Lecture - Ectoderm Development

From Embryology

Embryology - 18 Aug 2015 **Translate** **[Expand]**

Introduction

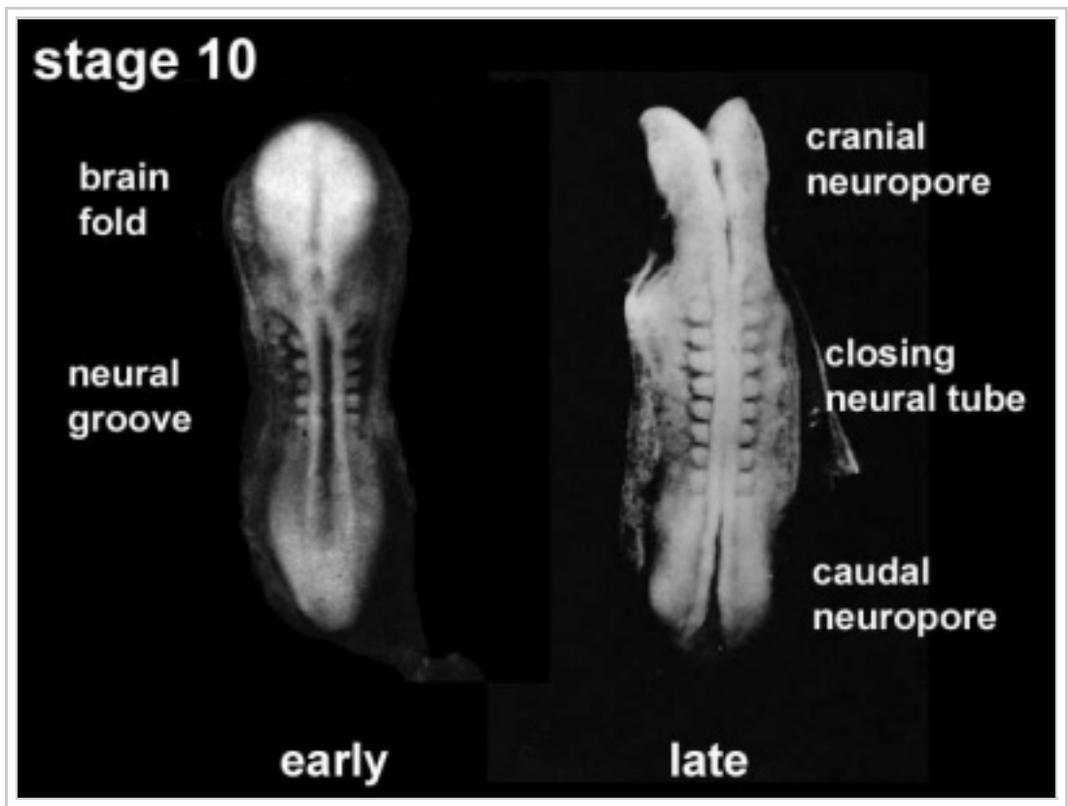
Covering the same period as the previous mesoderm lecture, lets now look at changes to the **ectoderm**.

The ectoderm will from the entire **nervous system** (both central and peripheral), the **epidermis** of the skin and in the head region specialised **placodes**.

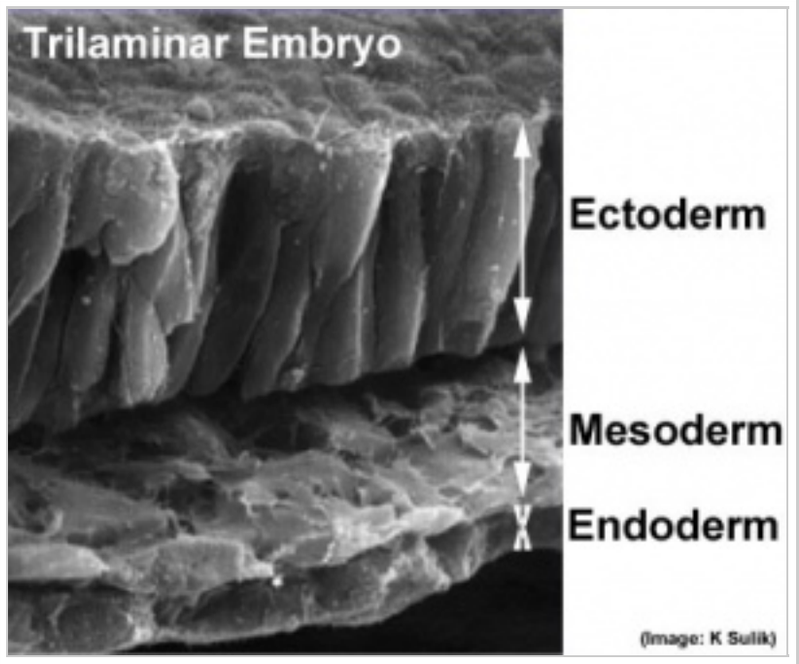
Later development of neural, neural crest, integumentary and head will be covered in future topic specific lectures. The current lecture will also introduce the significance of maternal diet to embryonic development.

Objectives

- Understanding of events during the third and fourth week of development
- Understanding the process of early neural development
- Brief understanding of neural crest formation
- Brief understanding of epidermis formation
- Understanding of the adult components derived from ectoderm
- Brief understanding of early neural abnormalities



Lecture Resources



Movies [Collapse]

Neural Plate

Page | Play

Neural Tube

Page | Play

Secondary Neurulation

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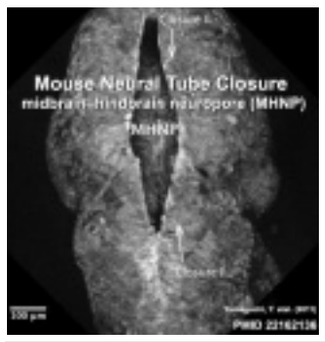

Neural Tube Close

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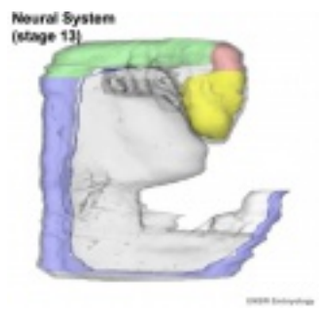

Neural

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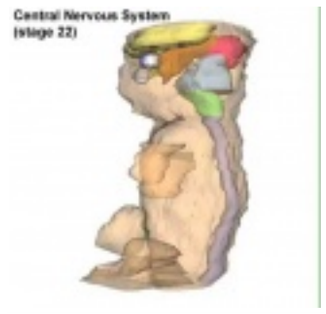

Neural

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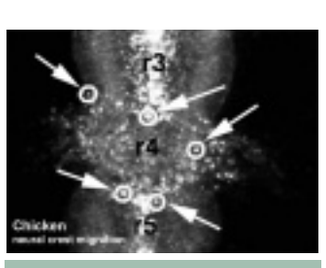

Neural Crest 1

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Cranial Neural Crest

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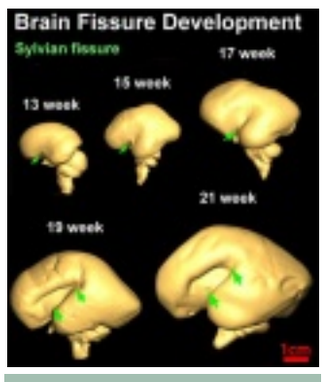

Sylvian Fissure

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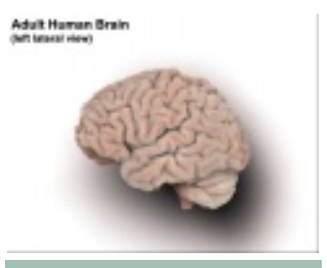

Adult Brain

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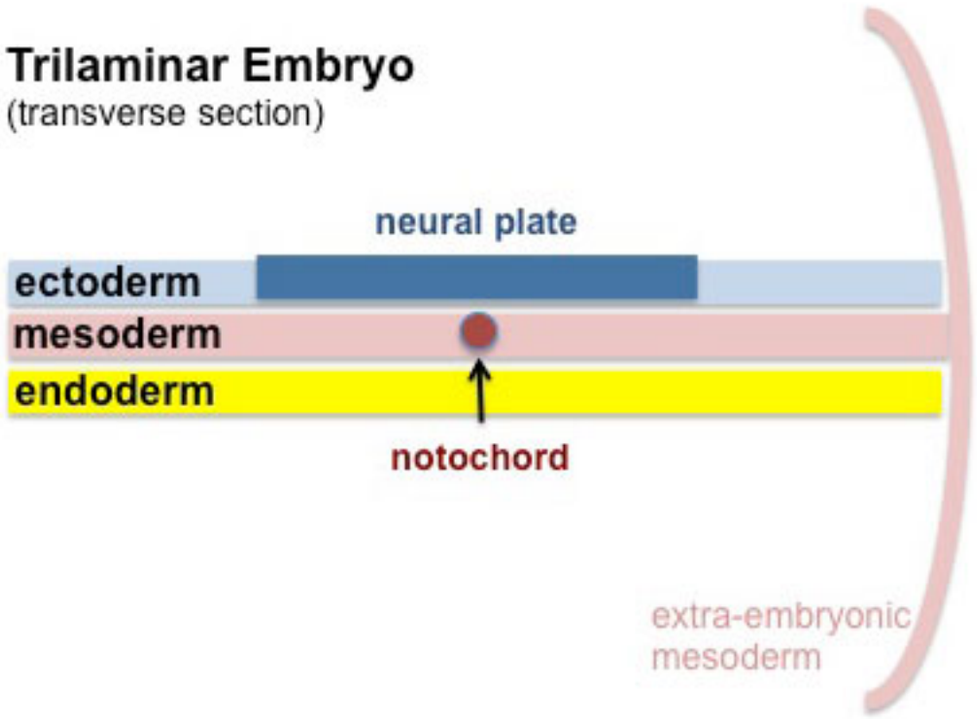
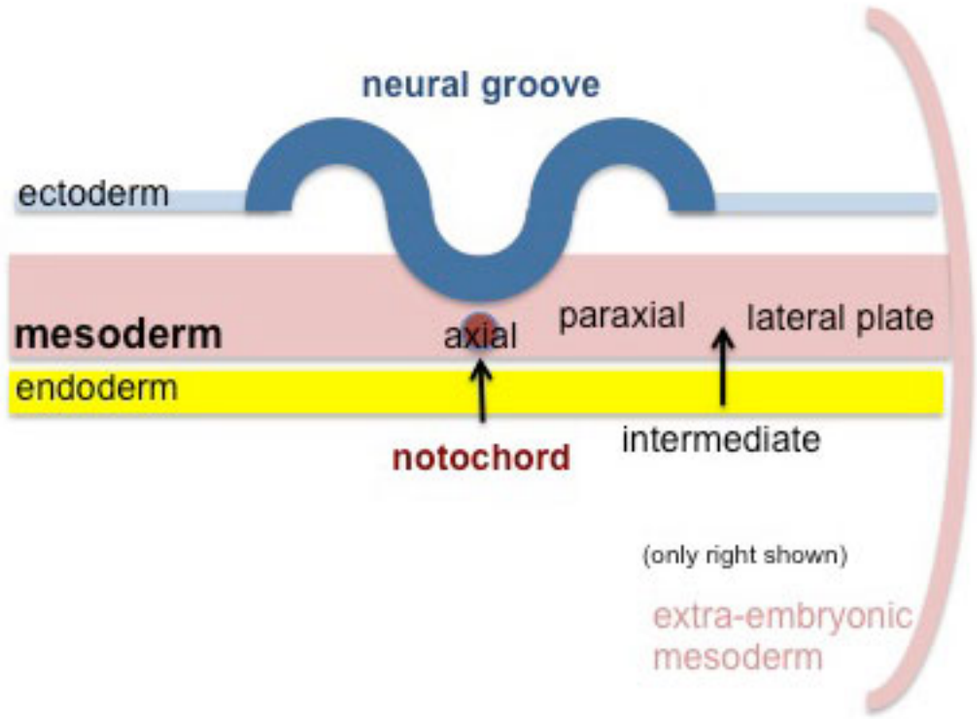
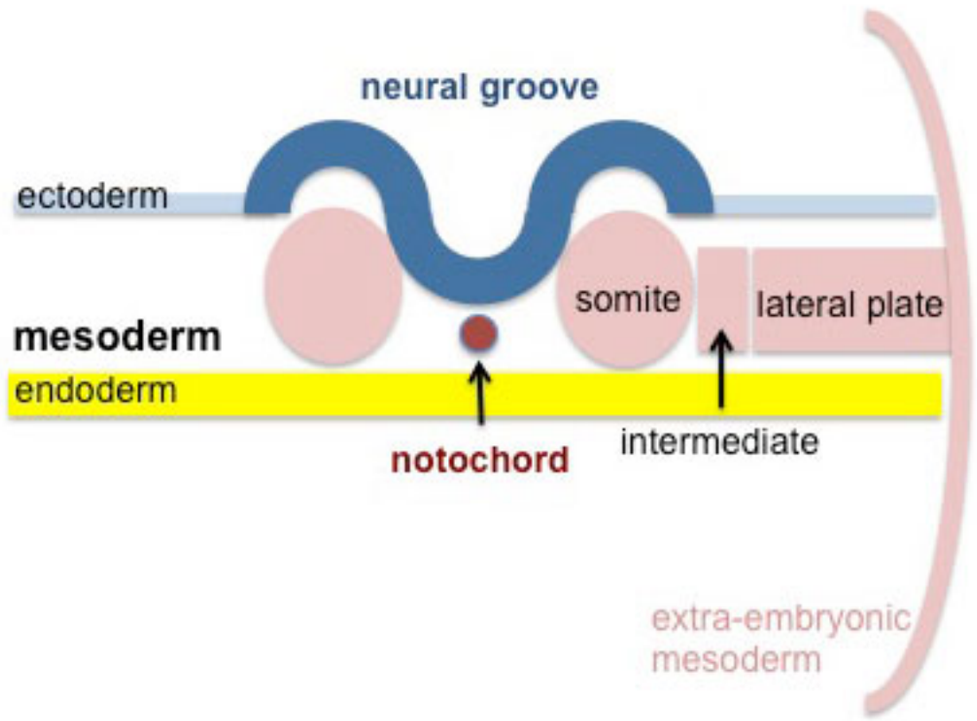
References	[Collapse]	
	Hill, M.A. (2015). *UNSW Embryology* (15th ed.) Retrieved August 18, 2015, from https://embryology.med.unsw.edu.au	▪ Week 4 | Neural System Development | Neural Crest Development | Notochord ▪ Lecture Archive: 2011 (http://php.med.unsw.edu.au/embryology/index.php?title=Lecture_-_Ectoderm_Development&oldid=64153) | 2012 (http://embryology.med.unsw.edu.au/embryology/index.php?title=Lecture_-_Ectoderm_Development&oldid=124901) | 2013
	Moore, K.L., Persaud, T.V.N. & Torchia, M.G. (2011). *The developing human: clinically oriented embryology* (9th ed.). Philadelphia: Saunders.	The following chapter links only work with a UNSW connection. ▪ Chapter 5 - Organogenetic Period: Fourth to Eighth Weeks (http://www.unsw.eblib.com.wwwproxy0.library.unsw.edu.au/patron/Read.aspx?p=1430154&pg=93) ▪ Chapter 17 - The Nervous System (http://www.unsw.eblib.com.wwwproxy0.library.unsw.edu.au/patron/Read.aspx?p=1430154&pg=411)
	Schoenwolf, G.C., Bleyl, S.B., Brauer, P.R. & Francis-West, P.H. (2009). *Larsen's human embryology* (4th ed.). New York; Edinburgh: Churchill Livingstone.	The following chapter links only work with a UNSW connection. ▪ Chapters listed below (https://login.wwwproxy0.library.unsw.edu.au/login?url=http://www.unsw.eblib.com/patron/FullRecord.aspx?p=2074524) ▪ Chapter 4 - Fourth Week: Forming the Embryo ▪ Chapter 9 - Development of the Central Nervous System ▪ Chapter 10 - Development of the Peripheral Nervous System

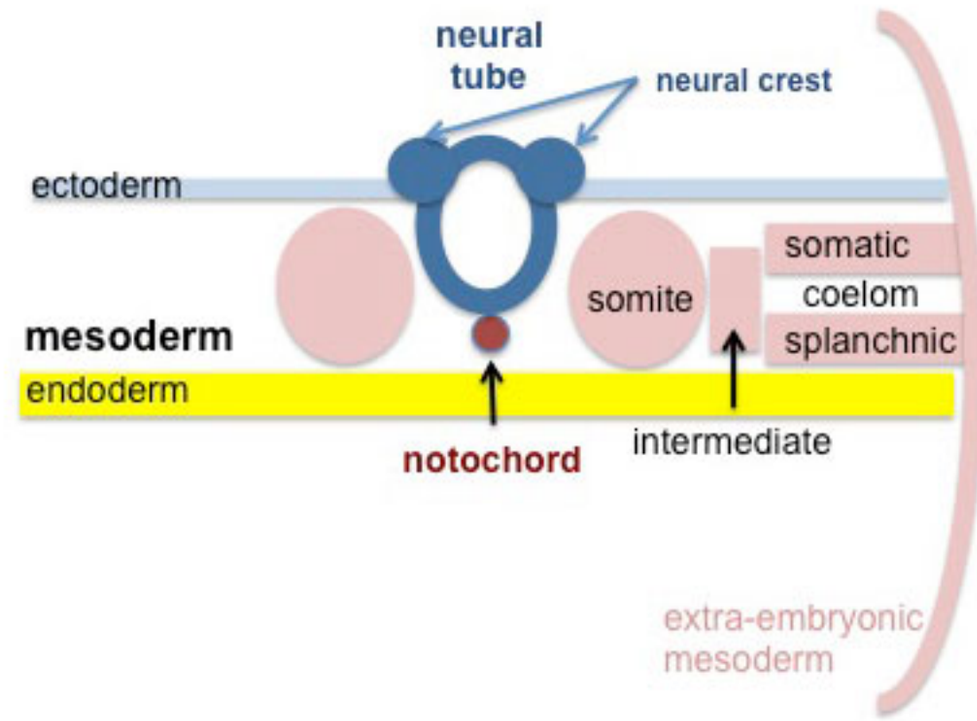
ECHO360 Recording[Expand]

Development Overview





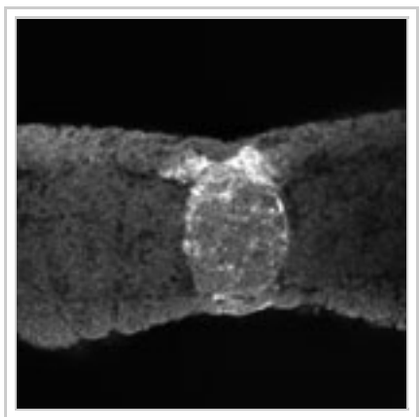




Animation

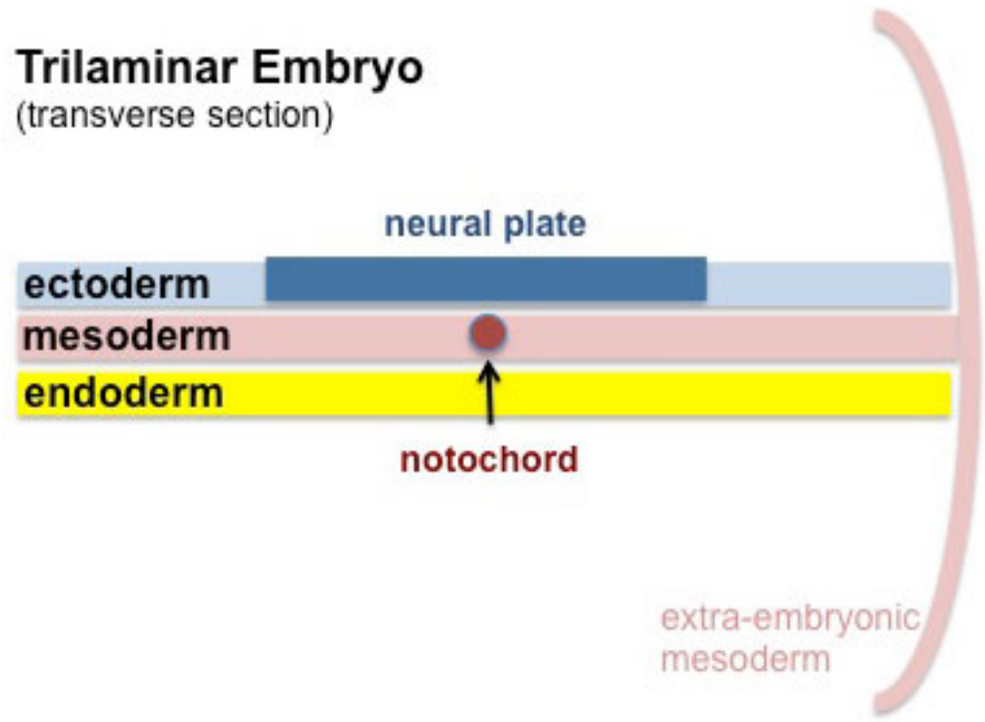
Notochord

- forms initially as the Axial Process, a hollow tube which extends from the primitive pit , cranially to the oral membrane
- the axial process then allow transient communication between the amnion and the yolk sac through the neuroenteric canal.
- the axial process then merges with the Endodermal layer to form the Notochordal Plate.
- the notochordal plate then rises back into the Mesodermal layer as a solid column of cells which is the Notochord.



Frog notochord SHH

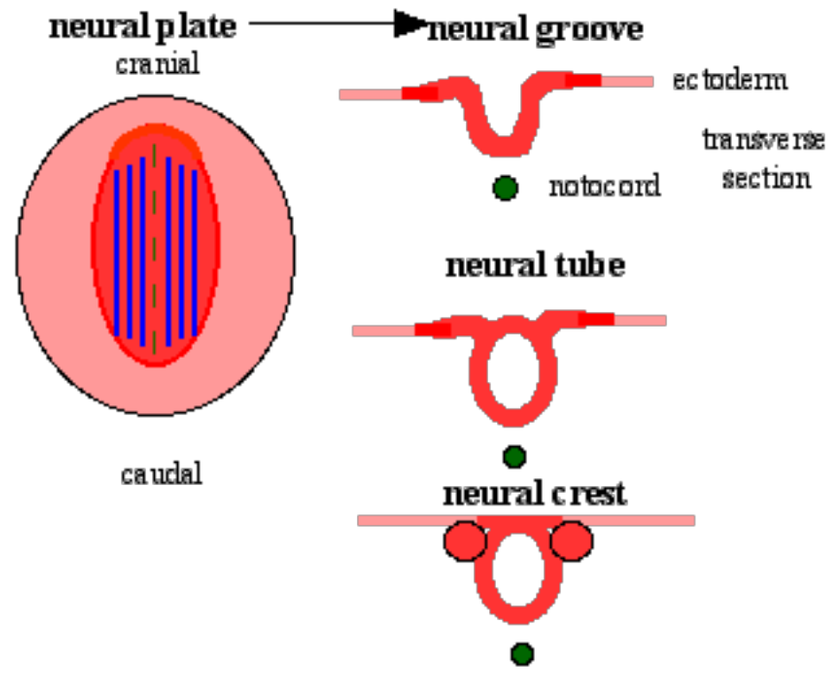
Ectoderm



Two parts

1. midline columnar epithelium - neural plate (central nervous system)
2. lateral cuboidal epithelium - surface ectoderm (epidermis) and sensory placodes Placodes

Neural Plate



Development of the neural plate region at the embryonic disc stage.

Dorsal view of the embryonic disc from the amniotic cavity side showing the ectoderm with the central region developing into the neural plate.

The neural plate extends from buccopharyngeal membrane to primitive node and forms above the notochord and paraxial mesoderm.The neuroectodermal cells form a broad brain plate and narrower spinal cord region.

Three specific regions medial to lateral can also be identified: midline region floor plate, neural plate, edge of neural plate neural crest

- **blue** - neural plate region
- **white and black midline strip** - primitive streak ending in primitive node
- **white** - ectoderm forming the epithelium of the skin
- **upper circular region** - buccopharyngeal membrane
- **lower circular region** - cloacal membrane

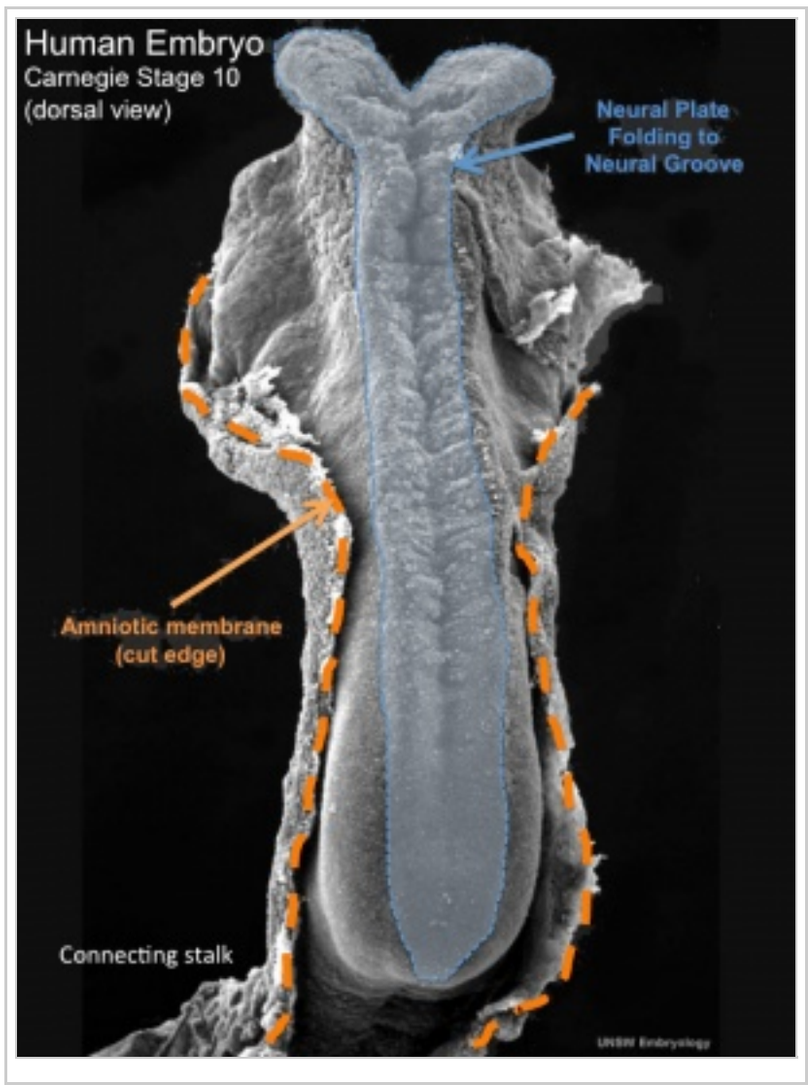
Click Here to play on mobile device

- extends from buccopharyngeal membrane to primitive node
- forms above notochord and paraxial mesoderm
- neuroectodermal cells
  - broad brain plate
  - narrower spinal cord
- 3 components form: floor plate, neural plate, neural crest

Neural Determination- neuronal populations are specified before plate folds

- signals from notochord and mesoderm - secrete noggin, chordin,follistatin
  - all factors bind BMP-4 an inhibitor of neuralation
  - bone morphogenic protein acts through membrane receptor
- lateral inhibition generates at spinal cord level 3 strips of cells
- expression of delta inhibits nearby cells, which express notch receptor, from becoming neurons
- Delta-Notch inetraction- generates Neural strips

Neural Groove



This animation of early neural development from week 3 onward shows the neural groove fusing to form the neural tube.

View - Dorsolateral of the whole early embryo and yolk sac. Cranial (head) to top and caudal (tail) to bottom. Yolk sac is shown to the left.

Beginning with the neural groove initially fusing at the level of the 4th somite to form the neural tube and closing in both directions to leave 2 openings or neuropores: a cranial neuropore (anterior neuropore) and a caudal neuropore (posterior neuropore).

The animation also shows as the embryo grows and folds it increases in size relative to the initial yolk sac. Note also the increasing number of somites over time.

Click Here to play on mobile device

- forms in the midline of the neural plate (day 18-19)
- either side of which are the neural folds which continues to deepen until about week 4
- neural folds begins to fuse, beginning at 4th somite level

Neural Tube

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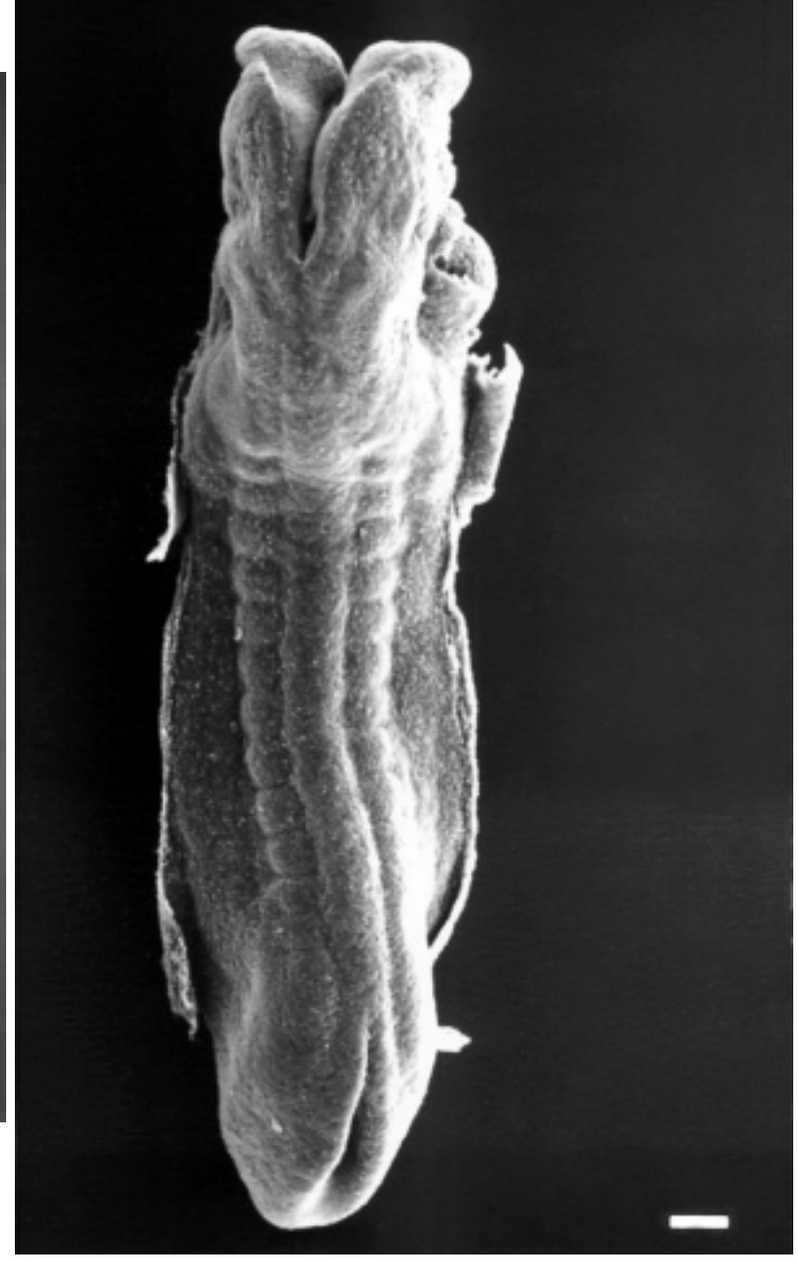


Mouse neural tube closure

Human Stage 10 neural groove to tube

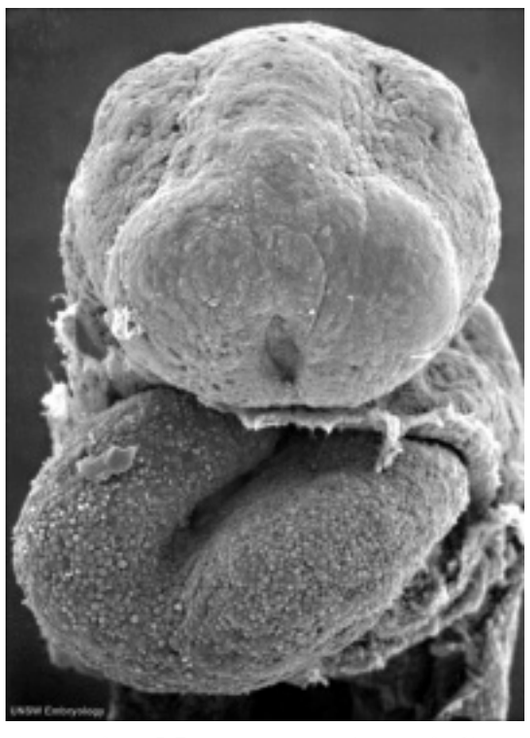
Human Stage 11 forming neuropores

- the neural tube forms the brain and spinal cord
- fusion of neural groove extends rostrally and caudally
- begins at the level of 4th somite
- closes neural groove "zips up" in some species.
    - humans appear to close at multiple points along the tube.

Last parts of neural groove to close are the **Neuropores**

- two openings at either end of the embryo
- cranial neuropore closes before caudal

Neuropores



About Neuropores

- Anatomically - lamina terminals is the location of the cranial neuropore.
- Failure of neural tube closure - a **neural tube defect**.
    - Maternal dietary folate is required for this closure.

Anterior Neuropore (cranial) Posterior Neuropore (caudal)

Secondary Neuralation

This animation shows the early developmental process often described as secondary neurulation.

Red - site of secondary neurulation | **Blue - neural tube**

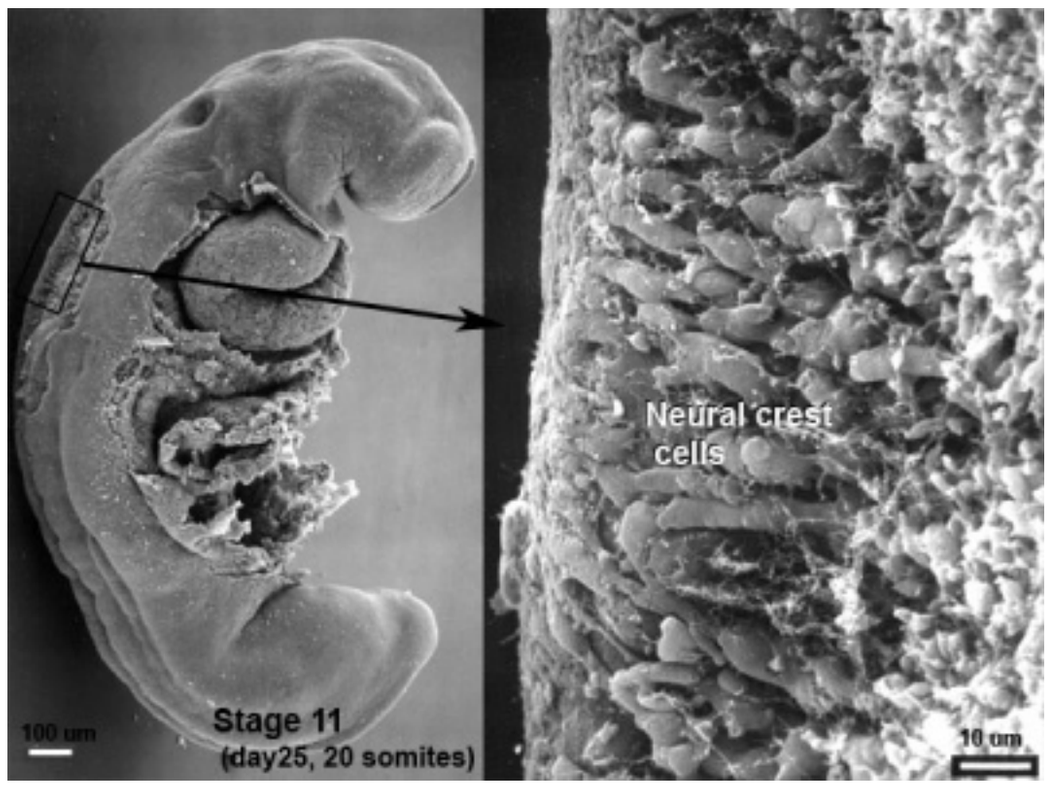
- caudal end of neural tube formed by secondary neuralation
- develops from primitive streak region
- solid cord canalized by extension of neural canal
- mesodermal caudal eminence

Links: Quicktime version | Neural System Development

Click Here to play on mobile device

Neural Crest

- a population of cells at the **edge of the neural plate** that lie dorsally when the neural tube fuses
- dorsal to the neural tube, as a pair of streaks
- pluripotential (forms many different types of cells)
- cells migrate throughout the embryo
- migration studied by quail-chick chimeras - transplanted quail cells have obvious nucleoli compared with chicken



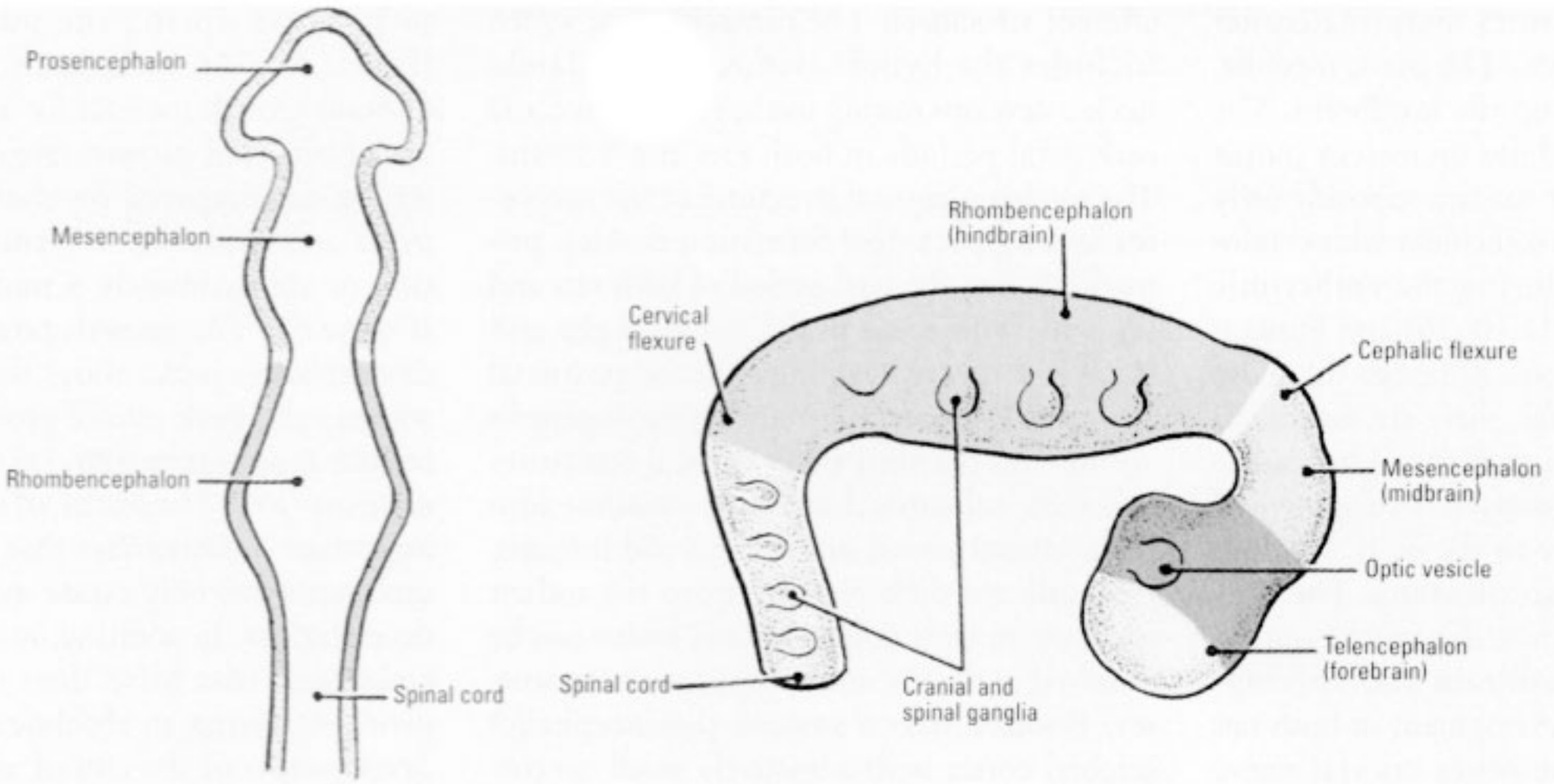
Neural Crest Derivitives

- dorsal root ganglia (DRG)
- autonomic ganglia
- adrenal medulla
- drg sheath cells, glia
- pia-arachnoid sheath
- skin melanocytes
- connective tissue of cardiac outflow
- thyroid parafollicular cells
- craniofacial skeleton
- teeth odontoblasts

Links: Lecture - Neural Crest Development | Neural Crest Development

Early Brain Structure

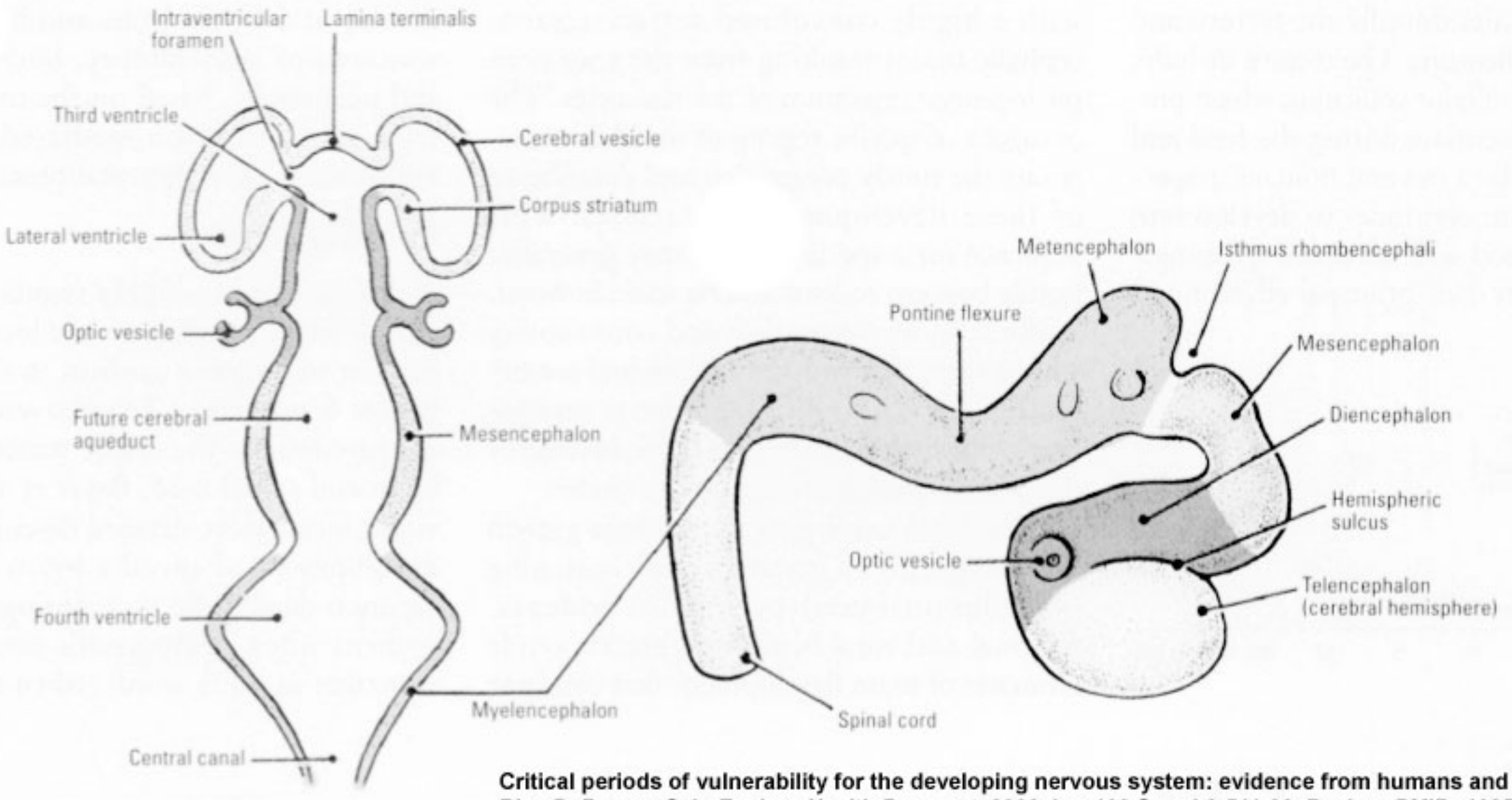
Primary Vesicles



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)

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** (behindbrain), **myelencephalon** (medullabrain)

Ventricles

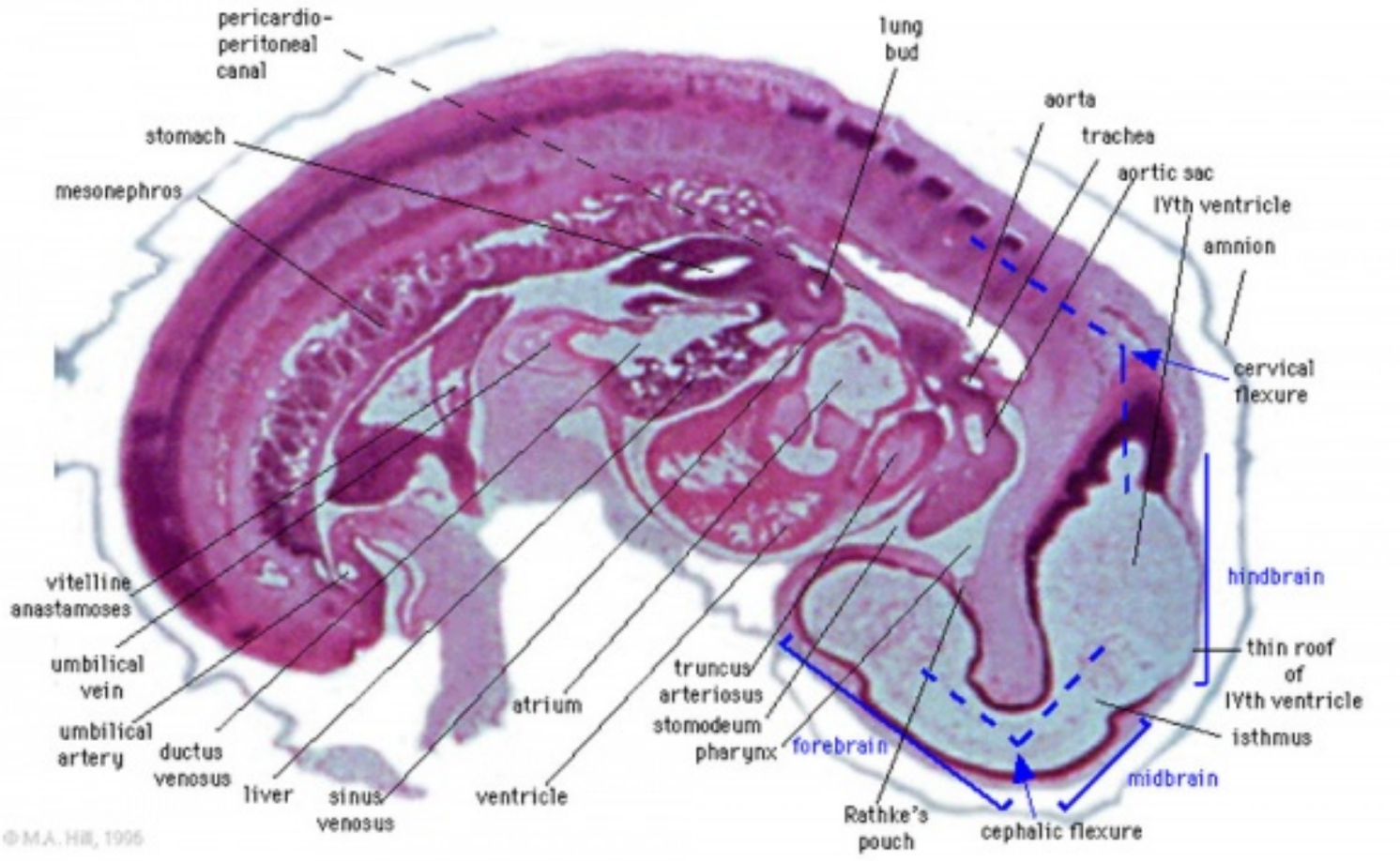
MH - this will be covered in detail in later neural development

- cavity within tube will form the contiguious space of the ventricules of the brain and central canal of spinal cord
- space is filled initially with amniotic fluid, later with CerebroSpinal Fluid (CSF)
- CSF is secreted by a modified vascular structure, the **chorioid plexus**, lying within the ventricles (More? Ventricular System)

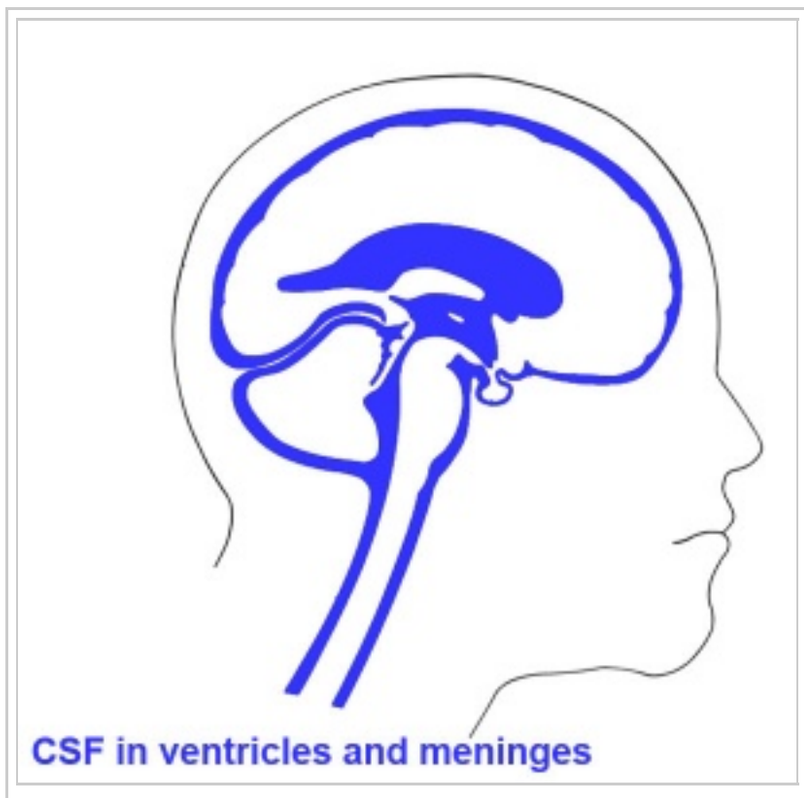
Brain Flexures

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



Carnegie stage 13 Embryo showing neural tube and brain flexures.



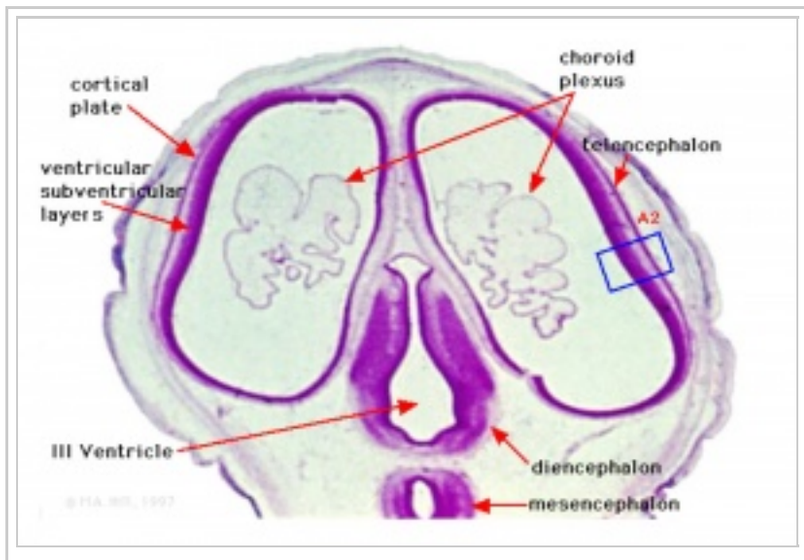
CNS ventricles

Neural Layers

- neural stem cells lie in the layer closest to the ventricular space, the **ventricular layer**
  - this layer generates both neuroblasts and glioblasts

Neuroblasts - neurons arise first as neuroblasts and migrate along radial gial, their migration stops at cortical plate. **Glioblasts** - glia arise later as glioblasts

Both neurons and glia undergo a complex process of growth, differentiation and interaction over a long developmental time period.



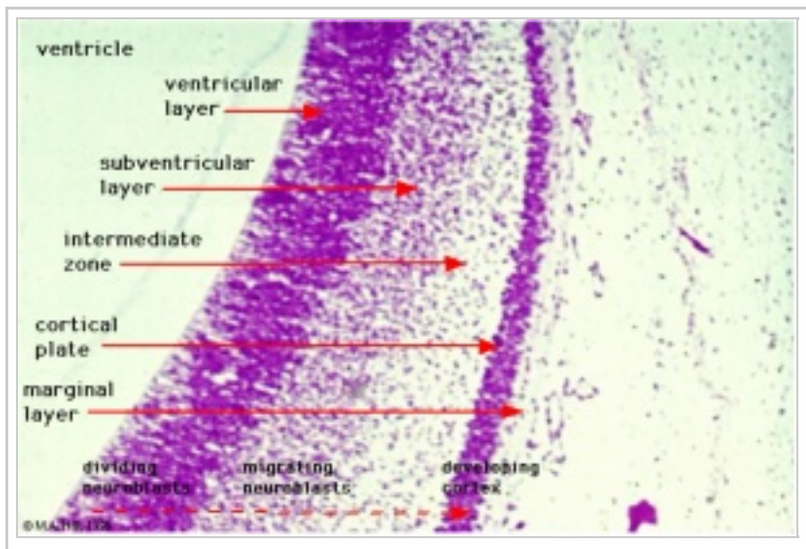
Stage 22 developing head cross section

Spinal Cord Axes

Identified by experimental manipulation of interactions.

- Initial experiments looked at how isolated tissues may influence the development of the spinal cord.
- Repositionining of specific tissues both in vivo and in vitro
- specific markers of or alteration of differentiation.
- today molecular signals - Sonic Hedgehog (ventral), Dorsalin (dorsal), Hox (rostrocaudal)

Additional Information - Spinal Cord Axes[Expand]



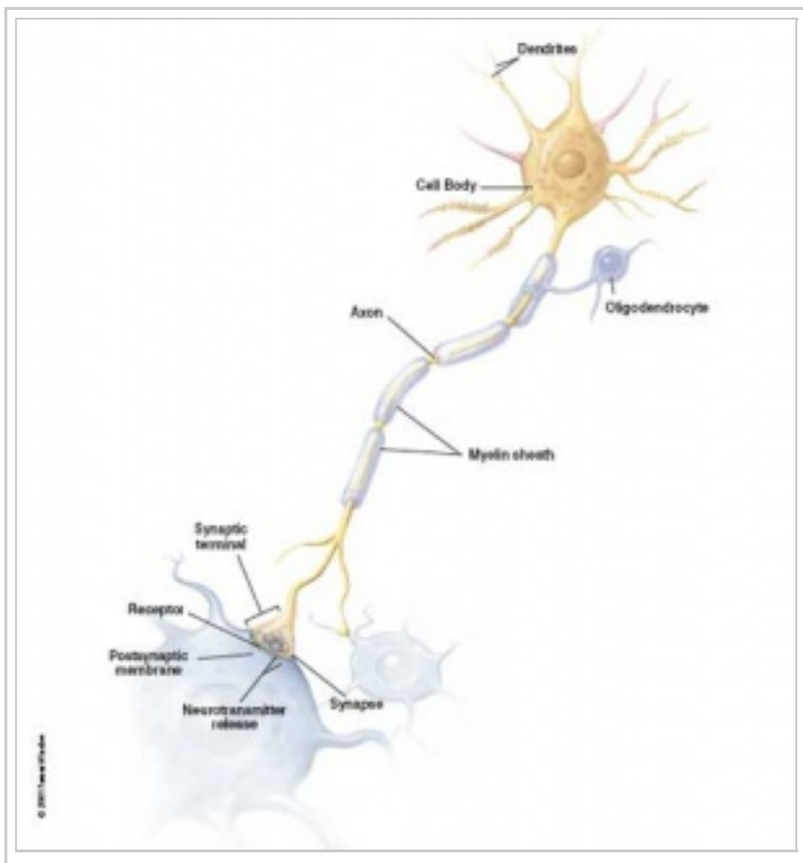
Stage 22 developing cortex

Ectodermal Placodes

- Specialized ectodermal "patches" in the head region
- Contribute sensory structures - otic placode (otocyst), nasal placode, lens placode
- Contribute teeth
- Covered in Head and Sensory Development Lectures

Human Neuralation - Early Stages

		
Carnegie stage 8 (about 18 postovulatory days) neural groove and folds are first seen.	Carnegie stage 9 the three main divisions of the brain, which are not cerebral vesicles, can be distinguished while the neural groove is still completely open.	Carnegie stage 10 (two days later) neural folds begin to fuse near the junction between brain and spinal cord, when neural crest cells are arising mainly from the neural ectoderm.
		
Carnegie stage 11 (about 24 days) the rostral (or cephalic) neuropore closes within a few hours; closure is bidirectional, it takes place from the dorsal and terminal lips and may occur in several areas simultaneously. The two lips, however, behave differently.	Carnegie stage 12 (about 26 days) The caudal neuropore takes a day to close. Level of final closure is approximately at future somitic pair 31, corresponds to the level of sacral vertebra 2.	Carnegie stage 13 (4 weeks) the neural tube is normally completely closed.



Neuron and supporting glial cells

File:Stage12_SEM3.jpg|Stage 12 (caudal neuropore)

Secondary neurulation begins at stage 12 - is the differentiation of the caudal part of the neural tube from the caudal eminence (or end-bud) without the intermediate phase of a neural plate. Above text modified from[1]

Carnegie Stages: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | About Stages | Timeline

Abnormalities

Links: Neural System - Abnormalities | Folic Acid and Neural Tube Defects | Iodine Deficiency

Neural Tube Defects (NTD)

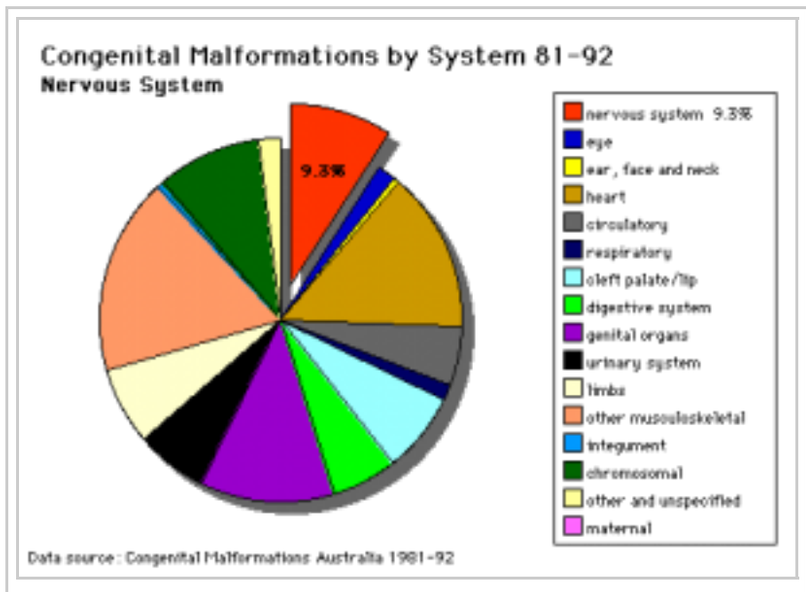
Failure of neural tube closure either incorrectly or incomplete

- **Dysraphism** is the term often used to describe the defective fusion of the neural folds. The position and degree of failure of fusion will result in either embryonic death or a range of different neural defects. The way (mode) in which the human neural tube fuses has been a source of contention. In humans, fusion appears to initiate at multiple sites but the mode is different from that found in many animal species used in developmental studies.
- severity dependent upon level within the tube and degree of failure
- caudal failure - spina bifida cranial failure - anancephaly

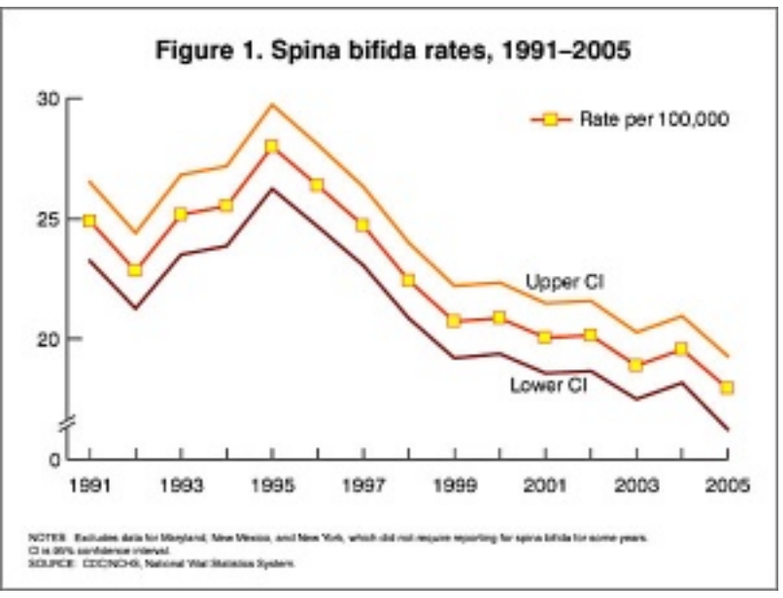
Maternal Diet

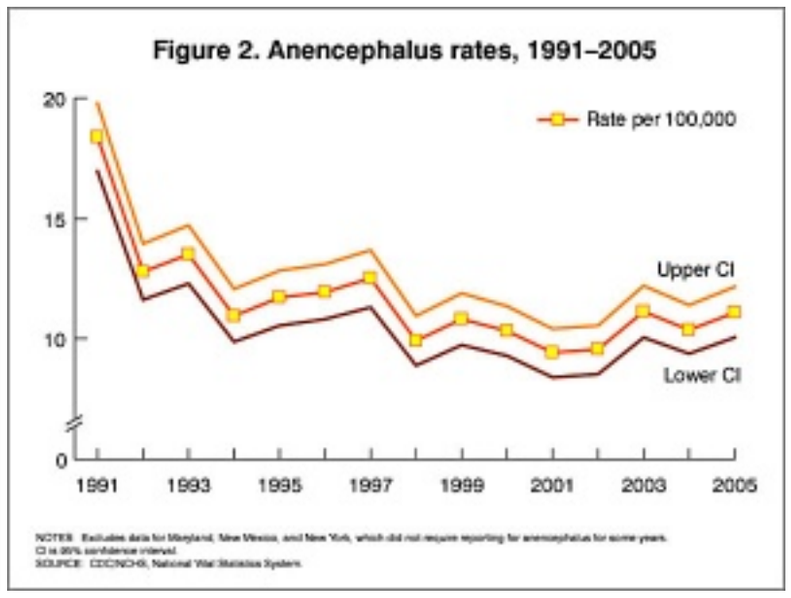
Found that supplementation of maternal diet with folate reduces incidence of NTDs.

- A randomised controlled trial conducted by the Medical Research Council of the United Kingdom demonstrated a 72% reduction in risk of recurrence by periconceptional (ie before and after conception) folic acid supplementation (4mg daily).
- Women who have one infant with a neural tube defect have a significantly increased risk of recurrence (40-50 per thousand compared with 2 per thousand for all births)

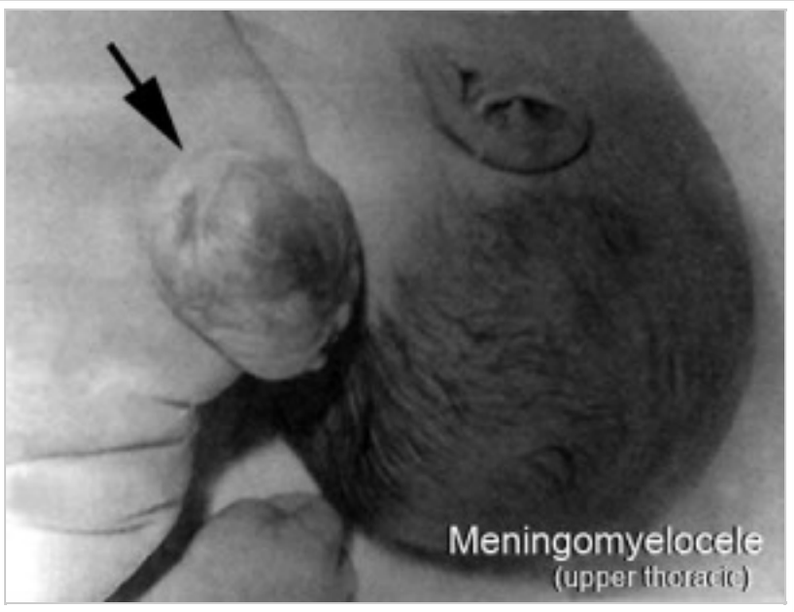


Australian Birth Statistics





In the U.S.A. the Food and Drug Administration in 1996 authorized that all enriched cereal grain products be fortified with folic acid, with optional fortification beginning in March 1996 and mandatory fortification in January 1998. The data in the above graphs show the subsequent changes in anencephaly and spina bifida rate over that period.



Neural tube defect - Meningomyelocele

Holoprosencephaly

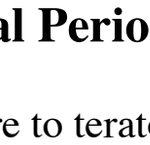
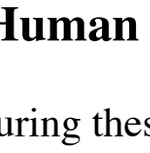
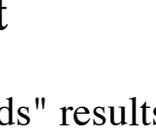
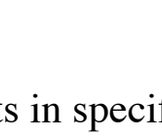
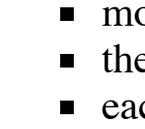
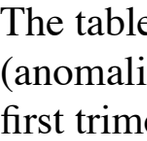
Holoprosencephaly (HPE) is developmental abnormality where the forebrain does not divide into the two separate hemispheres and ventricles.

Critical Periods of Human Development

Exposure to teratogens during these "critical periods" results in specific abnormalities.

- most systems are susceptible during embryonic development (first trimester)
- the earlier the exposure the more severe the effects
- each system has a different critical period
- longest critical periods
  - longest developing systems (neural, genital)
  - complicated developmental origins (sensory systems)

The table below identifies approximate windows of time, "critical periods", that following exposure to teratogens can lead to developmental abnormalities (anomalies, congenital). In general, the effects for each system are more severe (major anomalies) in the embryonic period during organogenesis in the first trimester. Later teratogen exposure are less severe (minor anomalies) in the fetal period during continued growth and differentiation in the second and third trimester.

Conceptus		**Embryonic development** (weeks)						**Fetal period** (weeks)			
1	2	3	4	5	6	7	8	9	16	20-36	38
											
Neural											
		**Heart**									
			Upper limbs								
				Lower limbs							
					Ear						
						Eye					
							**Palate**				
							Teeth				
								**External genitalia**			

Loss	Major abnormalities	Functional and Minor abnormalities

1. ↑ R O'Rahilly, F Müller **Neurulation in the normal human embryo.** Ciba Found. Symp.: 1994, 181;70-82; discussion 82-9 [PubMed:8005032]

Neural Development Terms

Only brief descriptions are given below, more complete definitions can be found in the glossary.

- **3DMRI** Three-dimensional magnetic resonance imaging. A new technique that allows 3D analysis of embryonic structures. (More? Magnetic Resonance Imaging)
- **3rd ventricle** a fluid-filled space formed from neural tube lumen, located within the diencephalon (from the primary vesicle prosencephalon, forebrain).
- **4th ventricle** a fluid-filled space formed from neural tube lumen, located within the rhombencephalon (from the primary vesicle, hindbrain).
- **adenohypophysis** (anterior pituitary) = 3 parts pars distalis, pars intermedia, pars tuberalis.
- **alar plate** afferent, dorsal horns
- **anlage** (German = primordium, structure or cells which will form a future structure.
- **arachnoid** - (G.) spider web-like
- **basal ganglia** - (basal nuclei) neural structure derived from the secondary vesicle telencephalon (endbrain) structure from the earlier primary vesicle prosencephalon (forebrain)
- **basal plate** efferent, ventral horns
- **brachial plexus** mixed spinal nerves innervating the upper limb form a complex meshwork (crossing).
- **brain** general term for the central nervous system formed from 3 primary vesicles.
- **buccopharyngeal membrane** (=oral membrane) at cranial (mouth) end of gastrointestinal tract (GIT) where surface ectoderm and GIT endoderm meet. (see also [#cloacal membrane cloacal membrane])
- **cauda equina** - (=horse's tail) caudal extension of the mature spinal cord.
- **central canal** lumen, cavity of neural tube within the spinal cord. Space is continuous with ventricular system of the brain.
- **cerebral aqueduct** ventricular cavity within the mesencephalon.
- **cervical flexure** most caudal brain flexure (of 3) between spinal cord and rhompencephalon. (sc-^V^)
- **choroid plexus** specialized vascular plexus responsible for secreting ventricular fluid that with further additions becomes cerebrospinal fluid (CSF).
- **cloacal membrane** at caudal (anal) end of gastrointestinal tract (GIT) where surface ectoderm and GIT endoderm meet forms the openings for GIT, urinary, reproductive tracts. (see also buccopharyngeal membrane)
- **cortex** - CNS structure derived from the secondary vesicle telencephalon (endbrain) from the earlier primary vesicle prosencephalon (forebrain).
- **cortical plate** outer neural tube region which post-mitotic neuroblasts migrate too along radial glia to form adult cortical layers.
- **cranial flexure** (=midbrain flexure) most cranial brain flexure (of 3) between mesencephalon and prosencephalon. (sc-^V^)
- **diencephalon** the caudal portion of forebrain after it divides into 2 parts in the 5 secondary vesicle brain (week 5). (cavity- 3rd ventricle) Forms the thalmus and other nuclei in the adult brain. (sc-My-Met-Mes-**Di**-Tel)
- **dorsal root ganglia** (=spinal ganglia) sensory ganglia derived from the neural crest lying laterally paired and dorsally to the spinal cord (in the embryo found ventral to the spinal cord). Connects centrally with the dorsal horn of the spinal cord.
- **dura mater**- "tough" (Latin, *mater* = mother)
- **ectoderm** the germ layer which form the nervous system from the neural tube and neural crest.
- **ependyma** epithelia of remnant cells after neurons and glia have been generated and left the ventricular zone
- **floorplate** early forming thin region of neural tube closest to the notochord.
- **ganglia** (pl. of ganglion) specialized neural cluster.
- **glia** supporting, non-neuronal cells of the nervous system. Generated from neuroepithelial stem cells in ventricular zone of neural tube. Form astrocytes, oligodendrocytes.
- **grey matter** neural regions containing cell bodies (somas) of neurons. In the brain it is the outer layer, in the spinal cord it is inner layer. (see white matter white matter)
- **growth factor** usually a protein or peptide that will bind a cell membrane receptor and then activates an intracellular signaling pathway. The function of the pathway will be to alter the cell directly or indirectly by changing gene expression. (eg shh)
- **hox** (=**h**omeob**ox**) family of transcription factors that bind DNA and activate gene expression. Expression of different Hox genes along neural tube defines rostral-caudal axis and segmental levels.
- **hydrocephalus** abnormality as the result of an imbalance between the rate at which the CSF is being formed and the rate at which the CSF is passing through the arachnoidal villi back into the blood (hydrocephalus rate is a function of the degree of imbalance in these two). Very small imbalance exhibit subtle, if any, symptoms. Large imbalances will have rapidly evolving symptoms of unmistakable import.
- **isthmus**- (G. narrow passage)
- **lamina terminalis** anterior region of brain where cranial neuropore closes.
- **lumbar plexus** mixed spinal nerves innervating the lower limb form a complex meshwork (crossing).
- **mantle layer** layer of cells generated by first neuroblasts migrating from the ventricular zone of the neural tube. Layers are rearranged during development of the brain and spinal cord. (Ven-**Man**-Mar-CP)
- **marginal zone** layer of processes from neuroblasts in mantle layer. (Ven-Man-**Mar**-CP)
- **mater** (Latin, *mater* = mother)
- **meninges** mesenchyme surrounding neural tube forms 3 layer (Dura-, pia-, arachnoid- mater) connective tissue sheath of nervous system. (D-P-A-cns)
- **mesencephalon** (=midbrain), the middle portion of the 3 primary vesicle brain (week 4). (sc-R-**M**-P)
- **metencephalon** the cranial portion of hindbrain after it divides into 2 parts in the 5 secondary vesicle brain (week 5). Forms the pons and cerebellum in the adult brain. (sc-My-**Met**-Mes-Di-Tel)
- **myelencephalon** the caudal portion of hindbrain after it divides into 2 parts in the 5 secondary vesicle brain (week 5). Forms the medulla in the adult brain. (sc-**My**-Met-Mes-Di-Tel)
- **neural tube** neural plate region of ectoderm pinched off to form hollow ectodermal tube above notochord in mesoderm.
- **neural tube defect** (NTD) any developmental abnormality that affects neural tube development. Commonly failure of neural tube closure.
- **neuroblast** undifferentiated neuron found in ventricular layer of neural tube.
- **neurohypophysis** (=posterior pituitary=pas nervosa)
- **neuron** The cellur "unit" of the nervous system, transmitting signals between neurons and other cells. The post-mitotic cells generated from neuroepithelial stem cells (neuroblasts) in ventricular zone of neural tube.

- **neuropore** opening at either end of neural tube: cranial=rostral=anterior, caudal=posterior. The cranial neuropore closes (day 25) approx. 2 days (human) before caudal.
- **notochord** rod of cells lying in mesoderm layer ventral to the neural tube, induces neural tube and secretes sonic hedgehog which "ventralizes" the neural tube.
- **olfactory bulb** (=cranial nerve I, CN I) bipolar neurons from nasal epithelium project axons through cribiform palate into olfactory bulb of the brain.
- optic cup-
- **optic nerve** (=cranial nerve II, CN II) retinal ganglion neurons project from the retina as a tract into the brain (at the level of the diencephalon).
- **otocyst** (=otic vesicle) sensory [#placode placode] which sinks into mesoderm to form spherical vesicle (stage 13/14 embryo) that will form components of the inner ear.
- **pars** (L. part of)
- **pharyngeal arches** (=branchial arches, Gk. gill) form structures of the head. Six arches form but only 4 form any structures. Each arch has a pouch, membrane and cleft.
- **pharynx** uppermost end of GIT, beginning at the buccopharyngeal membrane and at the level of the pharyngeal arches.
- pia mater-
- **placode** specialized regions of ectoderm which form components of the sensory apparatus.
- **pontine flexure** middle brain flexure (of 3) between cervical and cranial flexure in opposite direction, also generates thin roof of rhombencephalon and divides it into myelencephalon and metencephalon. (sc-^**V**^)
- **prosencephalon** (=forebrain), the most cranial portion of the 3 primary vesicle brain (week 4). (sc-R-M-**P**)
- **Rathke's pouch** a portion of the roof of the pharynx pushes upward towards the floor of the brain forming the anterior pituirary (adenohypophysis, pars distalis, pars tuberalis pars intermedia). Where it meets a portion of the brain pushing downward forming the posterior pituitary (neurohypophysis, pars nervosa). Rathke's pouch eventually looses its connection with the pharynx. (Martin Heinrich Rathke 1973-1860, embryologist and anatomist)
- **rhombencephalon** (=hindbrain), the most caudal portion of the 3 primary vesicle brain (week 4). (sc-**R**-M-P)
- **roofplate** early forming thin region of neural tube closest to the overlying ectoderm.
- **spinal cord** caudal end of neural tube that does not contribute to brain. Note: the process of secondary neuralation contributes the caudal end of the spinal cord.
- **spinal ganglia** (=dorsal root ganglia, drg) sensory ganglia derived from the neural crest lying laterally paired and dorsally to the spinal cord (in the embryo found ventral to the spinal cord). Connects centrally with the dorsal horn of the spinal cord.
- **spinal nerve** mixed nerve (motor and sensory) arising as latera pairs at each vertebral segmental level.
- **sonic hedgehog** (=shh) secreted growth factor that binds patched (ptc) receptor on cell membrane. SHH function is different for different tissues in the embryo. In the nervous system, it is secreted by the notochord, ventralizes the neural tube, inducing the floor plate and motor neurons.
- **sulcus** (L. furrow) groove
- **sulcus limitans** longitudinal lateral groove in neural tube approx. midway between roofplate and floorplate. Groove divides alar (dorsal) and basal (ventral) plate regions.
- **sympathetic ganglia**-
- **telencephalon** the cranial portion of forebrain after it divides into 2 parts in the 5 secondary vesicle brain (week 5). (cavity- lateral ventricles and some of 3rd ventricle) Forms the cerebral hemispheres in the adult brain. (sc-My-Met-Mes-Di-**Tel**)
- **thalamus** (G. *thalamos*= bedchamber) cns nucleus, lateral to 3rd ventricle, paired (pl thalami).
- **transcription factor** a factor (protein or protein with steroid) that binds to DNA to alter gene expression, usually to activate. (eg steroid hormone+receptor, Retinoic acid+Receptor, Hox, Pax, Lim, Nkx-2.2)
- **trigeminal ganglion** (=cranial nerve V, CN V) first arch ganglion, very large and has 3 portions.
- **vagal ganglion-** (=cranial nerve X, CN X) fourth and sixth arch ganglion, innervates the viscera and heart.
- **ventricles** the fluid-filled interconnected cavity system with the brain. Fluid (cerebrospinal fluid, CSF) is generated by the specialized vascular network, the choroid plexus. The ventricles are directly connected to the spinal canal (within the spinal cord).
- **ventricular zone** Neuroepithelial cell layer of neural tube closest to lumen. Neuroepithelial cells generate neurons, glia and ephendymal cells. (**Ven**-Man-Mar-CP)
- **vestibulocochlear nerve** (=cranial nerve VIII, CN VIII, also called statoacoustic)
- **white matter** - neural regions containing processes (axons) of neurons. In the brain it is the inner layer, in the spinal cord it is outer layer. (see grey matter)

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