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Embryogenesis: A comprehensive review

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Abstract
Embryogenesis start from the time of fertilization of female germ cell or ovum by a sperm. The zygote formed is surrounded by a strong membrane of glycoproteins called the zona pellucida which the successful sperm has managed to penetrate. The zygote undergoes cleavage, increasing the number of cells within the zona pellucida. After the 8-cell stage, mammalian embryos undergo compaction, where the cells bind tightly to each other, forming a compact sphere. After compaction, the embryo is in the morula stage (16 cells). Cavitation ocurrs next, where the outermost layer of cells - the trophoblast secrete water into the morula. As a consequence of this, when the number of cells reaches 40 to 150, a central, fluid-filled cavity known as blastocoel has been formed. The zona pellucida begins to degenerate, allowing the embryo to increase its volume. This stage in the developing embryo, reached after four to six days, is the blastocyst and lasts approximately until the implantation in the uterus. The blastocyst is characterized by a group of cells, called the inner cell mass (also called embryoblast) and the trophoblast (the outer cells).

Keywords: Embryogenesis, Fertilization, Germ cell, Zygote

Introduction
Embryogenesis refers to the process by which embryo forms and develop. In mammals, it refers to the early stages of prenatal development. It starts with the fertilization of egg by a sperm cell. When fertilized, the ovum is referred to as zygote, which is a single diploid cell. The zygote undergoes numerous mitotic division and cellular differentiation leading to the development of a multicellular organism. The development of multicellular organism depends on following processes:

Growth: It may be defined as the developmental increase in mass. After the rudimentary organs are formed, they begin to grow and greatly increase their volume. Growth results from synthesis of new protoplasm, both cytoplasmic and nucleic. Increase in mass is accompanied by cell division. Cell multiplication is a distinguishing characteristic of growth. In this way, the animal gradually achieves the size of its parents.

Differentiation: It refers to events by which cells and other parts become different from one another and also different from their original form. It occurs in two ways: firstly by morphogenesis which refers to a change in the shape and organization of the body and its parts. With multiplication division, individual cells and their groups become structurally different from other cells and group of cells. Secondly by histogenesis which refers to a change in the substance and structure of the cells and therefore various tissues are created. The total process by which cells differentiate into distinctive kinds and assume specific tissue characters is known as histogenesis. Morphogenesis and histogenesis are the processes resulting in the organogenesis, which resolve the early embryo into complete organs.

Integration: Although the new organs and organ systems possess structural unity, they need to be reintegrated into co-operative working mechanisms. This control is given by the nervous system and endocrine glands, which constitute the primary mechanism of physiological control and co-ordination. The supplying of organs with adequate nervous, vascular and hormonal influences will make the development to pass from a prefunctional period to a functional period.

Fertilization
The process of a single sperm cell combining with single egg cell to form a zygote is known as fertilization. The egg is the largest cell produced in most animal species. The eggs of different

species contain varying amounts of yolk which contain nutrients to support growth of the developing embryo. The egg is surrounded by layer of glycoproteins that releases species-specific chemoattractants that activate and guide sperm to the egg. In mammals, this layer is called the zona pellucida**.** The zona pellucida is separated from the egg by a membrane called the vitelline membrane, which is outside the cell's plasma membrane. Just underneath the egg's plasma membrane are cortical granules containing enzymes that will degrade the proteins that hold the vitelline envelope around the plasma membrane when fertilization occurs.

The sperm is one of the smallest cells produced in most animal species. The sperm consists of head containing tightly packed DNA, a flagellar tail for swimming and many mitochondria to provide power for sperm movement. The plasma membrane of the sperm contains proteins called bindin that recognize and bind to receptors on the egg plasma membrane. In addition to the nucleus, the sperm head also contains an organelle called the acrosome, which contains digestive enzymes that will degrade the zona pellucida to allow the sperm to reach the egg plasma membrane.

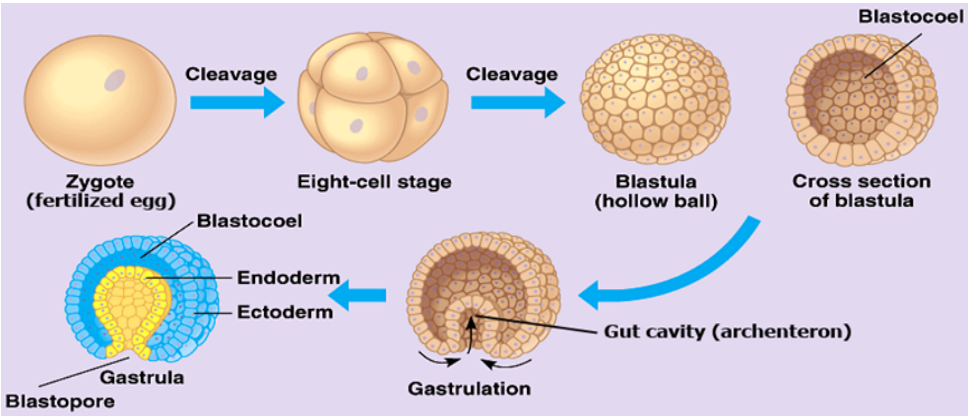
Cleavage

The series of cell division that transfom a single cell zygote into multicellular embryonic stage- the blastula is called cleavage or segmentation. The mitotic divisions during this phase are called cleavage divisions. The resulting daughter cells are called blastomere and form a compact mass called the morula. Cleavage ends with the formation of the blastula.

Depending mostly on the amount of yolk in the egg, the cleavage can be holoblastic (total or entire cleavage) or meroblastic (partial cleavage). [1] The pole of the egg with the highest concentration of yolk is referred to as the vegetal pole while the opposite is referred to as the animal pole. Holoblastic cleavage occurs in animals with little yolk in their eggs, such as humans and other mammals who receive nourishment as embryos from the mother, via the placenta or milk where as meroblastic cleavage occurs in animals whose eggs have more yolk (birds and reptiles). Because cleavage is impeded in the vegetal pole, there is an uneven distribution and size of cells, being more numerous and smaller at the animal pole of the zygote.

Morulla is a stage of cleavage where the blastomeres are compactly arranged inside the zona pellucida giving a mulberry fruit appearance. This change in shape of the embryo is called compaction. The morula consists of a small group of internal cells surrounded by a larger group of external cells. [2] Most of the descendants of the external cells become the trophoblast cells. This group of cells produces no embryonic structures. Rather, it forms the tissue of the chorion, the embryonic portion of the placenta. The chorion enables the fetus to get oxygen and nourishment from the mother. [3] Initially, the morula does not have an internal cavity. However, during a process called cavitation, the trophoblast cells secrete fluid into the morula to create a blastocoel. The inner cell mass is positioned on one side of the ring of trophoblast cells. The resulting structure is called the blastocyst. The blastomeres of a morula tend to assume a spherical shape. Their mutual pressure flattens the surfaces of blastomeres in contact with each other, but the free surfaces of each blastomere remain spherical.

At the end of cleavage, the embryo consist of hollow sphere of cells in holoblastic types and a layer of cells over yolk in meroblastic cleavage. This developmental stage is called blastula. The layer of cells is known as blastoderm and the cavity is blastocoele. At first, the blastocoele may be represented just by narrow cavities between the blastomeres, but it gradually increases as the cleavage goes on.



Implantation

As the cleavage divisions come to an end, the embryo gets attached to the wall of the uterus where the further development of the embryo starts. This attachment of the embryo to the wall of the uterus is called as implantation. The implantation of the embryo is carried out by the cells of the trophoblast. Two types of implantations are seen in animals:

1. In most mammals, the blastocyst becomes attached to the surface of the uterus and comes to lie in the cavity of the uterus.
2. In smaller number of mammals like rodents and including man, the blastocyst penetrates deep into the wall of the uterus and the development of the embryo occurs inside the uterine wall. The epithelial lining of the uterus at the site of penetration gets destroyed. This destruction is due to the activity of the trophoblast cells. The embryo derives the nutrition from the fluid filling the uterus to some extent but this supply of nutrients is insignificant when compared to the food supply that the embryo receives from the maternal blood vessels by diffusion. [4] However, the connection between the embryo and the uterine wall takes time, till then the uterine fluid provides the nutrition to the developing embryo. The formation of this connection of blood vessels between the embryo and the maternal tissues is called placentation. [5]

When the embryo is getting implanted, it is still in the blastocyst stage and gastrulation starts only after the

implantation. During this time, the embryonic membranes also start forming. However, the onset of these two processes differs in different animals. [6]

Gastrulation

The events which transform a single layered blastula into multi layered gastrula are collectively called gastrulation. Here formation of primordial gut cavity takes place known as gastrocoele/archenteron. In addition, all the three germ layers i.e. ectoderm (epiblast), mesoderm (meroblast) and endoderm (hypoblast) are differentiated in this process. It is the most critical period of development. Gastrulation is followed by organogenesis, when individual organs develop within the newly formed germ layers. Each layer gives rise to specific tissues and organs in the developing embryo. The ectoderm gives rise to epidermis, the nervous system, and the neural crest in vertebrates. The endoderm gives rise to the epithelium of the digestive system and respiratory system, and organs associated with the digestive system, such as the liver and pancreas. [7] The mesoderm gives rise to many cell types such as muscle, bone, and connective tissue.

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