Endoderm [1]

By: MacCord, Kate Keywords: mesendoderm

Endoderm is one of the germ layers—aggregates of cells that organize early during development 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 [2]. During gastrulation [3], a ball of cells transforms into a two-layered embryo made of an inner layer of endoderm [4] and an outer layer of ectoderm [5]. In more complex organisms, like vertebrates, two additional germ layers develop to give rise to a third germ layer, called mesoderm [6]. Regardless of the presence of two or three layers, endoderm 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 epithelial lining 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 [7] specific genes [8]. Cells in the mesendoderm have the ability to differentiate into either mesoderm [9] or endoderm [5], depending on their position among surrounding cells. Scientists have found mesendoderm is widespread among invertebrates, including the nematode Caenorhabditis elegans and the purple sea urchin. Strongylocentrotus purpuratus. Within vertebrates, mesendoderm has been found in the zebralox, Danio rerio, and has been indicated in mice, Mus musculus.

Endoderm, along with the other two germ layers, was first described in 1817 by Christian Pander, a professor at the University of Würzburg [5]. In 1849, Pander published his dissertation ‘Beiträge zur Entwicklungsgeschichte des Hühnerembruns im Eier’. During his work, Pander observed that two or three germ layers (endoderm [5] and mesoderm [7]) are present in the embryo from an early stage. These two germ layers interact to give rise to a third germ layer, called ectoderm [6]. Regardless of the presence of two or three layers, endoderm always the inner-most layer. Endoderm forms the epithelium—a type of tissue in which the cells are tightly associated together to form sheets—that lines the primitive gut. From this epithelial lining of the primitive gut, organs like the digestive tract, liver, pancreas, and lungs develop.

Early twentieth-century scientists sought to explain the fate mapping of cells in the embryo of the chicken. In 1953, Eric Davidson confirmed that network of pathways involved in later stages of development [10] prior to Haeckel. Investigated the formation of the endoderm in the eggs. Pander described how two layers give rise to a third in the chick callus gallus embryo. Pander’s description of the formation of the layers is the first account of gastrulation [11] in the chick, callus gallus embryos described by Pander. The association that Huxley made between the body plan of the adult jellyfish and the vertebrate embryo connected the study of growth and development, called ontogony [12], the study of relationships between organisms, called phylogeny [13]. Huxley’s support for a relationship between ontogony [12] and phylogeny [13], later known as the theory of recapitulation, would become fundamental to the works of late nineteenth-century scientists, like Charles Darwin [14], in 1859, and Ernst Haeckel [15], in 1866. These and other scientists began to look to embryos for evidence of evolution [16].

While germ layer theory garnered broad support, not everyone accepted it. Beginning in the late nineteenth century, embryologists such as Ernst Haeckel, Ernst Haeckel. In 1868, Haeckel published “The Gastraea Theory, the Phylogenetic Classification of the Animal Kingdom and the Homology [17] of the Germ Layers.” In ‘Jenaische Zeitschrift für Naturwissenschaft’, 8 (1874): 1–55. and Rudolf Virchow, in Germany, extended the concept of germ layer theory to include all vertebrates in his 1868 text ‘Die Gastraea-Theorie, die phylogenetische Classification des Thierreichs und die Homologie der Keimblätter’ [18]. Haeckel’s work on the theory of cranial nerves and brain development had a significant impact on the development of the nervous system. These opponents of germ layer theory belonged mainly to a new tradition of embryologists—those who used physical manipulations of embryos to research development.

By the 1920s, experiments by scientists like Wilhelm His [19] and his colleagues at the University of Jena, Germany. These and other scientists began to look to embryos for evidence of evolution [16]. By the 1920s, experiments by scientists like Hans Spemann [20] and Hilde Mangold [21], in Germany, and Sven Hörstadius, in Sweden, led scientists to dismantle the germ layer theory. Early twenty-century scientists sought to explain the germ layers more fully by investigating how embryos transformed from one cell to thousands of cells. Among these embryologists, Edwin Grant Conklin [22] at the University of Pennsylvania [23], 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’, Conklin described the differentiation and specific localization of the cells in the embryo of an invertebrate, an ascidian, a type of marine invertebrate that develops in a thin layer under 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, and showed that even at very early stages of development, the ability of some cells to differentiate becomes restricted.

Conklin’s fate mapping [24] experiments, along with questions about the capacity of cells to differentiate, influenced scientists like Robert Briggs, at Indiana University [25], in Bloomington, Indiana, and his collaborator, Thomas King, at the Institute for Cancer Research [24] in Philadelphia, Pennsylvania. In the 1950s Briggs and King began a series of experiments to test the developmental capacity of cells and embryos. In 1957 Briggs and King transplanted nuclei from the presumptive endoderm [26] of the northern leopard frog [27], Rana pipiens, into eggs from which they had removed the nuclei. This technique, which Briggs and King simplified create, called cloning [28], allowed them to explore the timing of cell differentiation. While there are some genetic elements conserved across the animal kingdom, like β-catenin, some portions of the endoderm [29] induction [30] pathway, especially signals like the proteins Nodal and Wnt, are vertebrate-specific. In 2002 Eric Davidson [31] and his colleagues at California Institute of Technology [32] in Pasadena, California, announced the full network of genes that regulate the specification of endoderm [33] and mesoderm [7] in sea urchins in their paper, “A Genetic Regulatory Network for Development.” Davidson confirmed that network of genes in a co-authored article published in 2012.

Sources

Published on The Embryo Project Encyclopedia (https://embryo.asu.edu)
Endoderm is one of the germ layers—aggregates of cells that organize 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. However, the process known as gastulation. During gastulation, a ball of cells transforms into a two-layered embryo made of an inner layer of endoderm and an outer layer of ectoderm. In more complex organisms, like vertebrates, two primary germ layers interact to give rise to a third germ layer, called mesoderm. Regardless of the presence of two or three layers, endoderm is always the innermost layer. Endoderm forms the epithelium—a type of tissue in which the cells are tightly linked together to form sheets—that lines the primitive gut. From this epithelial lining of the primitive gut, organs like the digestive tract, liver, pancreas, and lungs develop.

To the right of these two primary germ layers lies the third germ layer, the mesoderm. Mesoderm gives rise to the body’s supporting structures, including muscles, bones, and blood vessels. As the embryo develops, the layers interact with each other, leading to the formation of different tissues and organs. The process of these interactions is known as organogenesis, where the embryo begins to take shape through the formation of distinct structures.

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Publisher
Arizona State University. School of Life Sciences. Center for Biology and Society. Embryo Project Encyclopedia.

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Last Modified
Wednesday, July 4, 2018 - 04:40

DC Date Accessed
Sunday, November 17, 2013 - 17:47

DC Date Available
Sunday, November 17, 2013 - 17:47

DC Date Created
2013-11-17

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