THEME: ONTOGENESIS

Ontogenesis is an individual development of the organism from the formation of a zygote to death.

Fertilization

Fertilization is the fusion of gametes to initiate the development of a new individual organism. In animals, the process involves the fusion of an ovum with a sperm, which first creates a zygote and then leads to the development of an embryo.

Hundreds of millions of sperm cells are deposited in the vagina during sexual intercourse. A sperm cell can survive in the woman's body for up to six days, but the oocyte can only be fertilized in the 12 to 24 hours after ovulation.

Capacitation

At the beginning of the process, the sperm undergoes a series of changes, as freshly ejaculated sperm is unable or poorly able to fertilize. The sperm must undergo capacitation in the female's reproductive tract over several hours, which increases its motility and destabilizes its membrane, preparing it for the acrosome reaction.

Acrosomal reactions

After binding to the corona radiata the sperm reaches the zona pellucida, which is an extra-cellular matrix of glycoproteins. A special complementary molecule on the surface of the sperm head binds to a glycoprotein in the zona pellucida. This binding triggers the acrosome to burst releasing enzymes that help the sperm get through the zona pellucida.

Cortical reaction

After the sperm enters the cytoplasm of the oocyte, the tail and the outer coating of the sperm disintegrate and the cortical reaction occurs. Cortical granules inside the secondary oocyte fuse with the plasma membrane to make it hard and impermeable to sperm. This prevents fertilization of an egg by more than one sperm.

Fusion (Formation of synkaryon)

In preparation for the fusion of their genetic material both, the oocyte and the sperm, undergo transformations as a reaction to the fusion of cell membranes. The oocyte completes its second meiotic division. This results in a mature ovum. The nucleus of the oocyte is called a pronucleus. The sperm's tail and mitochondria degenerate with the

formation of the male pronucleus. The pronuclei migrate toward the center of the oocyte, rapidly replicating their DNA as they do so to prepare the zygote for its first mitotic division.

Cleavage

Cleavage is the division of cells in the early embryo. The zygotes of many species undergo rapid divisions, producing a cluster of cells the same size as the original zygote. It differs from other forms of cell division in that it increases the number of cells without increasing the mass. The different cells derived from cleavage are called *blastomeres* and form a compact mass called the *morula.*

Types of cleavage

Depending on the kind of egg, the cleavage may be: ***holoblastic*** (total or entire cleavage) and ***meroblastic*** (partial cleavage).

Holoblastic cleavage:

- ✓ Bilateral
- ✓ Radial
- ✓ Spiral
- ✓ Rotational

Meroblastic cleavage:

- ✓ Discoidal
- ✓ Superficial

Cleavage ends with the formation of a sphere of cells surrounding a blastocoele which are called a ***blastula***. The blastocoele is a fluid filled cavity which contains amino acids, proteins, growth factors, sugars, ions and other components which are necessary for cellular differentiation. The blastocoele also allows blastomeres to move during the process of gastrulation. The structure of blastula varies in different animals. It depends upon many factors, such as size of the egg, amount of yolk in the egg, pattern of distribution of yolk in the egg, and type, rate and number of cleavage division. There are the following types of blastules:

Coeloblastula (Typical blastula). It forms as result of holoblastic cleavage. It a single layered bubble with a large blastocoel (Amphioxus).

Periblastula. It is formed as a result of superficial cleavage. The blastocoel is absent. (Insects).

Discoblastula. It is formed as a result of discoidal cleavage. The blastocoel is small. (Boney fishes, reptile, birds).

Amphiblastula. It is formed of two types of structurally different blastomeres: micromeres and macromeres. (Amphibians).

Blastocyst. It is formed in mammals as a result of holoblastic cleavage. Outer cells are called trophoblast, inner cells are called as inner cell mass and they form the embryo. (Human).

Gastrulation

Gastrulation is a phase of the embryonic development of most animals, during which the single-layered blastula is reorganized into a three-layered structure known as the ***gastrula***. These three germ layers are known as the *ectoderm*, *mesoderm*, and *endoderm.*

At first ecto- and endoderm are formed in four possible ways (fig.1):

- ✓ *Immigration*
- ✓ *Invagination*
- ✓ *Epiboly*
- ✓ *Delamination*

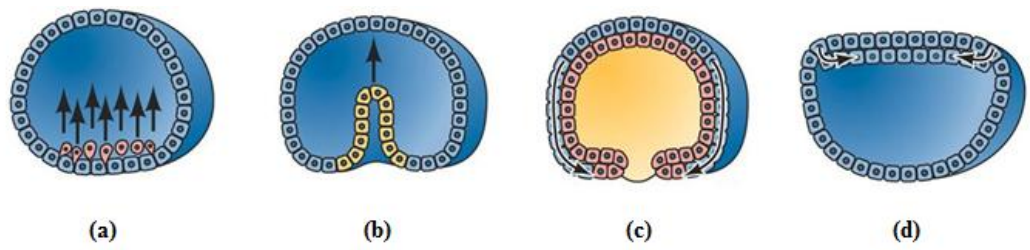

Fig. 1. Ways of Gastrulation: (a) Immigration; (b) Invagination; (c) Epiboly; (d) Delamination

A special place at this stage of embryonic development takes ***neurulation*** process.

Neurulation begins with the formation of a ***neural plate***, a thickening of the ectoderm. Than the edges of the plate fold and rise, meeting in the midline to form a ***tube***.

The cells at the tips of the neural folds come to lie between the ***neural tube*** and the overlying epidermis. These cells become the ***neural crest cells***. The closure of the neural tube disconnects the neural crest from epidermis. Neural crest cells diffirentiate to form most of the peripheral nervous system (fig.2).

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, and to the neural crest and other tissues that will later form the nervous system.

The **mesoderm** is found between the ectoderm and the endoderm and gives rise to somites, which form muscle; the cartilage of the ribs and vertebrae; the dermis, the notochord, blood and blood vessels, bone, and connective tissue.

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.

Following gastrulation, cells in the body are either organized into sheets of connected cells (as in epithelia), or as a mesh of isolated cells, such as mesenchyme

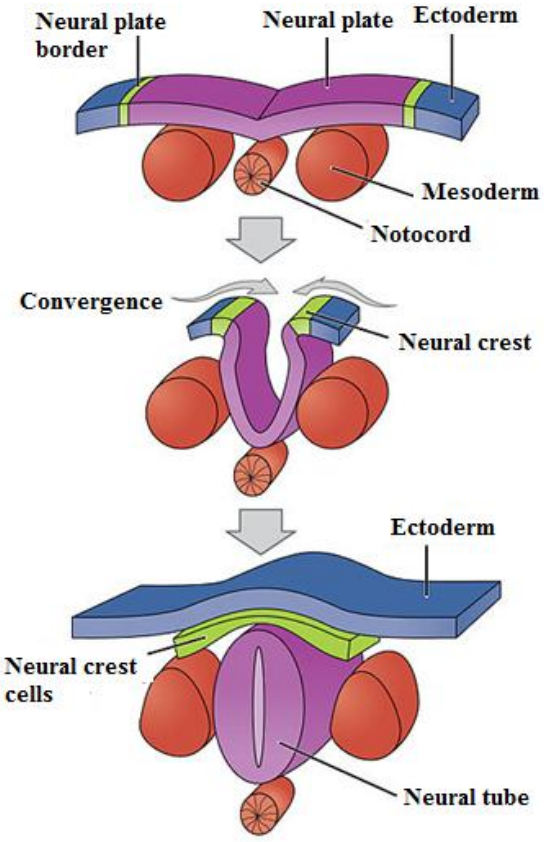

Fig. 2. Neurulation

Early development in Human

The period of the first eight weeks of embryo development is called a *prenatal* embryo period. The development after the eighth week is the *fetal period.* The human organism between the start of the ninth week and birth is a *fetus.*

About a day after fertilization, the zygote divides by mitosis, beginning a period of frequent cell division called cleavage (fig.3). The resulting early cells are called ***blastomeres***. When the blastomeres form a solid ball of 16 or more cells, the embryo is called a ***morula*** (Latin for "mulberry," which it resembles). During cleavage, organelles and molecules from the secondary oocyte's cytoplasm still control cellular activities, but some of the embryo's genes begin to function. The ball of cells hollows out and its center fills with fluid. It is now a ***blastocyst***, the "cyst" referring to the fluid-filled center. Some of the cells form a clump called the ***inner cell mass***. This is the first event that distinguishes cells from each other in terms of their relative positions, other than the inside and outside of the morula. The cells of the inner cell mass will continue developing to form the embryo.

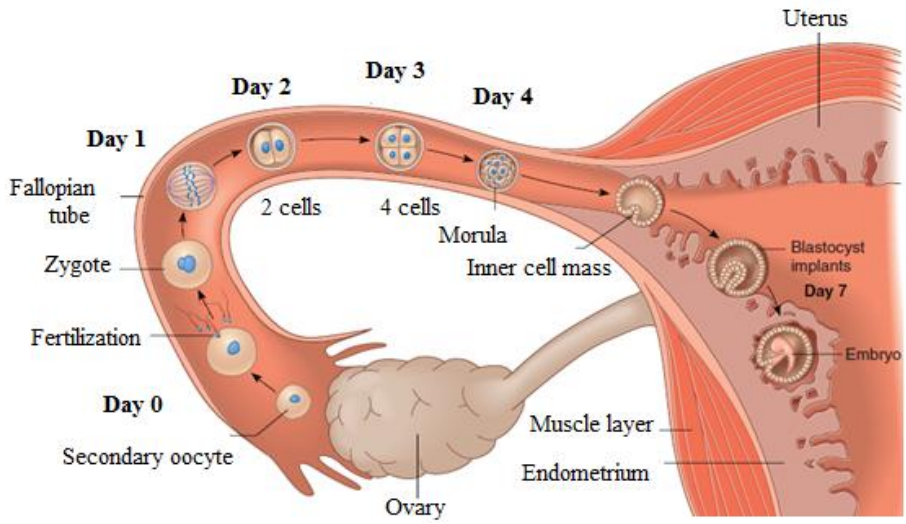

Fig. 3. Early development in Human: from ovulation to implantation

A week after conception, the blastocyst begins to nestle into the rich lining of the woman's uterus. This event, called ***implantation***, takes about a week. As it starts, the outermost cells of the embryo, called the ***trophoblast***, secrete the "pregnancy hormone," *human chorionic gonadotropin* (hCG), which prevents menstruation. hCG detected in a woman's urine or blood is one sign of pregnancy.

During the second week of prenatal development, a space called the ***amniotic cavity*** forms between the inner cell mass and the outer cells anchored to the uterine lining. Then the inner cell mass flattens into a two layered disc. The layer nearest the amniotic cavity is the ***ectoderm*** (Greek for "outside skin"). The inner layer, closer to the blastocyst cavity, is the ***endoderm*** (Greek for "inside skin"). Shortly after, a third layer, the ***mesoderm*** ("middle skin"), forms in the middle. This three-layered structure is called the primordial embryo, or the ***gastrula***. Once these three layers, called ***primary germ layers***, form, the fates of many cells become determined, which means that they are destined to develop as a specific cell type. Each layer gives rise to certain structures

Table 1 summarizes the stages of early prenatal development.

Table 1

Stages and Events of early Human prenatal development

Stage	***Time Period***	***Principal Events***
Fertilization	12-24 hours following ovulation	Oocyte fertilized; zygote has 23 pairs of chromosomes and is genetically distinct
Cleavage	30 hours to 3^{d} day	Mitosis increases cell number
Morula	3-4^{d} day	Solid ball of cells
Blastocyst	5th day through second week	Hollowed ball forms trophoblast (outside) and inner cell mass, which implants and flattens to form embryonic disc
Gastrula	End of the second week	Primary germ layers form

As the embryo develops, *supportive structures* form to support and protect it. These include ***chorionic villi***, *the* ***placenta***, *the* ***yolk sac***, *the* ***allantois***, *the* ***umbilical cord,*** *and the* ***amniotic sac*****.**

The Critical Period

The specific nature of a birth defect usually depends on which structures are developing when the damage occurs. The time when genetic abnormalities, toxic substances, or viruses can alter a specific structure is its ***critical period***.

Early embryonic development has at least three critical periods: Implantation (7^{th} day after fertilization); placentation and early organogenesis (from 3^{d} to 8^{th} weeks); enhanced brain development (from 15^{th} to 20^{th} weeks).