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ZO 355: Developmental Biology

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Gastrulation: Morphogenetic movements

At the end of cleavage, the typical blastula is a ball of cells with a hollow cavity in the middle (the blastocoel). The next stage in embryonic development is gastrulation, in which the cells in the blastula rearrange themselves to form three layers of cells and form the body plan. The embryo during this stage is called a gastrula. Gastrulation results in three important outcomes:

a. The formation of the embryonic tissues, called germ layers. The germ layers include the endoderm, ectoderm, and mesoderm. Each germ layer will later differentiate into different tissues and organ systems.
b. The formation of the embryonic gut, the archenteron.
c. The *appearance* of the major body axes. Recall that in some species, the *information specifying* the body axes was already present during cleavage as a result of cytoplasmic determinants and/or yolk polarity, but the axes actually become *visible* as a result of gastrulation.

The specific details of gastrulation are different in different animal species, but the general process includes dramatic movement of cells across and inside the embryo. In triploblasts (animals with three embryonic germ layers), one group of cells moves into the blastocoel, the interior of the embryo, through an invagination called the blastopore. These interior cells from the endoderm. Another group of cells move to completely surround the embryo, forming the ectoderm, and a third group of cells move into the locations in between the outer and inner layers of cells, to form the mesoderm. The endodermal cells continue through the interior of the embryo until they reach the other side, creating a continuous tract through the embryo; this tract is the archenteron, or embryonic gut. In protostomes, the blastopore becomes the embryo's mouth; in deuterostomes, the blastopore becomes the embryo's anus.
Diploplasts (animals with only two germ layers) do not have mesodermal cells. These animals, which include jellyfish and comb jellies, have radial rather than bilateral symmetry and have far fewer tissue types than triploplasts due the lack of a mesoderm.

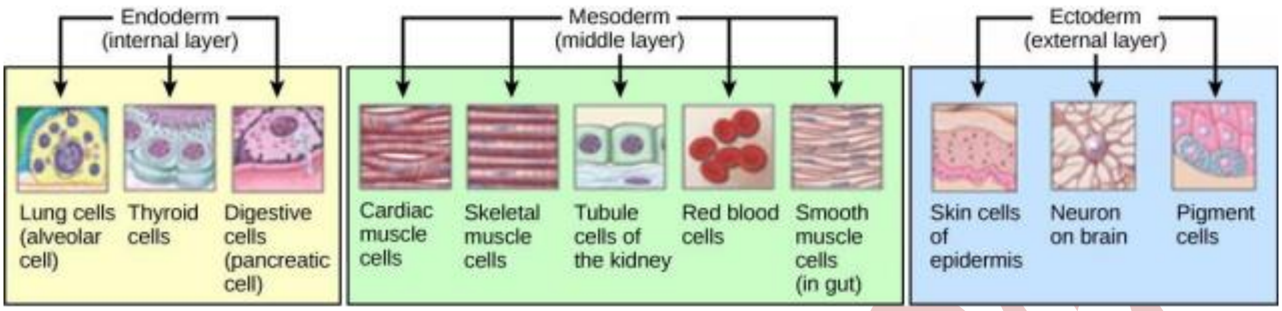

Fig. Three germ layers

3.1. Morphogenetic Movements

The following cell movements occur

1. **Epiboly**

It involves the extension along the anteroposterior axis and peripheral divergence.

2. **Emboly**

The inward movement of cells is classified into different types depending on the behaviour of migrating cells.

3. **Invagination**

During invagination, an epithelial sheet bends inward to form an inpocketing. One way to think of this in three dimensions is to imagine that you are poking a partially deflated beach ball inward with your finger. The resulting bulge or tube is an invagination. If the apical side of the epithelium forms the lumen (central empty space) of the tube, then the movement is termed invagination. If the lumen is formed by basal surfaces, then the movement is termed an evagination.

4. **Ingression**

During ingression, cells leave an epithellial sheet by transforming from well-behaved epithellial cells into freely migrating mesenchyme cells. To do so, they must presumably alter their cellular architecture, alter their program of motility, and alter their adhesive relationship(s) to the surrounding cells. Neural crest cell are an example of a mesenchymal cell type that emigrates out of an epithelium

5. **Involution**

During involution, a tissue sheet rolls inward to form an underlying layer via bulk movement of tissue. One helpful image here is of a tank tread or conveyor belt. As material moves in from the edges of the sheet, material originally at the sites of inward rolling (shown in blue here) is free to move further up underneath the exterior tissue.

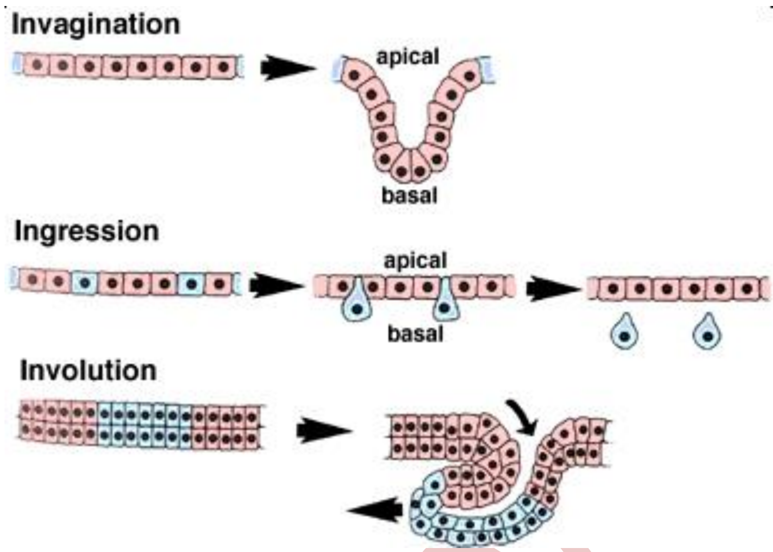

Figure.11. Different morphogenetic movements

6. **Divergence**

This phenomenon is opposite to convergence, when involuted cells diverge to take up their future positions inside the gastrula.

7. **Infiltration**

During this process, cells of the blastoderm infiltrate near the bottom of the blastocoel to form a second layer as seen in the gastrulation of chick.

8. **Delamination**

This is a process of separation of a group of cells from others to form discrete cellular masses.

9. **Extension**

The elongation of presumptive areas after they have moved inside the embryo is called the extension.

10. **Cell proliferation**

It means the increase in the number of cells during gastrulation.

11. **Concrescence**

It is similar to convergence. The cells from two sides migrate anteriorly along one axis, but in convergence the cells from two sides unite together and then move anteriorly.

The above terms are coined for the convenience of analysing the events in gastrulation. Recent observations have established that it is essentially a phenomenon of integration. It was, therefore, felt necessary to understand the whole process for a meaningful comprehension of individual event.

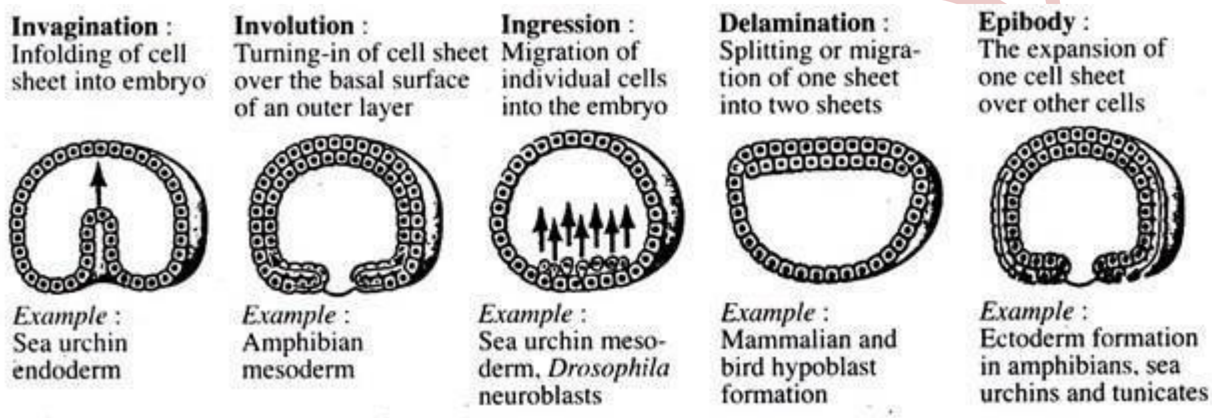

Figure.12. Different morphogenetic movements

Germ layers & fate maps in early embryos

Formation and Fate of Three Germ Layers

A germ layer is a primary layer of cells that forms during embryonic development. Germ layer, any of three primary cell layers, formed in the earliest stages of embryonic development, consisting of the endoderm (inner layer), the ectoderm (outer layer), and the mesoderm (middle layer). The germ layers form during the process of gastrulation, when the hollow ball of cells that constitutes the blastula begins to differentiate into more-specialized cells that become layered across the developing embryo. The germ layers represent some of the first lineage-specific (multipotent) stem cells (e.g., cells destined to contribute to specific types of tissue, such as muscle or blood) in embryonic development.

Hence, each germ layer eventually gives rise to certain tissue types in the body. Each germ layer gives rise to specific tissues, organs and organ-systems. The fate of the germ layers is the same in all triploblastic animals.

THE ECTODERM

Gives rise to the central nervous system (the brain and spinal cord); the peripheral nervous system; the sensory epithelia of the eye, ear, and nose; the epidermisand its appendages (the nails and hair); the mammary glands; the hypophysis; the subcutaneous glands; and the enamel of the teeth. Ectodermal development is called neurulation in regard to nervous tissue.

THE MESODERM

Gives rise to connective tissue, cartilage, and bone; striated and smooth muscles; the heart walls, blood and lymph vessels and cells; the kidneys; the gonads(ovaries and testes) and genital ducts; the serous membranes lining the body cavities; the spleen; and the suprarenal (adrenal) cortices

THE ENDODERM

Gives rise to the epithelial lining of the gastrointestinal and respiratorytracts; the parenchyma of the tonsils, the liver, the thymus, the thyroid, the parathyroids, and the pancreas; the epithelial lining of the urinary bladder and urethra; and the epitheliallining of the tympanic cavity, tympanic antrum, and auditory tube

a. The endoderm development is simpler than that of either mesoderm or ectoderm. It is a monocellular layer lining the yolk sac until cephalocaudal flexion of the embryo takes place

i. Flexion takes the embryo from a flat disk to its basic embryonic body form. The *primitive gut* originates from endoderm at the time of its flexion

ii. The yolk sac constricts, thus the intraembryonic endoderm (future digestive tube) and the extraembryonic endoderm (forms the inner lining of the yolk sac) are delineated

b. Three major parts of the primitive gut are the foregut, the midgut, and the hindgut (including the cloaca)

c. The oropharyngeal (buccopharyngeal) and cloacal membranes temporarily close the 2 ends of the primitive gut

i. In humans, the buccopharyngeal membrane disappears at the beginning of week 4

ii. The cloacal membrane lasts longer and at week 7, like the cloaca, it divides into an anterior *urogenital membrane* and posterior *anal membrane*, the latter being absorbed by week 9.

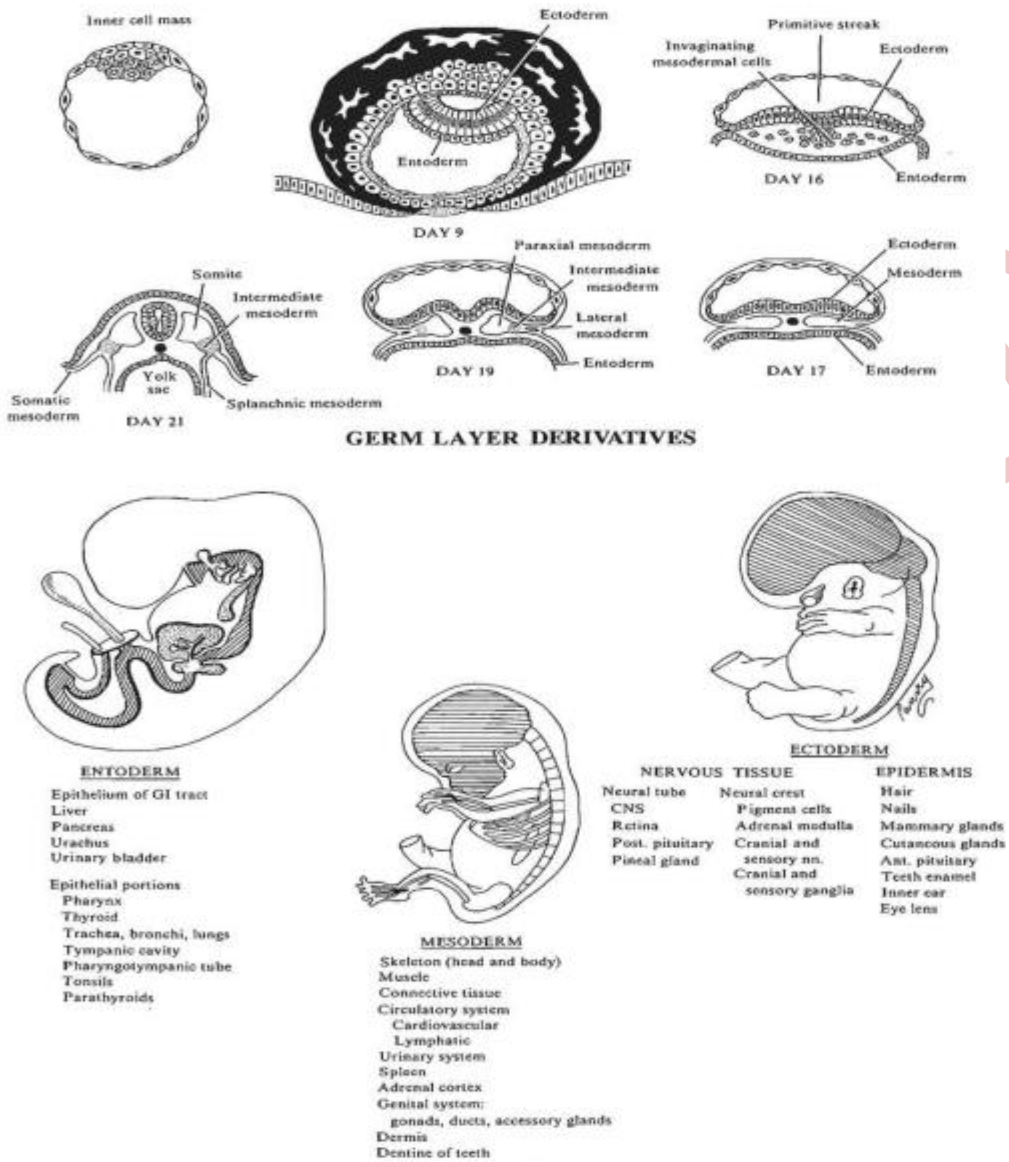

Figure- Different germ layer formation