Endoderm

By: MacCord, Kate Keywords: mesendoderm

Endoderm is one of the germ layers—aggregates of cells that originate early during embryonic life and from which all organs and tissues develop. All animals, with the exception of sponges, form either two or three germ layers, through a process known as gastrulation.[5] During gastrulation, a ball of cells transforms into a two-layered embryo made of an inner layer of endoderm[6] and an outer layer of ectoderm.[7]

In more complex species, like vertebrates, these two primary germ layers[3] interact to give rise to a third germ layer, called mesoderm[4]. Regardless of the presence of two or three layers, endoderm[5] always forms the innermost layer. Endoderm forms the epithelium—a type of tissue in which the cells are tightly joined together to form sheets—that lines the primitive gut. From this epiteliol of the primitive gut, organs like the digestive tract, liver, pancreas, and lungs develop.

Throughout the early stages of gastrulation,[4] a group of cells called mesendoderm expresses sets of both endoderm[6] and mesoderm[4] specific genes.[6] Cells in the mesendoderm have the ability to differentiate into either endoderm[5] or mesoderm[4], depending on their position among surrounding cells. Scientists have found mesendoderm is widespread among invertebrates, including the nematode Caenorhabditis elegans,[12] and the purple sea urchin.[13] Strongly defined anterior-posterior or body axes are seen within invertebrates, whereas in vertebrates, mesendoderm has been found to be present in the zebrafish, Danio rerio[14], and has been indicated in mice, Mus musculus[15].

Endoderm, along with the other two germ layers[3], was first described in 1817 by Christian Pander, a doctoral student at the University of Würzburg[16], in Würzburg, Germany. In his dissertation, Beiträge zur Entwicklungs geschichte des Nabels[17] im Eier, he contributed to the Developmental History of the Eggs. Pander described how two layers give rise to a third in the chick.[16] Gastrulation[17] in the embryo, Pander's description of the formation of these layers is the first account of gastrulation[17] in the chick[16] embryos described by Pander. The association he made between the body plan of the adult jellyfish and the vertebrate embryo connected the study of development and growth, and development, called ontogeny[21], to the study of relationships between organisms, called phylogeny[22].

By the 1860s researchers compared germ layers[3] across the animal kingdom. Beginning in 1864 embryologist Aleksandr Kollarovsky, who studied embryology[22], at the University of St. Petersburg, in St. Petersburg, Russia, found that the endoderm[5] and mesoderm[4] had the same primary germ layers.[28] In 1871, his research showed that invertebrate embryos had the same primary germ layers.[29] This discovery of the existence of three germ layers[3] in the vertebrate embryo, and that the layers arose in the same fashion across the animal kingdom. Kollarovsky's findings convinced many about the universality of the germ layers[3]—a result that some scientists made a principle of germ layer theory. Germ layer theory held that each of the germ layers[3], regardless of species, gave rise to a fixed set of organs. These organs were deemed homologous across the animal kingdom, effectively uniting ontogeny[21] with phylogeny[22].

By the mid-1870s, scientists like Hans Spemann[23] and Hilde Mangold[24], in Germany, and Sven Hörstadius, in Sweden, led scientists to dismantle the germ layer theory.

Early-twentieth-century scientists sought to explain the germ layers[3] more fully by investigating how embryos transformed from one cell to thousands of cells. Among these embryologists, Edwin Grant Conklin[25] at the University of Pennsylvania[26], in Philadelphia, Pennsylvania, was one of the first to trace cell lineages from the single-cell stage. In his 1905 text, The Organization and Cell-lineage of the Ascidian Egg[27], Conklin mapped the development of and spatial organization of the cells in the embryo of an ascidian, or sea squirt, a type of marine invertebrate that develops a tough outer layer and clings to the sea floor. By creating a plot, or fate map, of the developmental route of each of the cells, Conklin located the precursor cells, traced the formation of each of the germ layers[3], and showed that even at very early stages of development, the ability of some cells to differentiate becomes restricted.

Conklin's fate mapping[28] experiments, along with questions about the capacity of cells to differentiate, influenced scientists like Robert Briggs, at Indiana University[29], in Bloomington, Indiana, and his collaborator, Thomas King, at the Institute for Cancer Research[30], in Philadelphia, Pennsylvania. In the 1950s Briggs and King began a series of experiments to test the developmental capacity of cells in embryos. In 1957 Briggs and King transplanted nuclei from the presumptive endoderm[5] of the northern leopard frog[31], Rana pipiens, into eggs from which they had removed the nuclei. This technique, which Briggs and King had developed, called nuclear transplantation[32], allowed scientists to explore the timing of cell fate decisions[33] and how the technique became a basis for future experiments in cloning[34].

From their nuclear transplantation[32] experiments, Briggs and King found that during endodermal differentiation[35], the ability of the nucleus[36] to help cells specialize becomes progressively restricted. That result was supported in 1960 by the work of John Gurdon[37], at Oxford University in Oxford, England. Gurdon repeated Briggs and King's experiments using the African clawed frog[38], Xenopus laevis[39], and Gurdon found that there are significant differences between species in the rate and timing of onset of these endodermal restrictions. While Briggs, King, and Gurdon worked to understand the restriction of endodermal cell fates, other scientists, like Pieter Nieuwkoop, at the Royal Netherlands Academy of Arts and Science, in Utrecht, and Sven Hörstadius, in Sweden, led scientists to dismantle the germ layer theory.

Sources


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