Early Development of the Ectoderm

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Resources:
http://php.med.unsw.edu.au/embryology/
Larsen’s Human Embryology
The Developing Human: Clinically Oriented Embryology
Lecture overview

Early Development of the Ectoderm

Gastrulation and Embryonic Folding

Neurulation

Early Development of the Nervous System

Neural Crest

Epidermis Development

Ectodermal placodes

Neural Tube Defects

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Week 3: gastrulation:

- Primitive streak and node
- Ingression of epiblast cells: EMT transition
- Generation of endoderm
- Generation of mesoderm
- Generation of ectoderm
- Oropharyngeal and cloacal membrane
Week 3: Gastrulation

Epiblast forms 3 germ layers:
- Ectoderm: epithelium (previous epiblast)
- Mesoderm: mesenchymal layer (embryonic connective tissue)
- Endoderm: epithelium

Hypoblast:
- replaced by definitive endoderm

3 body axes:
- Anteroposterior or cranial to caudal body axis
- Dorsoventral body axis
- Left-Right body axis
Embryonic development:

3 weeks

37 weeks
End product gastrulation:

Trilaminar embryo

**Ectoderm** *(Neural crest)*
- Brain, spinal cord, eyes, *peripheral nervous system*
- Epidermis of skin and associated structures, *melanocytes, cranial connective tissues (dermis)*

**Mesoderm**
- Musculo-skeletal system, limbs, connective tissue of skin and organs, urogenital system, heart, blood cells

**Endoderm**
- Epithelial linings of gastrointestinal, liver, pancreas, thyroid and respiratory tracts
Embryo folding

Generation of primitive gut
Neural plate and neural tube

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http://php.med.unsw.edu.au/embryology/images/2/27/Week3_folding.mp4
Early ectoderm development:
Ectoderm

Midplate ectoderm: nervous system and neural crest
Lateral ectoderm: surface epidermis
Ectodermal placodes
Midplate Ectoderm

Neural induction by the primitive node
Neural plate = neuroepithelium
Neural plate gives rise to the CNS and the neural crest
Neural groove
Neurulation

Midplate ectoderm

4 main events:
- 1 neural plate formation
- 2 shaping of the neural plate
- 3 bending of the neural plate
- 4 closure of the neural groove

Source: Deborah S. Nichols-Larsen, Deborah A. Kegelmeyer, John A. Buford, Anne D. Kloos, Jill C. Heathcock, D. Michele Basso: *Neurologic Rehabilitation: Neuroscience and Neuroplasticity in Physical Therapy Practice*

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Neurulation
Midplate ectoderm

The neural tube zips up from center towards both ends
Cranial and caudal neuropores
Closure of caudal neuropore completes neurulation
Neurulation
Midplate ectoderm

1. Neuroectodermal tissues differentiate from the ectoderm and thicken into the neural plate. The neural plate border separates the ectoderm from the neural plate.

2. The neural plate bends dorsally, with the two ends eventually joining at the neural plate borders, which are now referred to as the neural crest.

3. The closure of the neural tube disconnects the neural crest from the epidermis. Neural crest cells differentiate to form most of the peripheral nervous system.

4. The notochord degenerates and only persists as the nucleus pulposus of the intervertebral discs. Other mesoderm cells differentiate into the somites, the precursors of the axial skeleton and skeletal muscle.
Ectoderm

Midplate ectoderm: nervous system and neural crest
Lateral ectoderm: surface epidermis
Ectodermal placodes
Neurulation
Neurulation
Secondary neurulation

Closure of caudal neuropore completes neurulation
Secondary neurulation occurs posteriorly of node
Condensation of tail bud cells into medullary cord
Cavitation
Lumen merges with neural canal
Neurulation
Early development of the CNS

3 primary brain vesicles
2 flexures

Cephalic flexure

Cervical flexure

Lateral view Three- to four-week embryo

(a)

Prosencephalon (Forebrain)
Mesencephalon (Midbrain)
Rhombencephalon (Hindbrain)
Early development of the CNS

5 secondary brain vesicles
3 flexures

Three primary brain vesicles
- Prosencephalon (Forebrain)
- Mesencephalon (Midbrain)
- Rhombencephalon (Hindbrain)

Three- to four-week embryo (a)

Five secondary brain vesicles
- Telencephalon
- Diencephalon
- Mesencephalon
- Metencephalon
- Myelencephalon

Five-week embryo (b)

Cephalic flexure
- Cerebrum
- Eye cup
- Thalamus, hypothalamus, and epithalamus

Pontine flexure
- Midbrain
- Pons
- Cerebellum
- Medulla oblongata

Cervical flexure
Early development of the CNS

5-week embryo
Early development of the CNS

3 Primary vesicles
- Wall
- Cavity
- Forebrain (Prosencephalon)
- Midbrain (Mesencephalon)
- Hindbrain (Rhombencephalon)

5 Secondary vesicles
- Telencephalon
- Diencephalon
- Mesencephalon
- Metencephalon
- Myelencephalon
- Spinal cord

Adult derivatives
- Olfactory lobes
- Smell
- Hippocampus
- Memory storage
- Cerebrum
- Association (“intelligence”)
- Optic vesicle
- Vision (retina)
- Epithalamus
- Pineal gland
- Thalamus
- Relay center for optic and auditory neurons
- Hypothalamus
- Temperature, sleep, and breathing regulation
- Midbrain
- Fiber tracts between anterior and posterior brain, optic lobes, and tectum
- Cerebellum
- Coordination of complex muscular movements
- Pons
- Fiber tracts between cerebrum and cerebellum (mammals only)
- Medulla
- Reflex center of involuntary activities
Early development of the CNS

Neural tube

Primary brain vesicles

Secondary brain vesicles

Postnatal CNS

Forebrain

Midbrain

Hindbrain

Telencephalon

Diencephalon

Mesencephalon (midbrain)

Metencephalon (pons & cerebellum)

Myelencephalon (medulla)

Spinal cord
Brain Ventricles

Amniotic fluid -> Cerebrospinal Fluid
Continuous with central canal of neural tube
CSF is produced by choroid plexus
Hydrocephalus
Spinal Cord Axes
Dorsoventral axis

Dorsal horns: interneurons receiving sensory input
Ventral horns: motor neurons

Sensory neurons enter the spinal cord. Motor neurons leave the spinal cord. Interneurons connect the sensory and motor neurons.
Spinal Cord Axes
Dorsoventral axis
Spinal Cord Axes
Anteroposterior axis

Adapted from Lewis Wolpert et al., 1998
Spinal Cord Axes
Anteroposterior axis
Hostikka et al., 2009
Cytodifferentiation of the Neural Tube

Mesencephalon  Rhombencephalon

Prosencephalon
Mesencephalic flexure

Time

Neuroepithelial cells
Young neuron
Glioblast
Marginal layer
Mantle layer
Ventricular layer
Ependymal cell
Mitosis
Radial glia

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Neural Crest Development
Neural Crest Development

**Mesenchymal cells**
- Chondroblasts/chondrocytes
- Osteoblasts/osteocytes
- Fibroblasts
- Odontoblasts
- Cardiac mesenchyme
- Myoblasts
- Adipocytes

**Neuronal cells**
- Sensory neurons
- Cholinergic neurons
- Adrenergic neurons
- Satellite cells
- Schwann cells
- Glial cells

**Secretory cells**
- Chromaffin cells
- Parafollicular cells
- Calcitonin-producing cells

**Pigmented cells**
- Melanocytes
Neural Crest Development
4 functional domains and lineages

Cranial neural crest:
Cranial mesenchyme, facial skeleton, cranial nerve ganglia

Cardiac neural crest:
Melanocytes, cartilage, connective tissue and neurons of some pharyngeal arches, Contributes to formation of regions of the heart

Trunk neural crest:
Melanocytes, dorsal root ganglia, sympathetic ganglia, adrenal medulla, nerves surrounding aorta

Vagal and Sacral neural crest:
Melanocytes, ganglia of the enteric nervous system Parasympathetic ganglia
Neural Crest Development
Neural Crest Development

Watch how neural crest cells spread out to cover a wide region adjacent to the neural tube.
Epidermal development
Lateral surface ectoderm

Interfollicular epidermis (surface epithelium)

Epidermal Appendages:
- Hair follicles
- Glands (sebaceous, sweat, apocrine)
- Mammary glands
- Nails
- Teeth
Ectodermal placodes

Specialized ectodermal thickenings in cranial region
Contribute to sensory structures, teeth and pituitary

Otic placodes
Olfactory (Nasal) placodes
Optic (Lens) placodes
Adenohypophyseal placode
Profundal/trigeminal placodes
Ectodermal placodes

Otic placodes
Olfactory (Nasal) placodes
Optic (Lens) placodes
Adenohypophyseal placode
Profundal/trigeminal placodes
Neural Tube Defects

Dysraphism:
Spina bifida and anencephaly

Folate protects against NTDs
Neural Tube Defects
Holoprosencephaly
Neural Tube Defects
Holoprosencephaly
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