Gastrulation in Mus musculus (common house mouse) [1]


As mice embryos develop, they undergo a stage of development called gastrulation [7]. The hallmark of vertebrate gastrulation [7] is the reorganization of the inner cell mass [8] (ICM) into the three germ layers [9]: ectoderm [10], mesoderm [11], and endoderm [12]. Mammalian embryogenesis [13] occurs within organisms; therefore, gastrulation [7] was originally described in species with easily observable embryos. For example, the African clawed frog [14] (Xenopus laevis [15]) is a widely used organism to study gastrulation [7] because the large embryos develop inside a translucent membrane. Domestic chickens (Gallus gallus) provided researchers another early model to study gastrulation [7] because researchers could open the egg [16] during development to look inside. Despite the challenges associated with studying mammalian gastrulation [7], the common house mouse [17] (Mus musculus) has helped to shed light on the unique adaptations associated with mammalian development.

Gastrulation in the mouse [6] begins shortly after a blastula [18] implants into the uterine wall of the mother, and is immediately followed by the development of the various organ systems (organogenesis [19]). This coordinated movement of cells results in a spatially organized embryo, and assembles the framework upon which future developmental processes will build the body. The term for an embryo undergoing gastrulation [7] is the gastrula [20], a term coined by Ernst Haeckel [21] Germany in 1872, and expanded upon in his 1874 Studien zur Gastraea-theorie (Studies for the Gastrea Theory). The Latin root gaster means stomach, and the term gastrulation [7] refers to the formation of the gut.

In the mouse [6] there is a two-day gap between implantation [22] and the beginning of gastrulation [7]; the blastocyst [23] implants in the uterine wall four and a half days post coitum (DPC), and gastrulation [7] begins six and a half DPC. During that two-day period, cells change within the developing fertilized egg [24] (zygote [25]). During cleavage cells are held together by adhesion proteins, which must be deactivated to allow individual cells to move. The relaxed cellular bonds allow the inner cell mass [8] (ICM) to expand and reorganize into distinct layers. One of these layers, the epiblast [26], is a sheet of cells, which are the precursors of all the cells of the embryo. As the epiblast [26] grows, it takes the shape of a cup, with the rim located on dorsal side of the embryo.

Gastrulation begins with the formation of the primitive node on the posterior side of the epiblast [26]. The primitive node is a knot of cells that secretes cellular signals in the form of proteins, such as fibroblast growth factor (FGF). Those signals help cells migrate within the embryo during gastrulation [7]. The appearance of the node is also the first indication of head to tail distinction (anterior-posterior polarity [27]). From the node a structure called the primitive streak [28] forms. The primitive streak [28] is a groove that extends from the primitive node towards the ventral side of the embryo. As the primitive streak [28] elongates, epiblast [26] cells that are on the inside of the cup ingress up into the streak. As a cell moves into the primitive streak [28], it interacts with cellular signals, which restrict the type of tissues the cell can form. The cells that move through the streak become mesendoderm, which are the precursors of mesoderm [11]
cells and endoderm[12] cells. After they exit the primitive streak[28], the cells disperse and create a wave of mesendoderm that expands to cover the outside of the embryo.

In the mouse[6] the mesendoderm engulfs the ectoderm[10], which will later form the nervous system and epidermis. The mesendoderm differentiates into mesoderm[11]; which becomes the skeleton, muscles, and various internal organs; and the endoderm[12], which then becomes the gastrointestinal and respiratory systems. The mesoderm[11] forms on the anterior portion of the embryo, and the endoderm[12] forms on the posterior side where the primitive streak[28] originated. The endoderm[12] and mesoderm[11] completely differentiate from each other around sixteen DPC.


Gastrulation is a process common to all animals, and researchers investigate its evolutionary origins partly to understand how complex animals evolved. Gastrulation recapitulates the evolutionary transition from organisms with two germ layers[9] (diploblastic), to organism with three germ layers[9] (triploblastic) and a digestive system. Some researchers map the gene regulatory networks[32] that operate during gastrulation[7]. They do so to expand our molecular knowledge of the signaling factors involved, and to uncover the evolutionary origins of gastrulation[7].

Sources

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