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]
Early Brain Structure

Primary Vesicles

- 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

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)

Carnegie stage 13 Embryo showing neural tube and brain flexures.

<table>
<thead>
<tr>
<th>Neural Tube</th>
<th>Primary Vesicles</th>
<th>Secondary Vesicles</th>
<th>Adult Structures</th>
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<tr>
<td>Prosencephalon</td>
<td>Telencephalon</td>
<td>Rhinencephalon, Amygdala, Hippocampus, Cerebrum (Cortex), Basal Ganglia, lateral ventricles</td>
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<tr>
<td>Diencephalon</td>
<td></td>
<td>Epithalamus, Thalamus, Hypothalamus, Subthalamus, Pituitary, Pineal,</td>
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</table>
Brain

<table>
<thead>
<tr>
<th>Brain</th>
<th>Brain</th>
<th>Tectum, Cerebral peduncle, Pretectum, cerebral aqueduct</th>
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<tr>
<td>Mesencephalon</td>
<td>Mesencephalon</td>
<td>Pons, Cerebellum</td>
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<tr>
<td>Rhombencephalon</td>
<td>Metencephalon</td>
<td>Medulla Oblongata</td>
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</tbody>
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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 levee lot 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
Hox-proteins crania-caudal expression (species comparison)

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

- 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)
**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).
- Choroid plexus is a modified vascular structure which will produce cerebrospinal fluid (CSF).

(FYI - you do not need to know detailed stage development)

**Human Ventricular Development Timeline**

### Cranial Nerves

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

### Fetal Neural
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, insulary 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)

### Brain Fissure Development

- 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.

Neural development will continue after birth with substantial glial development, growth, death and reorganization occurring during the
Folate one-carbon metabolism

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


Folate and Neural Development

Research over the last 20 years had suggested a relationship between maternal diet and the birth of an affected infant. Recent evidence has confirmed that folic acid, a water soluble vitamin (vitamin B<sub>9</sub>) found in many fruits (particularly oranges, berries and bananas), leafy green vegetables, cereals and legumes, may prevent the majority of neural tube defects.

Required for DNA metabolism in rapidly dividing cells.

USA 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 below shows the subsequent changes in anencephaly and spina bifida rate over that period.
Figure 1. Spina bifida rates, 1991–2005

Figure 2. Anencephalus rates, 1991–2005

Links: Folic Acid and Neural Tube Defects

Thyroid System and Neural Development
Timeline of human thyroid system and brain development from conception to birth.\cite{4} (Estimation of neurogenesis adapted from Bayer et al.\cite{5})

**Links:** Endocrine - Thyroid Development

Environmental Effects and Neural Development

The developmental environment can also impact upon neural growth; maternal drugs such as alcohol and heavy metals such as lead (mining, historically both petrol and paint).

**Postnatal**

Postnatal environment, diet and other sensory abnormalities (hearing) can also impact on achieving developmental milestones.

- **Neural System - Postnatal**

References

2. ↑ A Afif, R Bouvier, A Buener, J Trouillas, P Mertens Development of the human fetal insular cortex: study of the gyration from 13 to 28
Historic Embryology

Historic Disclaimer - information about historic embryology pages [Expand]


Images

Text-Book of Embryology - 1921[Expand]


Anatomy of the Human Bod - 1918[Expand]

2015 Course: Week 2 Lecture 1 Lecture 2 Lab 1 | Week 3 Lecture 3 Lecture 4 Lab 2 | Week 4 Lecture 5 Lecture 6 Lab 3 | Week 5 Lecture 7 Lecture 8 Lab 4 | Week 6 Lecture 9 Lecture 10 Lab 5 | Week 7 Lecture 11 Lecture 12 Lab 6 | Week 8 Lecture 13 Lecture 14 Lab 7 | Week 9 Lecture 15 Lecture 16 Lab 8 | Week 10 Lecture 17 Lecture 18 Lab 9 | Week 11 Lecture 19 Lecture 20 Lab 10 | Week 12 Lecture 21 Lecture 22 Lab 11 | Week 13 Lecture 23 Lecture 24 Lab 12 | Projects: Group 1 | Group 2 | Group 3 | Group 4 | Group 5 | Group 6 | Students | Student Designed Quiz Questions | Moodle page (http://moodle.telt.unsw.edu.au/course/view.php?id=15814)

Glossary Links

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