Embryology

Third week of human development: Trilaminar germ disc

The most event occurring during the third week of gestation is gastrulation. In human, similar mechanisms regulate gastrulation to those found in other vertebrates.

By the process of gastrulation:

- Bilaminar germ disc converts into trilaminar germ disc, and embryo is referred as gastrula.
- The embryo differentiates into three germ layers: (ectoderm, mesoderm, and endoderm) and axial orientation is established in embryo.
- Gastrulation begins with formation of the primitive streak on the surface of the Epiblast
- Primitive streak visible as a narrow groove with slightly bulging regions on either side, primitive streak has at its cephalic end the primitive node.
- In the region of the node and streak, epiblast cells move inward (invaginate) to form new cell layers (endoderm and mesoderm). Cells that do not migrate through the streak but remain in the epiblast form ectoderm.
- Hence, epiblast gives rise to all three germ layers in the embryo (ectoderm, mesoderm, and endoderm), and these layers form all of the tissues and organs, fig. (1).

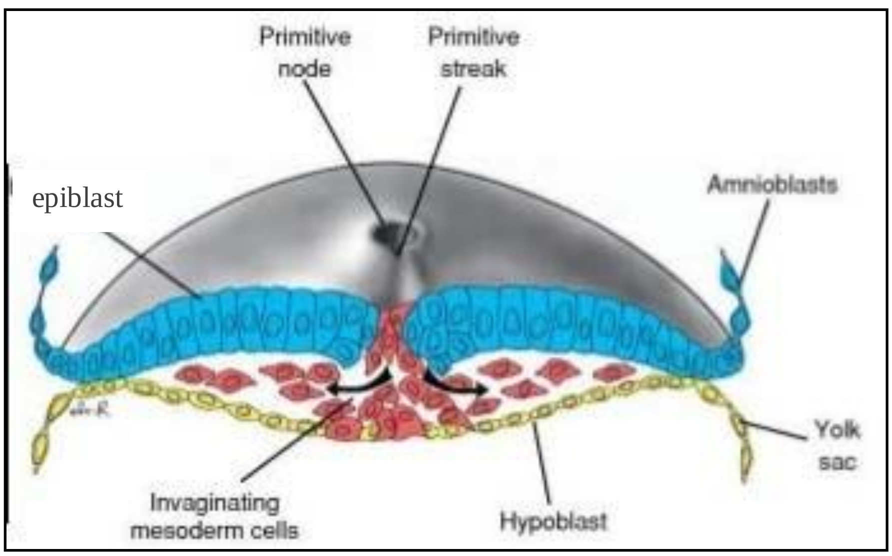

Figure-1: Cross section through the primitive streak showing invagination of epiblast cells

End product during gastrulation in vertebrate:

Ectoderm gives rise to: brain, spinal cord, eyes, peripheral nervous system, epidermis of skin and associated structures, melanocytes, and connective tissues (dermis).

Mesoderm gives rise to: notochord, muscles, skeletal system, connective tissue of skin, urogenital system, and circulatory system.

Endoderm gives rise to: epithelial linings of gastrointestinal and respiratory tracts.

Fate map established during gastrulation

Fate map of regions is established by cell migration and ingression from epiblast.

- The cells that enter in through the cranial region of the node will form the **notochord**.

- Cells migrating through the lateral edges of the node and from the cranial end of the streak will form **paraxial mesoderm**.

- Cells migrating through the midstreak region will form **intermediate mesoderm**.

- Cells migrating through the more caudal part of the streak will form **lateral plate mesoderm**.

- Cells migrating through the most caudal part will contribute to **extraembryonic mesoderm**.

Establishment of the body axis

Embryos must develop three very important axes that are the foundations of the body:

1- The anterior-posterior axis (or anteroposterior axis): is the line extending from head to tail (or mouth to anus in those organisms that lack heads and tails).

2- The dorsal-ventral axis (or dorsoventral axis): is the line extending from back to belly.

3- The right-left axis: is a line between the two lateral sides of the body.

Formation of the notochord

- The notochord found in embryos of all chordates, derived from the mesoderm.

- Formation of notochord starts by appearance of prechordal plate.

- Prechordal plate is derived from some of the first cells that migrate through the node in the midline and move in a cephalic direction.

- In the prechordal plate there is a contact between the ectoderm and endoderm without mesoderm between.

- Prenotochordal cells invaginating in the primitive node move forward cranially in the midline until they reach the prechordal plate. They intercalated in the endoderm as the notochordal plate.

- With further development, the plate detaches from the endoderm, and the notochord (solid cord) is formed.

- Notochord induces the overlying ectoderm to thicken and form the neural plate.

- Notochord underlies the neural tube and serves as the basis of the axial skeleton.

Derivatives of the ectodermal germ layer

The ectodermal germ layer gives rise to the organs and structures that maintain contact with the outside world:

1- Central nervous system

2- Peripheral nervous system

3- Sensory epithelium of ear, nose, and eye

4- Epidermis of skin, including hair and nails

5- Pituitary, mammary, and sweat glands and enamel of the teeth.

At the beginning of the embryonic development, the ectodermal germ layer has the shape of a disc that is broader in the cephalic than in the caudal region. Appearance of the notochord induces the overlying ectoderm to thicken and form the neural plate, which forms the neural tube in a process called **neurulation**.

Neurulation

Neurulation is a process of neural tube formation, which is the precursor of the brain and spinal cord. Neurulation begins with the formation of a **neural plate**, a thickening of the ectoderm caused when cuboidal epithelial cells become columnar; the lateral edges of the neural plate become elevated to form **neural folds**, and the mid region forms the **neural groove**. Gradually, the neural folds meet in the midline to form a **neural tube**. As the neural folds fuse, cells at the lateral border of the neuroectoderm begin to dissociate from their neighbors, this cells called **neural crest** and will migrate to enter the underlying mesoderm. Failure of neurulation results in neural tube defects, major anomalies associated with morbidity and mortality, fig. 2.

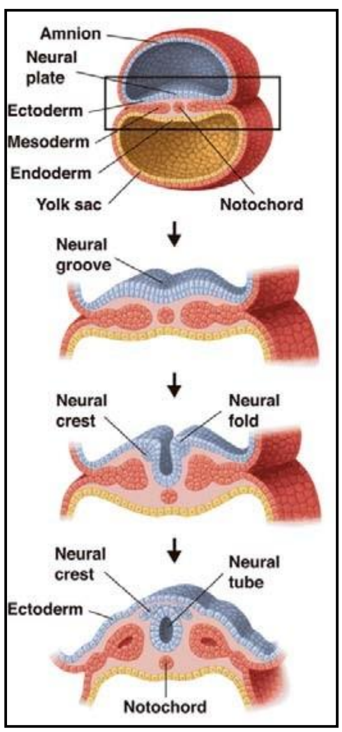

Figure-2: Neurulation process

In vertebrate embryos, neurulation occurs in two phases:

- Primary neurulation and -Secondary neurulation.

Primary neurulation, the formation of the neural plate and subsequent morphogenetic movements that transform it into a neural tube, forms the entire neural tube in amphibians and reptiles.

Secondary neurulation, the formation of an epithelial cord and neural tube, forms the entire neural tube in fishes.

Both primary and secondary neurulations occur in birds and mammals. The brain and trunk level of the spinal cord form by primary neurulation, whereas the tail spinal cord forms by secondary neurulation.

Neural crest derivatives in vertebrate

- Cranial nerve ganglia
- Septum in the heart
- Odontoblast
- Dermis in face and neck
- Spinal ganglia
- Sympathetic ganglia
- Parasympathetic ganglia of the gastrointestinal tract
- Connective tissue and bones of the face and skull
- Smooth muscles to blood vessels of the face and forebrain.
- Adrenal medulla
- Schwann cells
- Glial cells
- Meninges
- Melanocytes

Derivatives of the mesodermal germ layer

Important components of the mesodermal germ layer are:

1- Paraxial mesoderm **2-** Intermediate mesoderm **3-** Lateral plate mesoderm

Paraxial mesoderm begins to be organized into segments, known as somitomeres.

Somitomeres further organize into somites. Somites give rise to:

- **Sclerotome** which forms (tendon, cartilage, and bone)
- **Myotome** which providing the muscle component
- **Dermatome** which forms the dermis

Intermediate mesoderm

Intermediate mesoderm differentiates into:

- Reproductive system
- Collecting duct and tubules of the kidney
- Nephrons of the kidney

Lateral plate mesoderm

Lateral plate mesoderm splits into:

a- Somatic or (parietal) mesoderm layer **b-** Splanchnic or (visceral) mesoderm layer

Intraembryonic cavity found between these two layers, fig. (3).

The somatic mesoderm, which is

- Adjacent to the ectoderm
- Gives rise to: • Connective tissue and lining of the body wall
  • Bones, ligaments and dermis of the limbs

The splanchnic mesoderm, which is

- Adjacent to the endoderm
- Gives rise to: • Cardiac mesoderm
  • Blood vessels
  • Smooth muscle and connective tissues of the respiratory and digestive organs.

Intraembryonic cavity, gives rise to three cavities:

- Pericardial
- Pleural
- Peritoneal

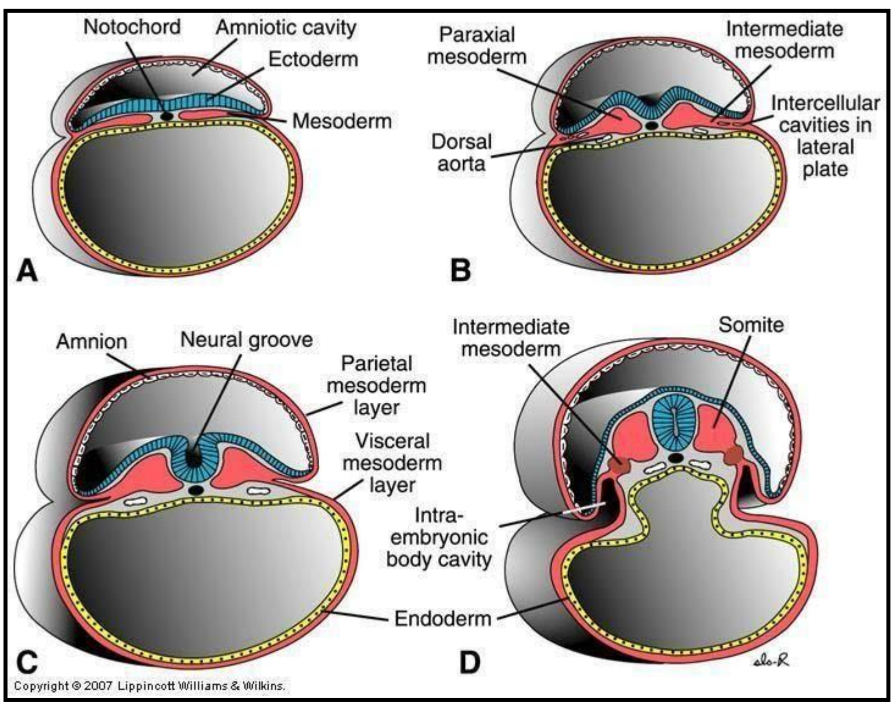

Figure-3: Illustrate important components of the mesodermal germ layer

Organogenesis

Organogenesis is the process by which the three germ tissue layers of the embryo, which are the ectoderm, endoderm, and mesoderm, develop into the internal organs of the organism. Organs form from the germ layers through the differentiation: the process by which a less-specialized cell becomes a more-specialized cell type. This must occur many times as a zygote becomes a fully-developed organism. During differentiation, the embryonic stem cells express specific genes which will determine their definitive cell type. For example, some cells in the ectoderm will express the genes specific to skin cells. As a result, these cells will differentiate into epidermal cells. Therefore, the process of differentiation is regulated by cellular signaling cascades.