

Embryogenesis and Development

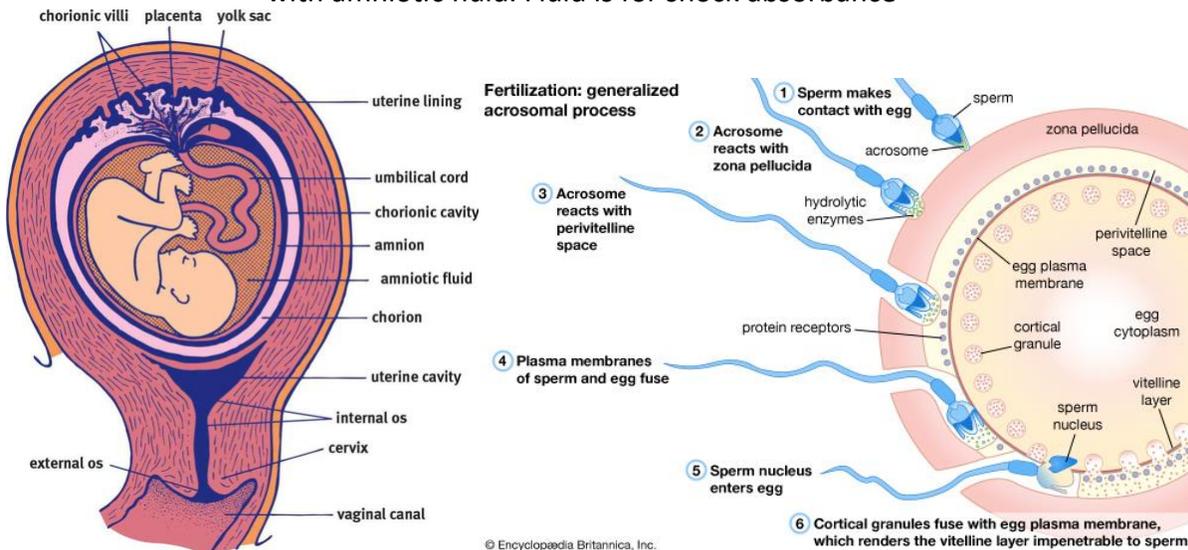
Early development stages

- Fertilization
 - Secondary oocyte is ovulated from follicle on day 14
 - Oocyte travels down fallopian tube where it can be fertilized for up to 24 hrs.
 - Fertilization usually occurs in the **ampulla**, the widest part of the tubes.
 - Sperm meets secondary oocyte and releases acrosomal enzymes
 - enzymes allow sperm to penetrate corona radiata and zona pellucida
 - **Acrosomal Apparatus** forms when sperm comes into direct contact with oocyte cell membrane.
 - **Cortical reaction**: happens once the sperm has penetrated the membrane. This is a release of calcium ions.
 - Calcium depolarized membrane (doesn't allow more sperm to fertilize egg) and increases the metabolic rate of the **Zygote**.
 - **Fertilization Membrane**: Depolarized and impenetrable membrane
 - Dizygotic or Fraternal Twins: two different eggs by two different sperm. Each zygote goes through its process. Sometimes they overlap.
 - Monozygotic or Identical Twins: Single Zygote splits into two.
 - Conjoined Twins: Occur if division is incomplete.
 - Are classified in the number of structures the twins share and this depends on the stage at which the Zygote splitting occurs.
- Cleavage: Rapid mitotic cell division while the zygote is in the process of moving to the uterus.
 - First cleavage creates embryo since the Zygote is not unicellular anymore.
 - Total size does not change as division occur
 - This increases the nuclear-to-cytoplasm ratio and the surface area to volume ratio. These increase the area for gas and nutrient exchange.
 - Indeterminate cleavage: results in cells that can still develop into complete organisms. Think identical twins
 - Determinate Cleavage: These cells are committed to **differentiating** into a certain type of cell.
- Blastulation: After several divisions the embryo becomes a solid mass of cells known as a **morula**.
 - The morula undergoes blastulation so that it then forms a **blastula**, which is a hollow ball of cells with a fluid-filled inner cavity called the **blastocoel**.
 - Blastocyst: Is the mammalian blastula and consists of the trophoblast and the inner cell mass.
 - Trophoblast Cells: surrounds blastocoel and gives rise to the chorion and the placenta. Specialized to create interface between maternal blood supply and developing embryo.
 - Inner Cell Mass: protrudes into the blastocoel and develops into organism

- Implantation: blastula moves through the fallopian tube to the uterus and burrows itself into the endometrium.
 - Chorion: extraembryonic membrane that develops into the placenta.
 - Chorionic Villi: formed from the trophoblasts and function to penetrate the endometrium by using fingerlike projections.
 - Develop into placenta which supports the exchange of maternal-fetal gases.
 - Embryo is connected to placenta through **umbilical cord**. Which has two arteries and one vein.
 - Vein carries nutrient rich blood from placenta to embryo. Arteries take waste and deoxygenated blood to placenta.

Remnants form the umbilical Cord

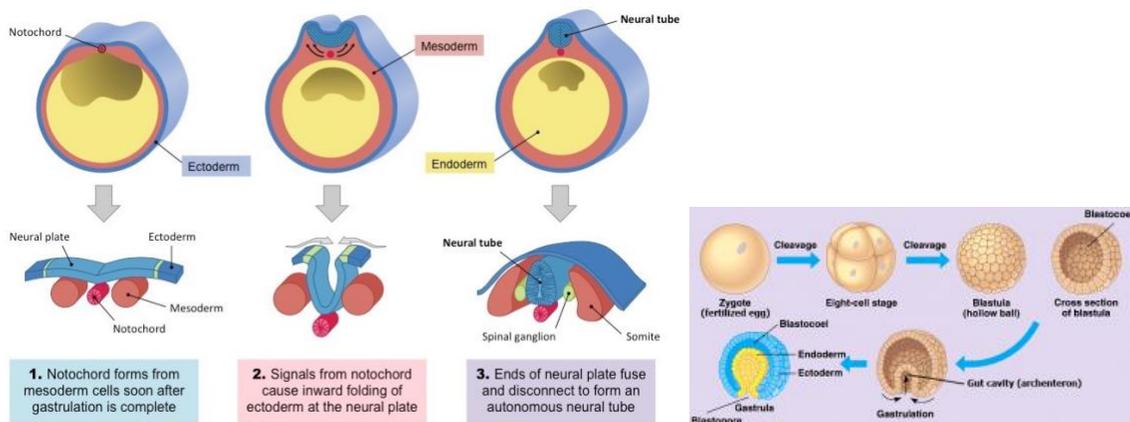
- Yolk Sac: embryo is supported through this until the placenta is functions, and it is also the site of early blood cell development.
- Allantois: involved in early fluid exchange between yolk sac and embryo.
- Amnion: surrounds the allantois and is a thin, tough membrane filled with amniotic fluid. Fluid is for shock absorbance



- Gastrulation: generation of three distinct cell layers. Begins with small indentation in the blastula. Invagination continues increasing and eventually eliminates the blastocoel.
 - Gastrula: The blastocyst after it has gone through invagination.
 - Archenteron: is the actual invagination itself and this develops into the gut
 - Blastopore: is the opening of the archenteron
 - This develops into the anus for **deuterostomes** (humans)
 - This develops into the mouth for **protostomes**
- Primary Germ Layers
 - Ectoderm: outermost layer and generates the **integument** (includes the epidermis, hair, nails) and the **epithelia** of the nose, mouth and lower anal canal. And the lens of the eye, nervous system and the inner develop from here
 - Mesoderm: develops into systems such as musculoskeletal, circulatory, and most of the excretory system. Also give rise to the **gonads** and to the muscular and

connective tissue layers of the digestive and respiratory systems and the adrenal cortex.

- **Endoderm:** forms epithelial lining of digestive and respiratory tracts. Additionally, the pancreas, thyroid, bladder and distal urinary tract and liver are derived from this tissue.
- **Differentiation: Selective Transcription** is used by the genomes to differentiate the function of cells. Only the genes needed for that particular cell type are transcribed.
 - **Induction:** ability of one group of cells to influence the fate of nearby cells. **Inducers** are chemical substances that diffuse from the organizing cell to the responsive cells. The inducers mediate this process.
- **Neurulation:** development of the nervous system begins when three germ layers are formed.
 - Nervous system is derived from the ectoderm.
 - **Notochord** is a rod of mesodermal cells that act like a primitive spine. This induces a group of ectodermal cells to slide inwards to form **neural folds**, which surround a **neural groove**.
 - Neural folds grow towards one another until they form the **neural tube** which eventually gives rise to the CNS.
 - **Neural Crest Cell** are found at the tip of the neural fold and these migrate out to form the PNS.
 - Ectodermal cells migrate over the neural tube and crests to cover the nervous system.



- **Teratogens** are substances that can interfere with the development of the fetus. Things such as alcohol, drugs, hydrocarbons.
 - Mothers maternal health can also influence development. Think diabetes, sugar intake, folic acid.

Mechanisms of Development

Cell Specialization

37 trillion cells which are organized into tissues that are organized into organs within systems.

Specification and Determination

Cell is reversibly designated to a specific cell type

- Followed by **Determination** which is the commitment of the cell to having a particular function. This can occur over multiple pathways.
 - Presence of certain proteins and mRNA may result in this
 - May occur due to secretion of morphogens.

Differentiation

Occurs after determination and includes changing the structure, function, biochemistry of the cell to match the cell type.

- **Stem Cells** are cells which give rise to other cells. Have no differentiated.
 - **Potency:** the number of tissues that a particular cell can differentiate into.
 - **Totipotent:** greatest potency, and include embryonic stem cells. Can differentiate into any cell type
 - **Pluripotent:** totipotent cells begin to differentiate into three germ layers. These cells can differentiate into any cell type except those found in the placental structures.
 - **Multipotent:** can differentiate into multiple types of cells with a group.

Cell to Cell Communication

- A **responder** cell must be **competent** in order to be induced.
- Autocrine: signals act on the same cell that secreted the signal in the first place
- Paracrine: signals act on cells in the local area
- Juxtacrine: signals do not usually involve diffusion, but rather feature a cell directly stimulating receptors of the adjacent cell.
- Endocrine: signals involve secretion of hormones that travel through the bloodstream.

Inducers

Are commonly **growth factors** which are peptides that promote differentiation and mitosis in certain tissues. These only function on specific cell types or in certain area which depends on the competence of the cells.

- **Reciprocal development:** Most tissues will be exposed to multiple inducers during the course of development.
- Main methods of signaling involve using concentration gradients. Locations closer to the origin will be subject to higher concentrations of a morphogens.

Cell Migration, Cell Death, and Regeneration

- Cell Migration: Is the ability of the cell to disconnect from its adjacent structures and migrate to their anatomically correct locations.
- Cell Death: Known as **apoptosis** and is needed at certain stages of development.
 - **Apoptotic Bulbs:** self-contained protrusions which can then be broken apart into **apoptotic bodies** and digested by other cells.
 - Allows for the recycling of material since cells are digested by other cells
 - Blebs are contained in membranes so harmful substances are not secreted into the ECF.
 - Necrosis: Cell dies as a result of injury and internal substances can be leaked.
- Regeneration: the capacity to regrow certain parts of the body is known as the **regenerative capacity**.

- Complete Regeneration: is when the stem cells can migrate to the necessary part of the body and start regrowth.
- Incomplete Regeneration: Newly formed tissue is not identical in structure or function to the tissue that has been injured or lost
- Humans typically exhibit incomplete regen. However, this capacity is strongly dependent on the type of tissue.

Senescence and Aging

- Senescence is biological aging which disrupts metabolism and eventually results in death.
 - At cellular level, this is the failure of cells to divide normally after 50 divisions. This may be due to shortened **telomeres**. Telomeres are the caps on the end of chromosomes and help prevent the DNA from unravelling. They shorten every round of DNA synthesis since they are difficult to replicate.
 - Telomerase is able to synthesize the ends of chromosomes and may play a part in why cancer cells survive.

Fetal Circulation

- Placenta is the organ where nutrients, gas and waste changes occur between the fetus and the mother. The placenta uses diffusion to move these materials since the blood should now be mixed in case the mother has a different blood type than the fetus.
- Diffusion usually runs along the oxygen gradient. Additionally, they also contain **fetal hemoglobin** which has a higher affinity to oxygen than adult hemoglobin.
- Placenta barrier also provided immune protection. Antibodies cross over in order to protect the fetus from possible exposure *in utero*.
- Umbilical Arteries carry blood away from the fetus and towards the placenta.
- Umbilical Veins carry blood towards fetus from the placenta. Carry oxygenated blood
- Lungs and liver do not serve important functions in the fetus until birth. The placenta mainly does their job.
 - Since they aren't used in development, are typically underdeveloped and sensitive to high blood pressures
 - **Shunts** are created to actively direct blood away from these organs when BP gets too high.

Shunts for Lungs

- **Foramen Ovale**: one-way valve that connects right atrium to left atrium. Allows blood to flow directly from right atrium to left atrium. Right side is at a higher pressure before birth (switches at birth)
- **Ductus arteriosus**: leftover blood from form pulmonary artery to the aorta.
- **Ductus Venous**: shunts blood from placenta directly into the vena cava. Liver gets blood from smaller arteries.

Gestation and Birth

Gestation lasts 280 days

First Trimester

- Major organs begin to develop. Heart begins to beat at 22 days. Eyes, gonads, limbs and liver start to form soon after.
- At five weeks, embryo is 10 mm and at six weeks embryo is 15 mm.
- Bone structure begins forming at seventh week
- End of eighth week: most organs have formed, brain is developed and embryo is known as a **fetus**.
- End of third month, fetus is 9 cm long.

Second Trimester

- Undergoes tremendous amount of growth, begins to move, and takes on human appearance in face toes and fingers.
- At the end of the sixth month, fetus measures 30 to 36 cm long

Third Trimester

- Seventh and eighth months are characterized by continued rapid growth and further brain development.
- Antibodies transported by highly selective active transport. Most active in ninth month
- Growth rate slows and fetus becomes less active since it has less room to move around.

Birth

- Vaginal Childbirth or **parturition** is accomplished by rhythmic movements of the smooth uterine lining which are controlled by the **prostaglandins** and the peptide hormone **oxytocin**.
- First the cervix thins out and amniotic sac ruptures (water breaking). Strong uterine contractions result in birth of fetus. **Afterbirth** is the last step and is the expulsion of the placenta and umbilical cord.

The Blastocyst

