Gastrulation

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The term gastrulation is applied to the process which produces the **gastrula** (Greek: gaster,stomach). It is a process of highly coordinated cell and tissue movement whereby the cells of the blastula are rearranged to form the three germ layers ectoderm, mesoderm and endoderm . The numerous cells of the blastula formed due to cleavage ,are given new positions and neighbours during gastrulation resulting in the establishment of multilayered body plan of the adult organism . during gastrulation the blasto-coelic cavity is obliterated and a new cavity called **archenteron** is formed .

Gastrulation can be defined " as the dynamic process during which the major ,presumptive organ-forming areas of the blastula become rearranged and reorganized in a way which permits their ready conversion into the body plan of the particular species". Thus gastrulation is the embryo's way of laying down its body plan .Gastrulation is a well integrated process ,controlled largely by intrinsic forces . These internal forces in turn are correlated with external conditions. Thus , the activities of gastrulation are subdivided as follows:

1. Morphogenetic movement of cells.
2. The organization centre and its organizing influences .
3. Chemodifferentiation.

1. Morphogenetic movement of cells

Morphogenetic movement may be defined as the movement of cells from one place in the embryo to another ,to establish a particular form or structural arrangement . It is of the following types.

a) Epiboly : The word epiboly is derived from a Greek word which means **throwing on** or **extending upon .** Epiboly otherwise known as ectodermal expansion involves the movements of the presumptive epidermal and neural areas during the process of gastrulation . These two presumptive areas undergo general migration on the surface , in direction of the antero-posterior axis of the future embryonic body. In simpler words it may be said as the expansion of one cell sheet over other cells.

b) Emboly : The word emboly is derived from a Greek word meaning to **throw in** or **thrust in** .Emboly refers to the inward movement of the presumptive chordamesodermal and endodermal areas and their extension along the anteroposterior axis of the future embryo . This inward movement of cells is due to innate forces within various cell groups . Embolic movement involves the following types of cell behavior:

i) Invagination : It implies an infolding or insinking of a sheet of cells into the embryo. It results in the formation of a cavity surrounded by these infolded cells . This process is executed in two ways :

- Mechanical or passive infolding of cells as seen in the lateral and ventral lip areas of the blastopore.
- Active inward streaming or inpushing of cells as exhibited by the dorsal lip region of the blastopore , into the blastocoelic space.

ii) Involution : The word involution means a " turning in" or inward rotation of cells. Involution is dependent much upon the migration of cells toward the blastoporal lip . These cells instead of piling up

along the outer edges of the blastoporal lip or along the primitive streak , tend to move over the lip to the inside edge of the lip and are thus deposited on the inside of the embryo along the inner margin of the blastopore.

iii) **Convergence and Divergence :** The migration of cells from outside surface of the blastula to the external margin of the blastoporal lip is called convergence , where the cells diverge after getting aggregated. For example , , the cells having involuted over the blastoporal lips into the interior, migrate away from that position to their future positions within the forming gastrula .

iv) **Concrescence:** the term used in older descriptions of gastrulation, denotes the movement of masses of cells toward each other,particularly in the region of the blastopore . It is used to imply the idea of fusion of cell groups . It probably does not occur.

v) **Cell proliferation :**Cell proliferation implies an increase in the number of cells. It is intimately associated with the gastrulative process in *Amphioxus,* while in frog it is of lesser importance.

vi) **Ingression :** when a cell or small groups of cells separate itself from other layers and migrate into the segmentation cavity within the developing body , then it is termed as ingression or **polyinvagination .**This is seen in the case of reptiles ,birds and mammals where the mesodermal cells detach themselves from the primitive streak and migrate into the space between epiblast and hypoblast.

vii) **Delamination :** Delamination is the splitting or separation of one sheet of cells either into two sheets or separation from other cell groups . The separation of notochordal , mesodermal, and endodermal tissues from each other , during gastrulation of frog , to form discrete cellular masses,is an example of delamination. Another example, is the formation of hypoblast in mammalians and birds.

viii) **Extension :** The extension of cellular masses also takes place in gastrulation . For example, the extension of the presumptive neural and epidermal areas externally and of the notochordal , mesodermal and endodermal cells after they have moved inward beneath the neural plate and epidermal material.

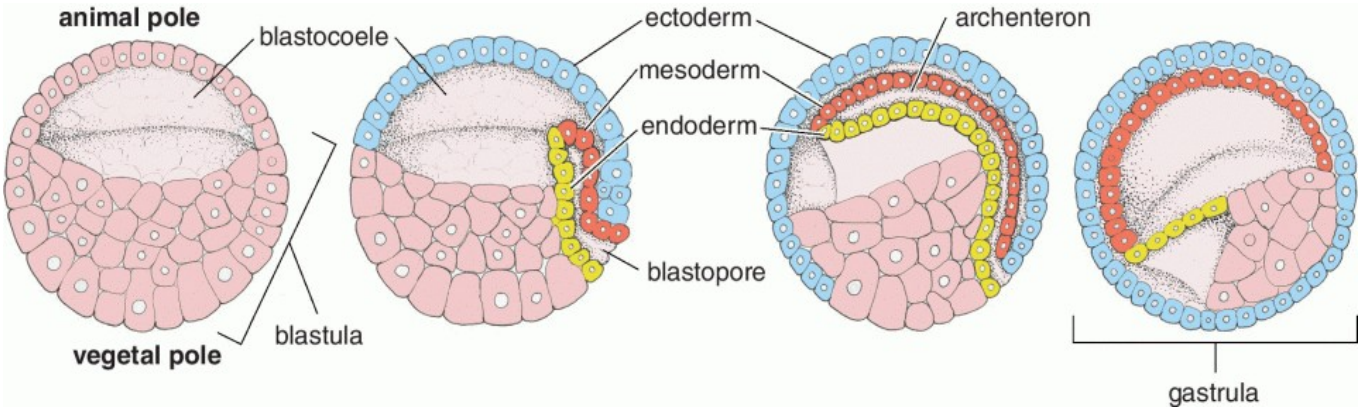

Fig. No. : 1 : Gastrulation - A.

2. The organization centre and its organizing influence

During early gastrulation the blue print of the future organ systems are established in a definite order depending upon the specific relationship of a particular group of tissue of the developing embryo with others.

When a group of cells located on one part of the embryo transmits a chemical stimulus ,it influences another part of the embryo to differentiate into a particular developmental fate. Thus , the morphogenetic

effect produced is called **embryonic induction .**The part of the embryo exerting such an influence is regarded as inductor or organizer and the chemical substance emitted by it is known as **evocator** . The tissue on which the evocator works and makes it respond is known as **responsive tissue.**

Organizer can be defined as those group of cells or tissue which are capable of transmitting a chemical stimulus upon other embryonic tissues situated at another part of the embryo and compelling it to differentiate into a particular developmental fate.

The concept of organizer was put forward by Spemann and Mangold (1924) and Spemann (1938) through their experiments of transplantation of the dorsal lip of blastopore in Salamanders. Their experiments suggested that the organizers not only possess the ability to organize but also to induce host tissue to differentiate . Further studies and experiments eventually showed that various types of tissues and tissue substances , some alive , some dead , from many animal species , including the invertebrates were able to induce amphibian neural plate and tube formation .

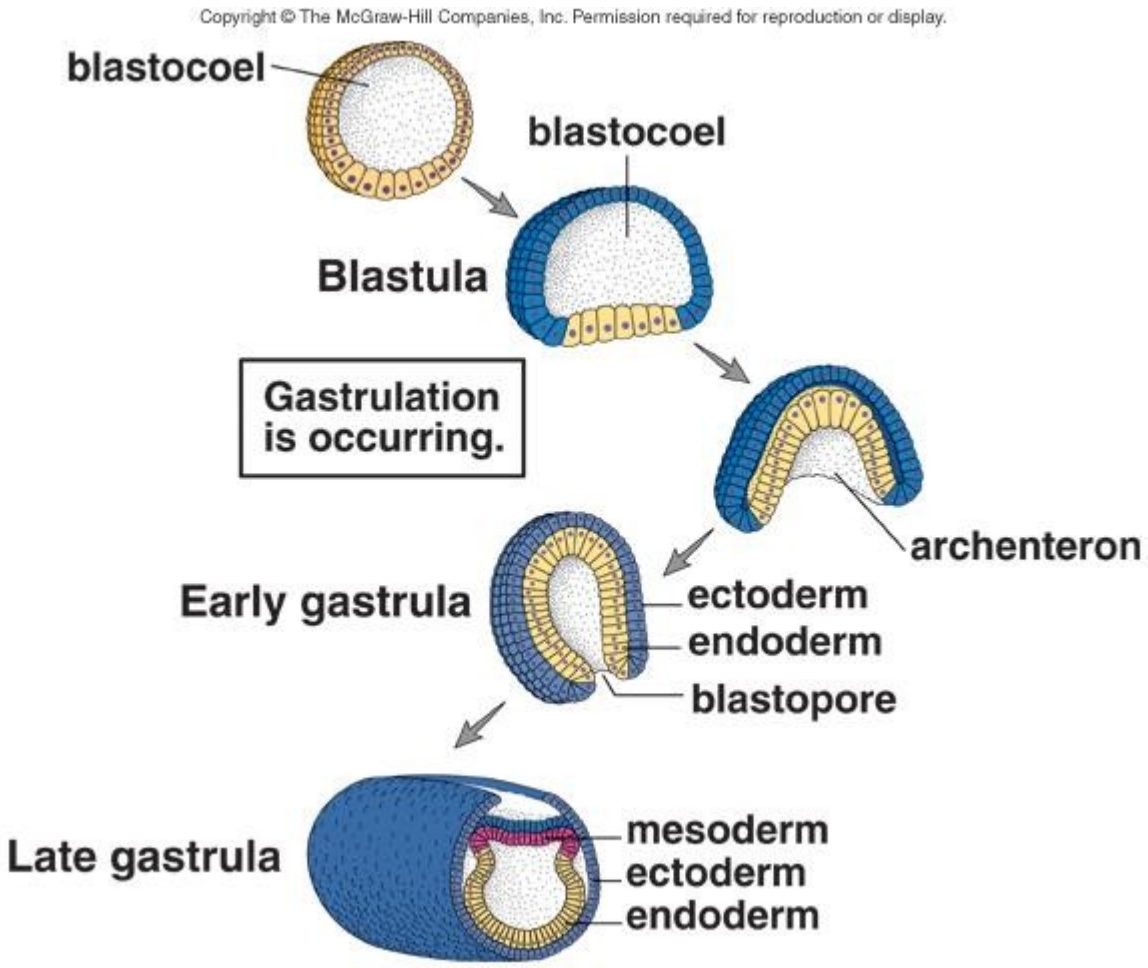

Fig. No. : 2 : Gastrulation – B.

3. Chemodifferentiation

As the late blastula converses into the late gastrula , the presumptive neural plate ectodermal and epidermal ectodermal areas become changed physiologically , as a result they no longer are determined in a presumptive sense but have undergone changes which make them self –determining . This change is

called **determination** and the biological change which effects this alteration is known as **chemodifferentiation** . As chemodifferentiation involves physiological changes , it restricts changes in potency upon many localized cellular areas. As a result various future organs and parts of organs have their respective fates rigidly and irrevocably determined at the end of gastrulation . Chemodifferentiation apparently occurs through inductive action .

Concept of potency and Totipotency :

Potency is referred to that property of a cell which enables it to undergo differentiation. **Potency** is defined as the power or ability of a cell to give origin to a specific kind of cell or structure or to various kinds of cells and structures.

Totipotent ,the word coined by Wilhelm Roux ,refers to the power or ability of an early blastomere or blastomeres of a particular animal species to give origin to the many different types of cells and structures characteristic of the individual species . To describe the ability of a cell , it is well to define two kinds of totipotency – **totipotency and harmonious totipotency** . The former term refers to the ability of a cell or cell group to give origin to all or nearly all the different cells or tissues of the particular species to which it belongs, but it lacks the ability to organize these cells or tissues into a harmonious organism. Harmonious totipotency possesses the above potency and in addition it has the power to develop a perfectly organized body .

A fertilized ovum has the capability to form an entire organism and this capability is retained by the individual cell resulting from the first few divisions after fertilization ,in many vertebrates . Such cells are said to be totipotent . As development proceeds ,the cells gradually loose the ability to form all the types of cells that are found in the adult body. This reduction in the developmental options permitted to a cell is called **restriction** .

Cleavage leads to the formation of the blastula which then undergoes gastrulation to form the three primary germ layers. This results in the formation of an outermost ectodermal layer, a middle mesodermal layer and an innermost endodermal layer.By this time atleat one stage of restriction has taken place and the cells of the three germ layers are now locked into different developmental channels and thus have lost their totipotency and are no longer interchangeable . Further,as development proceeds , the cells of the ectoderm becomes thickened and becomes committed to forming the brain ,the spinal cord and other associated structures . The remainder of the ectodermal cells can no longer form these structures and have thus undergone another phase of restriction .

When restriction ultimately results in a group of cells becoming committed to a single developmental fate (e.g. , formation of cornea), then the **determination** of these cells has taken place. The word determination is applied to those unknown and invisible changes occurring within a cell or cells which effect a limitation or restriction of potency. Often , tissue interactions called **inductions** take place shortly before determination.

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Ref. Book : - Introduction to Zoology, Vol. 1, Chaki-Kundu-Sarkar.