NORTH OSSETIAN STATE MEDICAL ACADEMY

BIOLOGY DEPARTMENT

ONTOGENESIS

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INDIVIDUAL DEVELOPMENT OF AN ORGANISM.

Definition of ontogenesis. The periods of ontogenesis.

Ontogenesis is the origination and development of an organism, usually from the time of fertilization of the egg to the organism's death.

The periods of ontogenesis.

Ontogenesis of multicellular organisms divides into 3 periods: **progenesis, embryonic** and **postembryonic periods.**

Progenesis is the process which results in gametes formation in gametogenesis.
Embryonic period or embryogenesis is from the zygote formation to the birth or hatching out.
Postembryonic period is from the hatching out or birth to the death.

GAMETOGENESIS.

The process of the formation and development of haploid gametes from undifferentiated diploid germ cells in the gonads for sexual reproduction is called gametogenesis.

The process of formation of sperm cells is called spermatogenesis, and the process of formation of eggs is called oogenesis.

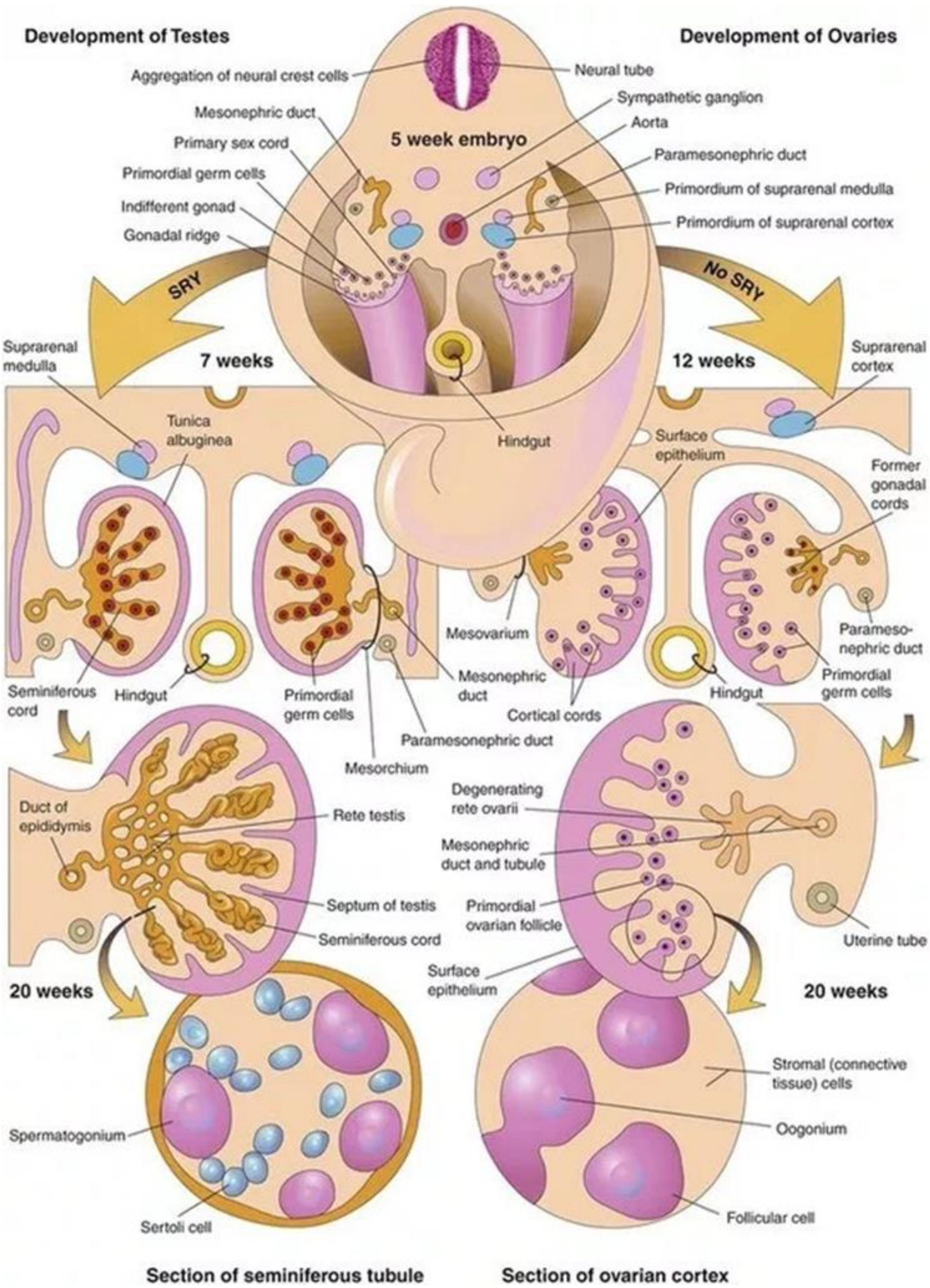
Both the process is basically similar, though minor differences exist. Both involve three important phases:

1) ***multiplication phase***, in which the germ cells of the gonads multiply by mitosis;
2) ***growth phase***, in which the germ cells growth is size;
3) ***maturation phase***, in which meiosis takes place to produce the gametes.

But spermatogenesis include additional phase – spermiogenesis.

Gametogenesis actually starts at the 6^{th} week of the embryonic period when cells from the wall of yolk sac migrate to a structure known as gonadal ridge. These migrating cells are known as gonocytes. In gonadal ridge gonocytes are become surrounded by the cells of the ridge and provide transformation it structure to testes or to ovaries. If the cells that contain Y chromosome (SRY gene), the gonadal ridge forms tubules known as somniferous tubules, whereas, in female, the gonadal ridge forms solitary follicles with the gonocytes in the middle surrounded by cells of the gonadal ridge knows as follicular cells.

The gonocytes undergo multiple mitotic divisions on the multiplication phase. In males, these division stops and cells remain silent until puberty. In females, the gonocytes increase in numbers till there is about 6 million in each ovary. They pass grow phase. But the maturation phase is arrested at prophase I (on the dictyotene phase) until puberty. This number of oocytes starts to degenerate and by birth, they will be about 2 million in each ovary. By the time of puberty, this number has reduced to 50,000 in each ovary.



SPERMATOGENESIS

Spermatogenesis starts at puberty. Normal spermatogenesis is provided by Sertoli or nurse cells, and by Leydig cells. During spermatogenesis, the developing sperms keep their heads embedded in the Sertoli cells to draw nourishment from them. And Leydig cells produce the male hormone testosterone, that induces spermatogenesis.

Spermatogenesis consist of 4 phases:

1) In multiplication phase the germ cells; which are called ***spermatogonia*** proliferated by mitotic divisions from the primary germ cells of the germinal epithelium lining the seminiferous tubules. The spermatogonia have nuclei which contain diploid number of chromosomes. The spermatogonia increase their population by repeated mitotic divisions so that, each newly-formed spermatogonium possesses the same number of chromosomes.

2) <u>Growth phase.</u> This phase is similar with interphase. During this phase growth of cells and replication of DNA occur. Now the germ cells are named the ***primary spermatocytes.*** The amount of heredity material is 2n4c.

3) <u>Maturation phase.</u> The primary spermatocytes then enter into the maturation phase, where each cell divides by meiosis. Meiosis consists of two divisions. In the result of firth meiotic division each primary spermatocyte divides into two cells of equal size, which are called ***secondary spermatocytes***. The amount of heredity material of this cells is n2c.

The secondary spermatocytes soon undergo the second meiotic division and produce ***spermatids.*** The amount of heredity material of this cells is nc.

4) <u>Spermiogenesis</u> is the process of morphological transformation of spermatids into ***spermatozoon*** without further cell division.

The spermatids are small cells that undergo several modifications during spermiogenesis as follows:

- The nucleus becomes condensed so as to occupy a small space
- It develops flagellum
- The Golgi body produces multiple numbers of lysosomes which fuse together to form a large structure known as acrosome

Development of a sperm cell takes about 2 months. The fully formed sperms become free in the cavity of the seminiferous tubule. From here, they pass via vasa efferentia into the epididymis for temporary storage. During this period they acquire mobility, perhaps under the influence of testosterone.

OOGENESIS

It is a process of maturation of female gametes, from oogonia to mature ovum. It takes place in the ovaries.

Oogenesis consist of 3 phases:

1) <u>In multiplication phase</u> the germ cells; which are called ***oogonia*** proliferated by mitotic divisions from the primary germ cells. The oogonia have nuclei which contain diploid number of chromosomes. The But unlike spermatogenesis which only begins at puberty, the production of ova in females begins before birth and is completed only after fertilization.

2) <u>Growth phase.</u> By the 3 to 7-th month of embryonic period, all the oogonia stop to divide and are transformed into primary oocytes. During this phase growth of cells and replication of DNA occur. The amount of heredity material of primary oocytes is 2n4c.

Each primary oocyte is surrounded by a layer of flattened ovarian epithelial cells, known as the follicular cells. They provide nourishment of oocyte and secret the steroid hormone estradiol. A primary oocyte, together with follicular cells forms the primary ovarian follicle or primordial follicle. As a rule, each follicle contains one oocyte.

3) <u>Maturation phase.</u> The primary oocytes enter into the maturation phase, where each cell divides by meiosis. But in dictyotene phase the meiosis is arrested until puberty. At this time hypophysis starts to secret follicle stimulating hormone which stimulates the growth of ovarian follicles. The primary oocyte from the dictyotene stage completes the first meiotic division. The result of this division is the formation of the two daughter cells that have amount of heredity material n2c. One cell is large, receives abundant cytoplasm of the mother cell and is known as the ***secondary oocyte*** the other cell is small carrying scanty amount of cytoplasm and persists as ***the first polar body.***

During this time follicular cells secret fluid with estradiol. Because of this the follicle is enlarged and become mature follicle named as Graafian follicle. It appears beneath the surface of the ovary. When a fully formed Graafian follicle ruptures on the surface of the ovary, it is called ***ovulation.***

The secondary oocyte, surrounded by the zona pellucida and the corona radiata, is shed from the ovary and enters the uterine tube through the fimbriated end.

The secondary oocyte immediately enters in the process of second meiotic division. But at the metaphase II division is stopped again until a sperm fuses with the oocytes.

If fertilization happens the secondary oocyte completes the second meiotic division and results in the formation of two unequal daughter cells, each having nc. The large cell presenting abundant cytoplasm is known as ***the mature ovum***, and the small cell forms ***the second polar body***, which appears in the per vitelline space. The first polar body also divided into two second polar bodies. Thus, the result of two meiotic divisions is: ***one mature ovum and three second polar bodies.*** All polar bodies are small cells. They have no role in oogenesis they eventually degenerate.

In absence of fertilization, the secondary oocyte does not complete the second meiotic division and degenerates as such within 24-48 hours after ovulation.

Differences between Spermatogenesis and Oogenesis.

Spermatogenesis	Oogenesis
1. It occurs in the testes	1. It occurs in the ovaries
2. Growth phase is short that spermatocytes are only twice the size spermatogonia. Spermatozoons are minute, yolkless, motile.	2. Growth phase is very long that oocytes are much larger than oogonia. Oocytes accumulate yolk for nutrition of future embrio. Ova are much larger then spermatozoons, often with yolk and non-motile.
3. One spermatocyte forms 4 similar spermatids	3. One oocyte forms 1 ovum and 3 polar bodies.
4. Spermatogenesis is a continuos process.	4. Oogenesis is discontinuos process. It has 2 pauses (at dictyotene and metaphase II)
5. Spermatogenesis consist of 4 phases.	5. Oogenesis consist of 3 phases.
6. Spermatogenesis appears in the seminiferous tubules of testes at purberty.	6. Oogenesis starts in the ovaries (prophase of meiosis I) in the 3-th month of embryonic period.

DISTINCTIONS GAMETES FROM SOMATIC CELLS.

1. Gametes have a haploid number of chromosomes.
2. Gametes have particular nuclear-cytoplasmic ratio.
3. Gametes have low metabolism.

MORPHOLOGICAL STRUCTURE OF OVUM AND SPERMATOZOON.

SPERMATOZOON

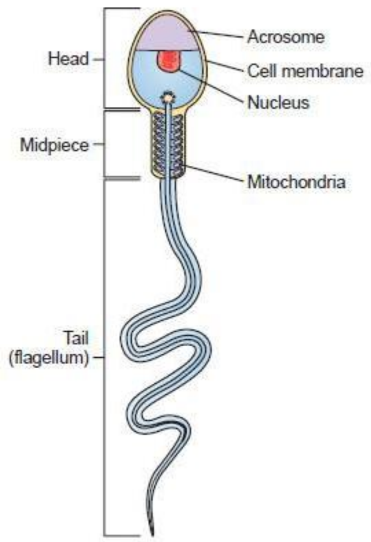
A spermatozoon consists of four parts: head, neck, middle piece and tail.

Head. The head varies in form in different species. It is flat and oval in human sperm. It is composed of a large nucleus and a small acrosome. The nucleus is very compact and consists only of condensed chromosomes. Acrosome lies at the tip of the nucleus. It is formed from the Golgi apparatus. It contains hydrolytic enzymes, and it used to contact and penetrate the egg in fertilization.

Neck. The neck is very short and contains centrosome. Centrosome provides formation of microtubules of tail and plays a role in first division of zygote.

Middle piece. The middle piece contains many mitochondria which produce ATP needed for movement of sperm cell. The middle piece is the power house of a sperm. The amount of energy is limited. If a sperm fails to contact an ovum within a specific period, it depletes its energy and dies.

Tail. The tail is very long, it formed of cytoplasm. The spermatozoon swim about by vibrating their tail in a fluid medium in search of ova.



OVUM

Ova have a round or oval shape from 60μm to several cm in diameter (human ovum - about 130 μm). Its size varies in different animals depending upon the amount of yolk in it. They are immovable, have haploid nuclei contain organelles and store nutrients (yolk). Their cytoplasm is species-specific. The peripheral cytoplasm layer of the human ovum contains cortical granules with proteolytic enzymes, polysaccharides and proteins.

The ovum shows polarity. Its side which contacts with polar bodies is called ***animal pole***. The opposite site is termed ***vegetal pole***.

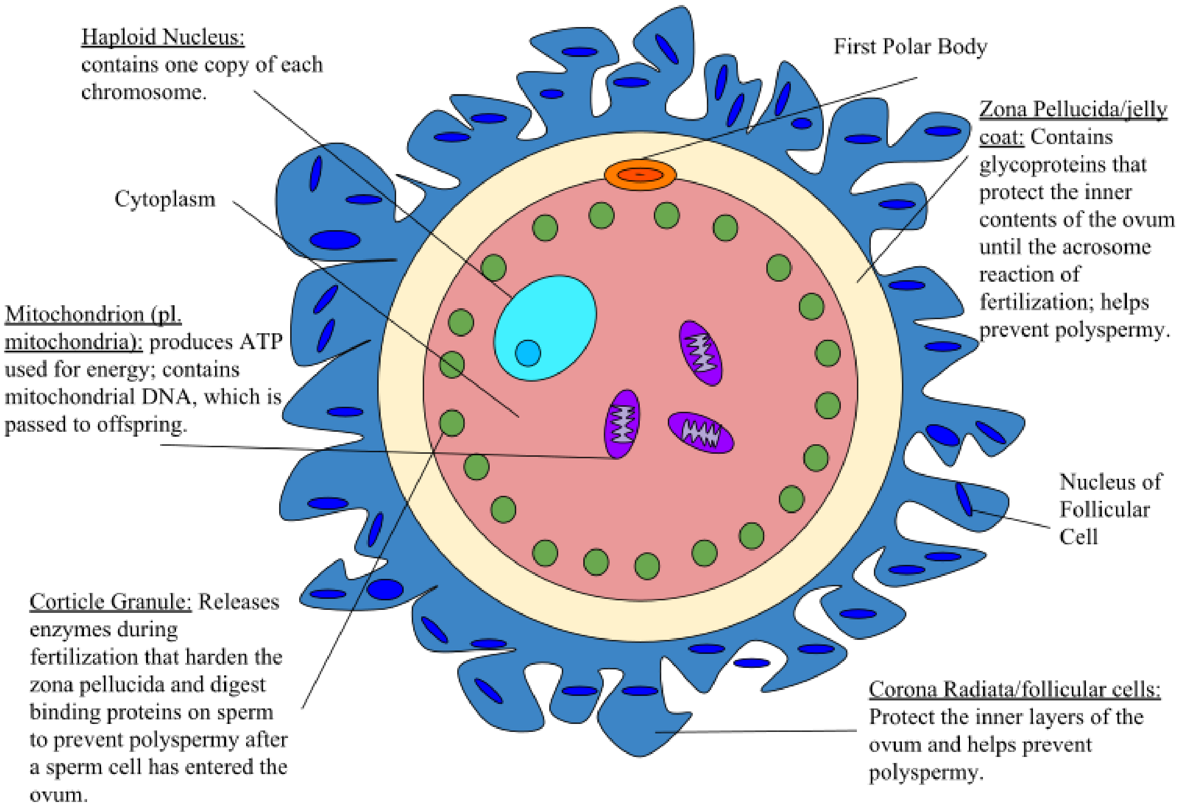
The human's ovum is enclosed by two additional egg coats:

1) inner thin, transparent, noncellular ***zona pellucida*** composed of protein and sugars, and probably secreted by ovum (primary membrane). This membrane prevents of polyspermy. Also it holds the cells during cleavage together.

2) outer thick ***corona radiata*** formed of radially elongated follicular cells (secondary membrane).

A narrow ***periviteline space*** exists between the zone pellucida and plasma membrane.

The eggs of many animals have tertiary membrane. It is a protective membrane, which may be soft and jellylike or hard and calcified, like shells. This membrane formed by epithelial cells of genital tract and needed to protect embryo in external environment.



Classification of Egg

On the Basis of the Amount of yolk

Eggs are grouped into three types on the basis of the amount of yolk present in them.

1. **Alecithal egg**: When the egg contains no yolk, it is called alecithal egg. (the eggs of eutherian mammals)
2. **Microlecithal (oligolecithal) egg:** This egg contain small amount of yolk (Amphioxus, Tunicates)
3. **Mesolecithal egg:** In such type of egg the amount of yolk present is moderate (Amphibious)
4. **Macrolecithal or Megalecithal or Polylecithal Egg.** The egg contains large amount of yolk (Reptiles, Birds, Egg laying mammals).

On the Basis of the distribution of yolk

1. **Isolecithal or Homolecithal** Egg: In isolecithal eggs, the very little amount of yolk present is uniformly distributed throughout the ooplasm (Amphioxus, mammals).
2. **Telolecithal Egg:** In eggs containing moderate or large quantity of yolk, the distribution of yolk is not uniform. lt is concentrated more towards the vegetal pole.

Telolecithal eggs may further classified into 2 types:

a). **Moderately Telolecithal** -This type of egg contains a moderate quantity of yolk which is distributed unevenly. Due to high concenteration of yolk in the vegetal pole, the nucleus is shifted more towards the animal pole (amphibian egg).

b). **Extremely Telolecithal** -In this type of egg, due to the heavy deposition of yolk, the entire vegetal hemisphere and a major portion of the animal hemisphere are occupied by yolk which is separated of cytoplasm. The ooplasm and nucleus are displaced towards the animal pole (reptilian and bird’s eggs).

3. **Centrolecithal Egg**. They are relatively large and elongate and have a very great amount of yolk at the center of the cell. The nucleus lies at the geometric center of the yolk mass, surrounded by a small amount of cytoplasm. A thin cytoplasmic layer covers the surface of the yolk. Fine strands of cytoplasm extend from the peripheral layer to the zone occupied by the nucleus. Such type of eggs are inherent for arthropods.

FERTILIZATION

Fertilization means the fusion of two mature germ cells, an ovum and a spermatozoon, to form a mono-nucleated single cell, the zygote. In mammals the fusion takes place usually in the ampulla or lateral third of the uterine tube.

Processes that provide contact of female and male gametes is **insemination**.
Types of the insemination:

a) Internal (in land animals, including humans) - male gametes are brought into the reproductive tracts of a female during the sexual intercourse
b) External (in aquatic animal) - gametes are excreted into the water where their fusion occurs.

The insemination is followed by fertilization: fusion of gametes with zygote formation.
A contact of gametes is provided by:
– movement of spermatozoa and contraction of wall of female reproductive tracts;
– ovum excrete gamones to which spermatozoa have positive chemotaxis.

Three substances have been discovered in the sexual products of female animals.

- The first is gynogamone I, which intensifies and prolongs the motility of spermatozoa; it is antagonistic toward androgamone I, a thermostable, nonprotein substance of low molecular weight.
- Gynogamone II (fertilizin) causes agglutination of the spermatozoa. It is an indispensable element in the union of spermatozoon and ovum; however, according to more modern data, its function is the elimination of a considerable number of the spermatozoa approaching the ovum.
- The third substance is one that inactivates the agglutinating principle—antifertilizin of the ovum. It is antagonistic toward gynogamone II and a protein.

Four substances have been found in the sexual products of male animals.

- The first is androgamone I, which suppresses the motility of spermatozoa.
- Androgamone II (antifertilizin of the spermatozoa) inactivates the agglutinating principle; it is similar in effect to antifertilizin of the ovum and is a relatively thermostable protein.
- Androgamone III causes liquefaction of the cortical layer of the ovum; it is a thermostable compound of low molecular weight.
- Lysines of the spermatozoon dissolve the ovum's membrane. These are thermolabile proteins (in mammals, the enzyme hyaluronidase).

A direct contact between the spermatozoa and the zona pellucida of the secondary oocyte is necessary before actual fusion of the gametes.

Before the penetration, the spermatozoa undergo a process of capacitation, followed by acrosome reaction in the female genital tract.

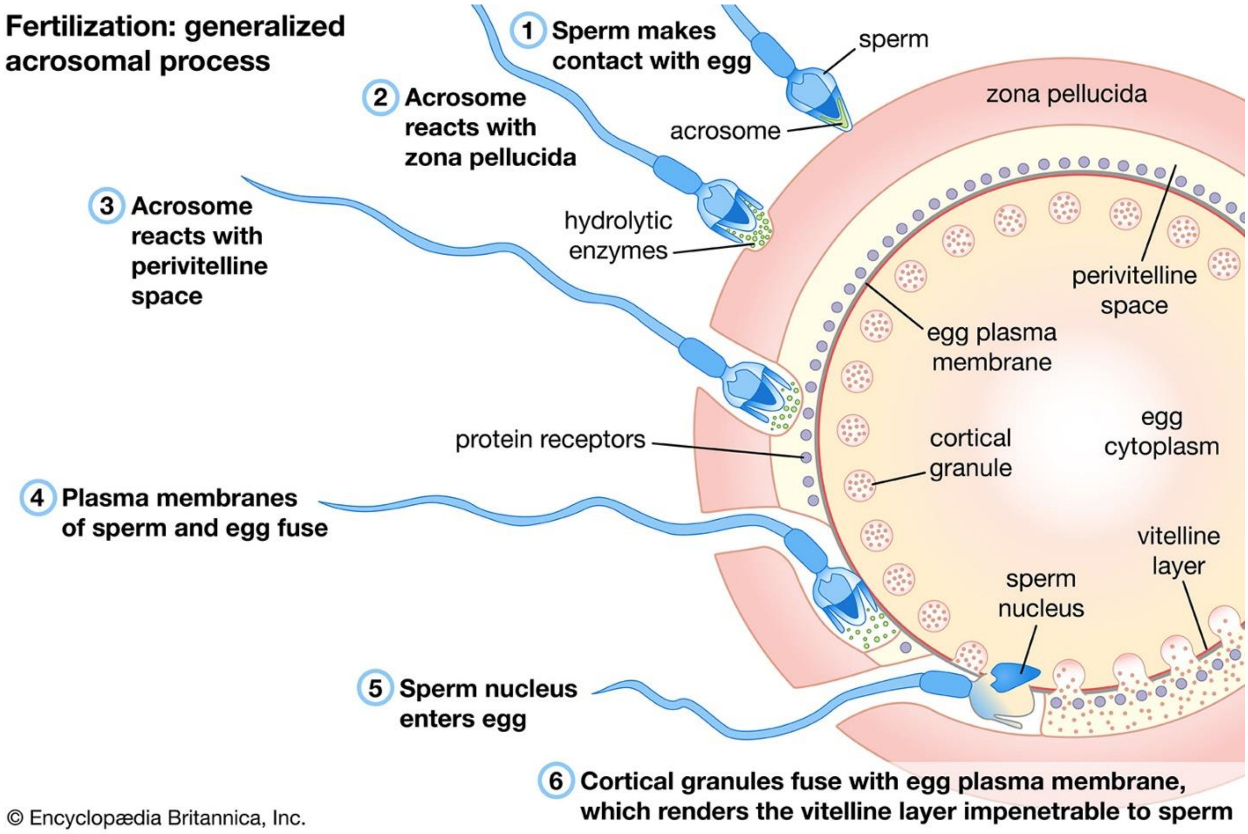
Capacitation is the process of removing of protective glycoprotein coat from the acrosomal region of the spermatozoa in the uterus.

Acrosome reaction. When the head of sperm cell touches the zona pellucida, the acrosomal enzymes begin to dissolve the zona pellucida.

A receptive spot is formed in this area of the ovum. It encloses the head and centriole of the spermatozoon and takes them into the ovum's cytoplasm.

Fertilization initially involves a binding of ovum membrane glycoproteides called fertilizins with specific sperm membrane proteins known as antifertilizins. Fertilizin-antifertilizin binding provides a sperm-egg interaction. Also this fertilizin-antifertilizin interaction may help to prevent sperm from one species initiating a fertilization reaction with an oocyte of another species.

Once first sperm cell pass through the zona pellucida, a Na+ influx to egg cell occurs, causing a signaling cascade which results in releasing of Ca++ from ER. There are cortical granules under the membrane of egg. Due to calcium influx, cortical granules are released. It leads to a modification of the zona pellucida that blocks polyspermy.

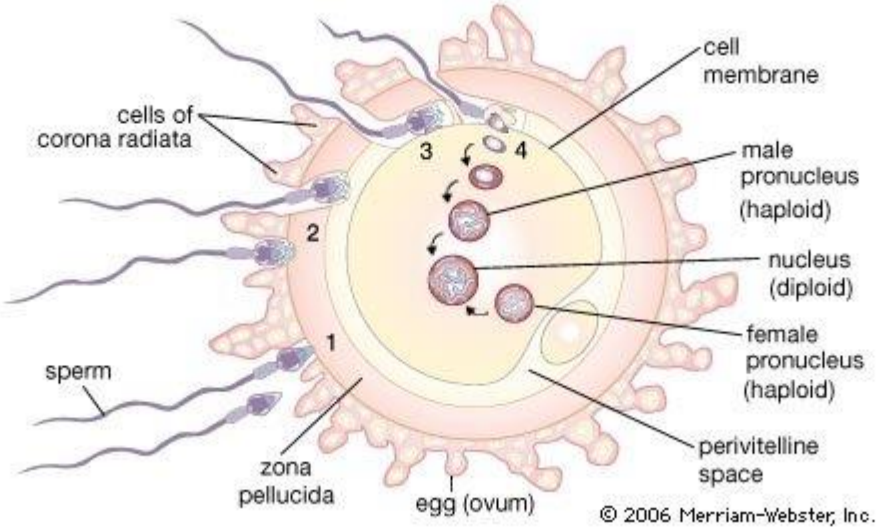


Syncaryogamia is associated with an internal stage of fertilization.

Immediately after the entrance of a spermatozoon into the secondary oocyte, the latter completes the second division and forms a mature ovum with the extrusion of the second polar body in the periviteline space.

A male pronucleus (nucleus of the spermatozoon) enlarges to the sizes of a female pronucleus (nucleus of the ovum), turns through 180° and moves (together with the centrosome at its front end) to the female pronucleus. The DNA replication occurs in both male and female pronuclei (n2c). After that the pronuclei fuse to restore the diploid chromosome complement and the zygote is now formed (2n4c).

The line of entry of the spermatozoon decides the cephalo-caudal polarity of the zygote and bilateral symmetry of the embryo.



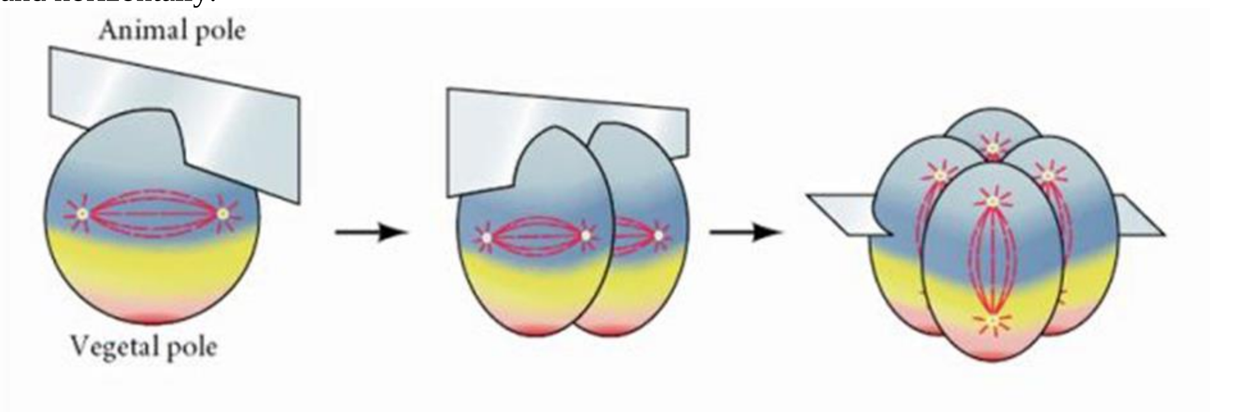
Embryonic development.

Embryonic period is passed from the zygote formation. It includes the following sub-stages:

1. Cleavage.
2. Gastrulation
3. Neurulation and Organogenesis

1. Cleavage of zygote. In embryology, **cleavage** is the division of cells in the early **embryo**. The zygotes of many species undergo rapid mitotic divisions. But cell cycle of this cells differs from cell cycle of somatic cells. In interphase G1 is absent, and G2 is much shorter. Therefore cell growth does not occur during cell-division and new cells (**blastomeres)** become smaller and smaller.

During cleavage first furrow appears that runs longitudinally through the poles of the egg resulting tow blastomeres. The second furrow also runs longitudinally through the poles of the egg resulting 4 blastomeres. The third furrow runs horizontally. After that furrows run longitudinally and horizontally.



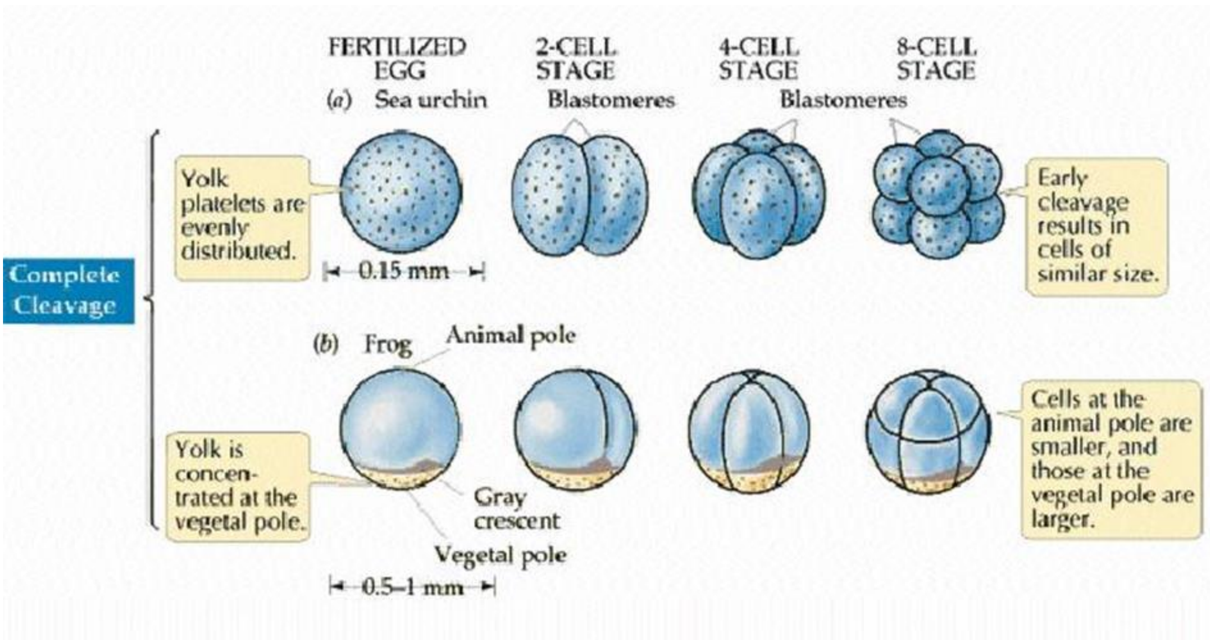
When the nuclear-cytoplasmic ratio becomes approximately 1:1 (like in mature somatic cells) the cleavage is stopped. The cells derived from cleavage form a compact mass called the **morula** (16 – 64 blastomeres, the number of blastomeres may vary in the different species). After that the blastocoel is formed and now it is **blastula.**

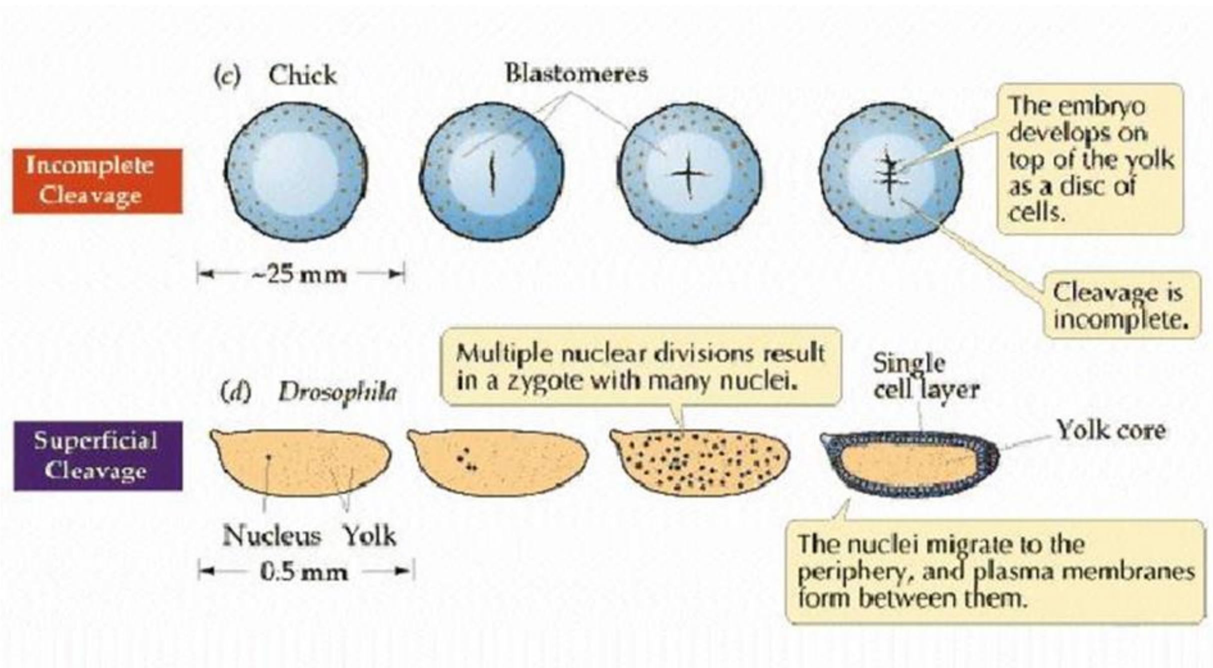
Blastula consist of single layer of cells, which is called blastoderm, and blastocoel, which is inside the blastula.

Types of cleavage of zygote.
The type of cleavage is depend on the amount and distribution of yolk in egg cell.

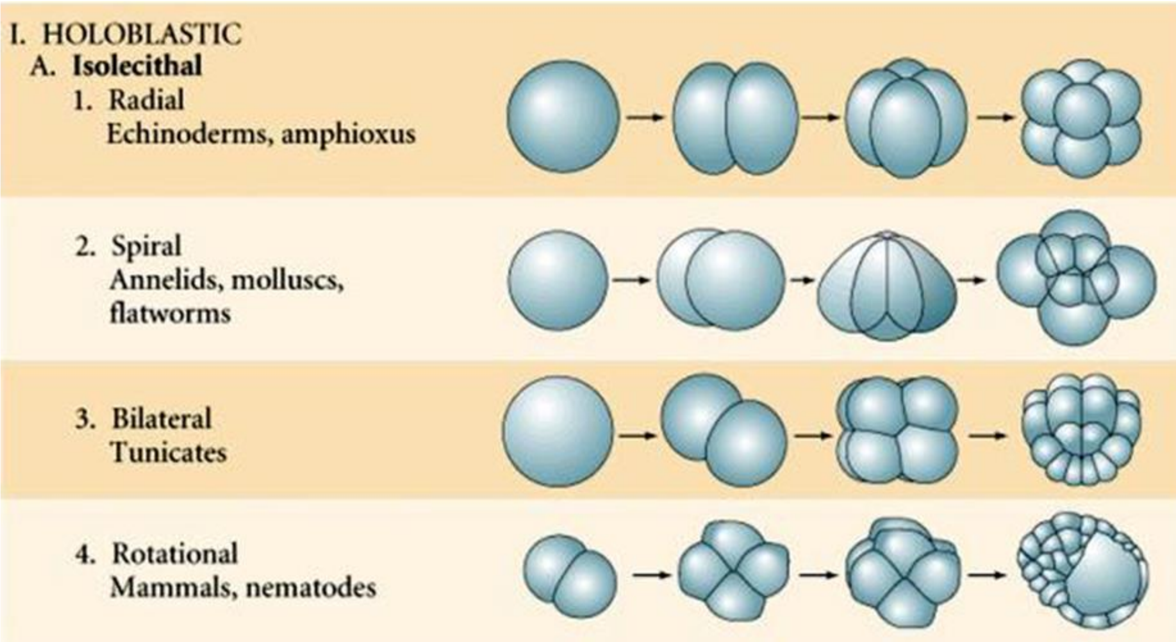
Depending mostly on the amount of yolk in the egg, the cleavage can be:
1. **Holoblastic (total or entire or complete cleavage)**
- **Equal** (amphioxus) - due to microlecithal and isolecithal egg cell all blastomeres are equal, so the **coeloblastula** is formed
- **Unequal** (due to mesolecithal and moderately telolecithal egg blastomeres are unequal. There are more rapidly dividing micromeres on the animal pole and slower dividing macromeres on the vegetal pole. The **amphyblastula** is formed)

2. **Meroblastic (partial or incomplete cleavage)**
- **Discoidal** (fish, birds, reptiles) the cells, which do not surround the whole embryo, lie only on the animal pole; nevertheless, a blastocoel may be formed by a fissure appearing between the blastomeres and the mass of yolk. The blastomeres then may be arranged as a saucer-shaped blastodisk covering the blastocoel. **Discoblastula** is formed.
- **Superficial** (insects) in which a layer of cells is produced about a central mass of yolk. **Periblastula** is formed.





There are several types of cleavage symmetry seen in nature: radial (echinoderms, amphibians), spiral (mollusks, annelids), Bilateral (ascidians, tunicates), Rotational (mammals).



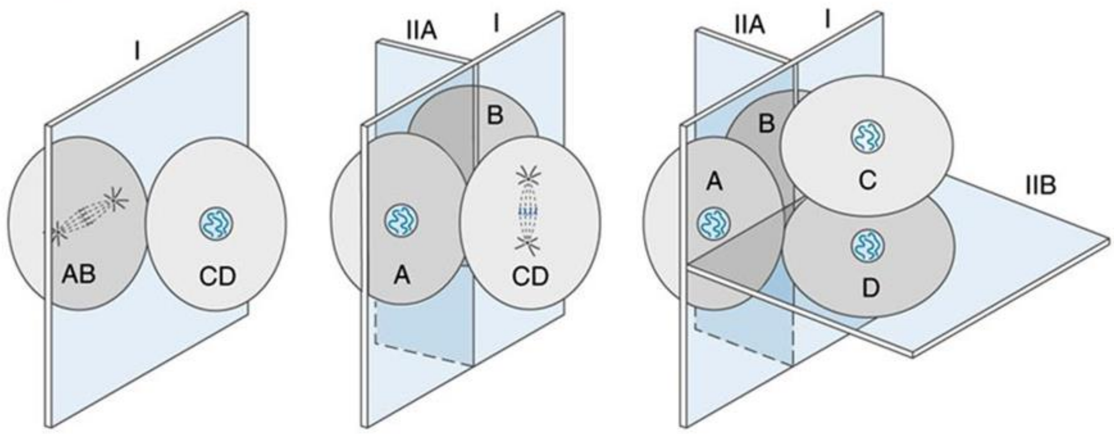
MAMMALIAN CLEAVAGE

The mammalian zygote gives rise to both the embryo and extraembryonic tissues, such as the placenta. Changes in cell behavior and cell cleavage patterns during early embrogenesis results in a 32-cell blastocyst consisting of the inner cell mass, which will form the embryo, and the trophoblast, which will form extraembryonic tissues.

Mammalian cleavage is **rotation holoblastic unqual and asynchronous.**

First cleavage begins about a day after fertilization within the oviduct. In sharp contrast to most animals, cleavage in mammals can be very slow---1/day. Additionally, the cleavage planes are somewhat different from other animals. First cleavage is meridional. However, the second cleavage division sees one of the blastomeres dividing meridionally and the other equatorially. This type of cleavage is called ROTATIONAL HOLOBLASTIC CLEAVAGE.

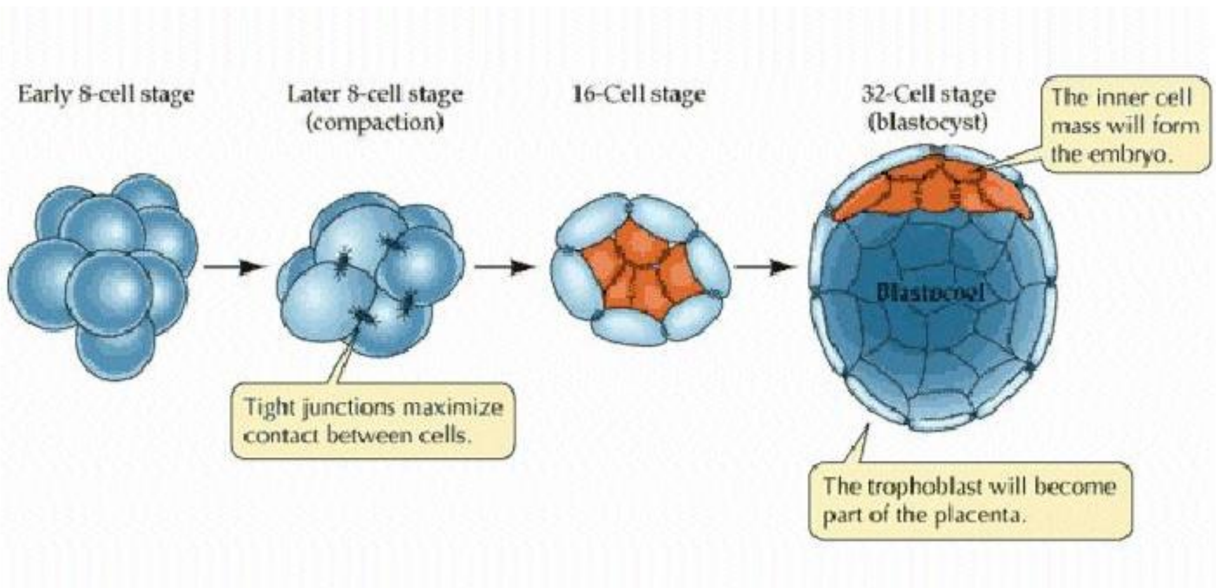
The first cleavage is meridional, and the second cleavage is rotational. The 2 blastomeres divide in different planes (one is equatorial and one is meridional.



Another unique feature of mammalian cleavage is that the blastomere cleavages are **asynchronous**. Cleavage of the mammalian embryo is regulated by the zygotic nucleus from the very start.

The result of cleavage of mammals is formation of **blastocyst**, which consist of trophoblast, inner cell mass (or embryoblast) and blastocoel.

The formation of the blastula signifies the end of the period of cleavage.

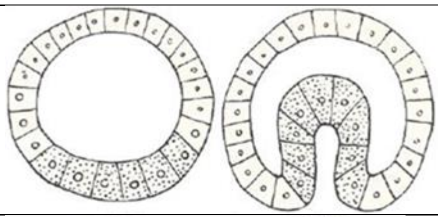
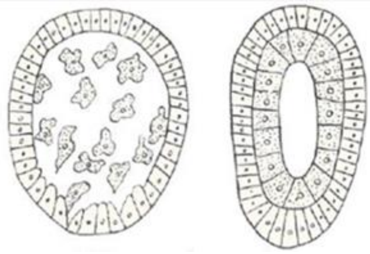
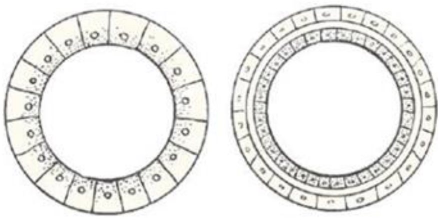
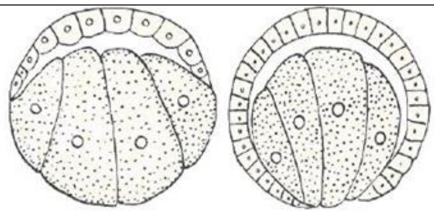


GASTRULATION

Gastrulation is the process of formation of double or third-layered embryo, which is called ***gastrula.***

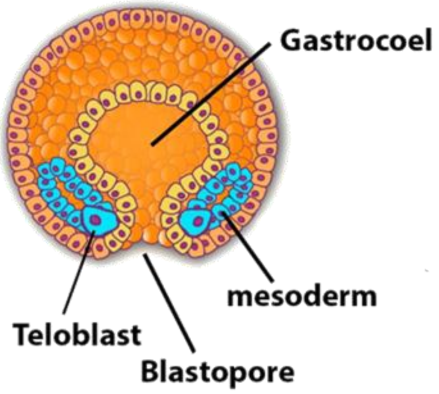
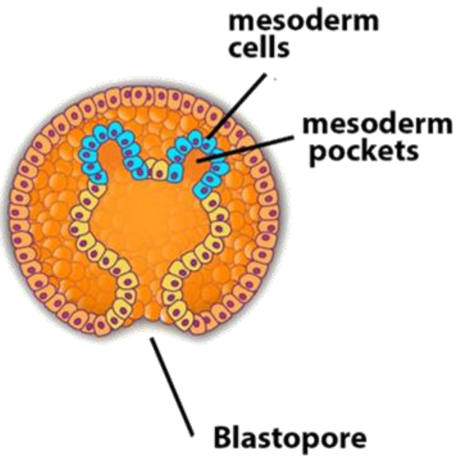
Coelenterates and spongy have two germ layers - ectoderm, entoderm, the other invertebrates and vertebrates have three germ layers - ectoderm, entoderm and mesoderm.

Modes of gastrulation:

Invagination – mode of gastrulation, in which some blastoderm cells invaginate to blastocoel and form the internal layer of gastrula – endoderm, and external layer is ectoderm.	
Immigration – mode of gastrulation, in which some blastomeres are active, divide very quickly and migrate into the blastocoel area to form the endoderm. The blastomeres which are not mitotically active, divide slowly and form the ectoderm.	
Delamination – the mode of gastrulation in which the blastoderm cells divide together at the same time to form two germ layers – ectoderm and endoderm.	
Epiboly – mode of gastrulation, in which the micromeres of blastula (the future ectoderm) are more active, divide quickly and cover the macromeres (the future endoderm)	

It should be noted that the modes of gastrulation in pure form are not found. Mostly there are combinations of different modes of gastrulation. For example, gastrulation of amphibian consist of two stages: Invagination and Epiboly. Gastrulation of reptiles, birds and mammals consist of Delamination and Immigration.

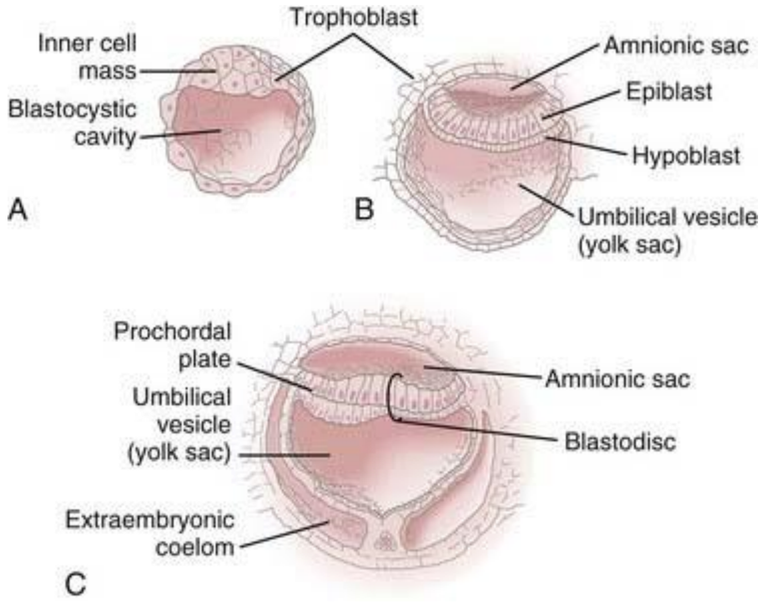
Modes of mesoderm formation:

Teloblastic – mode of mesoderm formation in which some blastoderm cells located near blastopore stop to divide and grow. They are called ***teloblasts***. Teloblasts increase in size, divides by mitosis and form the third layer - mesoderm. This type of mesoderm formation is typical for the pseudocoelomatic animals (example: round worms).	
Intracoelic - mode of mesoderm formation by the outpocketing of primitive gut. The cells of mesoderm pockets divide by mitosis and form the middle layer – mesoderm. This type of mesoderm formation is typical for the coelomatic animals (example: earth worms, chordate).	

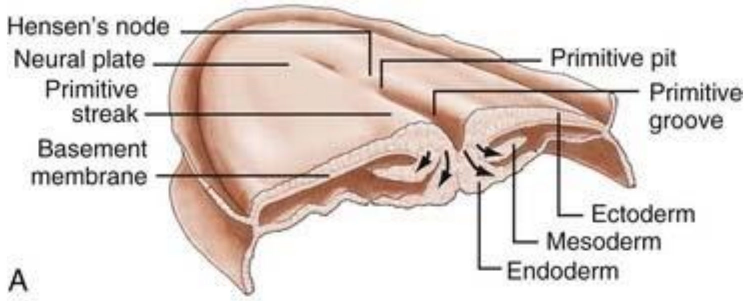
Human gastrulation

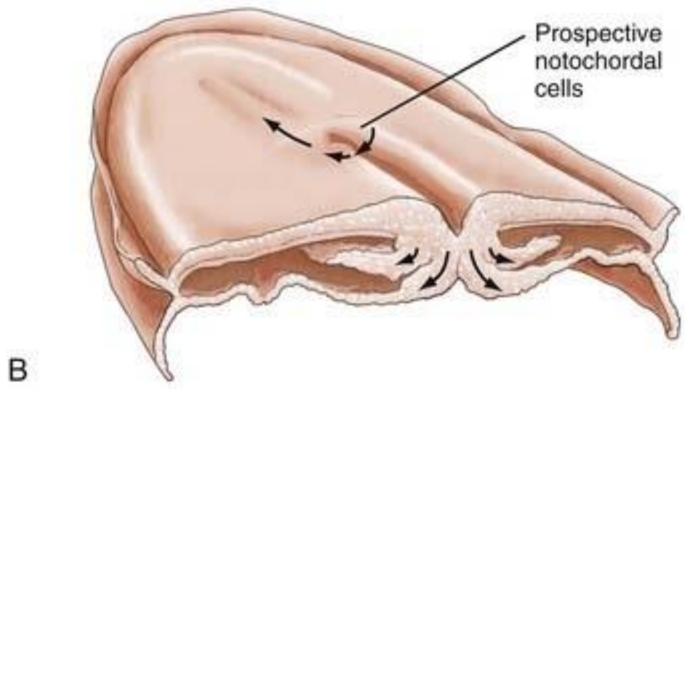
On the 5-6 day after fertilization the blastocyst is formed. It consist of outer layer of cells (the trophoblast) and an inner cell mass (the embryoblast). And the embryoblast forms embryonic (or germ) disc. The blastocyst is still enclosed within the zona pellucida.
Human gastrulation consist of 2 stages:

- early gastrulation (7-8 day) is provided by delamination of germ disc to the epiblast and hypoblast.
  The trophoblast is also develop two sub-layers: the cytotrophoblast, which is in front of the syncytiotrophoblast. Trophoblast is provided the implantation into the endometrium.
  The cells from epiblast proliferate and form a closed sac which further will be the amnion.
  At day 9-10 of embryonic development, cells from the hypoblast begin to migrate to the embryonic pole, forming a layer of cells just beneath the cytotrophoblast, called Heuser's Membrane. It surrounds the exocoelomic cavity (primitive yolk sac).



- Late gastrulation (15-17 day) is provided by immigration of cells of epiblast under the epiblast. At that time the proliferating cells of epiblast form the primitive streak and the primitive node (Hensen's node) which is in front of the primitive streak. The cells that migrate through the primitive streak form endoderm and mesoderm. The migrating cells replace the cells of hypoblast and form a definitive endoderm which will further develop into the gut tube.cells. The mesoderm is formed by the migrating cells that develop between the epiblast and endoderm.
  The cells that migrate through the primitive node form notochord which is the organiser of neurulation.



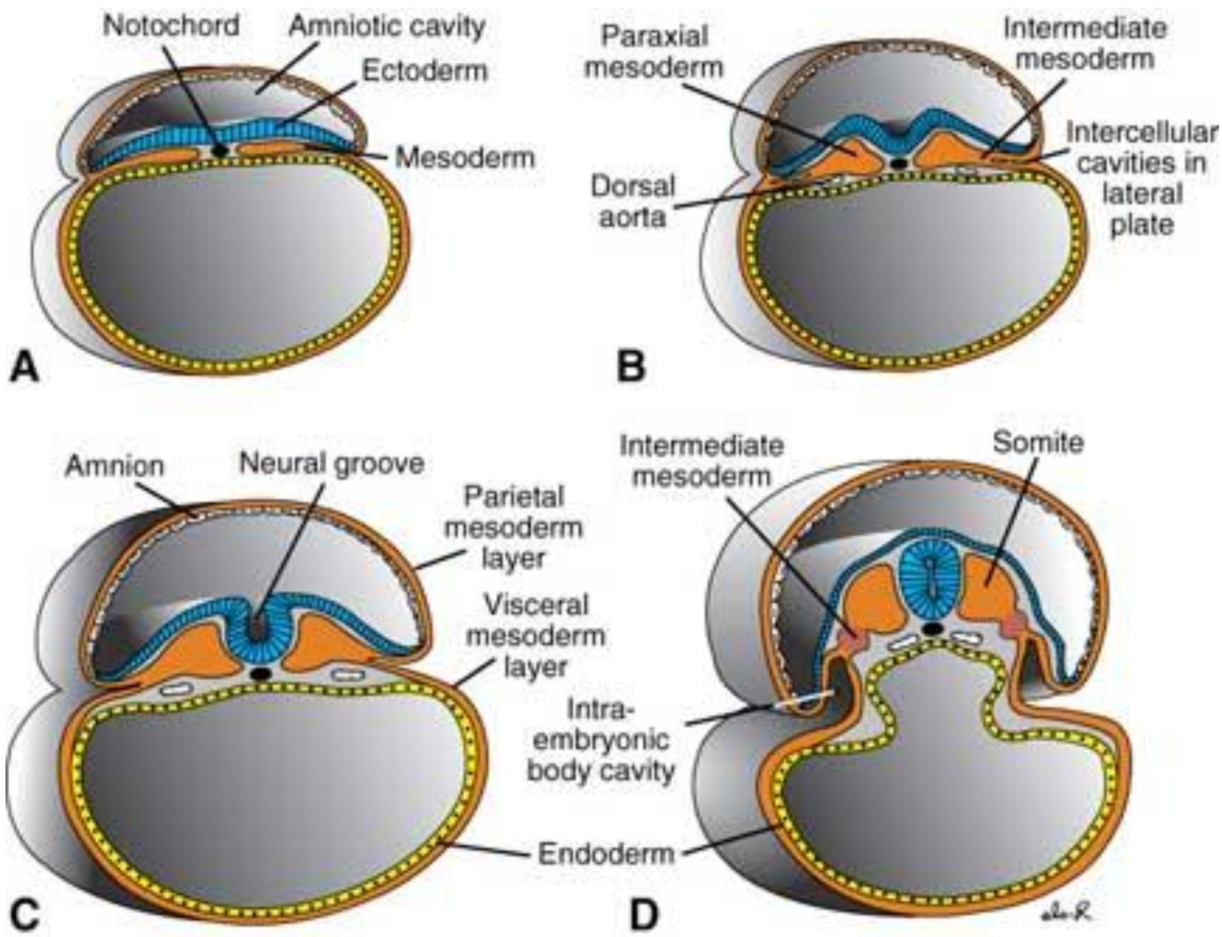


Neurulation

Neurulation in vertebrates results in the formation of the neural tube, which gives rise to both the spinal cord and the brain. Notochord and gut tube are also created during neurulation.

The early development of many organs is the result of cascade-like mechanism of reactions of embryonic induction. Thus, the action of one group of cells on another leads to the establishment of the developmental pathway in the responding tissue. The groups of cells which influence the responding cells are termed the inducing tissue. The cells of inducing tissue secret a specific inductive stimuli that may affect on close tissues only that may respond on this stimuli.
The first major induction phenomenon occurs during the end of gastrulation, when the cells of notochord (that migrate through the Hensen's node and are called the embryonic organizer) induce the cells of ectoderm which reside over the notochord to develop into the neural tube. The first induction event of early embryogenesis is called primary embryonic induction.

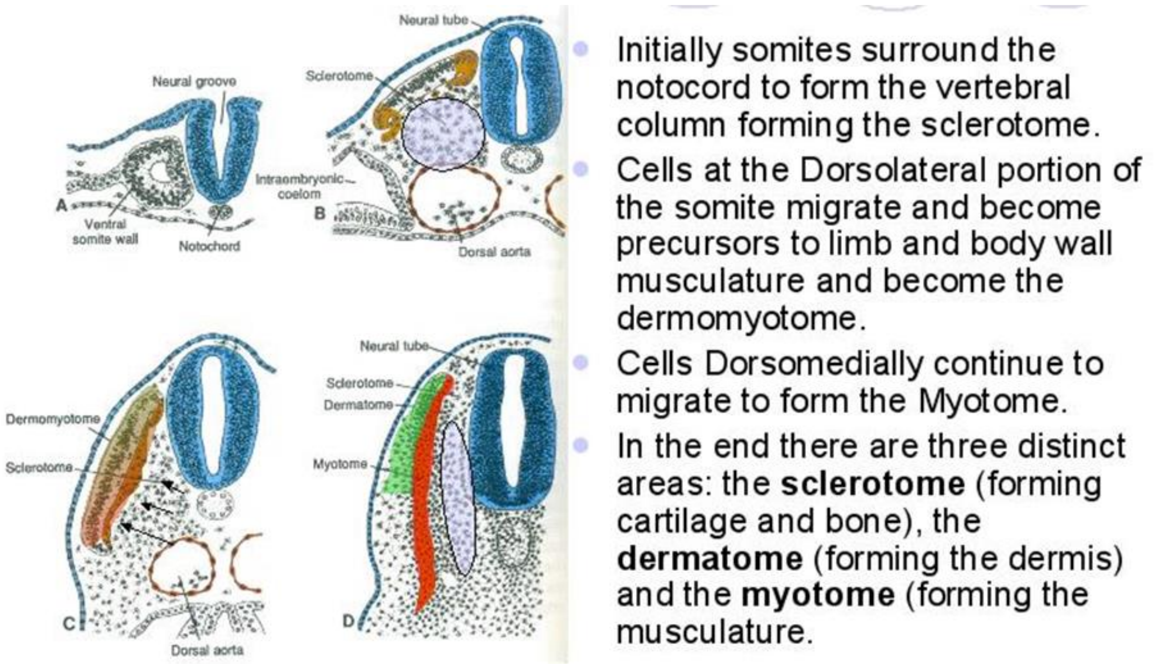
Under the inductive stimuli the cells of ectoderm that contact with notochord differentiate to nerve cells and form neural plate. Its ends start to fold upwards as neural folds. There is a neural groove between neural folds.
The neural folds grow toward to each other and fuse. This fusion occur in the middle at first, and then spread to the both ends of embryo. Thus, the neural tube is formed.



After that, both the notochord and neural tube induce development of the part of mesoderm that contact with them and give rise somites.
Somites subdivide into the sclerotomes, myotomes and dermatomes.

- **Sclerotomes** give rise to the vertebrae of the vertebral column, rib cage, and part of the occipital bone.

- **Myotomes** give rise to the skeletal muscle and tendons
- **Dermatomes** give rise to the inner layer of skin (dermis).

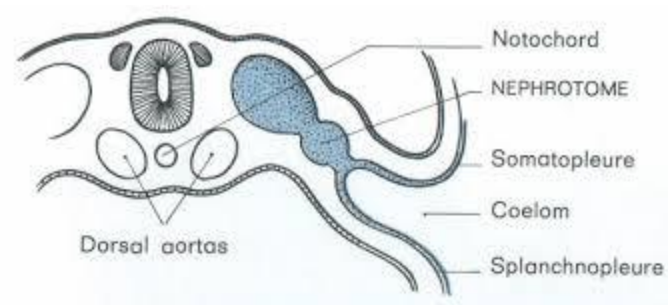


The intermediate mesoderm is a type of mesoderm that is located between the somites and the lateral plate. It develops into **nethrotome** and **gonotome**, which form the parts of the urogenital system (kidneys and gonads), as well as the reproductive system.

And the lateral plate of mesoderm is divided to **splanchnopleure** and **somatopleure**. Somatopleure covers inner side of body wall and forms the parietal peritoneum, parietal pleura and parietal pericardium.

Somatopleure covers the outer side of viscera and forms the visceral peritoneum, visceral pleura and visceral pericardium.

There is coelom between the splanchnopleure and somatopleure.



The products produced by the three germ layers

Ectoderm give rise to:

- epidermis of skin, its derivates;
- nervous system;
- medulla of adrenal gland
- posterior and intermediate lobes of pituitary gland;
- eye (cornea, lens, retina);
- internal ear;

nasal epithelium; the epithelium of stomodeum and proctodeunm; and epithelium of external auditory canal.

Mesoderm give rises to:
- dermis of skin;
- muscles;
- connective tissues;
- peritoneum;
- pleura;
- kidneys;
- cortex of adrenal glands
- gonads;
- urinary and reproductive ducts;
- heart;
- blood and lymph vessels;
- spleen

Endoderm gives rise to:
- epithelium of gut, except stomadaeum and proctodaeum;
- gastric and intestinal glands;
- liver;
- pancreas;
- anterior lobe of pituitary gland;
- thyroid gland;
- parathyroid gland;
- thymus gland;
- respiratory epithelium;
- epithelium of urinary bladder;
- notochord;
- epithelium of middle ear;
- primordial germ cells.

Extraembryonic organs (Extraembryonic membranes)

Complex of extraembryonic organs is a special temporary functional system that is one of the earliest to arise in ontogenesis. They originate from the embryo, but are not considered part of it. They typically perform roles in nutrition, gas exchange, and waste removal, until the definite embryonic organs are formed.

There are four standard extraembryonic organs in birds, reptiles, and mammals:
- the yolk sac
- the amnion
- the allantois
- the chorion

In accordance with the formation of extraembryonic organs, there are two groups of vertebrates:
- Anamniotes
- Amniotes

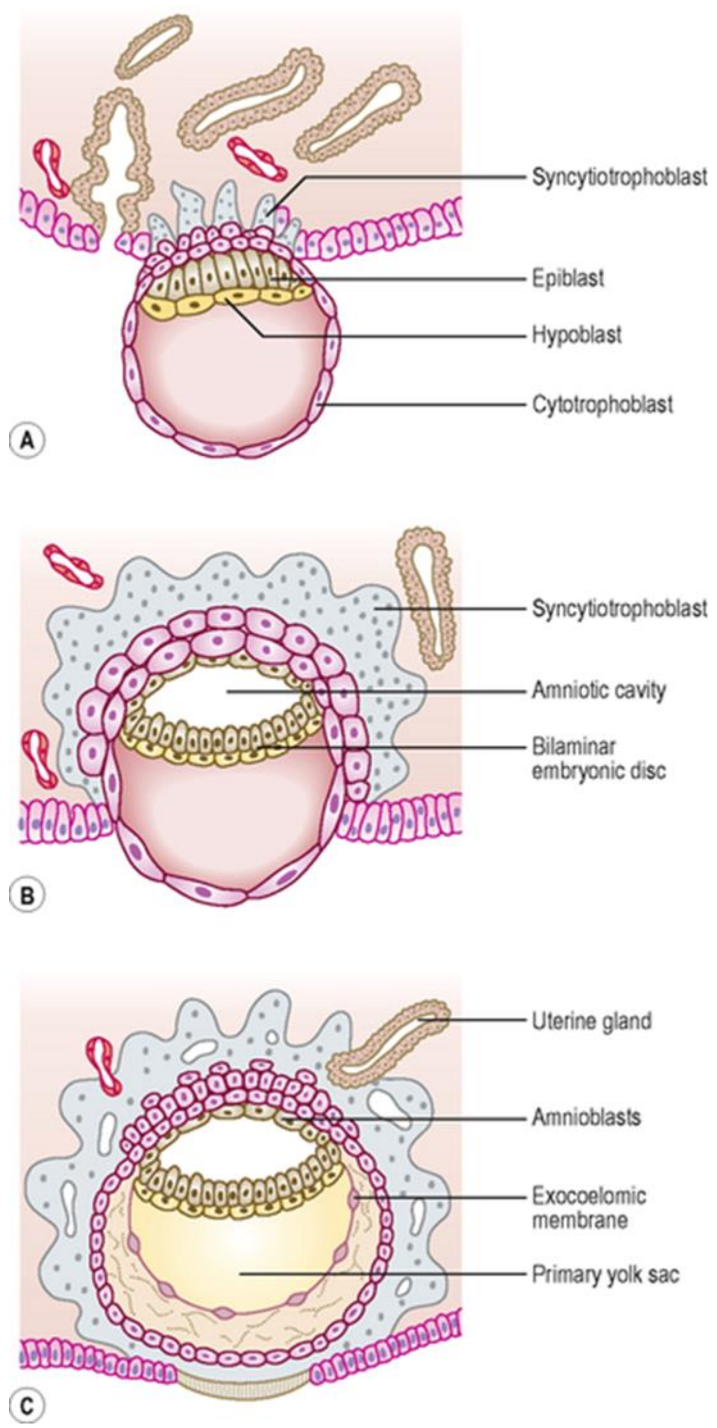
The group of anamniotes comprise the fishes and the amphibians, the so-called "lower vertebrates". They lay their eggs in water. Thus their embryos develop in a favorable environment. Anamniotes do not develop an amnion, allantois and chorion during fetal life and are able to exchange oxygen, carbon dioxide and waste metabolites with the surrounding water.

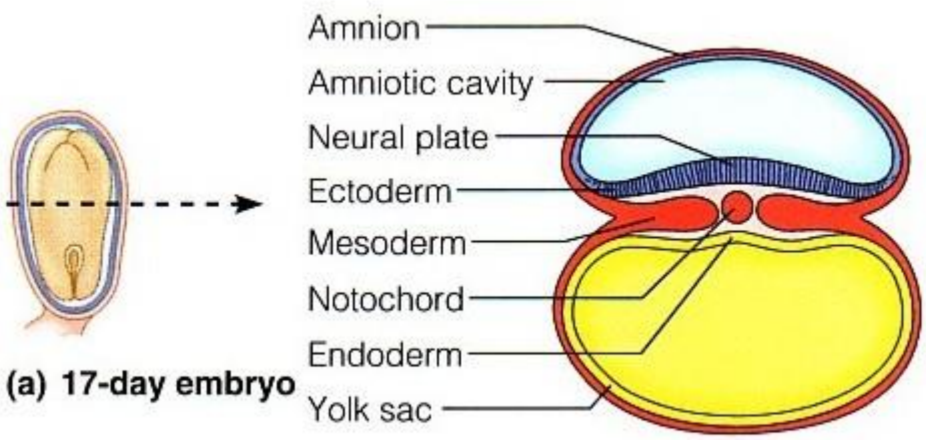
Amniotes are a group of tetrapod vertebrates comprising the reptiles, birds, and mammals. Amniotes lay their eggs on land or retain the fertilized egg within the mother. So their embryos protected and aided by extraembryonic organs.

Amnion

The amnion is a membrane that closely covers the embryo. It fills with the amniotic fluid, which serves to provide a protective environment for the developing embryo (or fetus).
In humans amnion is formed on 8^{th} day when embryonic disc is delaminated to the epiblast and hypoblast. Cells of epiblast proliferate and form the amniotic sac in the narrow space between embryoblast and trophoblast. Later the extraembryonic somatopleure covers outside the amniotic ectoderm as a thin layer.
Thus a wall of amniotic sac consist of 2 layers:

- inner layer is formed by epiblast (or extraembryonic ectoderm)
- outer layer is formed by extraembryonic somatopleure


Syncytiotrophoblast
Epiblast
Hypoblast
Cytotrophoblast
A
Syncytiotrophoblast
Amniotic cavity
Bilaminar
embryonic disc
B
Uterine gland
Amnioblasts
Exocoelomic
membrane
Primary yolk sac
C


Amnion
Amniotic cavity
Neural plate
Ectoderm
Mesoderm
Notochord
Endoderm
Yolk sac
(a) 17-day embryo

When first formed, the amnion is in contact with the body of the embryo, but about the fourth or fifth week amniotic fluid begins to accumulate within it. The amniotic fluid increases in quantity up to the sixth or seventh month of pregnancy.

The accumulation of amniotic fluide causes the amnion to expand and ultimately to adhere to the inner surface of the chorion, so that the extra-embryonic part of the coelom is obliterated.

The amniotic fluid makes favorable environment for the developing embryo, allows the free movements of the fetus during the later stages of pregnancy, and also prevent mechanical injuries.

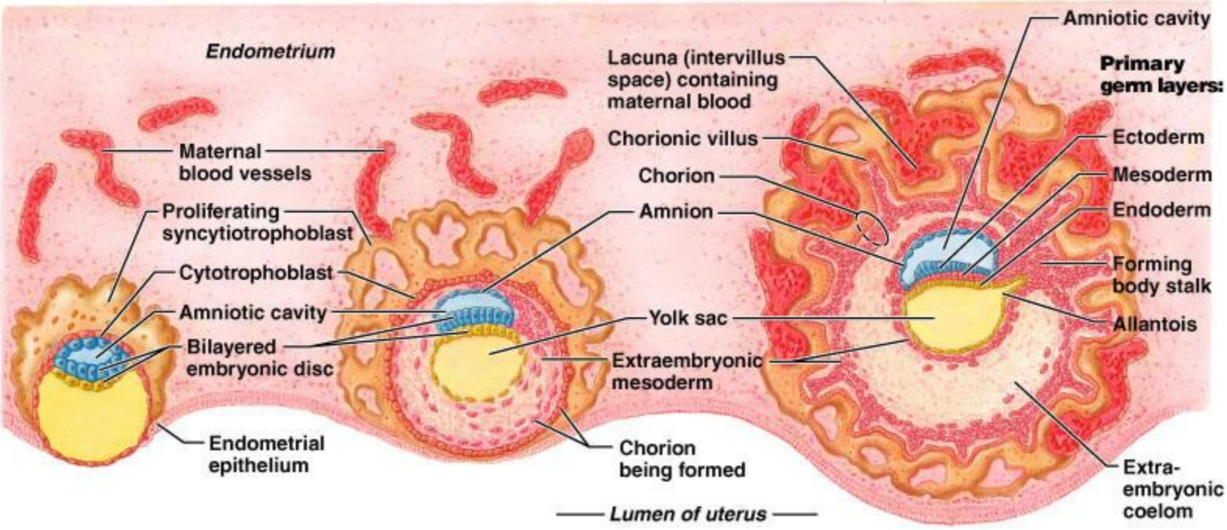
Chorion

The chorion is the outermost fetal membrane around the embryo in mammals, birds and reptiles. In humans it is formed by trophoblast that surround the embryo. During implantation (6-7th day) the trophoblast is divided to two layers cytotrophoblast and outer syncytiotrophoblast.
The cells of syncytiotrophoblast are fused and form a continuous, generally uninterrupted syncytial layer. Syncytiotrophoblast secrets many enzymes (proteases) which interrupt endometrium and provide implantation. Syncytiotrophoblast destroy maternal blood vessels and allow maternal blood fill the trophoblast lacunae.
The chorion undergoes rapid proliferation and forms numerous chorionic villi, which invade the uterine decidua, and absorbing nutritive materials from it for the growth of the embryo.

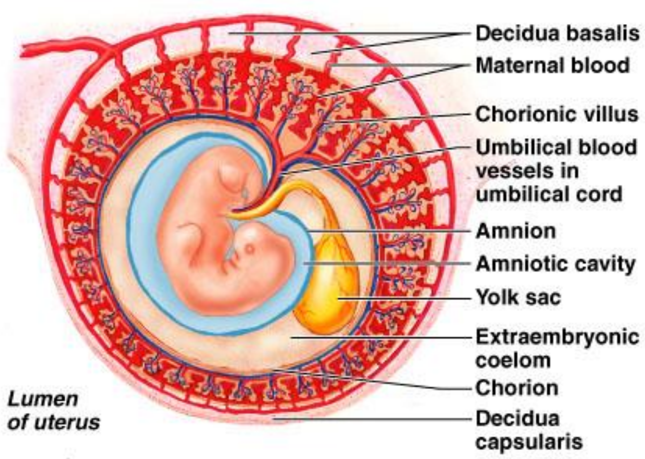
Chorionic villi undergo several stages, depending on their composition.

Stage	**Description**	**Period of gestation**	**Contents**
Primary	The chorionic villi are at first small and non-vascular.	13–15 days	trophoblast only
Secondary	The villi increase in size and ramify, while the mesoderm grows into them.	16–21 days	trophoblast and mesoderm
Tertiary	Branches of the umbilical artery and umbilical vein grow into the mesoderm, and in this way the chorionic villi are vascularized.	17-22 days	trophoblast, mesoderm, and blood vessels

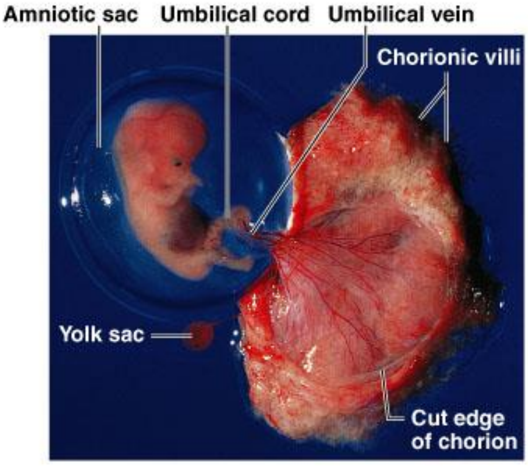
Chorion forms the placenta which begin working at 9 week after fertilization and complete formation at 16 week. Since the formation of the placenta (9 week) embryo become fetus.
The placenta is a temporary organ that connects the developing fetus via the umbilical cord to the uterine wall to allow nutrition, waste elimination and gas exchange via the mother's blood supply. Also the placenta secrete hormones which provide prolongation of pregnancy.



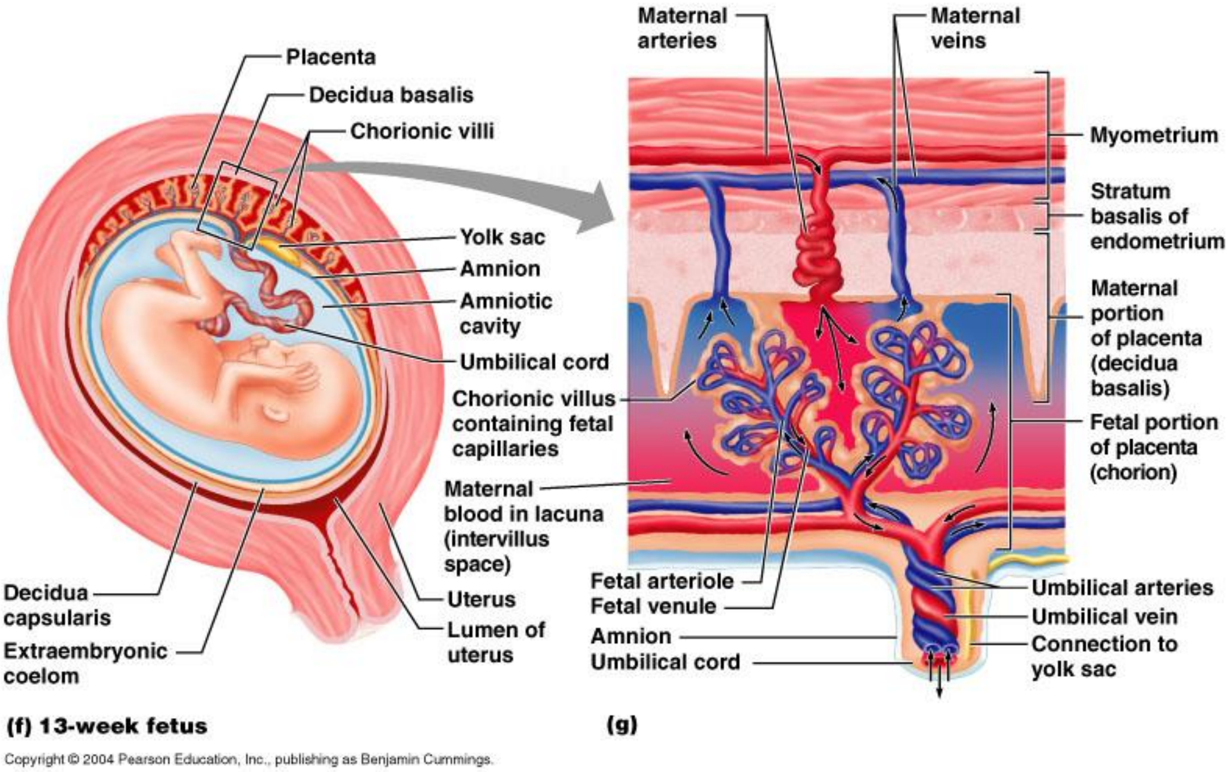
(a) 7½-day implanting blastocyst **(b) 9-day implanted blastocyst** **(c) 16-day embryo**



(d) 4½-week embryo

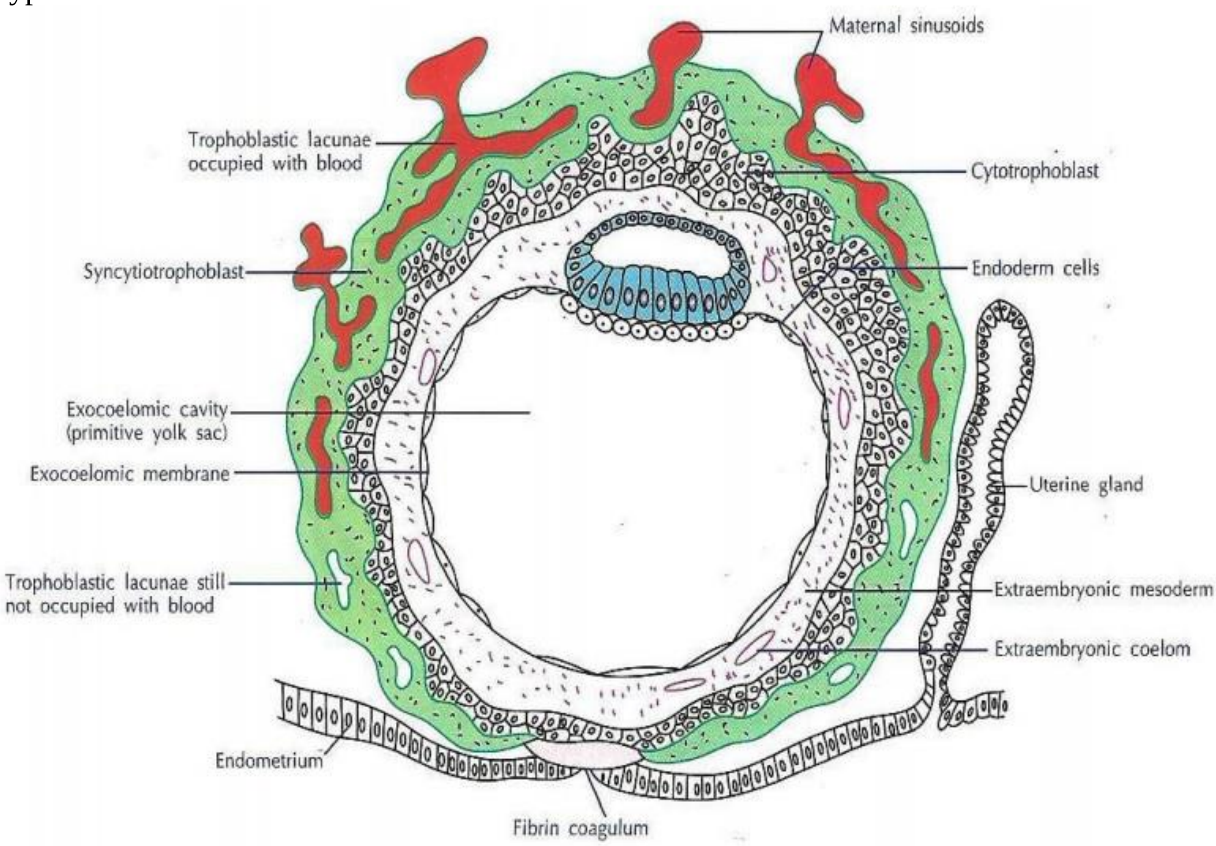


(e) 7-week embryo



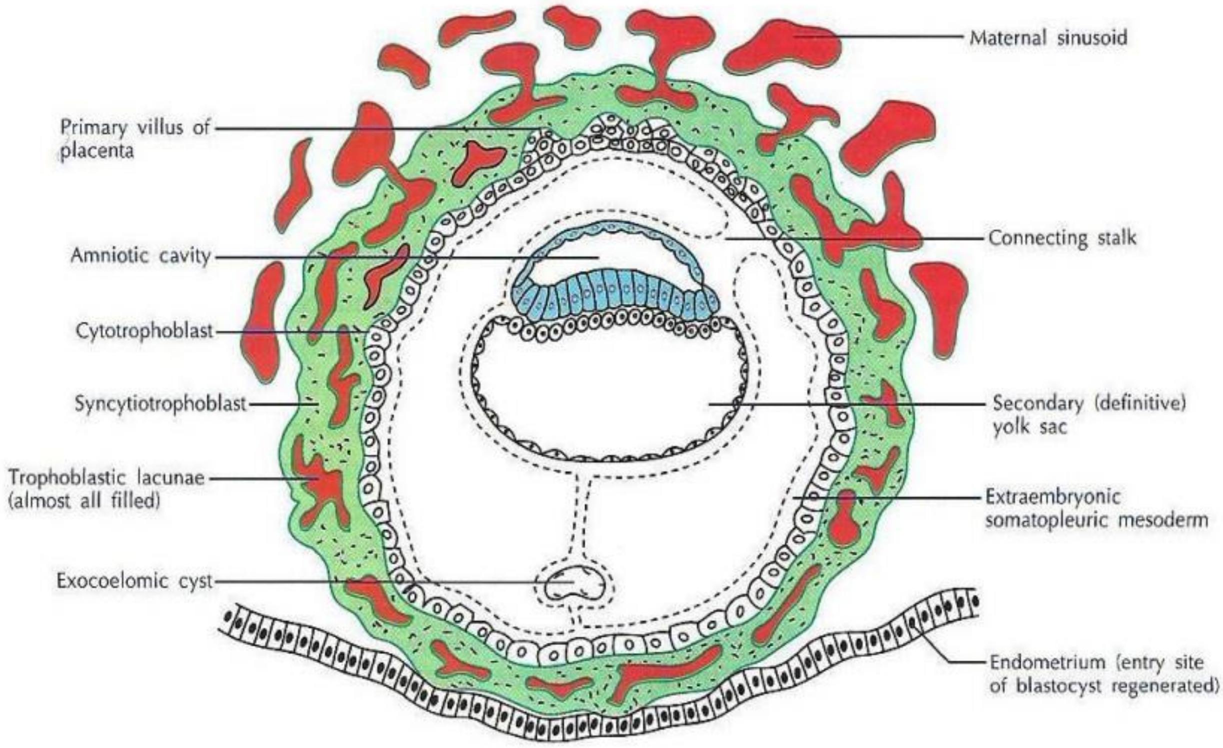
Yolk sac

The yolk sac is formed at 8-9th day after fertilization. It's formed by proliferating cells of hypoblast.



Stages of development of the yolk sac:

- Primary (or primitive) yolk sac: it is the vesicle which develops in the second week. The cells of hypoblast proliferate and migrate to the embryonic pole, forming a layer of cells under the cytotrophoblast, called Heuser's Membrane, which surrounds the exocoelomic cavity.
- Secondary yolk sac: this structure is formed at 13th day, when the extraembryonic mesoderm separates to form the extraembryonic coelom; cells from the mesoderm pinch off an area of the yolk sac, and what remains is the secondary yolk sac.



Thus, the wall of the yolk sac consist of 2 layers: inner layer is formed by cells of hypoblast, and outer layer is formed by splanchnopleure.

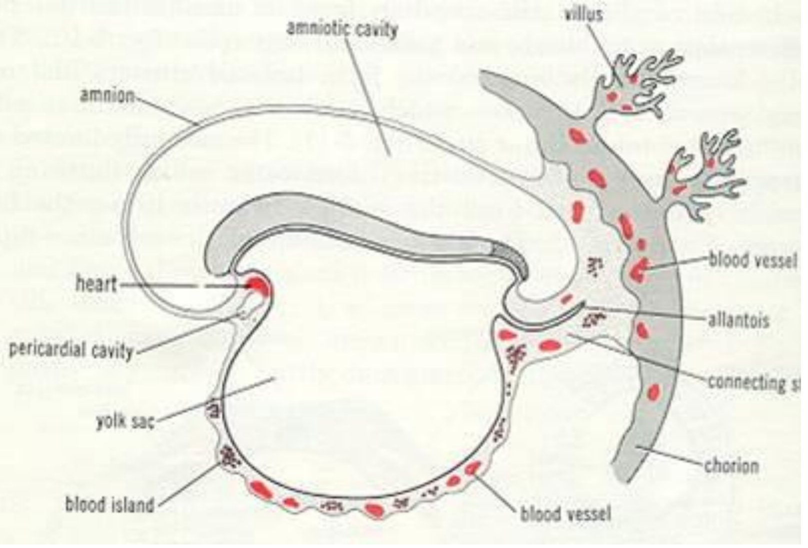
Yolk sac lies outside the embryo connected by a yolk stalk (vitelline duct, omphalomesenteric duct) to the midgut with which it forms a continuous connection. The endodermal lining is continuous with the endoderm of the gastrointestinal tract.
During the fourth week of development, during organogenesis, the yolk sac is reduce and present in umbilical cord as a thin duct. The duct undergoes complete obliteration during the seventh week.

Functions of yolk sac:

- Primary yolk sac is filled by vitelline fluide and provide nutrition of embryo
- First blood vessels are formed in the mesoderm of yolk sac which form the vitelline circulation
- first hematopoiesis – Hematopoietic cells are produced by mesoderm of yolk sac
- primary germ cells (spermatogonia and oogonia) are formed in mesoderm of yolk sac.

Allantois

Allantois is formed at 14-15th day as process of dorsal wall of yolk sac. It protrude into connective stalk.



It’s wall consist of 2 layers:

- Inner layer is the endoderm cells
- Outer layer is the mesoderm cells

It helps the embryo exchange gases and handle liquid waste.

The proximal intraembryonic part of allantois forms urinary bladder and distal part forms a hollow duct which called urachus. After 7th week urachus obliterates.
Mesodermal cells of allantois form blood vessels (the mature umbilical artery and vein) for Embryo supply from placenta