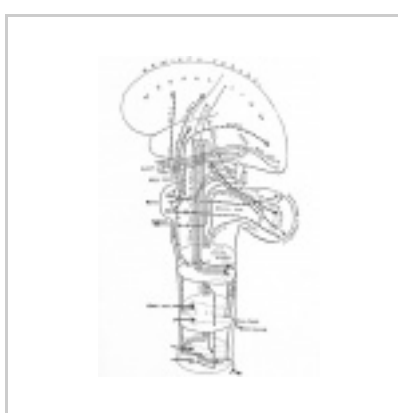
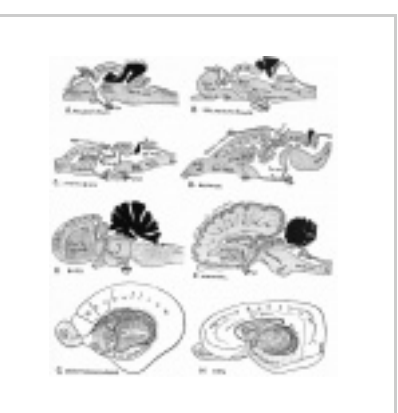


Fig. 370

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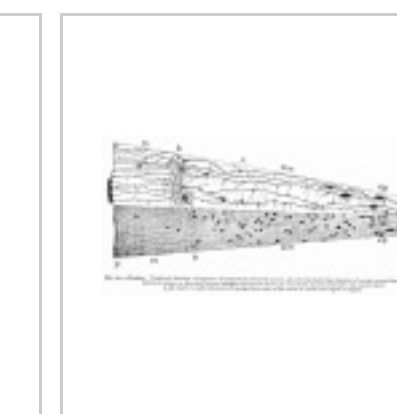
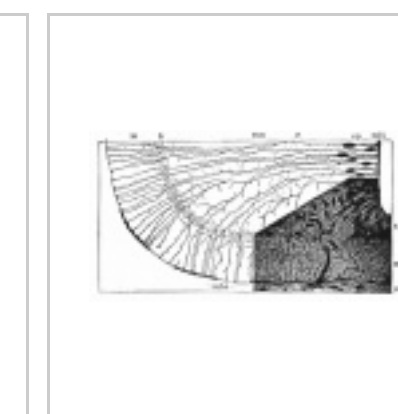
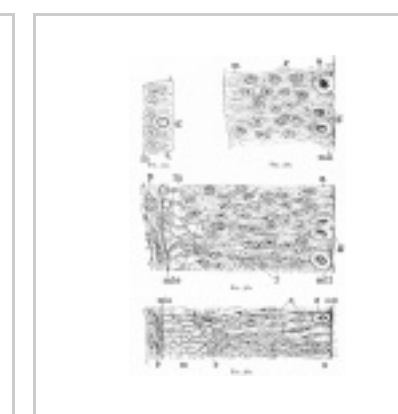
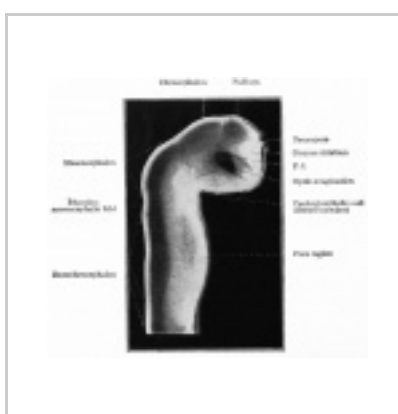


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Fig. 378

Fig. 379-382

Fig. 383

Fig. 384

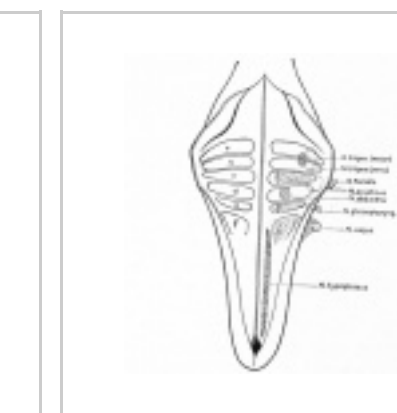
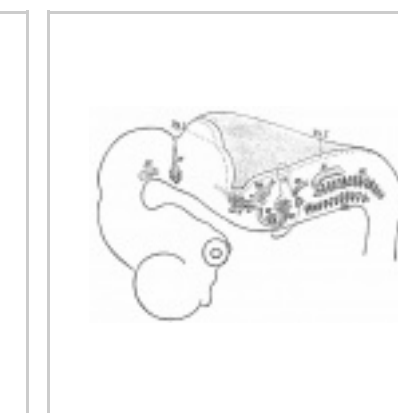
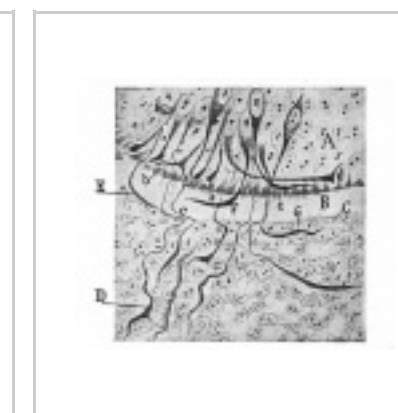
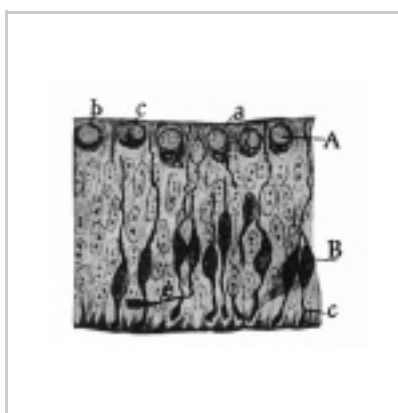
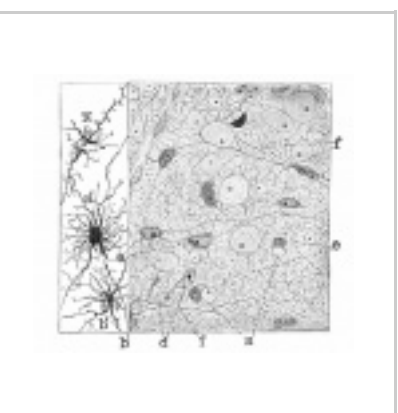


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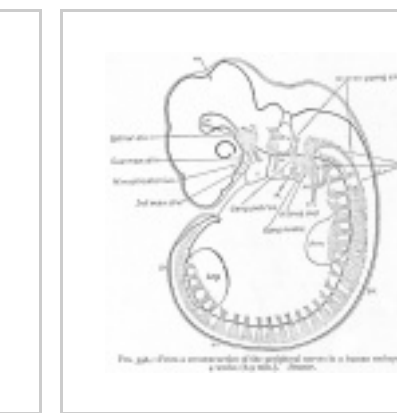
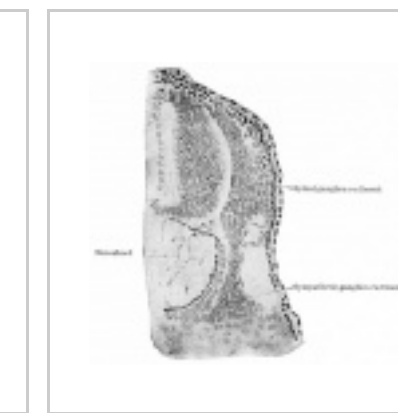
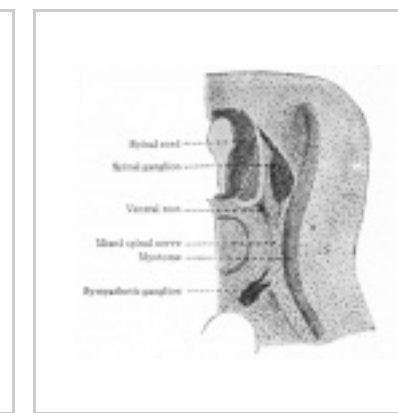
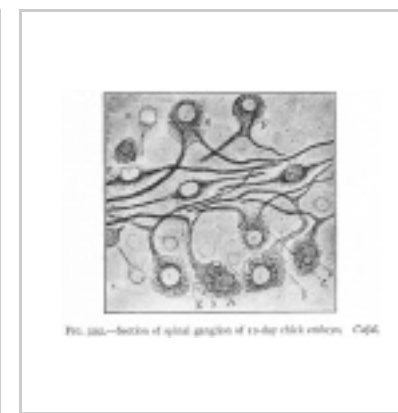
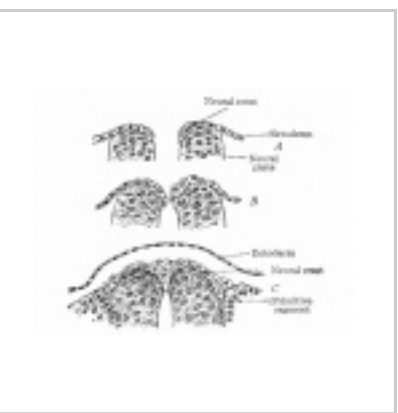


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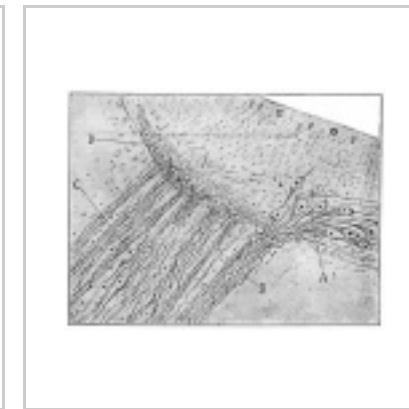
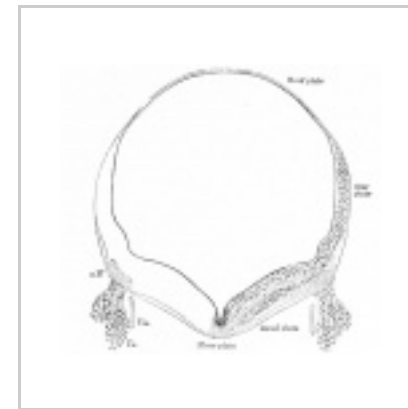
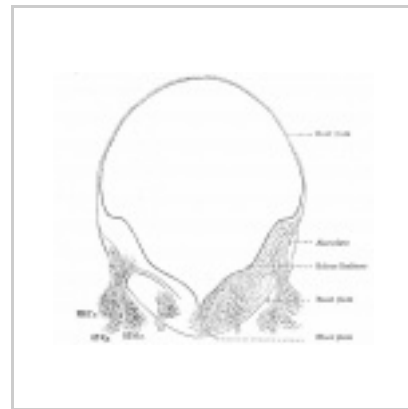
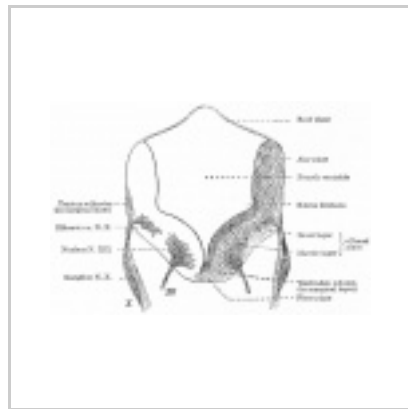
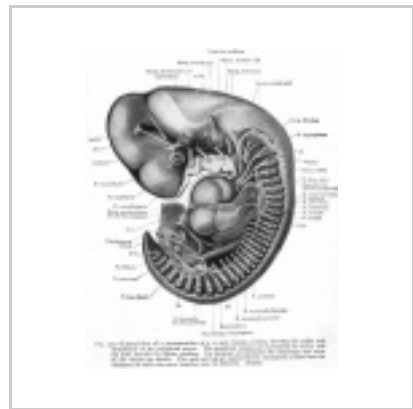


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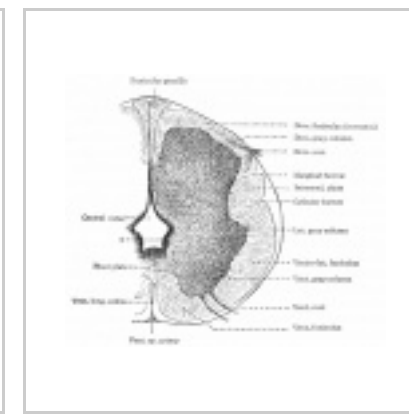
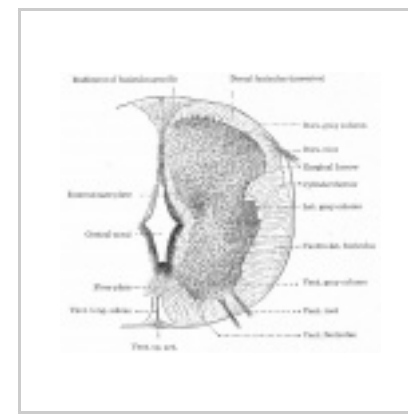
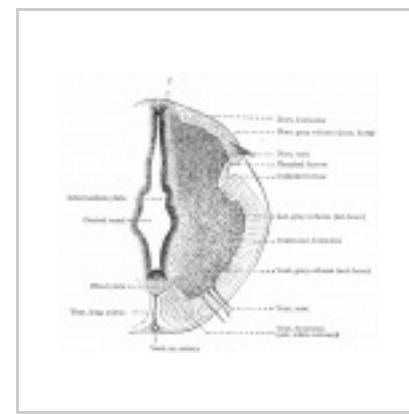
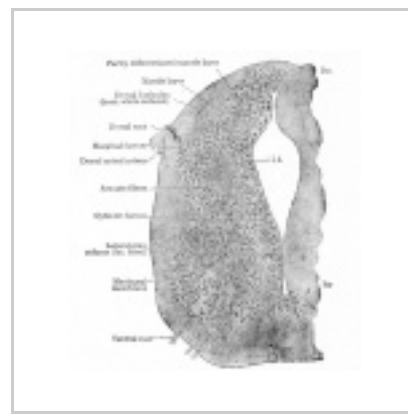
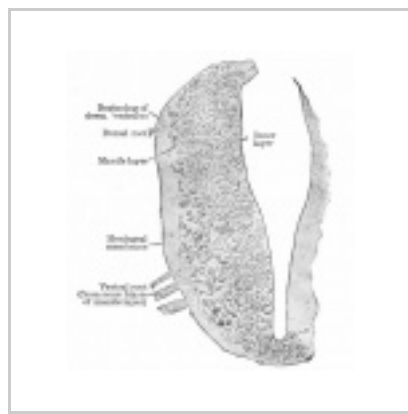


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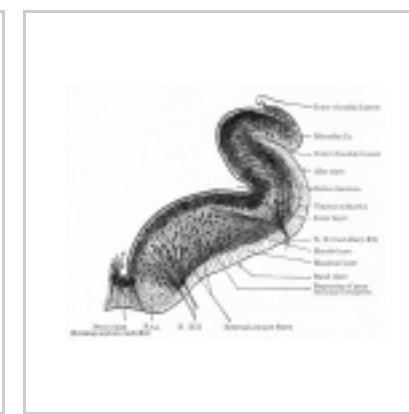
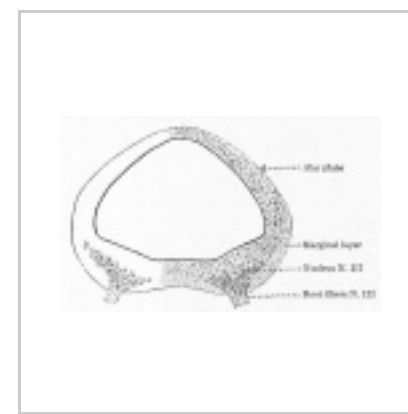
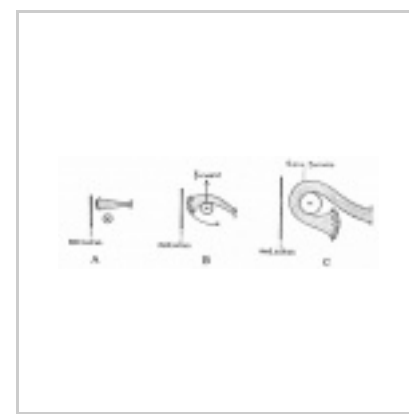
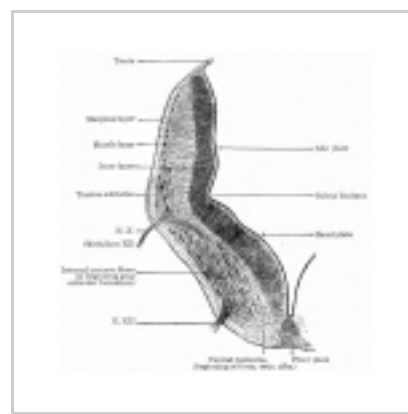
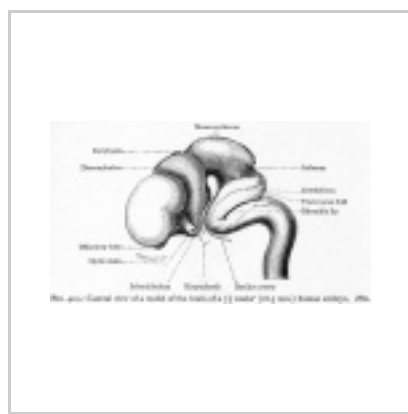
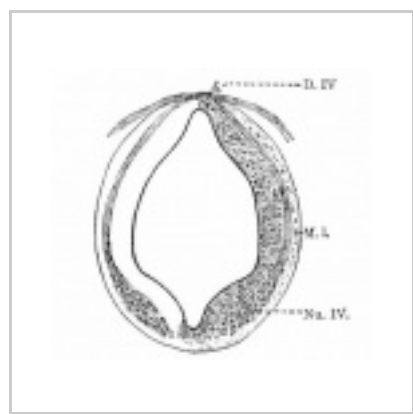


Fig. 409

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Fig. 414

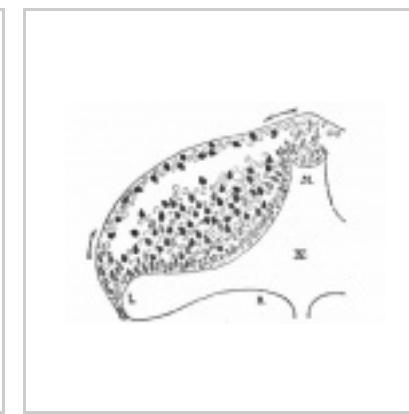
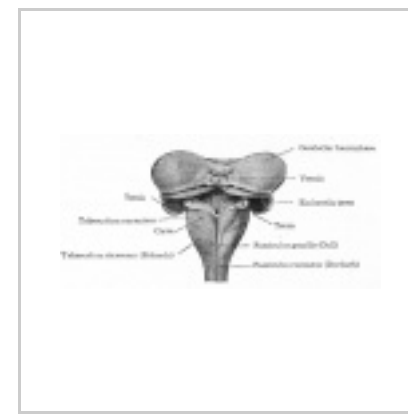
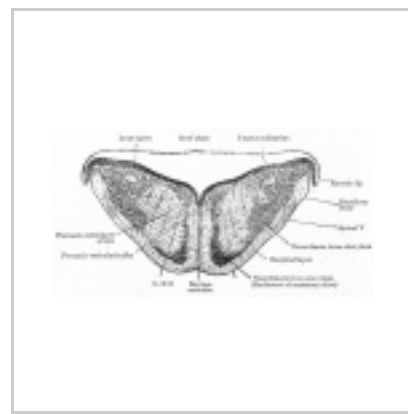
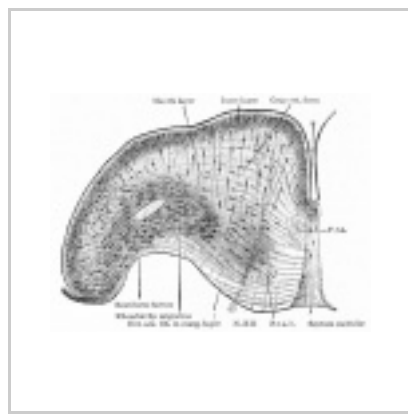
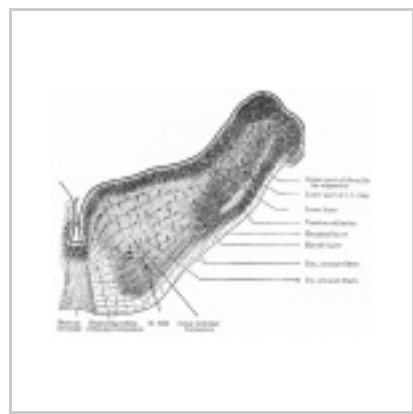


Fig. 415

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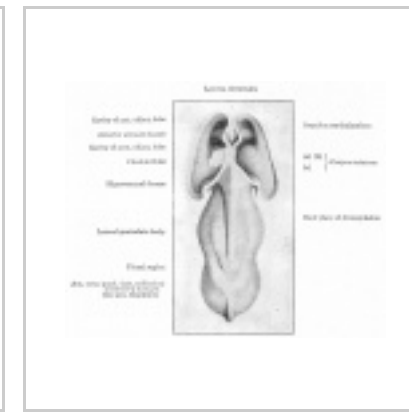
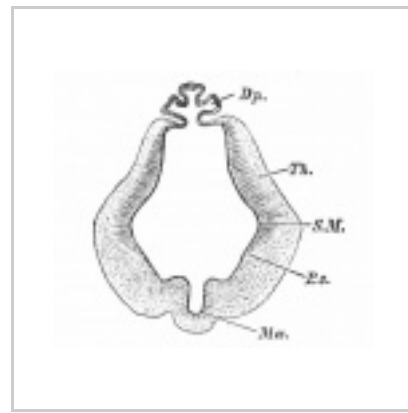
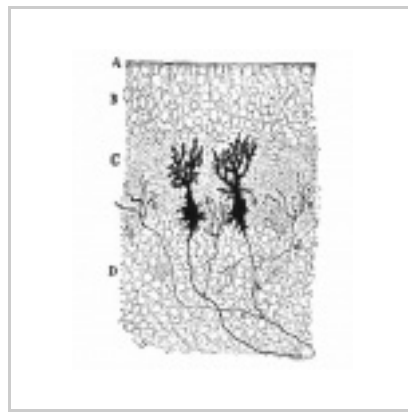
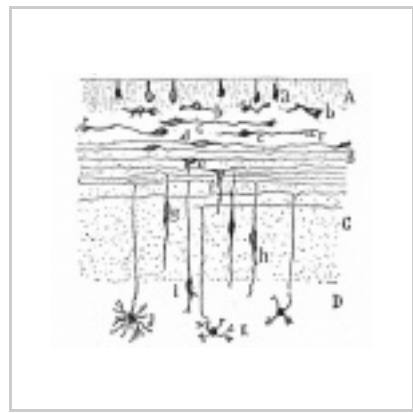


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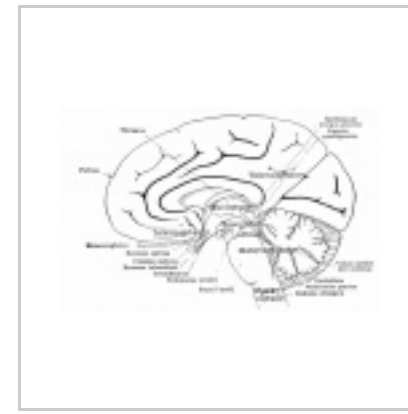
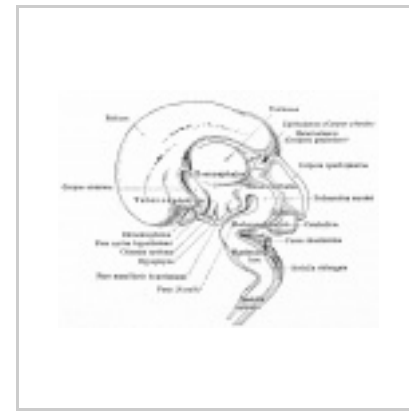
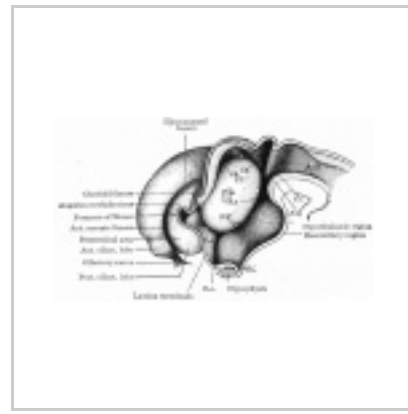
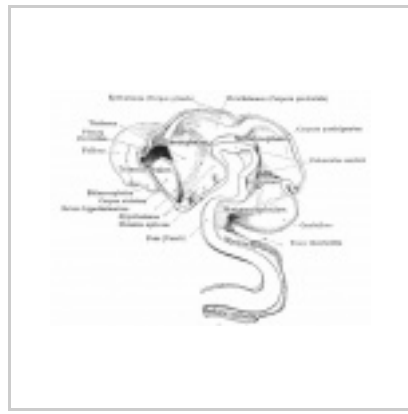


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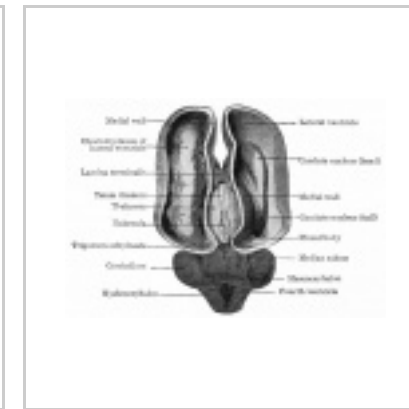
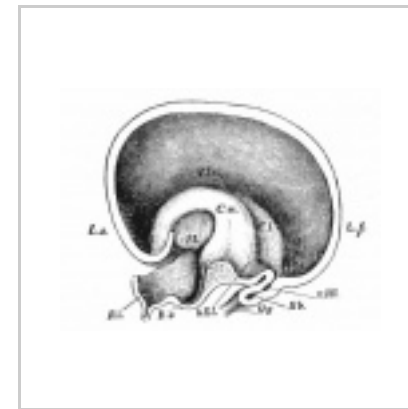
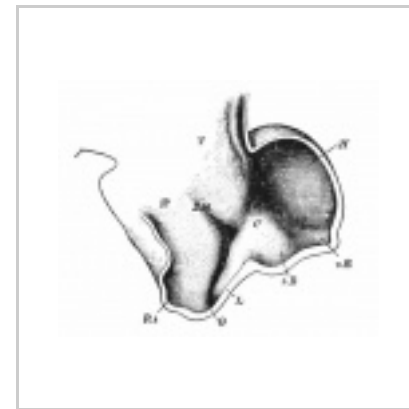
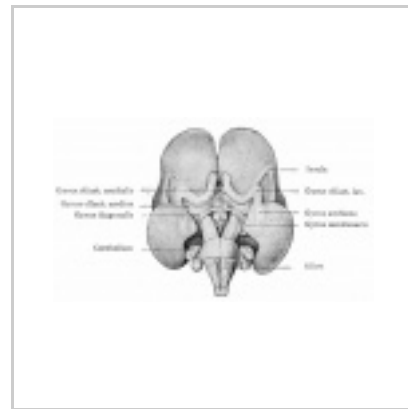
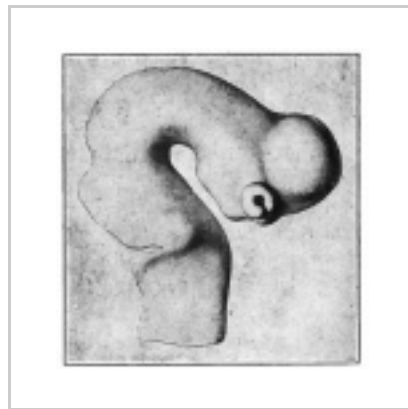
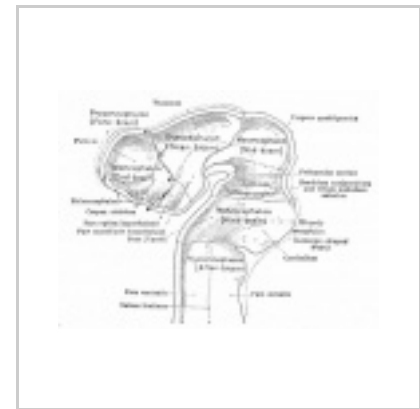


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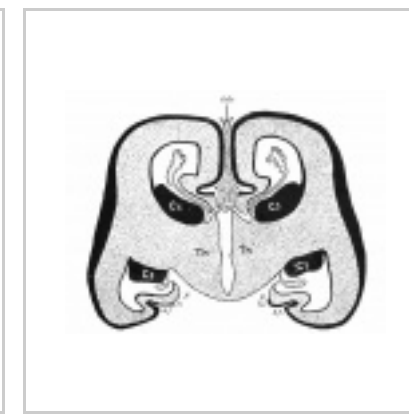
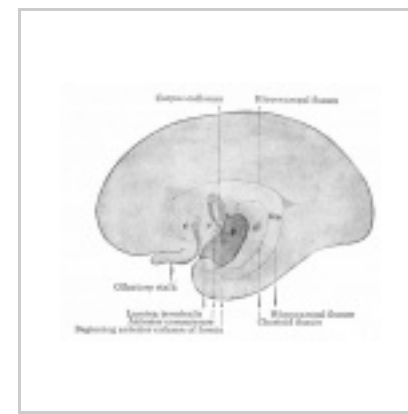
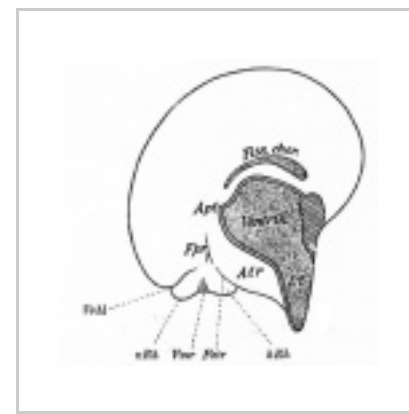
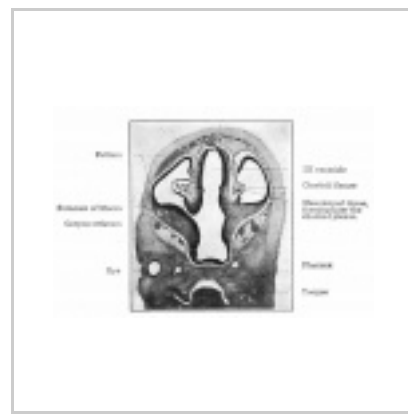
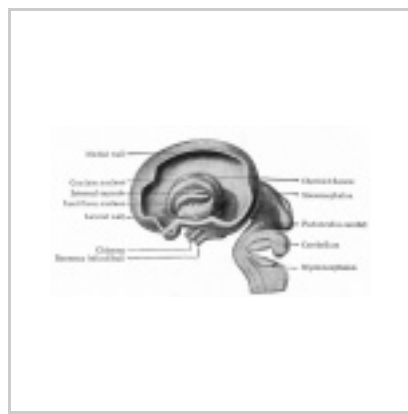
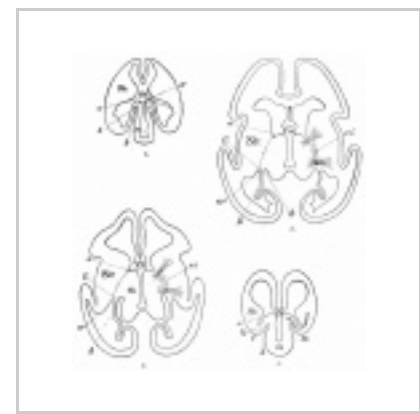


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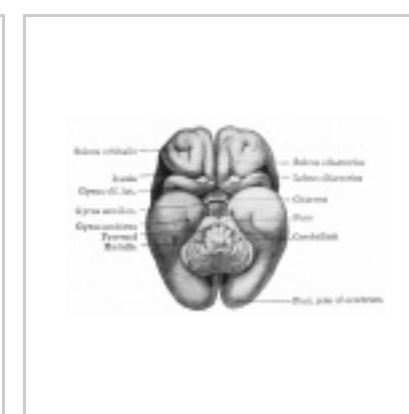
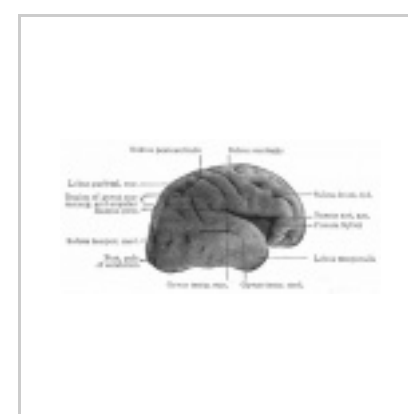
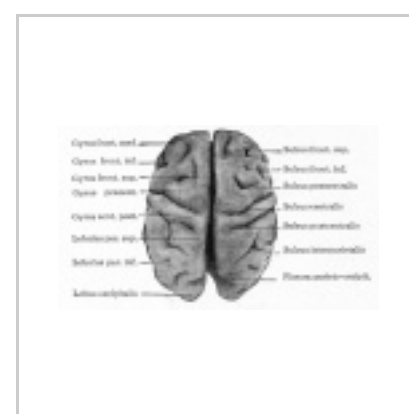
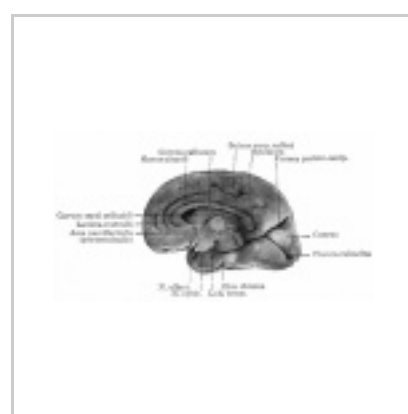
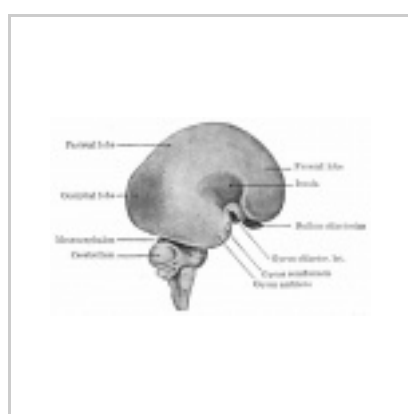
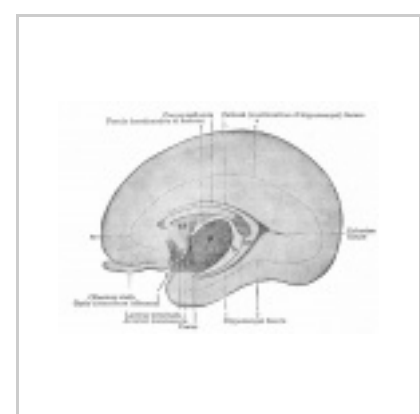


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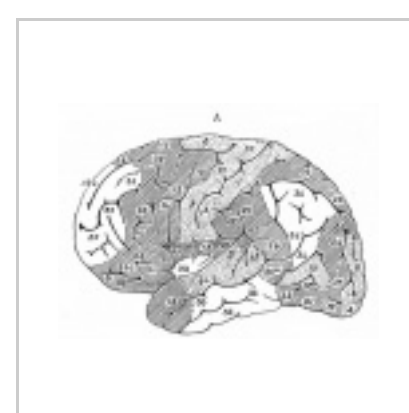


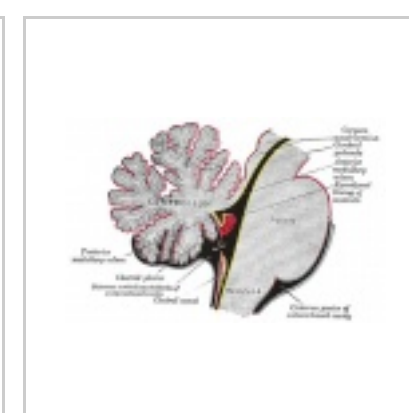
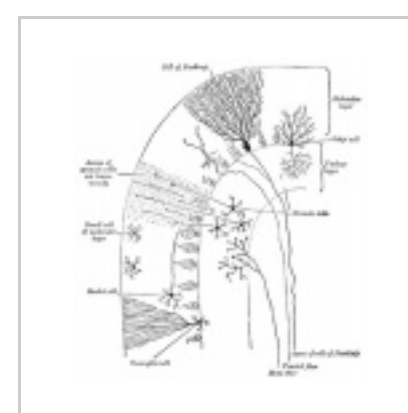
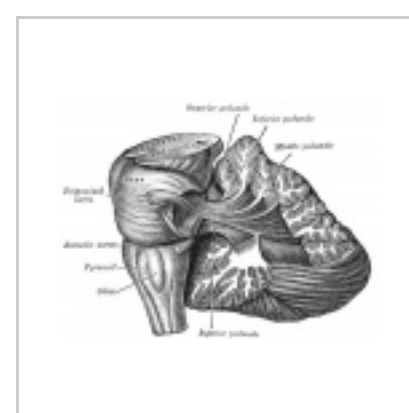
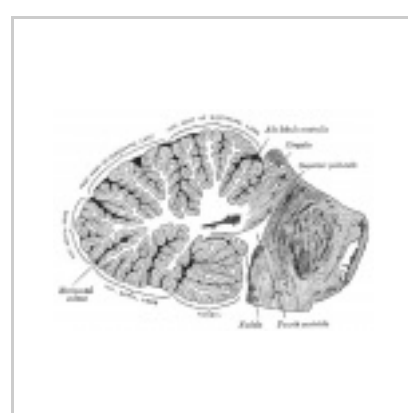
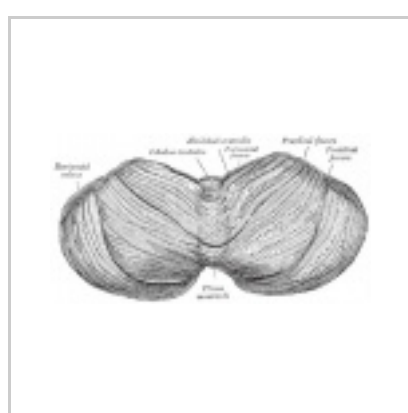
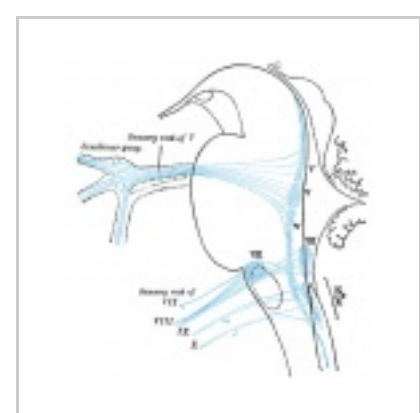
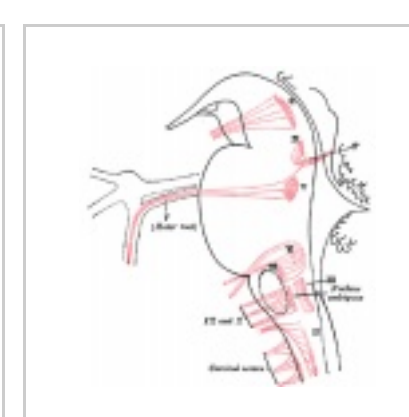
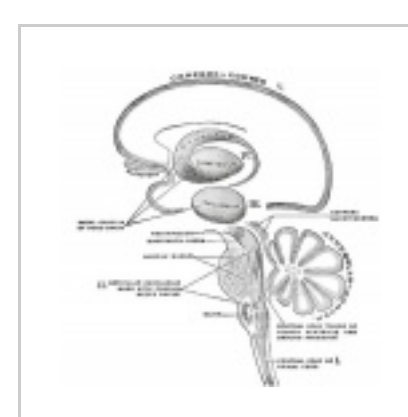
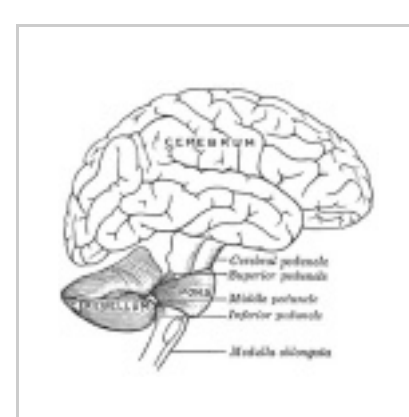
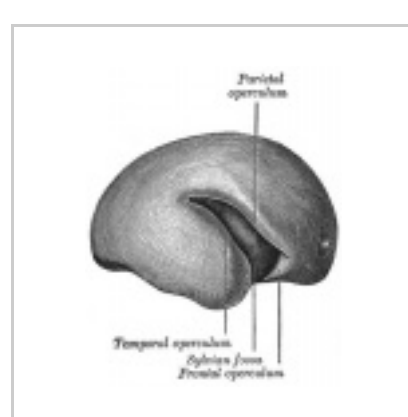
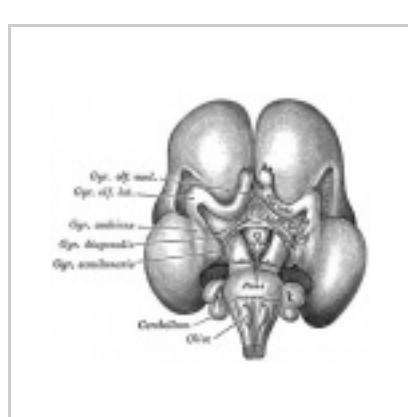
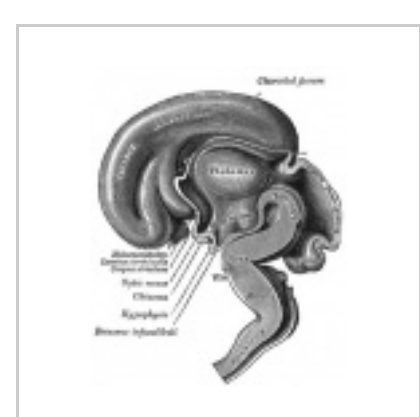
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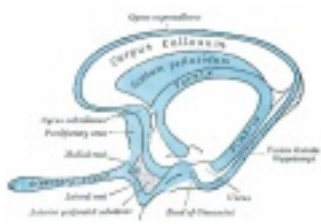
Fig. 453

Fig. 454

Fig. 455

Gray, Henry. Anatomy of the Human Body. Philadelphia: Lea & Febiger, 1918.





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