DEVELOPMENT AND AGING

KEY POINTS:

GESTATION

The period of time required for full development of fetus in utero is referred to as gestation (gestare = 'to carry' or 'to bear')

It can be subdivided into distinct gestational periods. The first two weeks of prenatal development are referred to as "pre-embryonic stage.

2) Embryonic stages

EMBRYO

A developing human is referred to as an embryo during weeks 3-8.

FETUS

It is named fetus from the 9th week of gestation until birth.

EMBRYONIC DEVELOPMENT

CONCEPTUS

Following fertilization, the zygote and its associated membranes, together referred to as the conceptus, continue to be projected towards the uterus by peristalsis and beating cilia.

CLEAVAGE

During its journey to the uterus, the zygote undergoes five or six rapid mitotic cell divisions. Although each cleavage results in more cells, it doesnot increase the total volume of the conceptus.

BLASTOMERE

Each daughter cell produced by cleavage is called a blastomere

MORULA

Approximately 3 days after fertilization, a 16-cell conceptus reaches the uterus. The cells that had been loosely grouped are now compacted and look more like a solid mass. The name given to this structure is the morula (morula = little mulberry).

FURTHER DIVISION

It continues to divide, creating a ball of approximately 100 cells, and consuming nutritive endometrial secretions called uterine milk while uterine lining thickens.

BLASTOCOEL

The ball of now tightly bound cells starts to secrete fluid and organize themselves

around a fluid-filled cavity, the blastocoel.

BLASTOCYST

At this developmental stage, the conceptus is referred to as blastocyst.

INNER ~~MASS~~ CELL MASS (20-30 rounded cells)

Within this structure, a group of cells forms into an inner cell mass, which is fated to become the embryo.

TROPHOBLASTS

The cells that form the outer shell are called trophoblasts (trophe = to feed' or 'to nourish'). These cells will develop into the chorionic sac and the fetal portion of the placenta (the organ of nutrient, waste, and gas exchange b.w mother and the developing offspring)

TOTIPOTENCY OF INNER CELL MASS

The inner mass of embryonic cells is totipotent during this stage, meaning that each cell has the potential to differentiate into any cell type in the human body. Totipotency lasts for only a few days before the cells' fates are set as being the precursors to a specific lineage of cells.

'HATCHING' PROCESS

As the blastocyst forms, the trophoblast excretes enzymes that begin to degrade the zona pellucida (external membrane). In a process called "hatching", the conceptus breaks free of the zona pellucida in preparation for implantation.

IMPLANTATION

At the end of the first week, the blastocyst comes in contact with the uterine wall and adheres to it, embedding itself in the uterine lining via the trophoblast cells. Thus begins the process of implantation, which signals the end of the pre-embryonic stage of development.

Implantation can be accompanied by minor bleeding. The blastocyst typically implants in the fundus of the uterus or on the posterior wall.

SYNCYTIOTROPHOBLAST

When implantation succeeds and the blastocyst adheres to the endometrium, the superficial cells of the trophoblast fuse with each other, forming the syncytiotrophoblast, a multinucleated body that digest endometrial cells to firmly secure the blastocyst to the uterine wall. In response, the uterine mucosa rebuilds itself and envelops the blastocyst.

HUMAN CHORIONIC GONADOTROPIN (hCG)

The trophoblast secretes human chorionic gonadotropin (hCG), a hormone that directs the corpus luteum to survive, enlarge, and continue producing progesterone and estrogen to suppress menses. These functions of hCG are necessary for creating an environment suitable for the developing embryo. As a result of this increased production, hCG accumulates in the maternal blood stream and is excreted in the urine. Implantation is complete by the middle of the second week.

Just a few days after implantation, the trophoblast has secreted enough hCG for an at-home urine pregnancy test to give a positive result.

FORMATION OF EXTRA-EMBRYONIC MEMBRANES

During the second week of development, with the embryo implanted in the uterus, cells within the blastocyst starts to organize into layers. Some grow to form the extra-embryonic membranes needed to support and protect the growing embryo: the amnion, the yolk sac, the allantois, and the chorion.

EMBRYONIC DISK

At the beginning of the second week, the cells of the inner cell mass form into a two-layered disc (epiblast and hypoblast) of embryonic cells, and a space - the amniotic cavity - opens up b.w it and the trophoblast.

AMNION

Cells from the upper layer of the disc (the epiblast) extend around the amniotic cavity, creating a membranous sac that forms into the amnion by the end of second week

AMNIOTIC FLUID

The amnion fills with amniotic fluid and eventually grows to surround the embryo. Earlyer in development, amniotic fluid consists almost entirely of a filterate of

maternal plasma, but as the kidneys of the fetus begin to function at approximately the eighth week, they add urine to the volume of amniotic fluid. Floating within the ~~embryonic~~ amniotic fluid, the embryo - and later, the fetus - is protected from trauma and rapid temperature changes.

YOLK SAC

On the ventral side of the embryonic disc, opposite to the amnion, cells in the lower layer of the embryonic disc (the hypoblast) extend into the blastocyst cavity and form a yolk sac. The yolk sac supplies some nutrients absorbed from the trophoblast and also provides primitive blood circulation to the developing embryo for the second and third week of development.

When placenta takes over nourishing the embryo at week 4, the yolk sac has been greatly reduced in size and its man function is to serve as the source of blood cells and germ cells (cells that will give rise to gametes)

ALLANTOIS

During week 3, a finger-like outpocketing of the yolk sac develops into allantois, a primitive excretory duct of the embryo that will become part of the urinary bladder. Together, the stalks of the yolk sac and allantois establish the outer structure of umbilical cord

CHORION

The last of the extra-embryonic

membranes is the chorion, which is the one membrane that surrounds all others. Chorion relates to the growth and development of placenta.

GASTRULATION

As the third-week of development begins, the two-layered disc of cells becomes a three-layered disc through the process of gastrulation, during which the cells transition from totipotency to multipotency.

PRIMITIVE STREAK

The embryo, which takes the shape of an oval-shaped disc, forms an indentation called the primitive streak along the dorsal surface of the epiblast.

GROWTH FACTORS

A node at the caudal or "tail" end of the primitive streak emits growth factors that direct cells to multiply and migrate. Cells migrate towards and through the primitive streak and then move laterally to create two new layers of cells.

ENDODERM

The first layer is the endoderm, a sheet of cells that displaces the hypoblast and lies adjacent to the yolk sac.

MESODERM

The second layer of cells fills in as the middle layer, or mesoderm

ECTODERM

The cells of the epiblast that remain (not having migrated through the primitive streak) become the ectoderm.

DEVELOPMENT OF GERM LAYERS

Each of the germ layers will develop into specific structures in the embryo. Whereas the ectoderm and endoderm form tightly connected epithelial sheets, the mesodermal cells are less organized and exist as a loosely connected cell community.

* The ectoderm give rise to cell lineages that differentiate to become the central and peripheral nervous systems, sensory organs, epidermis, hair and nails.

* Mesodermal cells ultimately become the skeleton, muscles, connective tissue, heart, blood vessels, and kidneys.

* The endoderm goes on to form the epithelial lining of the gastrointestinal tract, liver, and pancreas, as well as the lungs.

* Ectoderm layer becomes : 1) ~~Digits~~ Hair, 2) Nails 3) Skin 4) Nervous System
* Mesoderm layer becomes : 1) Circulatory System 2) Lungs (epithelial layers) 3) Skeletal System 4) Muscular System
* Endoderm Layer becomes : 1) Digestive system 2) Liver 3) Pancreas 4) Lungs (inner ~~tract~~ layers)

PLACENTATION

DECIDUAL CELLS

During the first several weeks of development, the cells of the endometrium - referred to as decidual cells - nourish the nascent embryo.

PLACENTA

During prenatal weeks 4-12, the developing placenta gradually takes over the role of feeding the embryo, and the decidual cells are no longer needed.

The mature placenta is comprised of tissues derived from the embryo, as well as maternal tissues of the endometrium.

UMBILICAL CORD

The placenta connects to the conceptus via the umbilical cord, which carries deoxygenated blood and wastes from the fetus through two umbilical arteries; nutrients and oxygen are carried from the mother to the fetus through the single umbilical vein.

The umbilical cord is surrounded by the amnion, and the spaces within the cord around the blood vessels are filled with Wharton's jelly, a mucous connective tissue.

MATERNAL PORTION OF PLACENTA

The maternal portion of the placenta develops from the deepest layer of the endometrium, the decidua basalis.

EMBRYONIC PORTION OF PLACENTA CHORION

The maternal portion of the placenta, the syncytiotrophoblast and the underlying cells of the trophoblast (cytotrophoblast cells) begin to proliferate along with a layer of extra embryonic mesoderm cells. These form the chorionic membrane, which envelops the entire conceptus as the chorion.

CHORIONIC VILLI

The chorionic membrane forms finger-like structures called chorionic villi that burrow into the endometrium like tree roots, making up the fetal portion of the placenta.

The cytotrophoblast cells perforate the chorionic villi, burrow further into the endometrium, and remodel maternal blood vessels to augment maternal blood flow surrounding the villi.

BLOOD VESSELS

Meanwhile, fetal mesenchymal cells derived from the mesoderm fill the villi and differentiate into blood vessels, including the three umbilical blood vessels that connect the embryo to the developing placenta.

DEVELOPMENT OF PLACENTA

The placenta develops throughout the embryonic period and during the first several weeks of the fetal period; placentation is complete by weeks 14–16.

FUNCTION

As a fully developed organ, placenta provides ~~nutrients~~ nutrition and excretion,

respiration and endocrine function. It receives blood from the fetus through the umbilical arteries. Capillaries in the umbilical arteries chrionic villi filter fetal wastes out of the blood and return clean, oxygenated blood to the fetus through the umbilical vein.

Nutrients and oxygen transferred from maternal blood surrounding the villi through the capillaries and into the fetal bloodstream. Some substances move across the placenta by simple diffusion, Oxygen, CO_2 and only other lipid-soluble substances take this route. Other substances move across by facilitated diffusion. This includes water-soluble glucose. The fetus has a high demand for amino acids and iron, and those substances are moved across the placenta by active transport.

SEPARATION OF MATERNAL AND FETAL BLOOD

Maternal and fetal blood doesnot commingle but blood cells cannot move across the placenta. This separation prevents the mother's cytotoxic T-cells from reaching and subsequently destroying the fetus, which bears "non-self" antigens.

Although blood cells are not exchanged, the chorionic villi provide ample surface area for the two-way exchange of substances b.w maternal and fetal blood. The rate of exchange increases through gestation as the villi become thinner and increasingly branched.

NEURULATION

Following gastrulation, rudiments of the CNS develop from the ectoderm in the process of neurulation.

NEURAL PLATE

Specialized neuroectodermal tissues along the length of the embryo thicken into the neural plate.

NEURAL FOLD

During the fourth week, tissues on either side of the plate fold upward into a neural fold.

NEURAL TUBE

The two folds converge to form the neural tube.

NOTOCHORD

The tube lies atop a rod-shaped, mesoderm-derived notochord, which eventually becomes the nucleus pulposis of intervertebral discs.

SOMITES

Block-like structures called somites form on either side of the tube, eventually differentiating into the axial skeleton, skeletal muscle, and dermis.

VESICLES

During the fourth and fifth weeks, the anterior neural tube dilates and subdivides

to form vesicles that will become the brain structures.

EMBRYONIC FOLDING

The embryo, which begins as a flat sheet of cells, begins to acquire a cylindrical shape through the process of embryonic folding. The embryo folds laterally and again at either end, forming a C-shape with distinct head and tail ends. The embryo envelops a portion of the yolk sac, which protrudes with the umbilical cord from what will become the abdomen. The folding essentially creates a tube, called the primitive gut, that is lined by the endoderm. The amniotic sac, which was sitting on top of the flat embryo, envelops the embryo as it folds.

ORGANOGENESIS

Like the CNS, the heart also begins its development in the embryo as a tube-like structure, connected via

Within the first 8 weeks of gestation, a developing embryo establishes the rudimentary structures of all its organs and tissues from the ectoderm, mesoderm, and endoderm. This process is called organogenesis.

DEVELOPMENT OF HEART

Like the CNS, the heart also begins its development in the embryo as a tube-like structure, connected via capillaries to the chorionic villi. Cells of the primitive tube-shaped heart are

capable of electrical conduction and contraction. The heart begins beating in the beginning of the fourth week, although it doesnot actually pump embryonic blood until a week later, when the oversized liver has begun producing RBCs (This is a temporary responsibility of the embryonic liver that the bone marrow will assume during fetal development)

WEEK 4-5

During weeks 4-5, the eye pits form, limb buds become apparant, and the rudiments of the pulmonary system are formed

SIXTH WEEK

During the sixth week, uncontrolled fetal limb movements begin to occur. The gastrointestinal system develops too rapidly for the embryonic abdomen to accomodate it, and the intestines temporarily loop into the umbilical cord. Paddle-shaped hands and feet develop fingers and toes by the process of apoptosis, which causes the tissues b.w the fingers to disintegrate.

WEEK 7

By week 7, the facial structure is more complex and includes nostrils, outer ears, and lenses

WEEK 8

By the eighth week, the head is nearly as large as the rest of embryo's body, and all major brain structures are in phase. The external genitalia is apparant, but

at this point, male and female embryos are indistinguishable. Bone begins to replace cartilage in the embryonic skeleton through the process of ossification.

By the end of the embryonic period, the embryo is approximately 3cm from crown to rump and weighs approximately 8g