Embryology of the Nervous System

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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.
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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.
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.
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Flexures allow us to stand upright.
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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.
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 cells migrate throughout the body and develop into most of the cells of the peripheral nervous system, as well as other cell types.
• 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

<table>
<thead>
<tr>
<th>Neuron Group</th>
<th>Origin</th>
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</thead>
<tbody>
<tr>
<td>olfactory receptors</td>
<td>nasal placode</td>
</tr>
<tr>
<td>ciliary ganglion</td>
<td>neural crest</td>
</tr>
<tr>
<td>trigeminal ganglion</td>
<td>neural crest &amp; trigeminal placode</td>
</tr>
<tr>
<td>geniculate ganglion</td>
<td>neural crest &amp; 1&lt;sup&gt;st&lt;/sup&gt; epibranchial placode</td>
</tr>
<tr>
<td>sphenopalatine ganglion</td>
<td>neural crest</td>
</tr>
<tr>
<td>submandibular ganglion</td>
<td>neural crest</td>
</tr>
<tr>
<td>cochlear ganglion</td>
<td>otic placode</td>
</tr>
<tr>
<td>vestibular ganglion</td>
<td>otic placode &amp; neural crest (minor)</td>
</tr>
<tr>
<td>superior glossopharyngeal g.</td>
<td>neural crest</td>
</tr>
<tr>
<td>inferior glossopharyngeal g.</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; epibranchial placode</td>
</tr>
<tr>
<td>otic ganglion</td>
<td>neural crest</td>
</tr>
<tr>
<td>superior vagal ganglion</td>
<td>neural crest</td>
</tr>
<tr>
<td>inferior (nodose) vagal g.</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; &amp; 2&lt;sup&gt;nd&lt;/sup&gt; epibranchial placodes</td>
</tr>
<tr>
<td>dorsal root ganglia</td>
<td>neural crest</td>
</tr>
<tr>
<td>sympathetic ganglia</td>
<td>neural crest</td>
</tr>
<tr>
<td>sacral parasympathetic g.</td>
<td>neural crest</td>
</tr>
</tbody>
</table>
Review of the Cell Cycle
(steps involved in cell division)

- **G₁** 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

- **G₂** 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

- **G₀** permanent arrest in G₁; 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 plate (sensory functions)
- Sulcus limitans
- Basal plate (motor functions)
Alar and basal plates represent functional domains.

dorsal horn (sensory)

ventral horn (motor)
Sensory Input from the Body into the Spinal Cord

sensory

sensory neuron in dorsal root ganglion

dorsal root

dorsal horn

sensory receptor

spinal nerve
Motor Output from the Spinal Cord to the Body

- spinal nerve
- neuromuscular synapse
- ventral root
- motor neuron in ventral horn
- muscle
- motor
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.

- Alar plate (sensory): vestibular nucs (SVA)
- Basal plate (motor): spinal trigeminal nuc (GSA), nuc solitarius (GVA for IX, X & XI), sulcus limitans, dorsal motor nuc of vagus (GVE), nuc ambiguus (SVE for IX, X & XI), hypogloassal nuc (GSE)
Along the length of the adult brainstem, nuclei are discontinuous columns of functionally related cells.
Metencephalon (Pons and Cerebellum)

Some cells migrate from the alar and basal plates and undergo further cell division.
Adult Pons and Cerebellum
Diencephalon

- roof plate - choroid plexus
- epithalamus
- prethalamus
- thalamus
- pretectum
- rostral to caudal
- 3rd ventricle
- hypothalamic sulcus (sulcus limitans)
- hypothalamus
- subthalamus
- optic chiasm
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

<table>
<thead>
<tr>
<th>Ectoderm</th>
<th>Mesoderm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PNS</strong></td>
<td><strong>CNS</strong></td>
</tr>
<tr>
<td>Neural Placodes</td>
<td>Neural Crest</td>
</tr>
<tr>
<td>some sensory neurons</td>
<td>most sensory neurons</td>
</tr>
<tr>
<td></td>
<td>autonomic neurons</td>
</tr>
<tr>
<td></td>
<td>schwann cells</td>
</tr>
<tr>
<td></td>
<td>satellite cells</td>
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