Neurulation and axis induction

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Figure 1.6

Gastrulation
germ layers form

Organogenesis
germ layers interact to form
the organ rudiments

Tissue differentiation
organ rudiments become
functional organs
Organogenesis

- basic body plan is formed during organogenesis
  - head with brain, eyes, ear rudiments
  - dorsally segmented trunk with tail & limbs
  - internal organs: rudiments of gut, heart, lung, kidney etc.

- basic body plan is typical for entire phylogenetic group
Organogenesis is controlled by inductive interaction

**Principles & definitions:**

**Induction** increases complexity of an organism

(mesoderm induction, induction during organogenesis)

**Induction** is the primary mechanism for the generation of different structures along body axes

inducing cells (signal producing) → responding cells (signal receiving)

**Competence:** responding cells react to inducing signals only for a short period of time
Neurulation as an example of organogenesis

- neural plate formation: area along dorsal midline with columnar cells (a)
- formation of a neural groove (b)
- neural folds (c)
- neural folds close the neural plate into the neural tube (d)
- neural tube forms brain & spinal cord
Medical implications of neurulation

spina bifida = ‘divided spine’

- spina bifida occulta: arches of one vertebra fail to fuse (b)
- spina bifida cystica: several ‘open’ vertebrae (c)
- spina bifida with open neural plate (d): severe form that may result in anencephaly and acrania
  - folic acid in maternal diet lowers frequency of spina bifida
Neurulation in amphibians

Two main phases:

1. Changes in cell shape
   - neural plate formation = ‘keyhole stage’ (a)
     anterior region forms brain
     posterior region forms spinal cord

2. Anteroposterior extension and further changes in cell shape
   - closure of neural folds into the neural tube (c)
Coordinated cell shape changes:
- columnar neural plate cells
- wedge-shaped cells form hinges in brain region:
  - median hinge point
  - dorsolateral hinge point
- in posterior region:
  - only median hinge

Mediolateral cell intercalation and mitosis with anteroposterior spindle orientation
- results in elongation of neural plate

Mitosis with mediolateral spindle orientation in adjacent epidermis
- lateral extension supports closure of neural tube

Formation of tube structure = **Primary neurulation**
Neurulation in humans

Coordinated changes in cell shape and cell intercalations:
- similar to neurulation in birds: median hinge point along neural groove

Neural tube closure:
- starts in neck region; proceeds anteriorly and posteriorly
- anterior and posterior neuropores - temporary connections with amniotic cavity

Figure 12.7
Neurulation in fishes

Coordinated changes in cell shape:
- columnar neural plate cells
- neural plate infolds at midline
  - cells merge at their apical faces
  - form neural keel (looks like boat)
- keels rounds up to neural rod
- cells in neural rod separate to form the lumen of the neural tube
  = secondary neurulation

NOTE - In amphibians, birds, mammals:
- primary neurulation in head and trunk
- secondary neurulation in tail region

Figure 12.8
Embryonic axis

**Neural tube:**
Formed in association with underlying notochord, lateral somites & other mesodermal structures.

- set of dorsal organ rudiments in vertebrates = **embryonic axis**

- coordinated development of these structures suggests inductive events

Figure 9.19
Dorsal blastopore lip - ‘organizer’ in amphibians

- transplantation of dorsal blastopore lip tissue organizes a secondary axis in amphibians
- blastopore lip from early gastrula donor induces anterior axis structures in host
- blastopore lip from late gastrula donor induces posterior axis structures
- induction of anterior or posterior structures organized by early or late involuting mesoderm
Hensen’s node - ‘organizer’ in birds & mammals

- transplanted Hensen’s node induces secondary axis
- graft forms notochord and neural tube tissue & induces neural tube in host
Mechanisms of neural induction

Neural induction:

- development of ectoderm into a neural tube under the influence of adjacent mesoderm

**planar** or **vertical** signals?

Figure 12.21
Mechanisms of neural induction

**Newt embryos:**
- high salt = exogastrulation (normally involuting tissue moves outward)
  - no neural tissue develops in exogastrulae
  - underlying mesoderm is necessary for neural induction in newt
  - planar and vertical signals are necessary for neural induction
    (planar signals alone are not sufficient)