إعداد

د .زينب كمال سيد

كلية العلوم

قسم علم الحيوان

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The Normal Sequence of Events in Embryology

1- Gametogenesis 2-Fertilization 3- Cleavage and blastula formation 4- Gastrulation 5- Organgenesis

1-Gametogenesis

The embryogenesis is started from the time of differentiation and organization of haploid male and female sex cells, *viz*., *sperm* and *ova* respectively, from diploid somatic cells of each parent during a process called gametogensis. The gametogenesis include spermatogenesis and oogenesis. The spermatogenesis is a process which occurs in male gonads (testes) and produces small-sized, motile, haploid sex cell, the *sperms* or *spermatozoa*. The oogenesis occurs in female gonads (ovaries) and produce a large, non-motile, nutrient-*polar bodies* or *polocytes*.

2-Fertilization

Fertilization is the initial event in development in sexual reproduction. Union of male and female gametes. Provides for recombination of paternal and maternal genes. Restores the diploid number. Activates the egg to begin development.

The process of fertilization involves a number of independent biological and physiological events

1-The nucleus and cytoplasm of spermatozoon fuse with the nucleus and cytoplasm of the egg

2- The cortical reaction in the egg cytoplasm to elevate a fertilization membrane outside the plasma membrane

3- Activation of egg to start its rapid cleavage by mitosis.

3-Cleavage and blastula formation

During third phase of embryogenesis, the *cellulation*, *segmentation* or *cleavage*, no growth of egg-cytoplasm (*ooplasm*) takes place, but, rate of synthesis of some macromolecules such as DNA and proteins is increased is increased at the expense of reverse food substances of egg (*viz*., glycogen, fats and yolk); and the fertilized egg undergoes repeated and successive mitotic cell divisions and produces a compact heap of cells or *blastomeres*, called *morula*. The blastomeres of morula soon get arranged in a hollow spherical body, a *blastula*, with a layer of blastomeres, called blastoderm, surrounding a fluid-filled central space or cavity, called *blastocoel*. The conversion of a fertilized egg into a multicellular blastula is called *blastulation*.

4-Gastrulation

Following blastulation a part of the blastoderm disappears from the surface of the blastula by *morphogenetic movements* of cells and is enclosed by the reminder of the blastoderm. The part of the blastoderm that remains on the surface becomes *ectoderm*; the part of migrating into the interior becomes *endoderm* and *mesoderm*. In this way a simple spherical body becomes converted into two or three layered embryo known as the *gastrula*. The process involved in gastrula formation is called *gastrulation*, (gastrula, diminutive from the greek word gaster , meaning stomach) and the cellular layers of gastrula are known as the *primary germinal layer*. The germinal layers are complex rudiments from which various organs of the animal's body are derived.

The fully formed gastrula has a cavity called *archenteron*, which is lined by endoderm. The opening leading from this cavity to the exterior is called the *blastopore*. During later development, the archenteron or part of it eventually gives rise to the cavity of the alimentary canal.

The fate of blastopore (the opening from the outside into the archenteron) differs in the three main groups of metozoa:

1- In Coelenterate it becomes the mouth.
2- In Protostomia (including Annelida , Mollusca, Arthropoda and allied groups), it becomes subdivided into two opening, one of which becomes the mouth and other the anus.
3- In Deuterostomia (including Echinodermata and Chordata), only the anus is formed.

5-Organogenesis

During the fifth phase of development, the *organogenesis* or organs formation, the continuous masses of cells of the three germinal layers split up into smaller groups of cells, called the *primary organ rudiments*, each of which is destined to produce a certain organ or part of the adult animal body. The primary organ rudiments, further, subdivide into *secondary organ rudiments* which are rudiments of the subordinate and simpler organs and parts. With the appearance of primary and secondary organ rudiments the embryo begins to show some similarity to the adult animal, or to the larva, if the development includes a larval stage.

Gametogenesis

The reproductive cells, which unite to initiate the development of a new individual, are known as *gametes*- the *ova* of the female and the *spermatozoa* of the male. The gametes themselves and the cells that give rise to them constitute the individual's *germ plasm*. The other cells of the body, which take no direct part in the production of gametes, are called somatic cells or, collectively, the *somatoplasm*. The somatoplasm can thus be regarded as the material that protects and nourishes the germ plasm.

Gametogenesis (oogenesis in the female and spermatogenesis in the male) is a broad term that refers to the processes by which germ plasm is

converted into highly specialized sex cells that are capable of uniting at fertilization and producing a new being. Commonly, gametogenesis is divided into four major phases:

1-The origin of the germ cells and their migration to the gonads

2- The multiplication of the germ cells in the gonads through the process of mitosis

3- Reduction of the number of chromosomes by one-half by meiosis

4- The final stages of maturation and differentiation of the gametes

Into spermatozoa or ova.

Primordial germ cells

The cells which are destined to develop into gametes are called primordial germ cells. The germ cells either arise from the germinal epithelium of grads (*germinal epithelial origin*) or may arise outside the gonad at an early period of embryonic development and then migrate to garads (extra gonadal origin).

The origin of primordial germ cells and their migration to the gonads.

Primordial germ cells of birds, reptiles, and mammals arise in the epiblast of the early embryo and then take up temporary residence in the extraembryonic tissue before returning to the body of the embryo proper. In birds they are recognizable in the *germinal crescent*, which is located well beyond the future head region of the embryo.

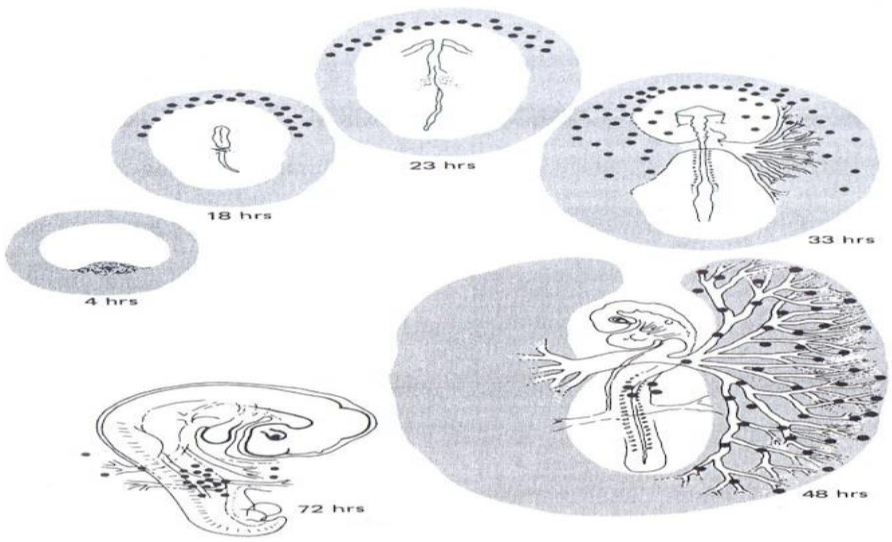
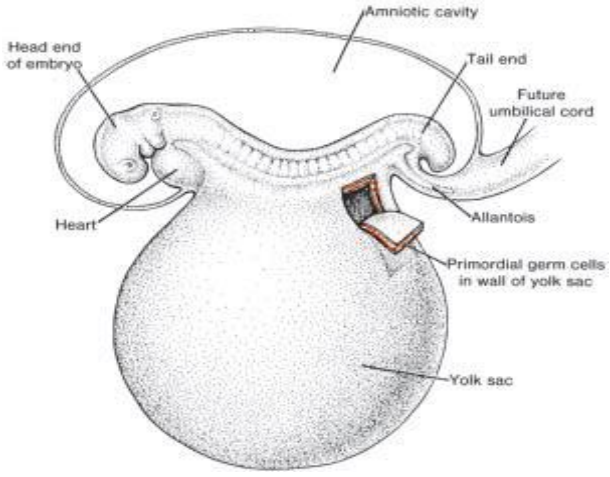


FIGURE 3-3
The migration of primordial germ cells (*dark circles*) in the avian embryo: 4 hours—no identifiable germ cells before the primitive streak is formed; 18 and 23 hours—passive accumulation of primordial germ cells in the anterior germinal crescent; 33 hours—active penetration into blood islands and their entry into the circulation; 48 hours—circulation of germ cells and their early egress into the gonadal primordia; 72 hours—colonization of the gonads. (*Redrawn from Nieuwkoop and Sutasurya, 1979.*)

In mammals the germ cells originate in the endoderm of adjoining region of the yolk sac in human before migrating into the gonds (tests or ovary)



Primordial germ cells in vertebrates migrate to the gonads by to principal mechanisms. In birds and reptiles, they pass through the walls of local blood vessels and enter the circulation. From the bloodstream they are apparently able to recognize the blood vessels of the gonads, because there they penetrate the walls of the blood vessels and settle down in the gonads.

Spermatogenesis

The transition from mitotically active primordial germ cells to mature spermatozoa is called *spermatogenesis*, and it involves a sweeping series of structural transformation. Although is a wide variety in the morphology of mature, the overall process of spermatogenesis is much the same throughout the vertebrate classes. This process can be broken down into three principal phases: (1) mitotic multiplication, (2) meiosis, and (3) spermiogenesis.

Mitosis of sperm-forming cells occurs throughout life, and the mitotically active cells within the seminiferous tubules are known as *spermatogonia*. These cells are concentrated near the outer wall of the seminiferous tubules. Spermatogonia have been subdivided into two main populations. *Type-A spermatogonia* represent the stem-cell population. Within this population is a group of noncycling dark A cells that may be long-term reserve cells. Some of these cells become mitotically active pale A cells, which ultimately give rise to *type-B spermatogonia*. These are cells that have become committed to leaving the mitotic cycle and which go on to finish the process of spermatogenesis.

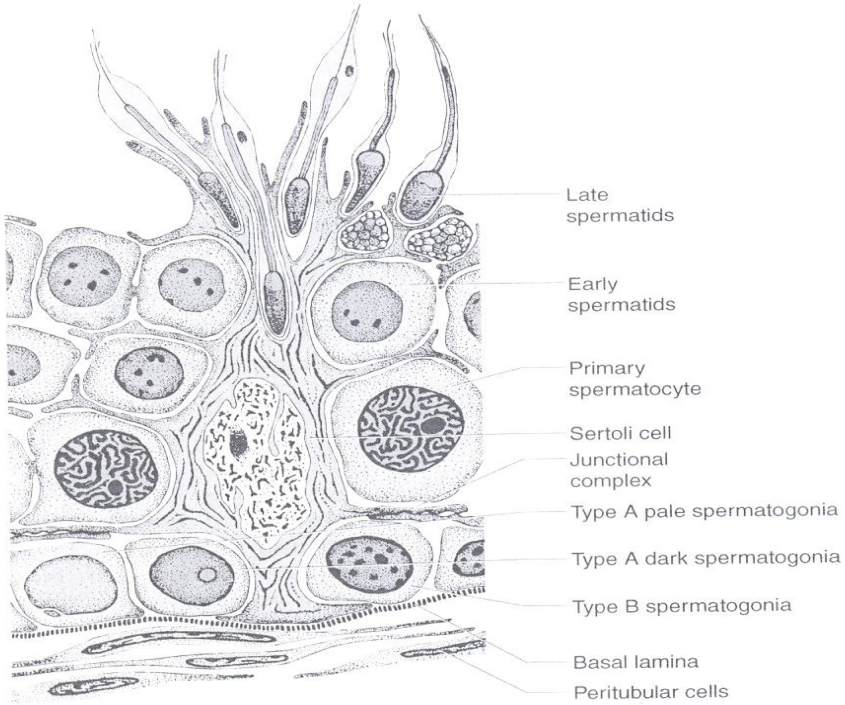
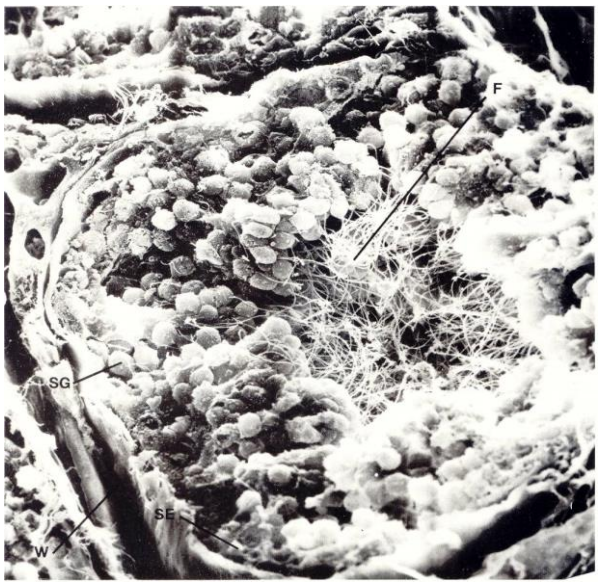
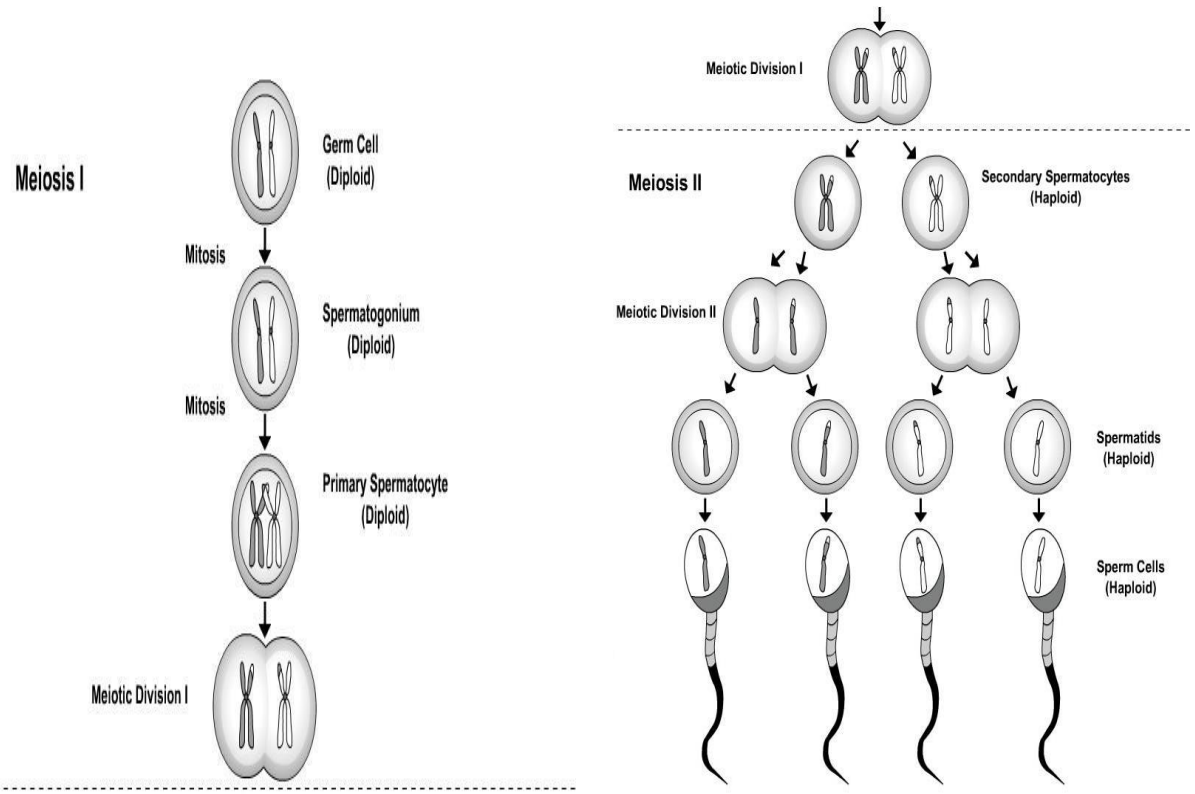


Figure 1.24 Sertoli cells and maturing spermatocytes. Spermatogonia, spermatocytes, and early spermatids occupy depressions in basal aspects of the cell; late spermatids are in deep recesses near the apex.



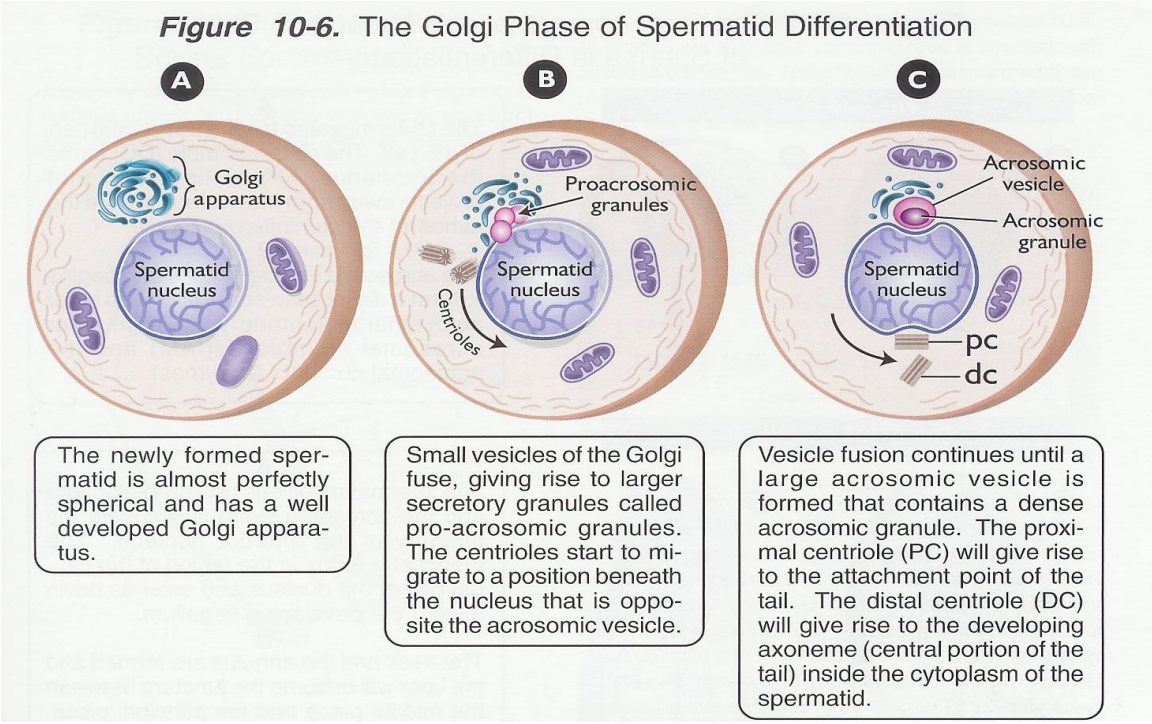
During the first meiotic division each *primary spermatocytes* divides into two equal daughter cells. With the onset of the second meiotic division these cells are known as *secondary spermatocytes*. In the human the first meiotic division lasts for several weeks, whereas the second one is completed in about 8 hours. Four haploid *spermatids* result from the meiotic phase of spermatogenesis.

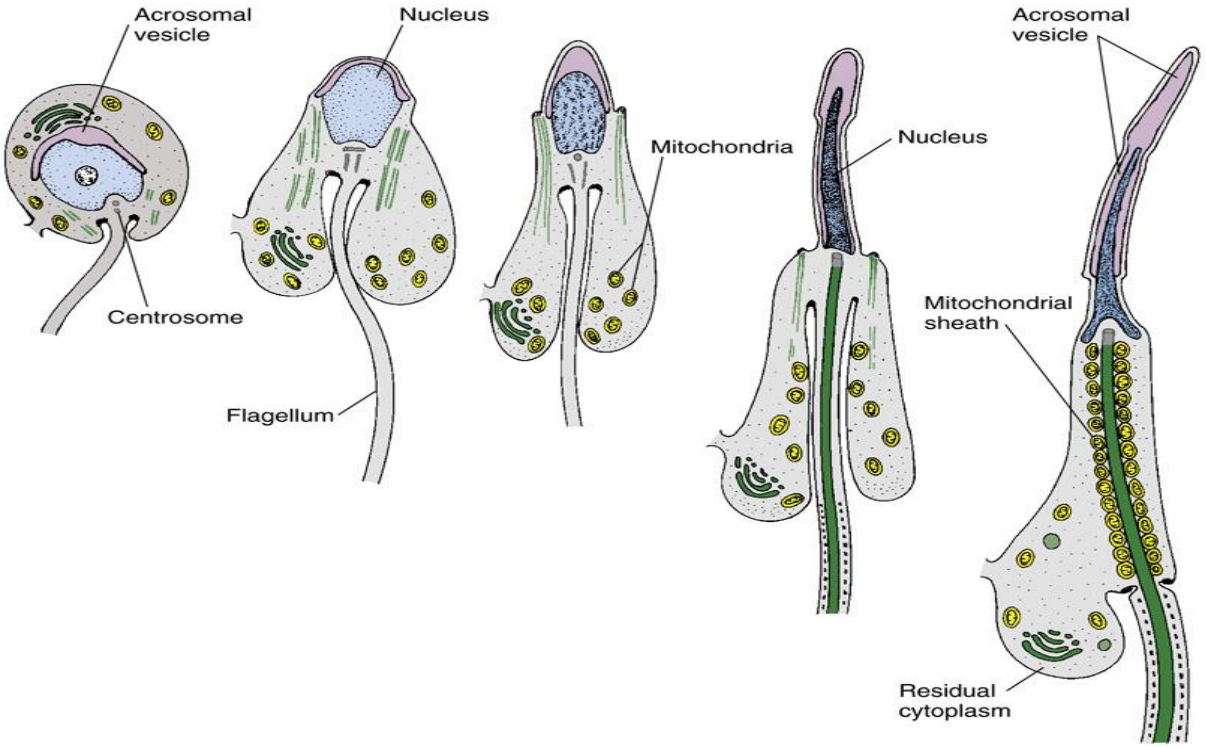


Although they no longer divide, the spermatids undergo a profound transformation from relatively ordinary looking cells to extrermely specialized *spermatozoa*.

The third phase in spermatogenesis is called spermiogenesis.

The cytoplasm streams away from the nucleus, which will become the sperm head, leaving only a thin layer covering the nucleus. At the apical end the developing sperm head, the Golgi complex forms proacrosomal granules, which fuse to form the *acrosome* . within the cytoplasm the centrioles become more conspicuous and appear to be a point of anchorage for the developing flagellum. The distal centriole moves away from the proximal one, and microtubules from it become continuous with microtubules in the flagellum. Mitochondria begin to form a spiral investment around the proximal part of the flagellum. As spermiogenesis continues, the remaining cytoplasm becomes aggregated into a remnant, or residual bodies, which sloughed off and phagocytized by the Sertoli cells.

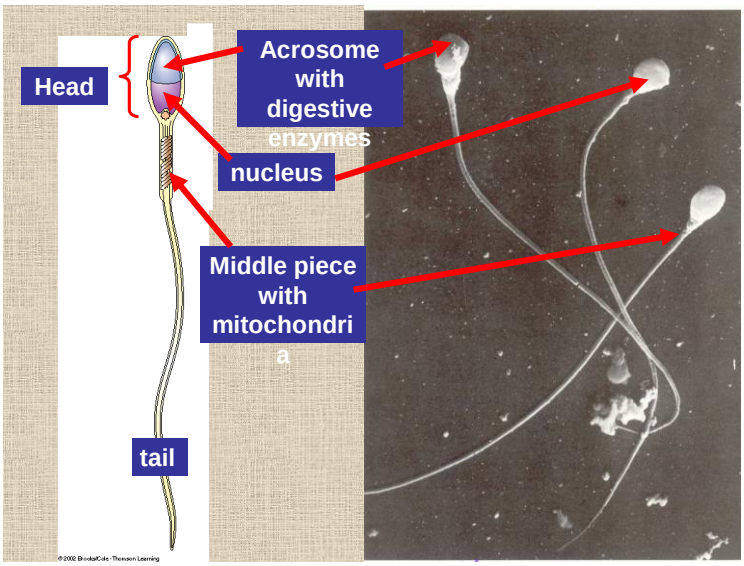




This leaves the mature spermatozoon stripped of all nonessential parts. It consists of,

1- A head containing the nucleus and acrosome
2- A neck containing the proximal centriole
3- A middle piece containing the proximal part of the flagellum, the centrioles, and the mitochondrial helix, which acts as an energy source.
4- The tail, a highly specialized flagellum (Fig.).

During spermatogenesis, the cells are also closely associated with Sertoli cells, which lie at regular intervals along the seminiferous tubule (Fig.). Sertoli cells serve a wide variety

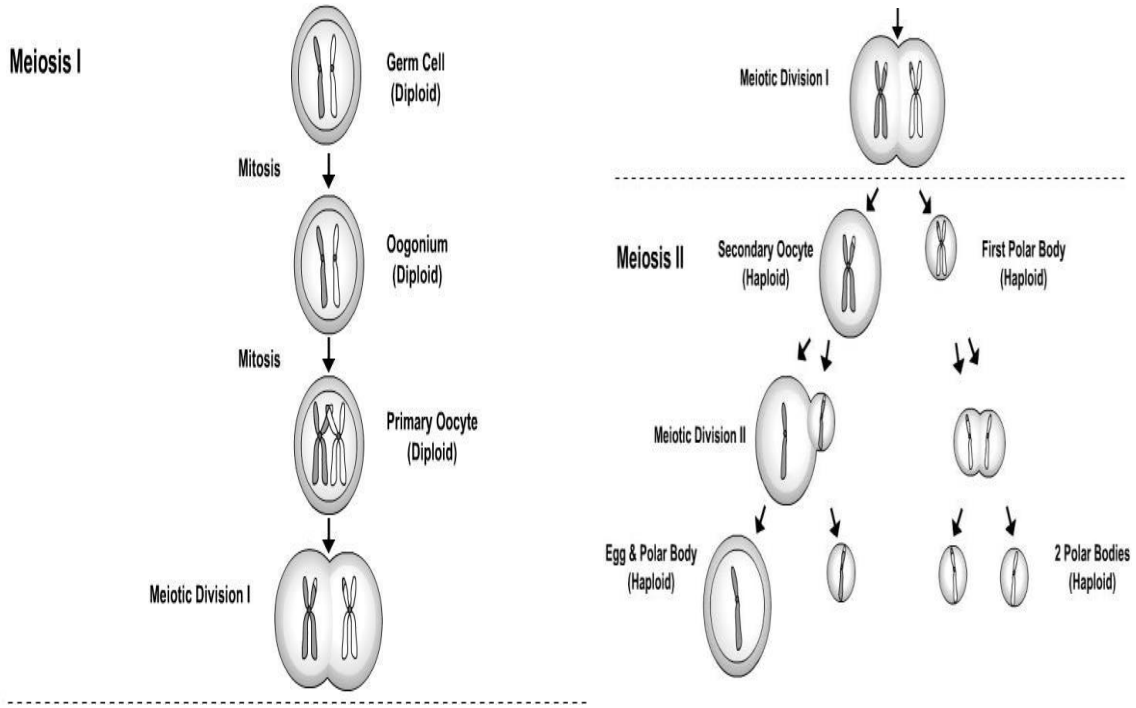


Oogenesis

The goal of oogenesis is to produce one egg with massive amounts of cytoplasm

1-The primary oocyte divides by Meiosis Division I to produce a secondary oocyte.The other nucleus resulting from Division I is a throw-away nucleus known as a polar body.

2- The secondary oocyte divides by Meiosis Division II to produce the egg cell and a polar body. The earlier polar body also divides to form two polar bodies.



Oogenesis in mammals

Maturation of Oocytes Begins Before Birth

1- Once primordial germ cells have arrived in the gonad of a genetic female, they differentiate into **oogonia**

These cells undergo a number of mitotic divisions and, **by the end of the third month**, are arranged in clusters surrounded by a layer of flat epithelial cells, known as **follicular cells,** originate from surface epithelium covering the ovary. The majority of oogonia continue to divide by mitosis, but some of them arrest their cell division in prophase of meiosis I and form **primary oocytes**

During the next few months, oogonia increase rapidly in number, and **by the fifth month**, the total number of germ cells in the ovary reaches **7 million**. At

this time, cell death begins, and many oogonia as well as primary oocytes become atretic.

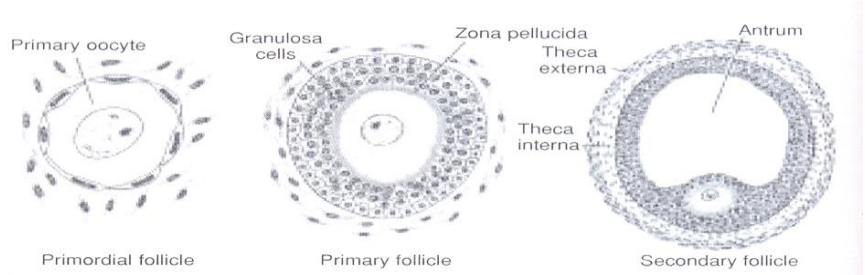


Figure 2.1 From the pool of primordial follicles, every day some begin to grow and develop into secondary (preantral) follicles, and this growth is independent of FSH. Then, as the cycle progresses, FSH secretion recruits primary follicles to begin development into secondary (antral, Graafian) follicles. During the last few days of maturation of secondary follicles, estrogens, produced by follicular and thecal cells, stimulate increased production of LH by the pituitary (Fig. 2.13), and this hormone causes the follicle to enter the preovulatory stage, to complete meiosis I, and to enter meiosis II where it arrests in metaphase approximately 3 hours before ovulation.

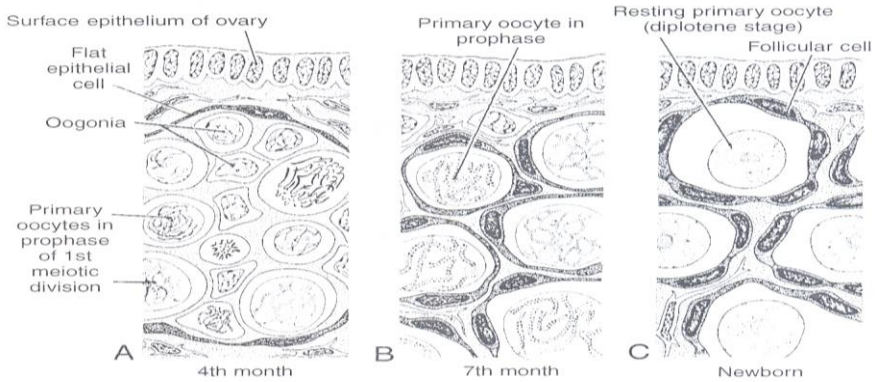


Figure 1.17 Segment of the ovary at different stages of development. **A.** Oogonia are grouped in clusters in the cortical part of the ovary. Some show mitosis; others have differentiated into primary oocytes and entered prophase of the first meiotic division. **B.** Almost all oogonia are transformed into primary oocytes in prophase of the first meiotic division. **C.** There are no oogonia. Each primary oocyte is surrounded by a single layer of follicular cells, forming the primordial follicle. Oocytes have entered the diplotene stage of prophase, in which they remain until just before ovulation. Only then do they enter metaphase of the first meiotic division.

By the seventh month, the majority of oogonia have degenerated except for a few near the surface. All surviving primary oocytes have entered prophase of meiosis I, and most of them are individually surrounded by a layer of flat epithelial cells known as a **primordial follicle**.

Near the time of birth, all primary oocytes have started prophase of meiosis I, and enter the **diplotene stage,** a resting stage during prophase. **Primary oocytes remain in prophase** and **do not finish their first meiotic division before puberty is reached,** apparently because of **oocyte maturation inhibitor** (OMI), a substance secreted by follicular cells.

The total number of primary oocytes at birth is estimated to vary from **700,000 to 2 million**. During childhood most oocytes become atretic; only approximately **400,000** are present **by the beginning of puberty**, and fewer than **500 will be ovulated**.

Some oocytes that reach maturity late in life have been dormant in the diplotene stage of the first meiotic division **for 40 years** or more before ovulation.

Whether the diplotene stage is the most suitable phase to protect the oocyte against environmental influences is unknown. The fact that the risk of having **children with chromosomal abnormalities** increases with maternal age indicates that primary oocytes are vulnerable to damage as they age.

At puberty, Each month, 15 to 20 follicles begin to mature, passing through three stages:

1) **primary** or **preantral**
2) **secondary** or **antral** (also called **vesicular** or **Graafian)** the longest stage
3) **preovulatory. (** 37 hours before ovulation **)**

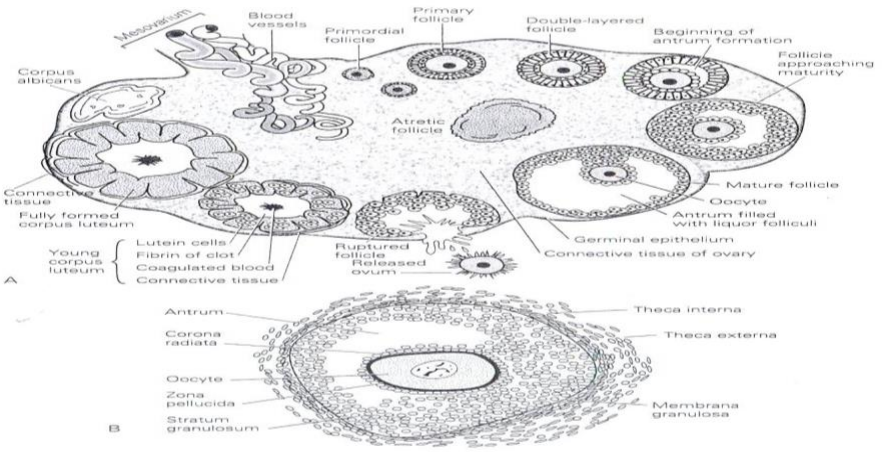
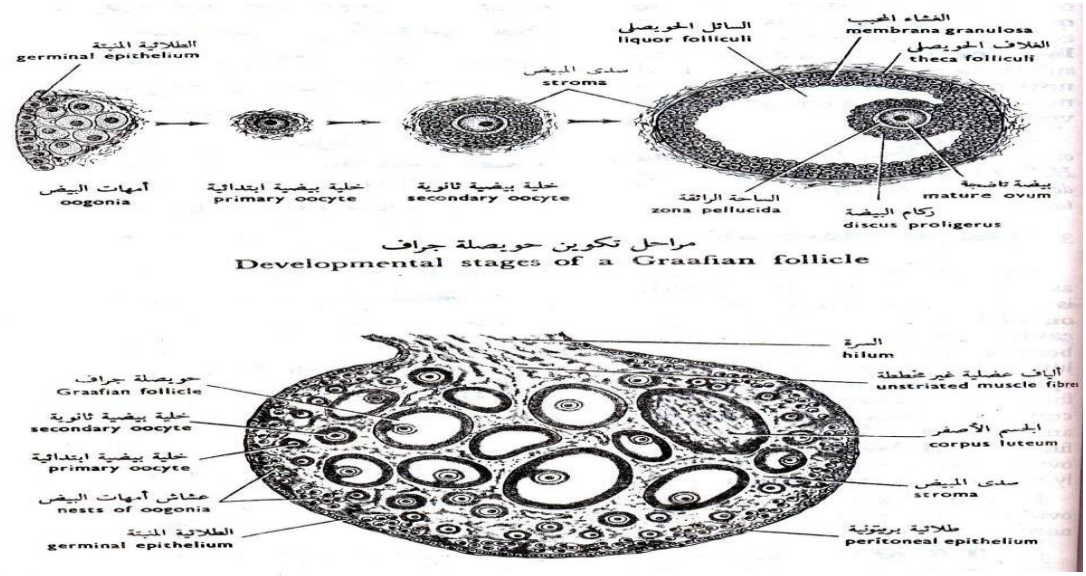


FIGURE 3-21
(A) Schematic diagram of ovary showing sequence of events in origin, growth, and rupture of ovarian (Graafian) follicle and in formation and retrogression of corpus luteum. Follow clockwise around ovary, starting at mesovarium. (B) Drawing of a secondary follicle.



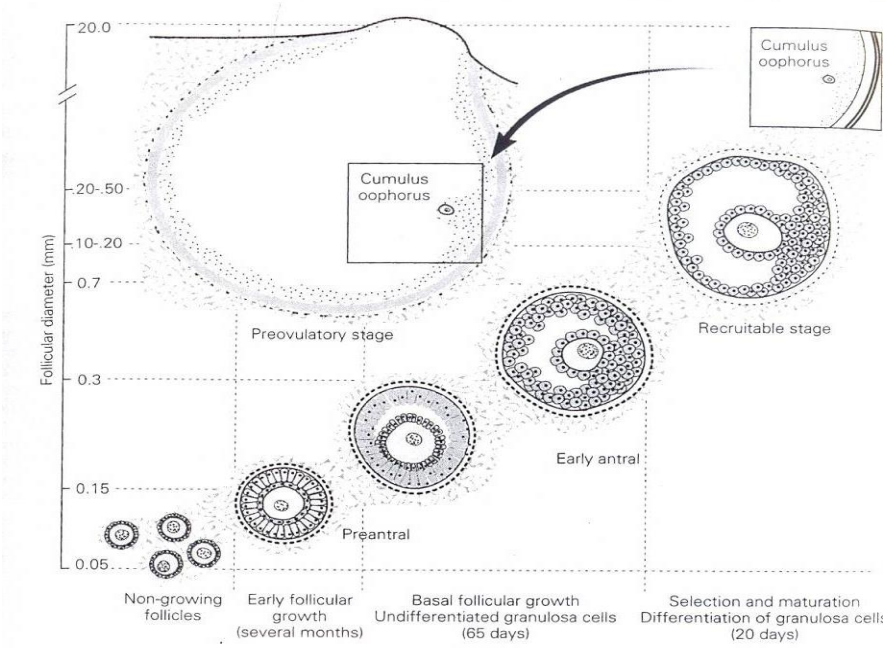


FIGURE 3-22
Representation of the growth and development of the human oocyte. (*After A. Gougeon, 1993.*)

As the **primary oocyte** begins to grow, surrounding follicular cells change from flat to cuboidal and proliferate to produce a stratified epithelium of **granulosa cells,** and the unit is called a **primary follicle**

Granulosa cells rest on a basement membrane separating them from surrounding stromal cells that form the **theca folliculi.**

Granulosa cells and the oocyte secrete a layer of glycoproteins on the surface of the oocyte, forming the **zona pellucida**.

Theca folliculi organize into an inner layer of secretory cells, the **theca interna,** and an outer fibrous capsule, the **theca externa.** Also, small, finger-like processes of the follicular cells extend across the zona pellucida and interdigitate with microvilli of the plasma membrane of the oocyte. These processes are important for transport of materials from follicular cells to the oocyte. As development continues, fluid-filled spaces appear between granulosea cells. Coalescence of these spaces forms the **antrum,** and the follicle is termed a **secondary (vesicular, Graafian) follicle.** Initially, the antrum is crescent shaped, but with time, it enlarges. (Granulosa cells surrounding the oocyte remain intact and form the **cumulus oophorus.** At maturity, the **secondary follicle** may be **25 mm** or more in diameter.

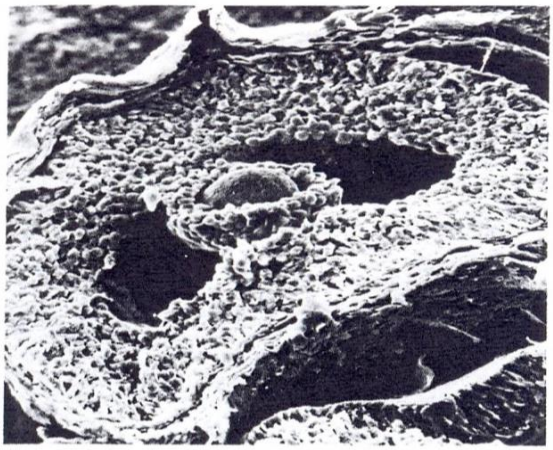
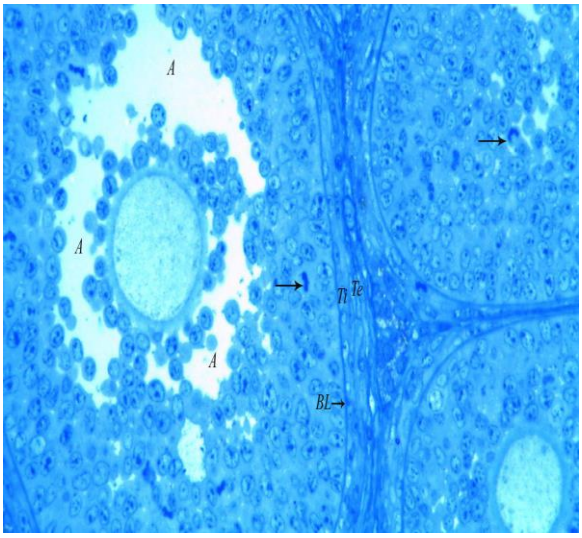


FIGURE 3-23
Scanning electron microscope of a mature follicle in the rat, showing the spherical oocyte (*center*) surrounded by smaller cells of the corona radiata, which projects into the antrum. x840. (*Courtesy of P. Bagavandoss.*)



With each ovarian cycle, a number of follicles begin to develop, but usually only one reaches full maturity. The others degenerate and become atretic.

When the secondary follicle is mature, a surge in **luteinizing hormone (LH)** induces the preovulatory growth phase. **Meiosis I is completed**, resulting in

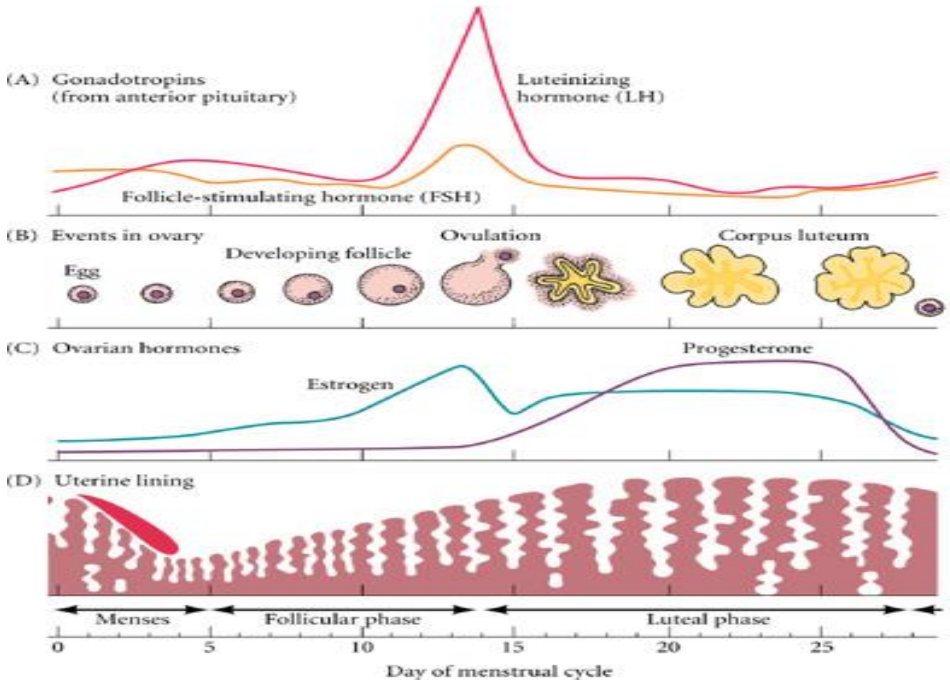
formation of two daughter cells of unequal size, each with 23 double structured chromosomes.

- One cell, the **secondary oocyte,** receives most of the cytoplasm; the other, the **first polar body**, receives practically none. The first polar body lies between the zona pellucida and the cell membrane of the secondary oocyte in the perivitelline space.

The cell then enters **meiosis II** but arrests in metaphase approximately 3 hours before ovulation. Meiosis II is completed only if the oocyte is fertilized; otherwise, the cell degenerates approximately 24 hours after ovulation. The first polar body also undergoes a second division.

Ovarian Cycle

At puberty, the female begins to undergo regular monthly cycles. These **sexual cycles** are controlled by the hypothalamus. **Gonadotropin-releasing hormone (GnRH)** produced by the hypothalamus acts on cells of the anterior pituitary gland, which in turn secrete **gonadotropins.** These hormones, **follicle-stimulating hormone (FSH)** and **luteinizing hormone (LH),** stimulate and control cyclic changes in the ovary.

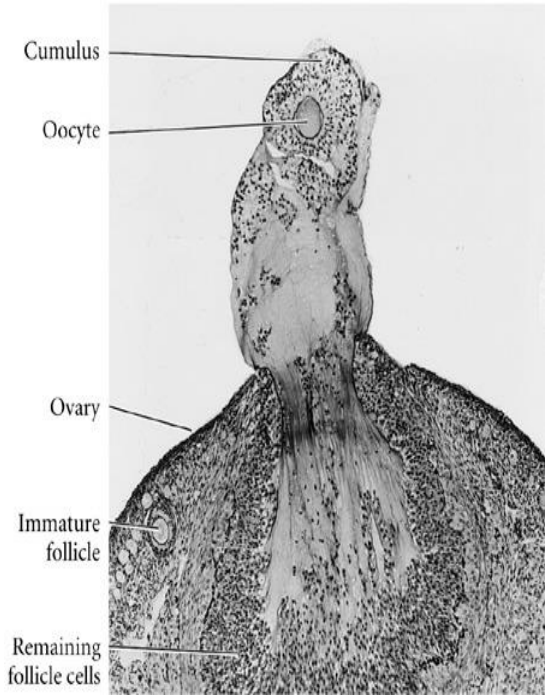


At the beginning of each ovarian cycle, 15 to 20 primary (preantral) stage follicles are stimulated to grow under the influence of FSH. Under normal conditions, only one of these follicles reaches full maturity. The others degenerate and become atretic. When a follicle becomes atretic, the oocyte and surrounding follicular cells degenerate and are replaced by connective tissue, forming a **corpus atreticum.** FSH also stimulates maturation of **follicular (granulosa)** cells surrounding the oocyte.

OVULATION

In the days immediately preceding ovulation, under the influence of FSH and LH, the secondary follicle grows rapidly to a diameter of 25 mm. Increase in LH causes the primary oocyte to complete meiosis I and the follicle to enter the preovulatory stage. Meiosis II is also initiated, but the oocyte is arrested in metaphase approximately 3 hours before ovulation. In the meantime, the surface of the ovary begins to bulge locally, and at the apex, an avascular spot, the **stigma,** appears. The high concentration of LH increases collagenase activity, resulting in digestion of collagen fibers surrounding the follicle. The muscular contractions in the ovarian wall extrude the oocyte, which together with its

surrounding granulosa cells from the region of the cumulus oophorus, breaks free **(ovulation)** and floats out of the ovary.



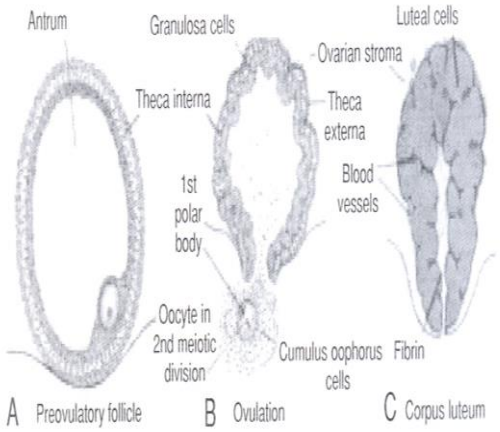


Figure 2.2 A. Preovulatory follicle bulging at the ovarian surface. **B.** Ovulation. The oocyte, in metaphase of meiosis II, is discharged from the ovary together with a large number of cumulus oophorus cells. Follicular cells remaining inside the collapsed follicle differentiate into lutean cells. **C.** Corpus luteum. Note the large size of the corpus luteum, caused by hypertrophy and accumulation of lipid in granulosa and theca interna cells. The remaining cavity of the follicle is filled with fibrin.

During ovulation, some women feel a slight pain, known as **middle pain** because it normally occurs near the middle of the menstrual cycle. Ovulation is also generally accompanied by a rise in basal temperature.

CORPUS LUTEUM

After ovulation, granulosa cells remaining in the wall of the ruptured follicle, together with cells from the theca interna, are vascularized by surrounding vessels. Under the influence of LH, these cells develop a yellowish pigment and change into **lutean cells,** which form the **corpus luteum** and secrete the hormone **progesterone** (Fig. 2.2*C*). Progesterone, together with estrogenic hormones, causes the uterine mucosa to enter the **progestational** or **secretory stage** in preparation for implantation of the embryo.

CORPUS ALBICANS

If fertilization does not occur, the corpus luteum reaches maximum development approximately 9 days after ovulation. It can easily be recognized as a yellowish projection on the surface of the ovary. Subsequently, the corpus luteum shrinks because of degeneration of lutean cells and forms a mass of fibrotic scar tissue, the **corpus albicans.** Simultaneously, progesterone production decreases,precipitating menstrual bleeding.

If the oocyte is fertilized, degeneration of the corpus luteum is prevented by **human chorionic gonadotropin** (hCG), a hormone secreted by the developing embryo. The corpus luteum continues to grow and forms the **corpus luteum of pregnancy (corpus luteum graviditatis).**

By the end of the third month, this structure may be one-third to one-half of the total size of the ovary. Yellowish luteal cells continue to secrete progesterone until the end of the fourth month; thereafter, they regress slowly as secretion of progesterone by the trophoblastic component of the placenta becomes adequate for maintenance of pregnancy. Removal of the corpus luteum of pregnancy before the fourth month usually leads to abortion.

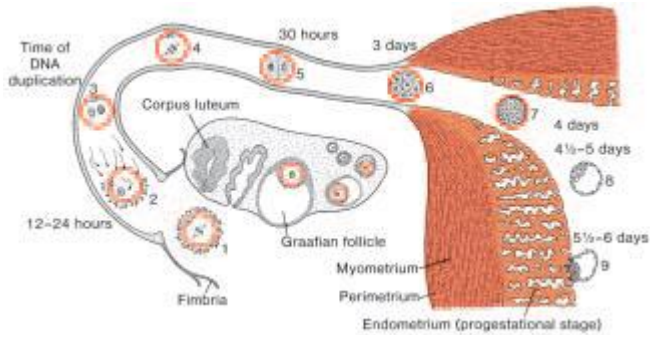
The timing of meiosis differs in females and males

In males, the spermatogonia enter meiosis and produce sperm from puberty until death. The process of sperm production takes only a few weeks. In females, this process is more complex. The first meiotic division starts before birth but fails to proceed. It is eventually completed about one month before ovulation in humans. In humans, the second meiotic division occurs just before the actual process of fertilization occurs. Thus, in females, the completion of meiosis can be delayed for over 50 years. This is not always good. In addition, all meiosis is ended in females at menopause.

Uterus at Time of Implantation

The wall of the uterus consists of three layers: (a) endometrium or mucosa lining the inside wall; (b) myometrium, a thick layer of smooth muscle; and (c) perimetrium, the peritoneal covering lining the outside wall. From puberty (11–13 years) until menopause (45–50 years), the endometrium undergoes changes in a cycle of approximately 28 days under hormonal control by the ovary. During this menstrual cycle, the uterine endometrium passes through three stages, the follicular or **proliferative phase**, the secretory or **progestational phase**, and the **menstrual phase**.

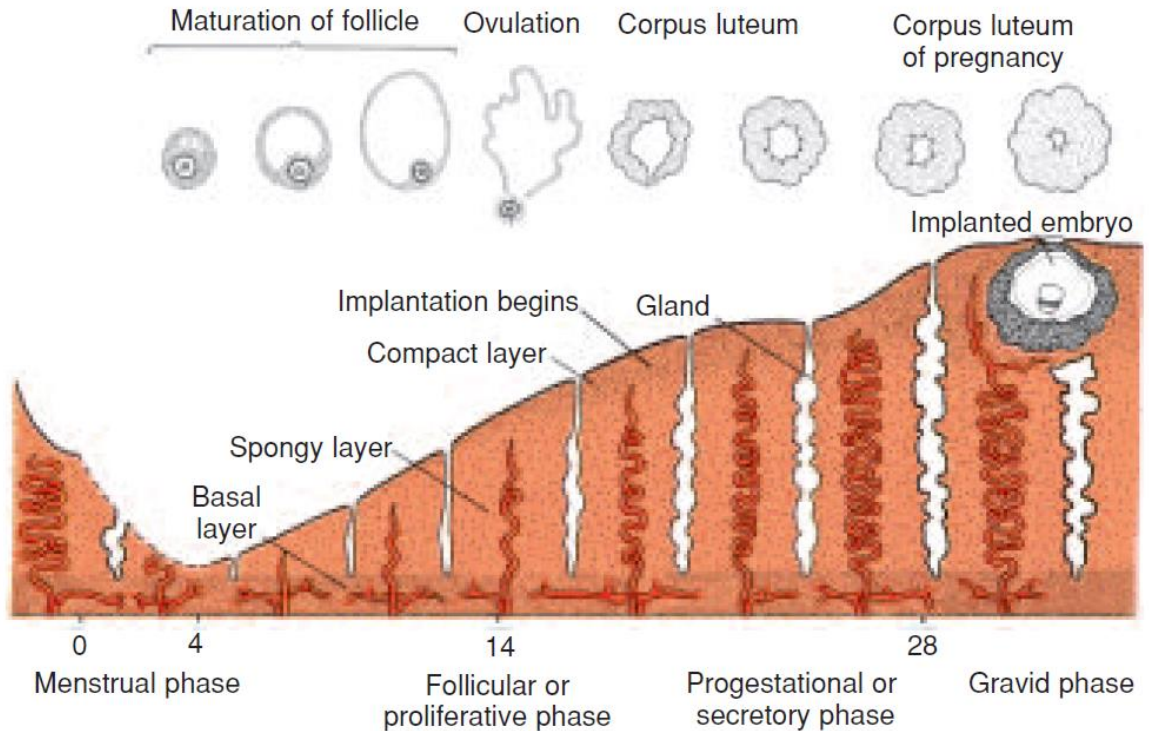
The proliferative phase begins at the end of the menstrual phase, is under the influence of estrogen, and parallels growth of the ovarian follicles. The secretory phase begins approximately 2 to 3 days after ovulation in response to progesterone produced by the corpus luteum. If fertilization does not occur, shedding of the endometrium marks the beginning of the menstrual phase. If fertilization does occur, the endometrium assists in implantation and contributes to formation of the placenta.



Events during the first week of human development. 1, Oocyte immediately after ovulation. 2, Fertilization, approximately 12 to 24 hours after ovulation. 3, Stage of the male and female pronuclei. 4, Spindle of the first mitotic division. 5, Twocell stage (approximately 30 hours of age). 6, Morula containing 12 to 16 blastomeres (approximately 3 days of age). 7, Advanced morula stage reaching the uterine lumen (approximately 4 days of age). 8, Early blastocyst stage (approximately 4.5 days of age). The zona pellucida has disappeared. 9, Early phase of implantation (blastocyst approximately 6 days of age). The ovary shows stages of transformation between a primary follicle and a preovulatory follicle as well as a corpus luteum. The uterine endometrium is shown in the progestational stage.

At the time of implantation, the mucosa of the uterus is in the secretory phase , during which time uterine glands and arteries become coiled and the tissue becomes succulent. As a result, three distinct layers can be recognized in the endometrium: a superficial **compact layer**, an intermediate **spongy layer**, and a thin **basal layer**. Normally, the human blastocyst implants in the endometrium , where it becomes embedded between the openings of the glands;

If the oocyte is not fertilized, venules and sinusoidal spaces gradually become packed with blood cells, and an extensive diapedesis of blood into the tissue is seen. When the menstrual phase begins, blood escapes from superficial arteries, and small pieces of stroma and glands break away. During the following 3 or 4 days, the compact and spongy layers are expelled from the uterus, and the basal layer is the only part of the endometrium that is retained. This layer, which is supplied by its own arteries, the basal arteries, functions as the regenerative layer in the rebuilding of glands and arteries in the proliferative phase.

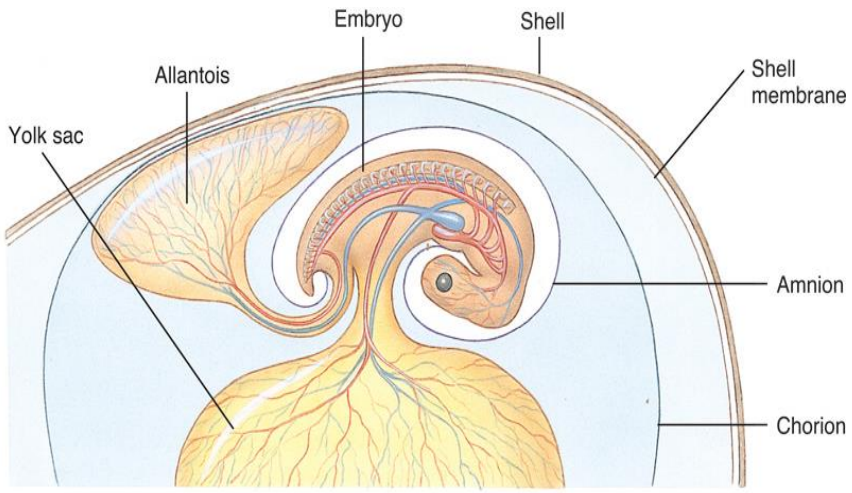


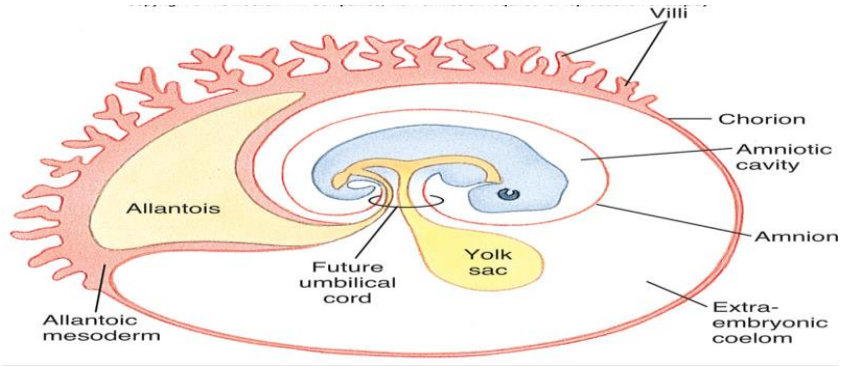
Changes in the uterine mucosa correlated with those in the ovary. Implantation of the blastocyst has caused development of a large corpus luteum of pregnancy. Secretory activity of the endometrium increases gradually as a result of large amounts of progesterone produced by the corpus luteum of pregnancy.

Extraembryonic Membranes

An almost universal requirement of embryonic development is that the embryo develop in a moist, protective environment. In most fishes, this requirement is met by laying and fertilizing massive numbers of eggs in water . The eggs that are fertilized develop within simple spherical membranes. Amphibians must return at each spring to pounds and streams to lay eggs which, upon fertilization, develop within simple noncellular membranes.

A significant evolutionary step occurred when the first reptiles laid eggs capable of developing on land. This made possible by the elaboration of a protective shell and a series of cellular membranes surrounding the embryonic body. These membranes assist the embryo in vital functions, such as nutrition, gas exchange, and removal or storage of waste materials. Four sets of extraembryonic membranes are common to the embryo of the terrestrial vertebrates.





1- **The amnion** is a thin ectodermally derived membrane which eventually encloses the entire embryo in a fluid-filled sac. The amniotic membrane is functionally specialized for the secretion and absorption of the amniotic fluid that bathes the embryo. So characteristic is this structure that the reptiles, birds, and mammals as a group are often called amniotes. The fishes and amphibians, lacking an amnion, are collectively called anamniotes.

2- The yolk sac : The endodermal yolk sac is intimately involved with nutrition of the embryo in large-yolked forms such as reptiles and birds. Despite the lack of stored in mammalian eggs, the yolk sac has been preserved, possibly because other important secondary functions are associated with it. For example, the yolk sac endoderm induces the surrounding extraembryonic mesoderm to form the first blood cells and blood vessels.

3- The allantois is an endodermally lined evagination originating from the ventral surface of the early hindgut. Its principal functions are to act as a reservoir for storing or removing urinary wastes and to mediate gas exchange between the embryo and its surroundings.

In reptiles and birds the allantois is a large sac, and because the egg is a closed system with respect to urinary wastes, the allantois must sequester nitrogenous by-product so that they do not subject the embryo to osmotic stress or toxic effects.

In mammals the role and prominence of the allantois vary with the efficiency of the interchange that takes place at the fetal-maternal interface. The allantois of the pig embryo rivals that of the bird in both size and functional importance, whereas the human allantois has been reduced to a mere vestige that contributes only a well-developed vascular network to the highly efficient placenta.

4-The chorion is the outermost extraembryonic membrane, which abuts onto the shell or the maternal tissue and thus represents the site of exchange between the embryo and the environment around it.

In reptiles and birds, the principla function of the chorion is the respiratory exchange of gases.

In mammals, the chorion serves a much more all-embracing function which includes not only respiration but also nutrition, excertion, filtration, and synthesis-with hormone production begin an important example of the last function.

Embryonic development of mammals

Gametes

The sperm: It is microscopic. It is formed of a head, a middle piece and a tail.

- The head is pear-shaped. It has a nucleus and an acrosome surrounded by a plasma membrane.
- The middle piece is connected with head by a neck , and contain two centrioles and the mitochondria.
- The tail is long. Its central core is occupied by an axial filament.

The egg: is spherical in shape. In therian mammals (both marsupials and placentals) the eggs are very small. Placentals: range from 0.1 - 0.2 mm.

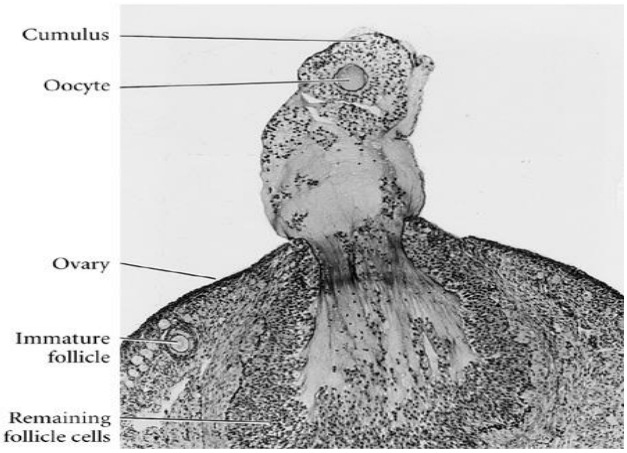
(Humans ~0.15 mm). Eggs - microlecithal - cleavage - holoblastic. the egg is released from the ovary surrounded by three membranes

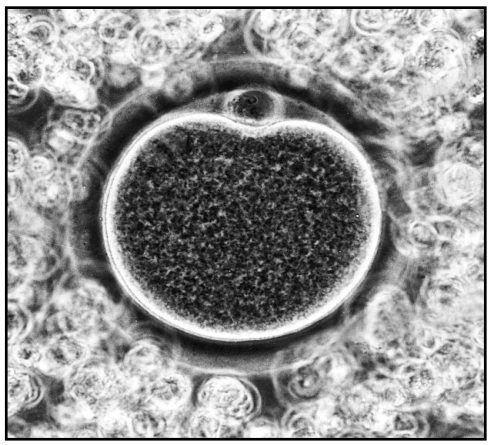
1- Corona radiate (formed of follicle cells)

2 - A middle zona pellucida

3 - An inner plasma membrane.

There is a fluid-filled space between zona pellucida and the surface of the egg and it is called perivitelline space.



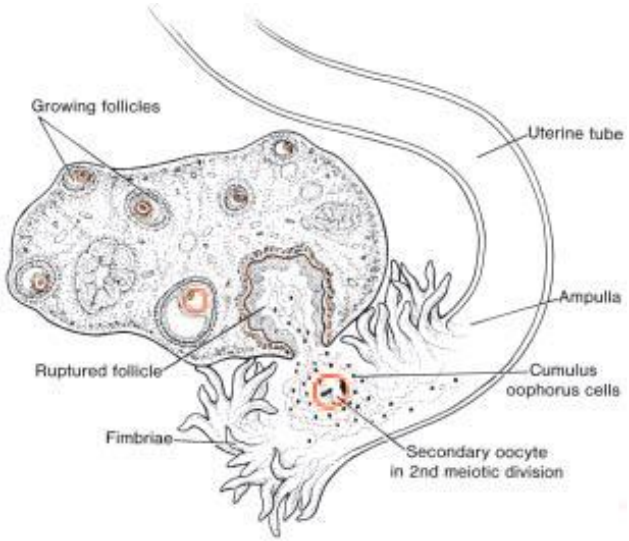


Fertilization in mammals

Fertilization, the process by which male and female gametes fuse, occurs in the **ampullary region of the uterine tube.** This is the widest part of the tube and is close to the ovary. Spermatozoa may remain viable in the female reproductive tract for several days. Only 1% of sperm deposited in the vagina enter the cervix, where they may survive for many hours. The trip from cervix to oviduct requires a minimum of 2 to 7 hours, and after reaching the isthmus, sperm become less motile and cease their migration. Spermatozoa are not able to fertilize the oocyte immediately upon arrival in the female genital tract but must undergo (*a*) **capacitation** and (*b*) the **acrosome reaction** to acquire this capability.

(a)-Capacitation is a period of conditioning in the female reproductive tract that in the human lasts approximately 7 hours. Much of this conditioning, which occurs in the uterine tube, entails epithelial interactions between the sperm and mucosal surface of the tube. During this time a glycoprotein coat and seminal plasma proteins are removed from the plasma membrane that overlies the acrosomal region of the spermatozoa. Only capacitated sperm can pass through the corona cells and undergo the acrosome reaction.

(b) The **acrosome reaction,** which occurs after binding to the zona pellucida, is induced by zona proteins. This reaction culminates in the release of enzymes needed to penetrate the zona pellucida, including acrosin and trypsin-like substances.



Fimbriae collect the oocyte and sweep it into the uterine tube.

The phases of fertilization

Phase 1, penetration of the corona radiate.

phase 2, penetration of the zona pellucida.

phase 3, fusion of the oocyte and sperm cell membranes.

PHASE 1: PENETRATION OF THE CORONA RADIATA

Of the 200 to 300 million spermatozoa deposited in the female genital tract, only 300 to 500 reach the site of fertilization. Only one of these fertilizes the egg. It is thought that the others aid the fertilizing sperm in penetrating the barriers protecting the female gamete. Capacitated sperm pass freely through corona cells.

PHASE 2: PENETRATION OF THE ZONA PELLUCIDA

The zona is a glycoprotein shell surrounding the egg that facilitates and maintains sperm binding and induces the acrosome reaction. Both binding and the acrosome reaction are mediated by the ligand ZP3, a zona protein. Release of acrosomal enzymes (acrosin) allows sperm to penetrate the zona, thereby coming in contact with the plasma membrane of the oocyte.

Permeability of the zona pellucida changes when the head of the sperm comes in contact with the oocyte surface. This contact results in release of lysosomal enzymes from cortical granules lining the plasma membrane of the oocyte. In turn, these enzymes alter properties of the zona pellucida **(zona reaction)** to prevent sperm penetration and inactivate species-specific receptor sites for spermatozoa on the zona surface. Other spermatozoa have been found embedded in the zona pellucida, but only one seems to be able to penetrate the oocyte. These reactions prevent polyspermy (penetration of more than one spermatozoon into the oocyte).

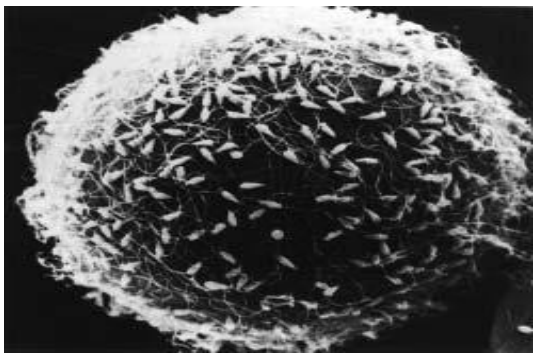
PHASE 3: FUSION OF THE OOCYTE AND SPERM CELL MEMBRANES

After adhesion, the plasma membranes of the sperm and egg fuse. Because the plasma membrane covering the acrosomal head cap disappears during the acrosome reaction, actual fusion is accomplished between the oocyte membrane

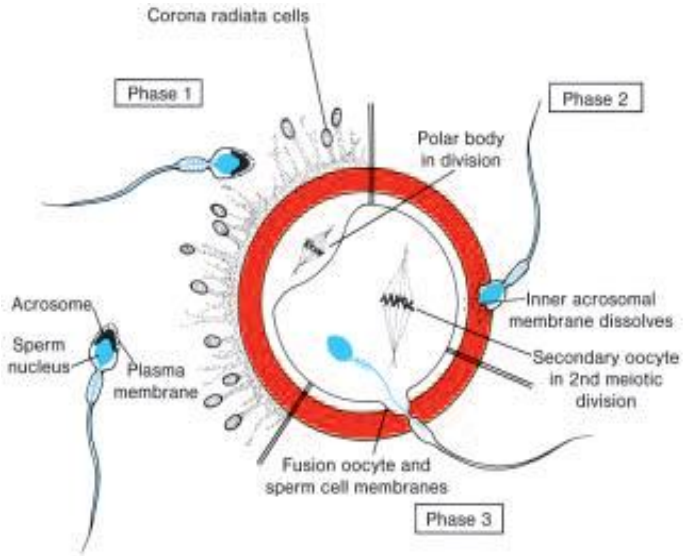
and the membrane that covers the posterior region of the sperm head. In the human, both the head and tail of the spermatozoon enter the cytoplasm of the oocyte, but the plasma membrane is left behind on the oocyte surface. As soon as the spermatozoon has entered the oocyte, the egg responds in three ways.

The oocyte finishes its second meiotic division immediately after entry of the spermatozoon. One of the daughter cells, which receives hardly any cytoplasm, is known as the **second polar body;** the other daughter cell is the **definitive oocyte.** Its chromosomes (22+X) arrange themselves in a vesicular nucleus known as the **female pronucleus**.

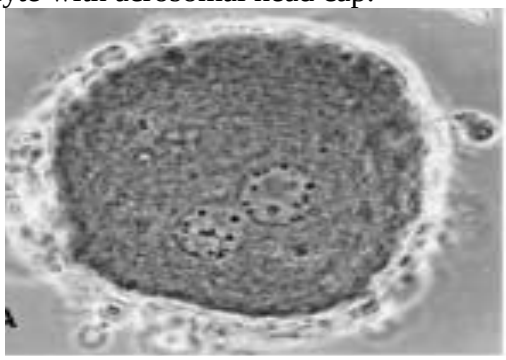
The spermatozoon, meanwhile, moves forward until it lies close to the female pronucleus. Its nucleus becomes swollen and forms the **male pronucleus** ; the tail detaches and degenerates. Morphologically, the male and female pronuclei are indistinguishable, and eventually, they come into close contact and lose their nuclear envelopes. Each pronucleus must replicate its DNA.



Scanning electron micrograph of sperm binding to the zona pellucida.



The three phases of oocyte penetration. In phase 1, spermatozoa pass through the corona radiata barrier; in phase 2, one or more spermatozoa penetrate the zona pellucida; in phase 3, one spermatozoon penetrates the oocyte membrane while losing its own plasma membrane. Inset. Normal spermatocyte with acrosomal head cap.



Phase contrast view of the pronuclear stage of a fertilized human oocyte with male and female pronuclei.

The main results of fertilization are as follows:

1- **Restoration of the diploid number of chromosomes,** half from the father and half from the mother. Hence, the zygote contains a new combination of chromosomes different from both parents.

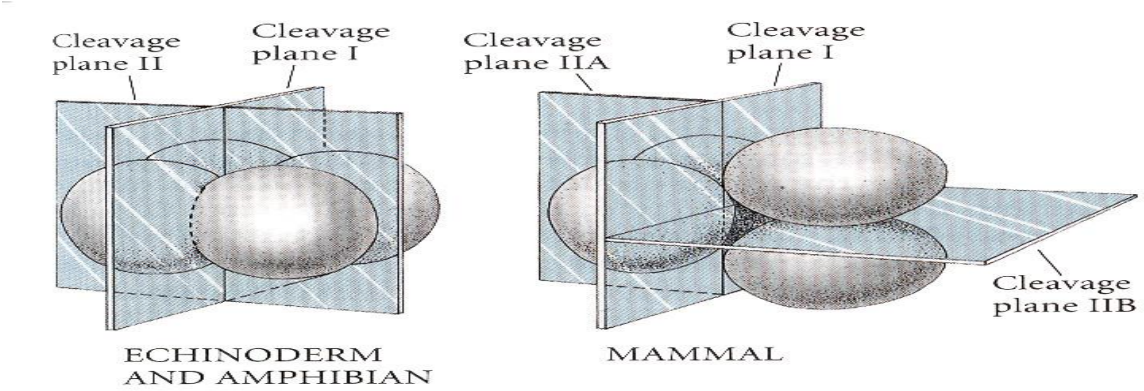
2- **Determination of the sex of the new individual**. An X-carrying sperm produces a female (XX) embryo, and a Y-carrying sperm produces a male (XY) embryo. Hence, the chromosomal sex of the embryo is determined at fertilization.

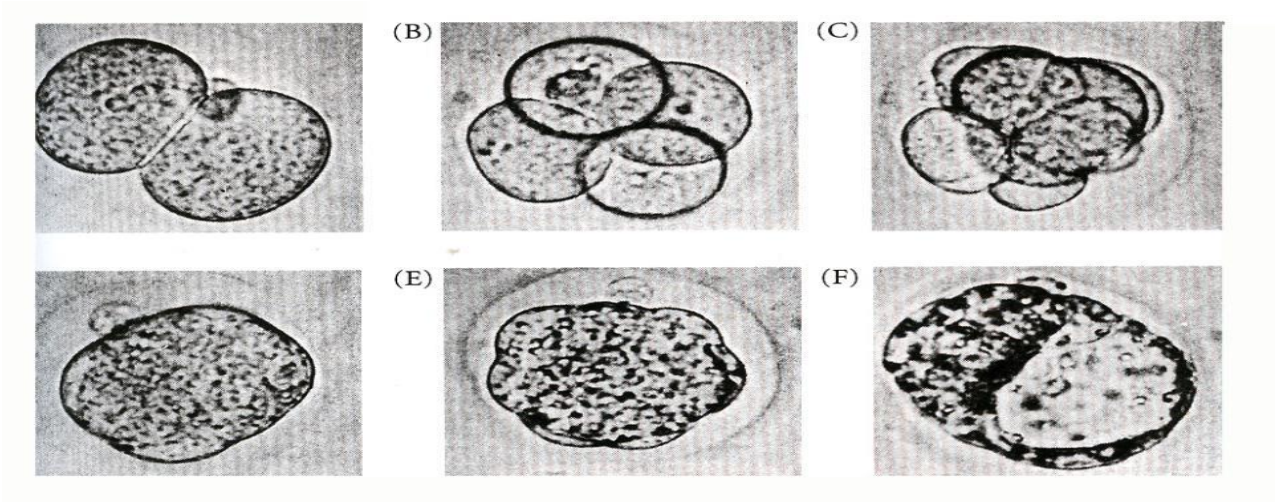
3- **Initiation of cleavage.** Without fertilization, the oocyte usually degenerates 24 hours after ovulation.

Early cleavage in mammals

Cell division occurs with travel down the tube and into the uterus. First Cleavage - takes place while embryo is still in the uterine tubes of the mother.

Second Cleavage: Mammals have what's known as rotational cleavage wherein one of the blastomeres divides meridianally, and the other equatorially. Subsequent cleavages are relatively less organized. Once the zygote has reached the two-cell stage, it undergoes a series of mitotic divisions, increasing the numbers of cells.These cells (blastomeres) become smaller with each cleavage division. After the third cleavage, blastomeres maximize their contact with each other, forming a compact ball of cells held together by tight junctions.

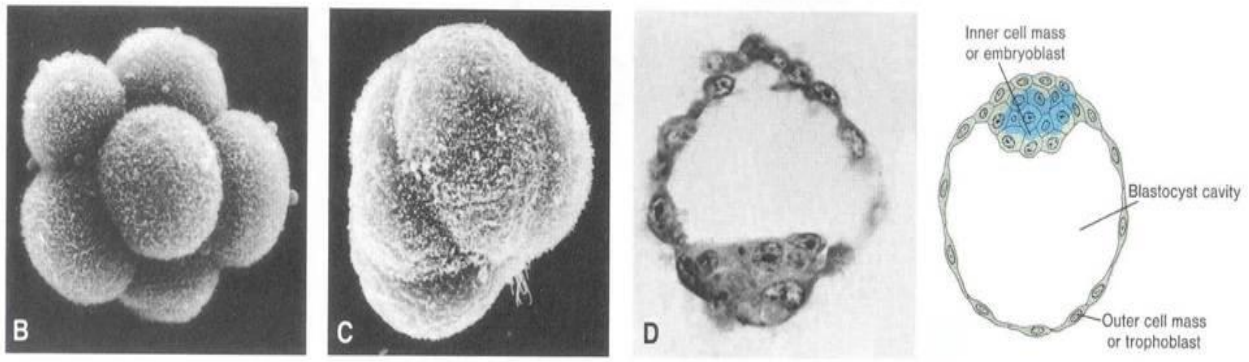




Development of the zygote from the two-cell stage to the late morula stage. The two-cell stage is reached approximately 30 hours after fertilization; the four-cell stage, at approximately 40 hours; the 12- to 16-cell stage,

at approximately 3 days; and the late morula stage, at approximately 4 days. During this period, blastomeres are surrounded by the zona pellucida, which disappears at the end of the fourth day.

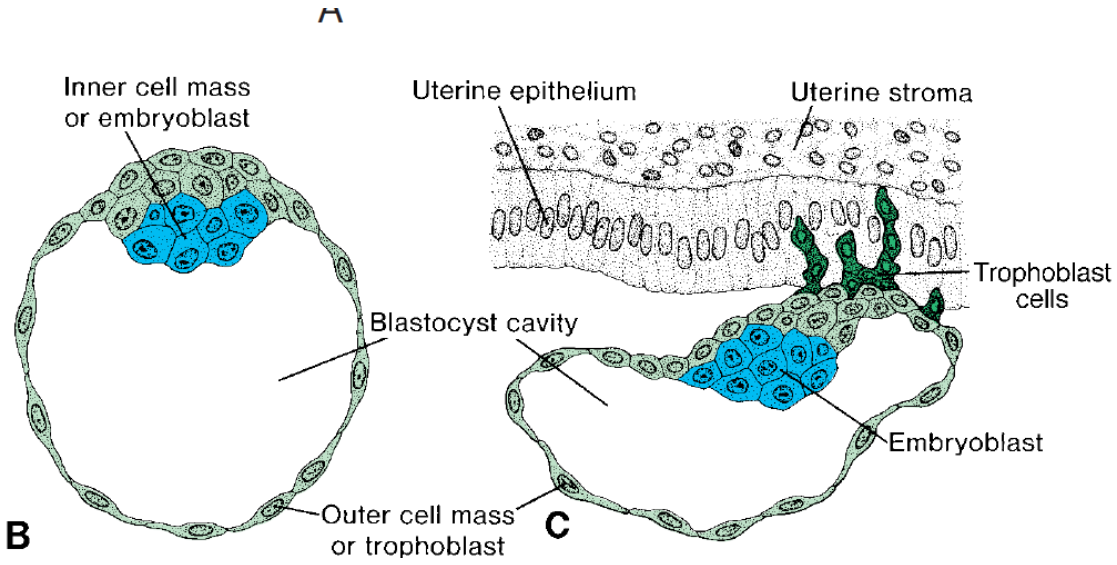
Approximately 3 days after fertilization, cells of the compacted embryo divide again to form a 16-cell morula. the developing organism has usually reached the uterus. It is about the size of a head of a pin. Inner cells of the morula constitute the inner cell mass, and surrounding cells compose the outer cell mass.



Scanning electron micrographs of uncompacted (B) and compacted (C) eight-cell mouse embryos. In the uncompacted state, outlines of each blastomere are distinct, whereas after compaction cell-cell contacts are maximized and cellular outlines are indistinct.

Blastocyst Formation

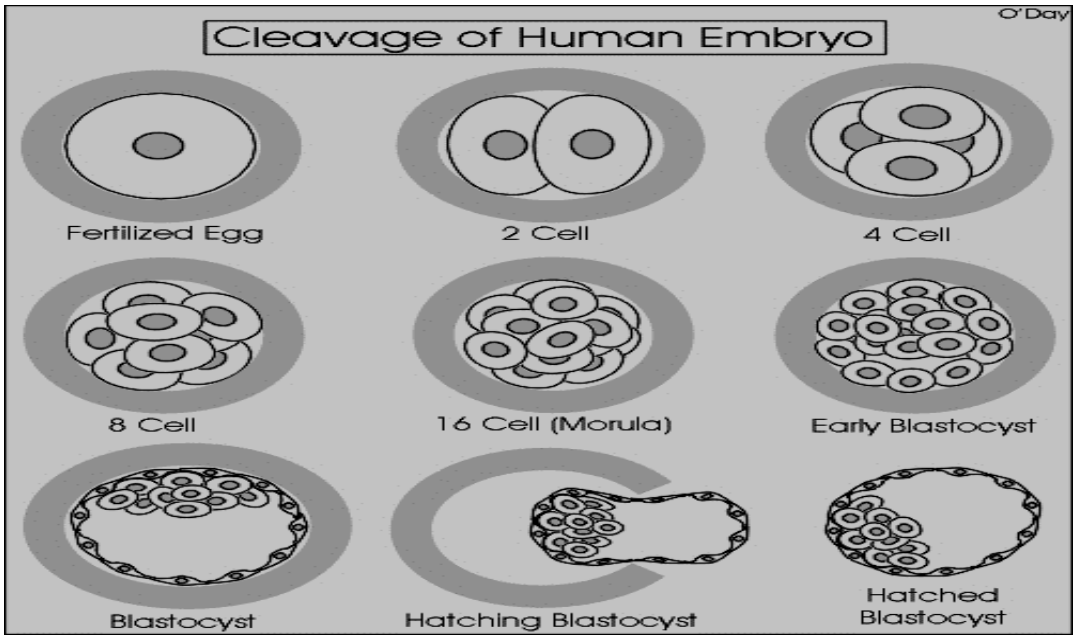
About the time the morula enters the uterine cavity, fluid begins to penetrate through the zona pellucida into the intercellular spaces of the inner cell mass. Gradually the intercellular spaces become confluent, and finally a single cavity, the blastocele, forms. this cavity is eccentrically placed. At this time, the embryo is a blastocyst. Cells of the inner cell mass, now called the embryoblast, are at one pole, and those of the outer cell mass, or trophoblast, flatten and form the epithelial wall of the blastocyst. The inner cell mass gives rise to tissues of the embryo proper the embryoblast, and the outer cell mass forms the trophoblast, which later contributes to the placenta.

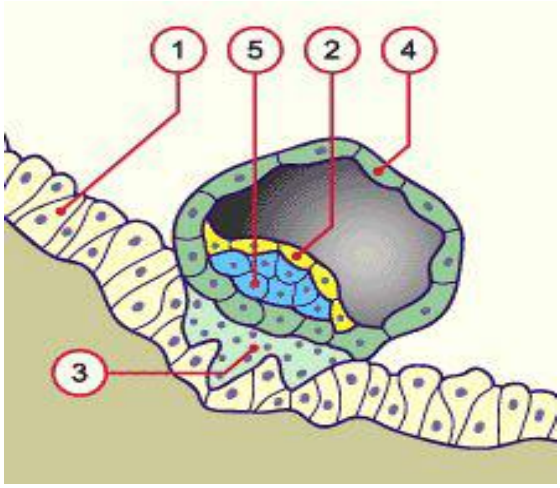


Implantation

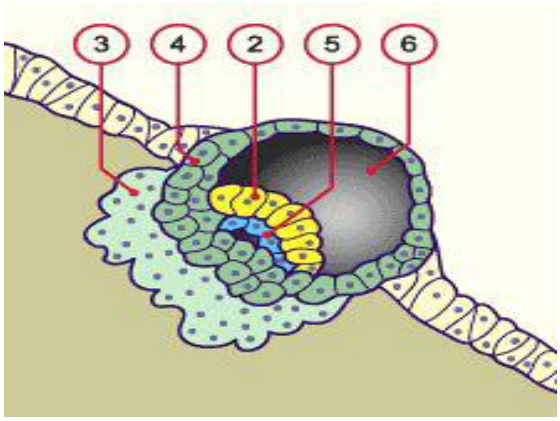
At the 6th day, the zona pellucida become lysed after the blastula reached to the proper side of the endometrium and disappeare (Hatching of blastula) allowing implantation to begin. At the time of implantation, the mucosa of the uterus is in the secretory phase, In the human, trophoblastic cells over the embryoblast pole begin to penetrate between the epithelial cells of the uterine mucosa about the sixth day. The trophoblast cells exert microvilli which exert a histolytic action on the endometrium epithelium facilitating penetration and implantation. By the end of 8 days implantation is completed. After implantation the endometrium is closed by fibrin clott.

- Abnormal site of implantation (Ectopic pregnancy):Tubal pregnancy, ovarian pregnancy and abdominal pregnancy.

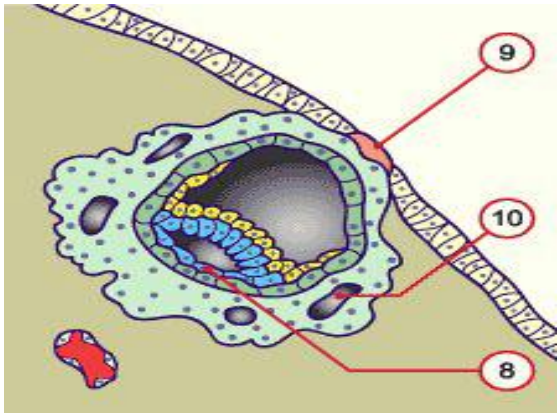




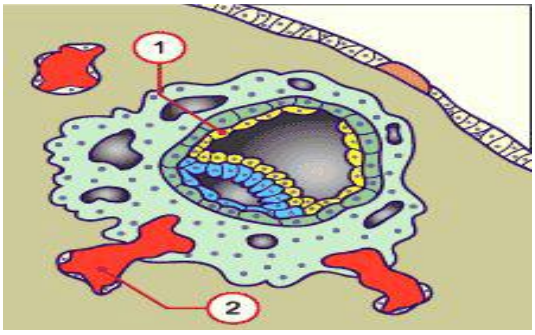
6-7 days



7-8 days



9 days



9-10 days

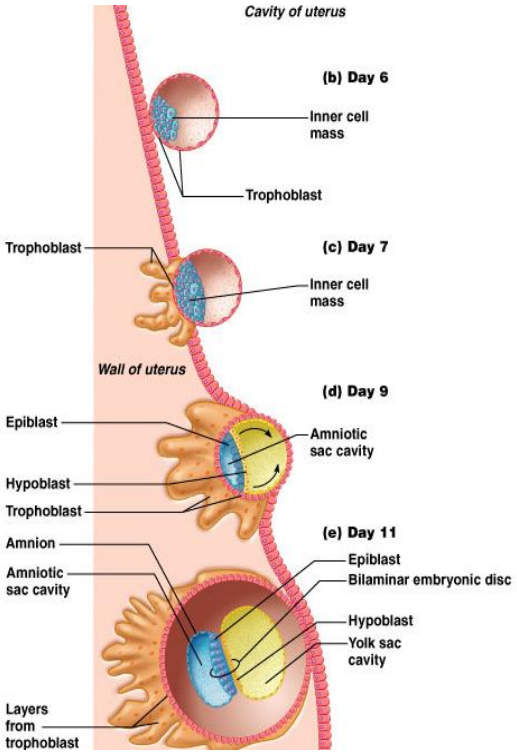
1 = uterine epithelium 2 and 5 = inner cell (mass or future embryo)

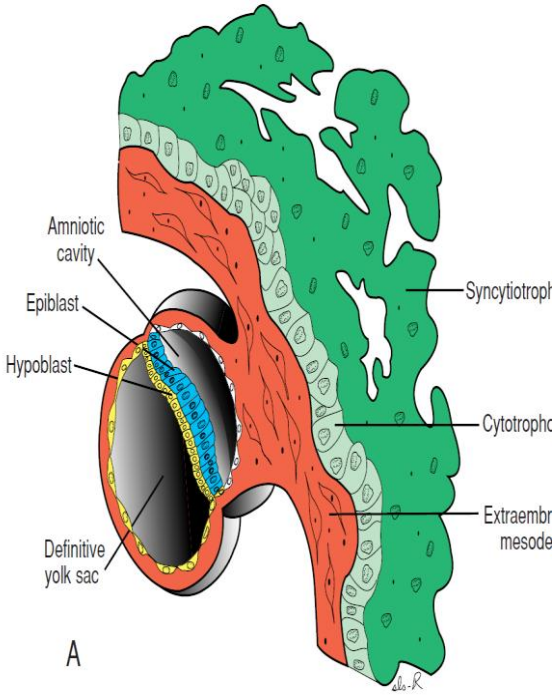
3 and 4 = trophoblast or future placenta 3 = syncytiotrophoblast 4 = cytotrophoblast

6 = yolk sac cavity 8 = Amnion 9 = Fibrin plug 10 = Intervillous spaces

Week 2

Inner cell mass divides into epiblast and hypoblast, two fluid filled sacs amniotic sac from epiblast and yolk sac from hypoblast. Bilaminar embryonic disc.





Week 3

Bilaminar to Trilaminar disc :Three primary germ layers: all body tissues develop from these layers, ectoderm, endoderm and mesoderm.

1- Primitive streak (groove) on dorsal surface of epiblast

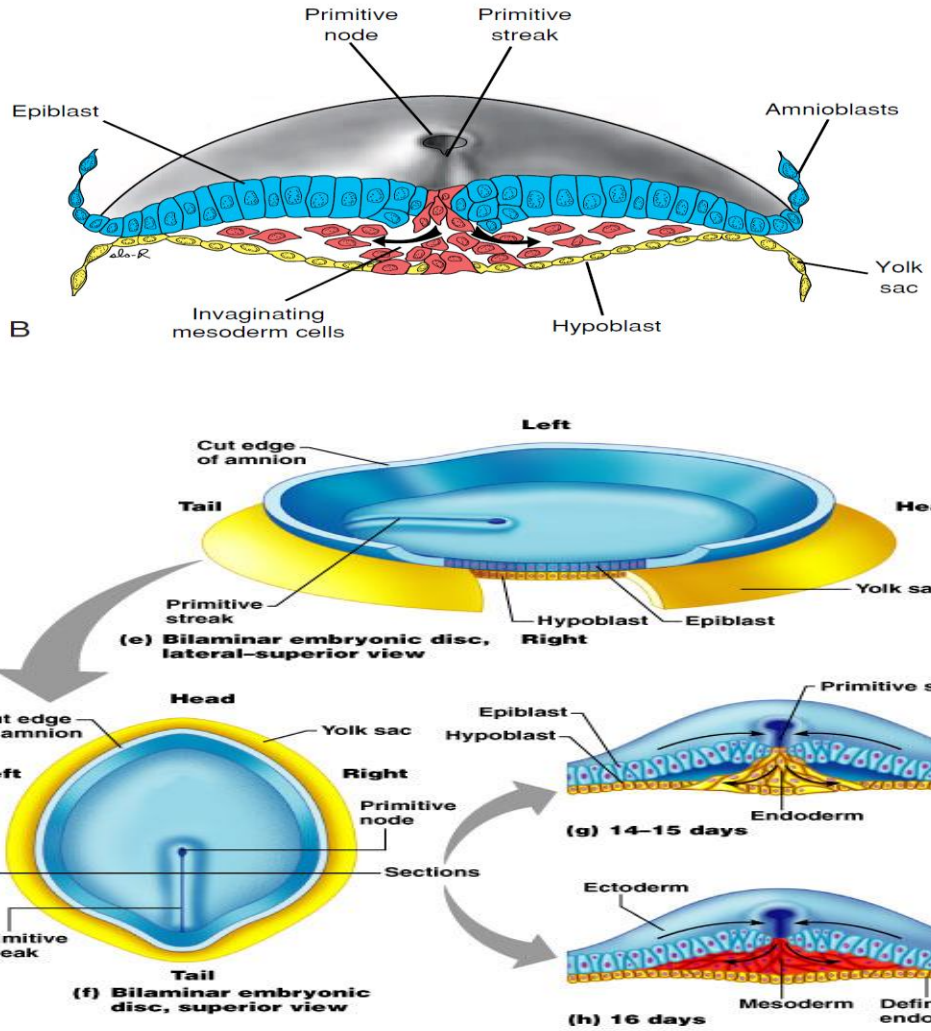
2- Grastrulation: invagination of epiblast cells

3- Days 14-15: they replace hypoblast becoming endoderm

4- Day 16: mesoderm (a new third layer) formed in between

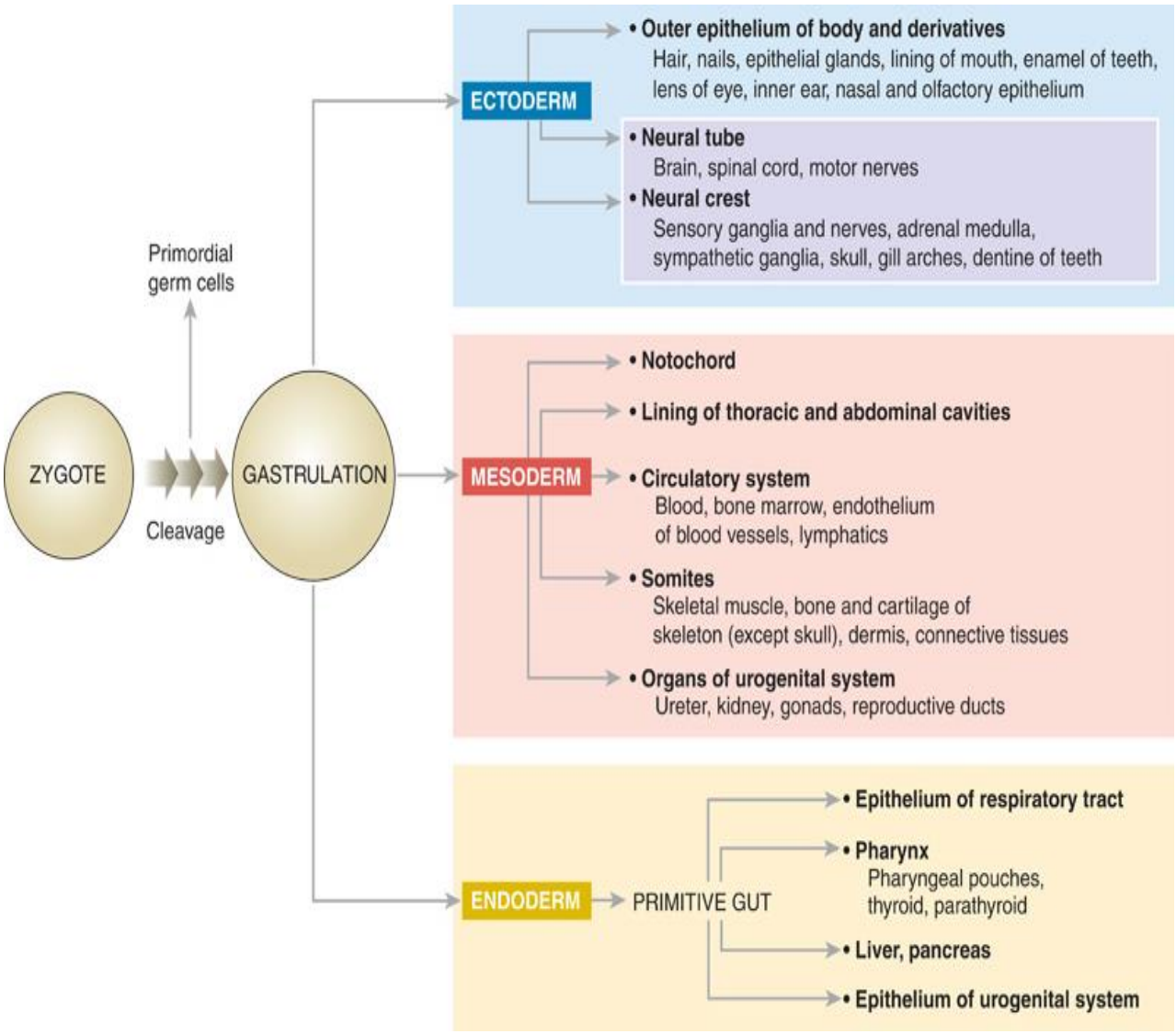
5- Epiblast cells remaining on surface: ectoderm

Ectoderm and endoderm are epithelial tissue (form sheets of tissue). Mesoderm is a mesenchyme tissuem, mesenchyme cells are star shaped and do not attach to one another, therefore migrate freely.



Organogenesis

Many different structures are derived from the three embryonic germ layers during organogenesis. By 8 weeks, about 2 months, all major organs are in place in at least a rudimentary form; this is why drugs early in pregnancy are so important to avoid many cause birth defects.



Notochord

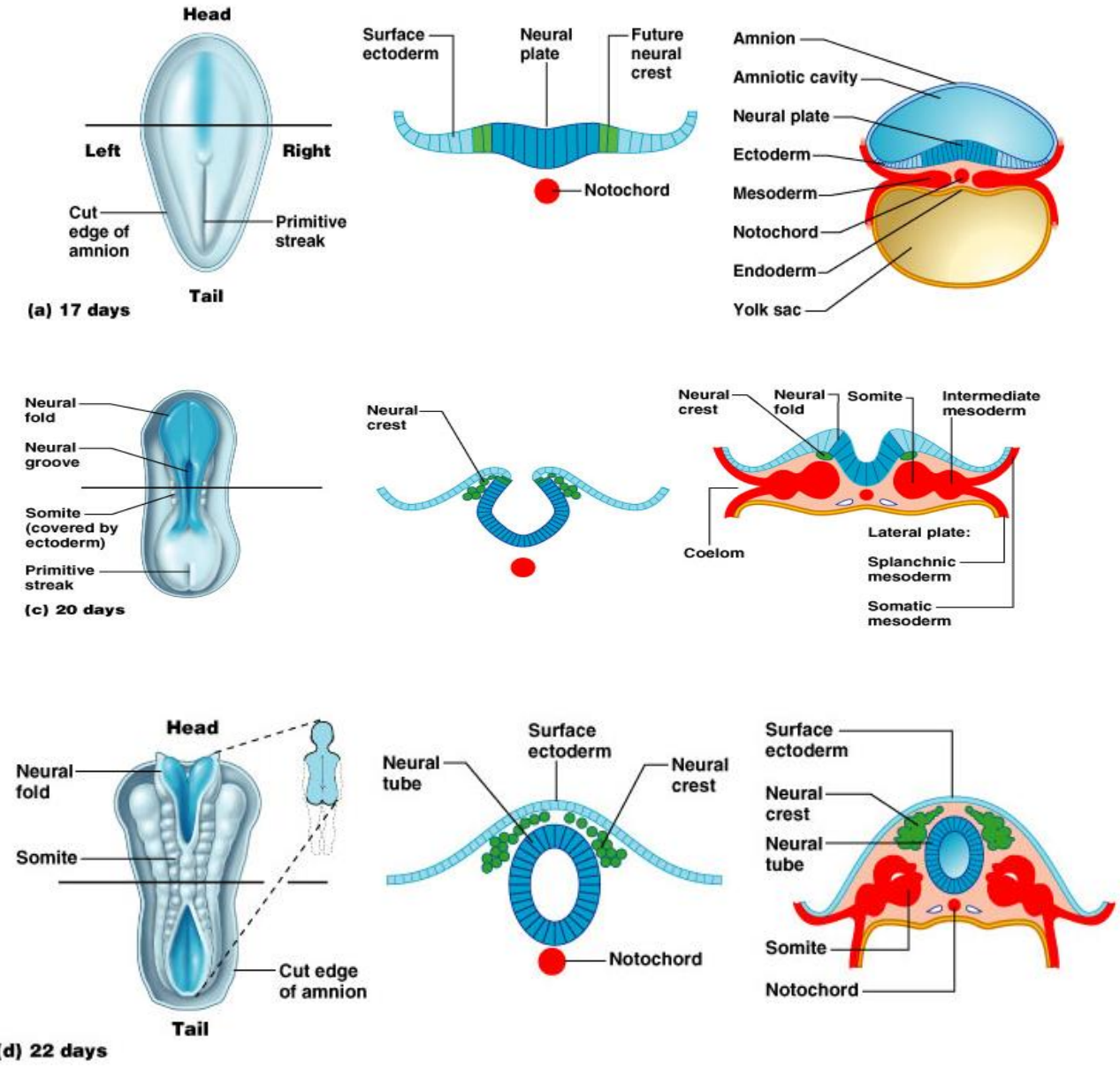
Days 16-18. Primitive node epiblast cells invaginate and migrate anteriorly with some endoderm cells. Rod defining the body axis is formed extends cranially and caudally (from head to tail or crown to rump). Future site of the vertebral column.

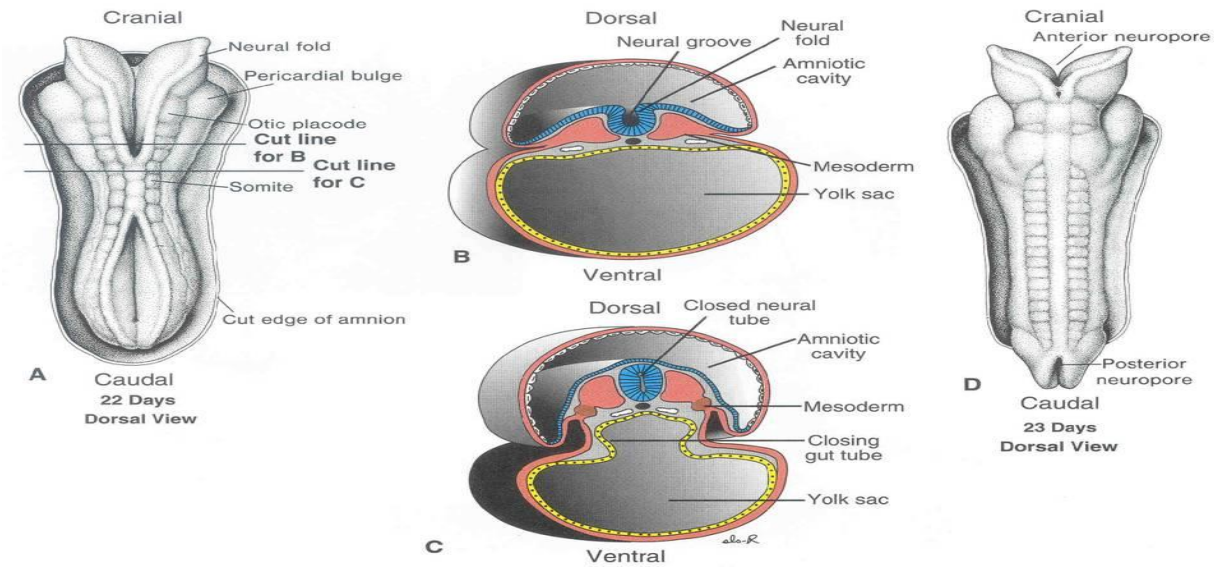
Derivatives of Ectoderm

Nervous System (Neurulation)

Just above the notochord (mesoderm), the ectoderm thickens to form a neural plate. (Notochord signals overlying ectoderm). Edges of the neural plate fold up to create an elongated, hollow neural tube. Anterior end of neural tube enlarges

to form the brain and cranial nerves. Posterior end forms the spinal cord and spinal motor nerves. Closure of neural tube: begins at end of week 3; complete by end of week 4 (folic acid important for this step)





Neural crest lateral ectodermal cells pinch off from the neural tube. Give rise to Portions of cranial nerves , Pigment cells , Cartilage , Bone Ganglia of the autonomic system , Medulla of the adrenal gland , Parts of other endocrine glands. Neural crest cells are unique to vertebrates. Important in evolution of the vertebrate head and jaws.

At Week3, mesoderm begins to differentiate lateral to notochord. **Division of mesoderm** into three regions by end **week 4**,

- Somites: 40 pairs of body segments (repeating units, like building blocks).
- Intermediate mesoderm: just lateral to somites.
- Lateral plate: splits to form coelom (cavity)

Divisions of the mesodermal lateral plate

1- Somatic mesoderm: apposed to the ectoderm

2- Splanchnic mesoderm: apposed to the endoderm, Coelom in between will become the serous cavities of the ventral body cavity: Peritoneal , Pericardial , Pleural

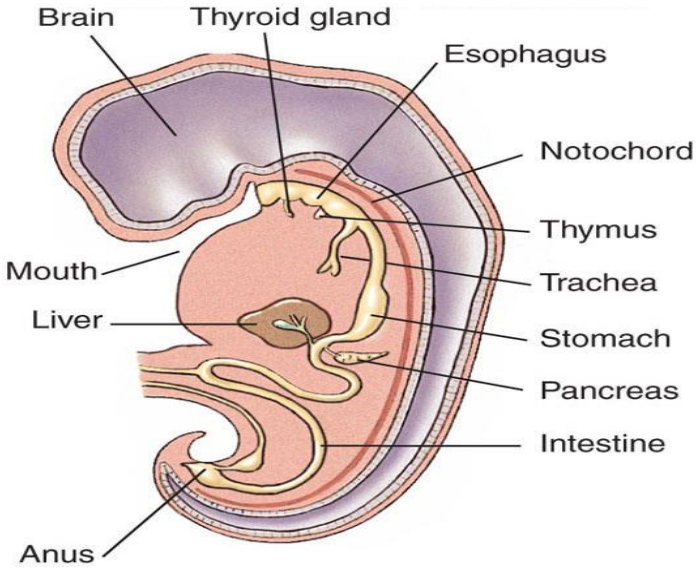
Derivatives of Endoderm: Digestive Tube and Gill Arches

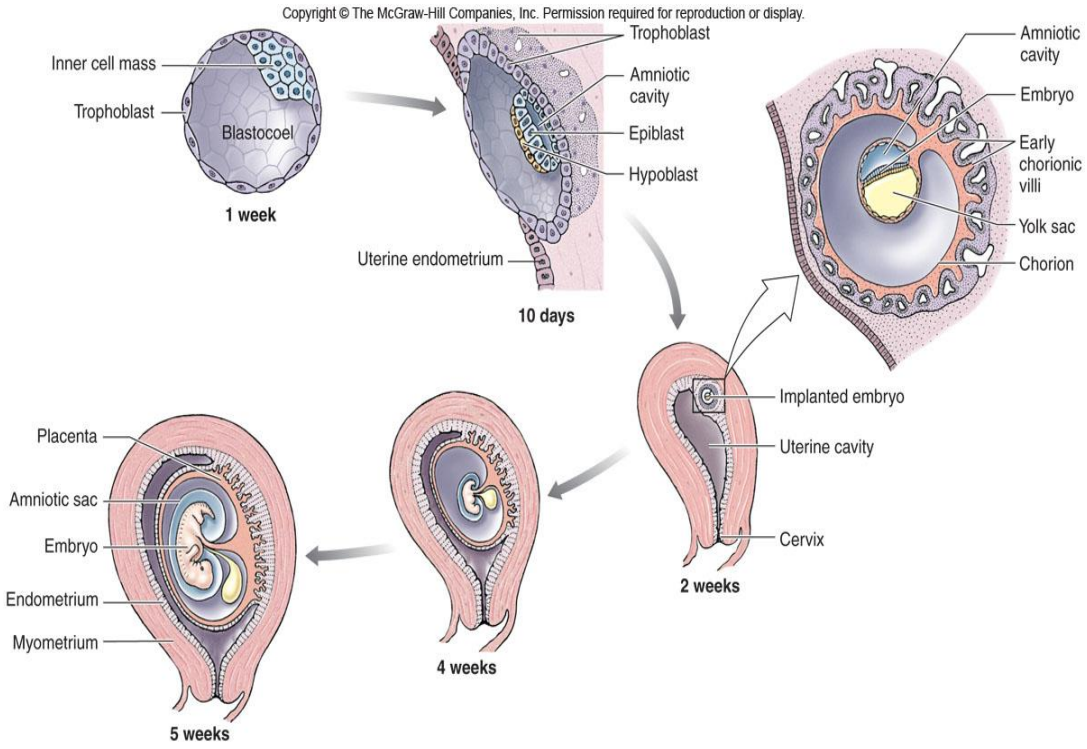
During gastrulation,the archenteron forms as the primitive gut. This endodermal cavity eventually produces: Digestive tract, Lining of pharynx and lungs, most of the liver and pancreas, thyroid, parathyroid glands and thymus.

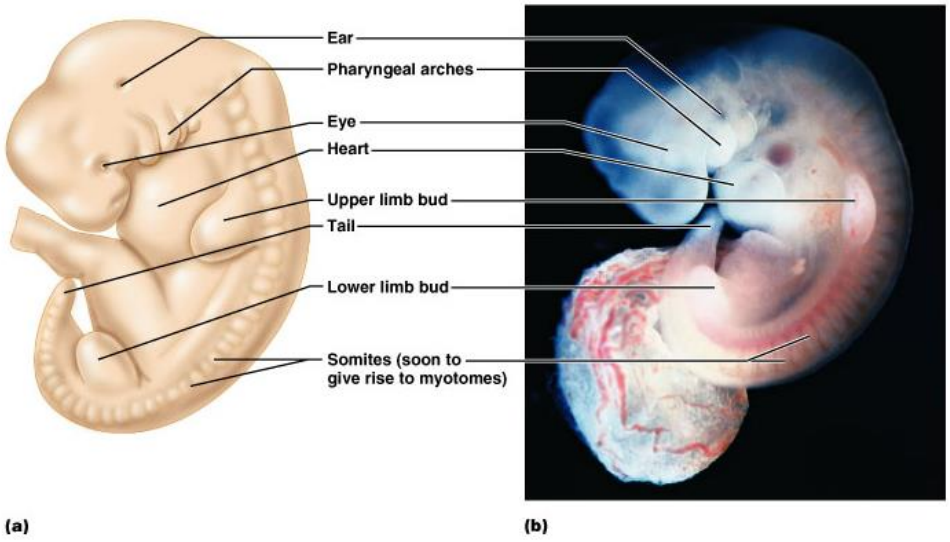
Pharyngeal pouches are derivatives of the digestive tract. Arise in early embryonic development of all vertebrates. During development, endodermally-lined pharyngeal pouches interact with overlying ectoderm to form gill arches.

In fish, gill arches develop into gills.

In terrestrial vertebrates: No respiratory function, 1st arch and endoderm-lined pouch form upper and lower jaws, and inner ear. 2nd, 3rd, and 4th gill pouches form tonsils, parathyroid gland and thymus.







29 day embryo (this is when the heart starts pumping, about 4 weeks or 1 month, ½ cm size)

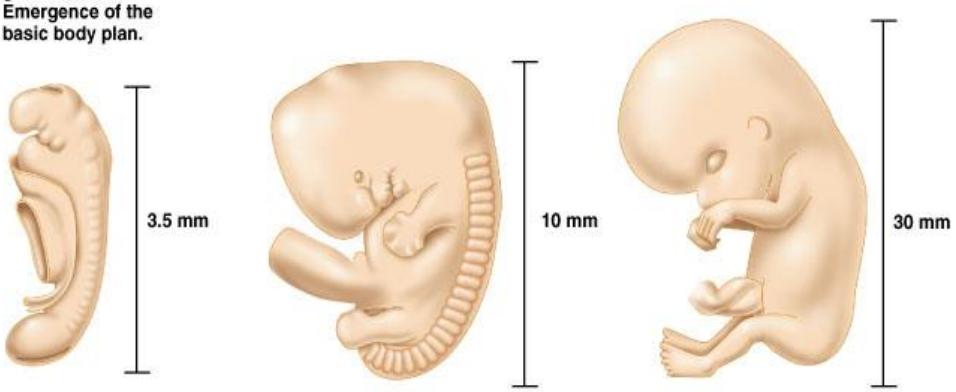
Prenatal period (before birth): 38 weeks from conception to birth. Date of conception has been difficult to time. Gynecologic timing has been from LMP (last menstrual period) LMP is on average two weeks before ovulation. (therefore refers to 40 weeks "gestational" age. By convention, pregnancies are dated in weeks starting from the first day of a women̓ s last menstrual peroid (LMP) . If her menstrual periods are regular and ovulation occurs on day 14 of her cycle, conception takes place about 2 weeks after her LMP. A women is therefore considered to be 6 weeks pregnant 2 weeks after her first missed period. A women̓ s obstetric date is different from the embryologic date (the age of the embryo). The obstetric date is about 2 weeks longer than the embryologic date. Traditional (artificial) division:

- Embryonic" period: first 8 weeks - All major organs formed
- Fetal" period: remaining 30 weeks - Organs grow larger and become more complex

Embryonic Period

Duration: First 8 weeks after conception.

Major embryological events: Organs form from three primary germ tissues. Emergence of the basic body plan.



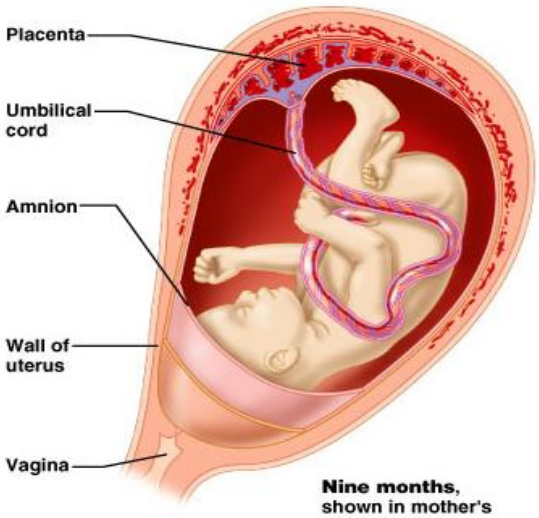
25 days | 36 days | 56 days

Fetal Period

Duration: Weeks 9 to 38 after conception (or until birth).

Major fetal events: Organs grow in size and complexity.

20-week fetus



Nine months, shown in mother's womb (uterus)

The " test-tube baby

The " test-tube baby" is now not only a reality but a commonplace event in many medical centers. In humans, the technique, called *in vitro fertilization and embryo transfer* (IVF). The process by which one or more eggs (oocytes) are fertilised outside the body and allowed some childless couples to have children from their own genetic heritage. It is used in cases where both the mother and father are capable of producing viable eggs and sperm cells, but because of a blockage in the women's uterine tubes the ovulated eggs are unable to be fertilized in her body and then to become transported to her uterus.

The first problem is obtaining fertile eggs from the mother. This is accomplished through **two technical advances**.

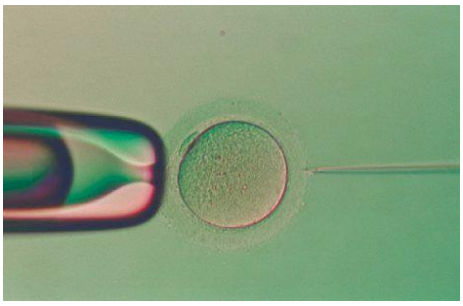
1- In vitro fertilization and embryo transfer (IVF)

The administration of a fertility-enhancing drug (gonadotropins) to the mother results in her producing several eggs, rather than the usual single egg, at the time of ovulation. (Many women who in recent years have given birth to four to seven babies at one time had previously taken fertility-promoting drugs.)

Just before the eggs would normally be shed from the ovary , a doctor, using a technique called ***laparoscopy***, inserts a tube into her pelvic cavity and under direct observation removes the ripe eggs from the ovary, just before ovulation the egg remove from ovarian follicles, without the need for a major surgical procedure.

When the oocyte is in the late stages of the first meiotic division. The egg is placed in a simple culture medium in a dish (hence the term *in vitro,* which means in glass) and father's sperm by placing a droplet of washed sperm

(~50,000) onto each egg immediately. If the sperm count is low a single sperm can be injected into each egg (Intra-Cytoplasmic Sperm Injection – ICSI).



The fertilized egg is then allowed to develop for a few days in an artificial incubator. Embryos can be placed into the uterus at the 6-8 cell stage (3-days culture) but some clinics culture the embryos for 5 or 6 days to ensure healthy blastocyst stage. After many years of unsuccessful attempts, reproductive biologists learned what environmental conditions are required for fertilization outside the body.

Meanwhile, the body of the mother is hormonally conditioned so that her uterus can accept the embryo. While the embryo still consists of just a tiny ball of the cells, it is sucked up into a tube and then released inside the cavity of the mother's uterus, where if all goes well it will attach and then complete a normal pregnancy. It is still not possible to rise a mammalian embryo from conception to maturity entirely outside the body.

It is common to fertilize all of the woman's eggs at the same time. After several embryos have been implanted in her uterus, the remainder are frozen. With the proper technique, a mammalian embryo can be frozen, stored, and even years later thawed as needed and then implanted into a uterus. This technique is routinely used with domestic animals and humans; if the first implanted embryos fail to survive, frozen ones can be thawed and implanted until the supply of embryos has run out. Thus embryo banks are now a reality. In actual

practice the extra human embryos are destroyed when a baby resulting from an artificial conception is born.

Some women who are able to produce fertile eggs but are unable to carry an embryo to term in their own uteri have made arrangements with other women to act as *surrogate mothers.* The surrogate mother agrees to have another couple's embryo implanted into her uterus and bring it to term. (In some cases the surrogate mother herself supplies the egg.). When the baby is delivered, the surrogate mother turns the baby over to its genetic parent.

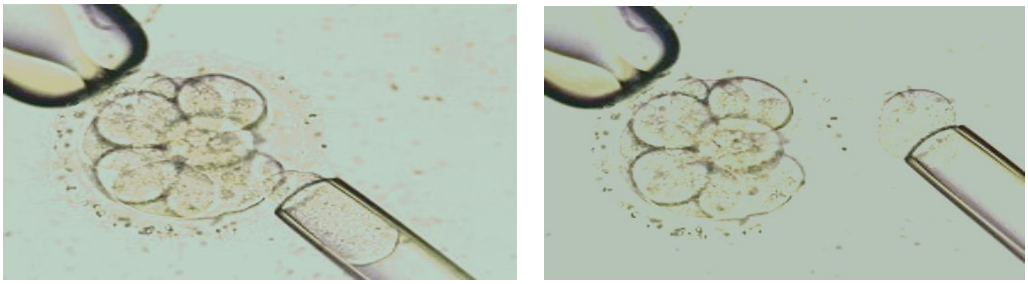
ICSI (intracytoplasmic sperm injection). Severe male infertility, in which the ejaculate contains very few live sperm (oligozoospermia) or even no live sperm (azoospermia), can be overcome using intracytoplasmic sperm injection (ICSI). With this technique, a single sperm, which may be obtained from any point in the male reproductive tract, is injected into the cytoplasm of the egg to cause fertilization. This approach offers couples an alternative to using donor sperm for IVF. The technique carries an increased risk for fetuses to have Y chromosome deletions but no other chromosomal abnormalities.

2- Another technique, **gamete intrafallopian transfer (GIFT)**, introduces oocytes and sperm into the ampulla of the fallopian (uterine) tube, where fertilization takes place. Development then proceeds in a normal fashion. In a similar approach, zygote intrafallopian transfer (ZIFT), fertilized oocytes are placed in the ampullary region. Both of these methods require patent uterine tubes.

IVF and Preimplantation Genetic Diagnosis

All cells in the early embryo (until about the 8-cell stage) are said to be totipotent. That means that each cell is capable of forming a complete human.

So couples using IVF can use genetic screening of their embryos by having a cell removed from their embryo(s) and tested for its genotype. The embryo will still develop normally. More than 100 diseases can be detected including hemophilia A, muscular dystrophy, Tay-Sachs disease, cystic fibrosis and Down syndrome.



A disadvantage of IVF is its low success rate; only 20% of fertilized ova implant and develop to term. Therefore, to increase chances of a successful pregnancy, four or five ova are collected, fertilized, and placed in the uterus. This approach sometimes leads to multiple births.

Contraceptive Methods

The contraceptive pill is a combination of estrogen and the progesterone analogue progestin, which together inhibit ovulation but permit menstruation.

Both hormones act at the level of FSH and LH, preventing their release from the pituitary. The pills are taken for 21 days and then stopped to allow menstruation, after which the cycle is repeated.

Depo-Provera is a progestin compound that can be implanted subdermally or injected intramuscularly to prevent ovulation for up to 5 years or 23 months, respectively.

A male “pill” has been developed and tested in clinical trials. It contains a synthetic androgen that prevents both LH and FSH secretion and either stops sperm production (70–90% of men) or reduces it to a level of infertility.

The intrauterine device (IUD) is placed in the uterine cavity. Its mechanism for preventing pregnancy is not clear but may entail direct effects on sperm and oocytes or inhibition of preimplantation stages of development.

The drug RU-486 (mifepristone) causes abortion if it is administered within 8 weeks of the previous menses. It initiates menstruation, possibly through its action as an antiprogesterone agent.

Vasectomy and tubal ligation are effective means of contraception, and both procedures are reversible, although not in every case.

Barrier techniques of contraception include the male condom, made of latex and often containing chemical spermicides, which fits over the penis; and the female condom, made of polyurethane, which lines the vagina. Other barriers placed in the vagina include the diaphragm, the cervical cap, and the contraceptive sponge.

Infertility

Infertility is a problem for 15% to 30% of couples.

Male infertility may be a result of insufficient numbers of sperm and/or poor motility. Normally, the ejaculate has a volume of 3 to 4 ml, with approximately 100 million sperm per ml. Males with 20 million sperm per ml or 50 million sperm per total ejaculate are usually fertile.

Infertility in a woman may be due to a number of causes, including occluded oviducts (most commonly caused by pelvic inflammatory disease), hostile cervical mucus, immunity to spermatozoa, absence of ovulation, and others.

Embryonic Development of Chick

Gastrulation

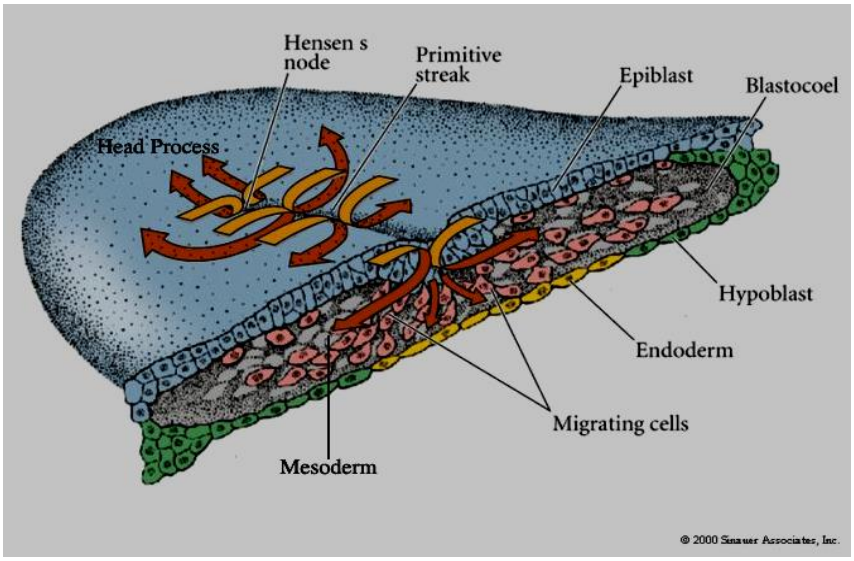
Gastrulation is a complex process where the simple blastula is transformed into a complex gastrula. There are two steps in gastrulation. They are

1-The formation of endoderm and

2- The formation of primitive streak , and mesoderm.

Formation of Endoderm

The endoderm or hypoblast develops as a single layer of cells inside the primary blastocoel. After the formation of he endoderm the upper layer is called epiblast or ectoderm. The space lying between them forms blastocoel. The cavity lying below the hypoplast and above the periplastis called archenteron.



Formation of primitive streak and mesoderm

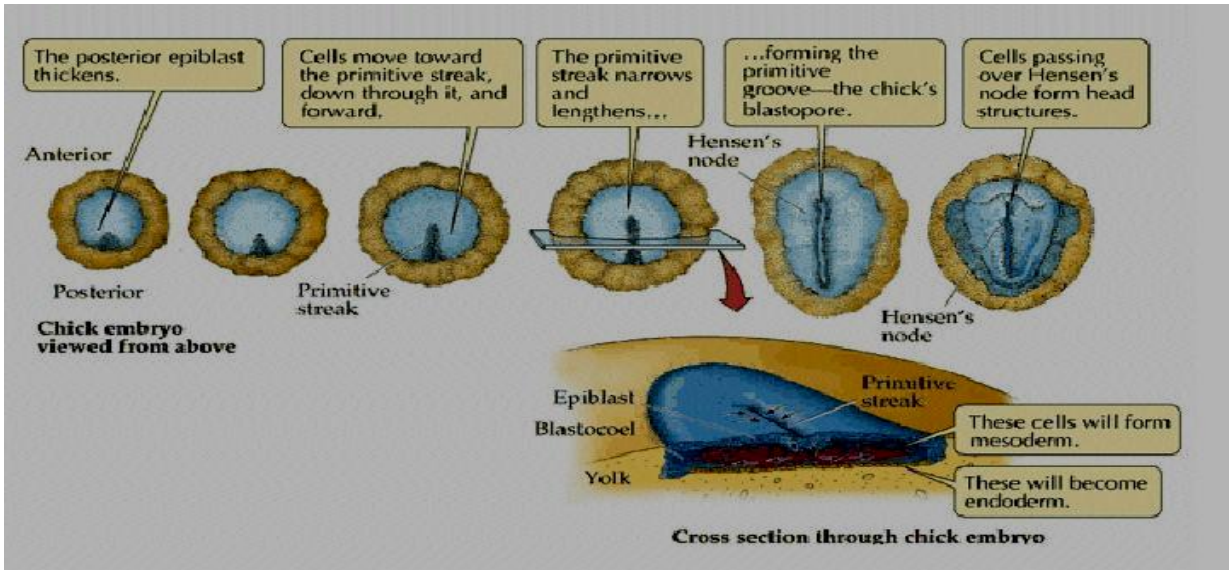
The second step in gastrulation is the development of primitive streak and the subsequent formation of mesoderm. **The primitive streak** appears as a thickened area in the middorsal line at the posterior region of area pellucida at about eight hours after incubation. The thickening is due to the convergence of

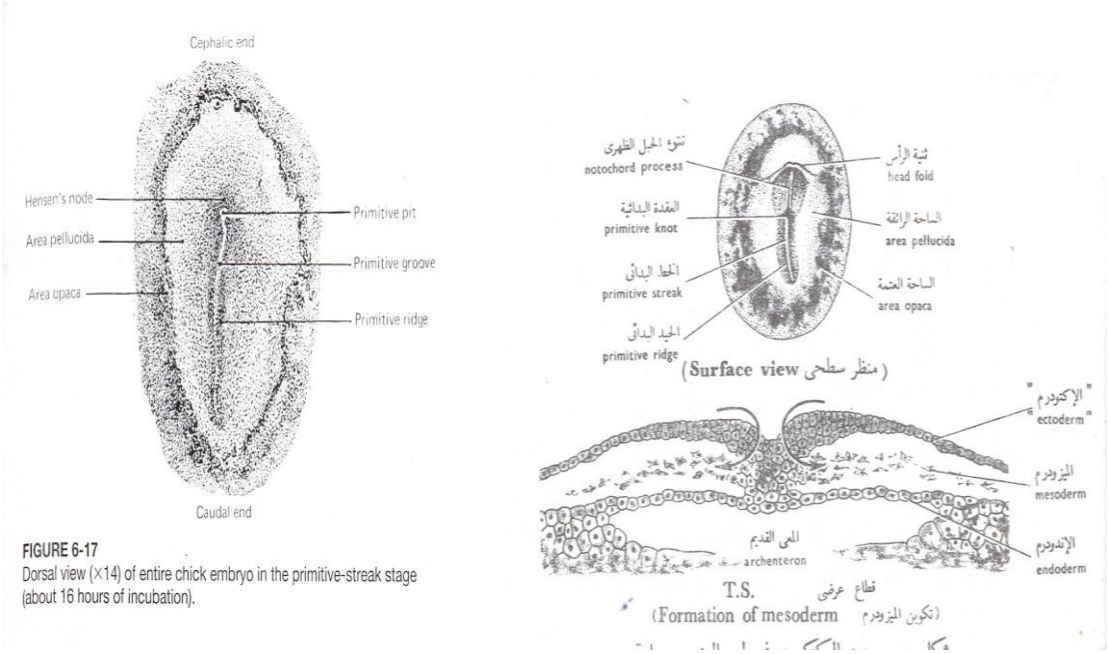
the cells of blastoderm towards the center. In the early stage the primitive streak is broad and short. It gradually extends forwards and reaches the middle of the blastoderm. The primitive streak is well developed at about 18 to 19 hours of incubation.

Along the middle of the primitive streak, there runs a narrow furrow called the **primitive groove**. The edges of the groove are thick and are named **primitive folds**. At the anterior end of the primitive groove , there is a mass of closely packed cells called **Hensen's node** or primitive knot. The center of Hensen's node has a funnel-shaped depression called primitive pit.

The mesoderm cells migrate as two sheets on either side of the primitive streak inside the blastocoel (inbetween the epiblast and hypoblast). The mesoderm cells will not migrate anterior to the primitive streak. This mesoderm free area is called proamnion. This region is site for the development of the head.

The notochordal cells are proliferated from Hensen's node. The notochordal cells spreads under the epiblast infront of the primitive streak. Theses cells arrange themselves to form a cylindrical rod called head process or notochordal process. By the end of gastrulation, the primitive streak is reduced. The residue becomes partly incorporate into the tail bud.





Stages of chick embryo development

Between Laying and Incubation: No growth; stage of inactive embryonic life.

On the second day of incubation, the blood islands begin linking and form a vascular system, while the heart is being formed elsewhere. By the 44th hour of incubation, the heart and vascular systems join, and the heart begins beating. Two distinct circulatory systems are established, an embryonic system for the embryo and a vitelline system extending into the egg.

At the end of the **third day of incubation**, the beak begins developing and limb buds for the wings and legs are seen. **Torsion and flexion** continue through the fourth day. The chick's entire body turns 90o and lies down with its left side on the yolk. The head and tail come close together so the embryo forms a "C" shape. The mouth, tongue, and nasal pits develop as parts of the digestive and respiratory systems. The heart continues to enlarge even though it has not been enclosed within the body. It is seen beating if the egg is opened carefully. The other internal organs continue to develop.

By the end of **the fourth day of incubation**, the embryo has all organs needed to sustain life after hatching, and most of the embryo's parts can be identified. The chick embryo cannot, however, be distinguished from that of mammals.

By the seventh day. The embryo grows and develops rapidly, digits appear on the wings and feet, the heart is completely enclosed in the thoracic cavity, and the embryo looks more like a bird.

After the tenth day of incubation, feathers and feather tracts are visible, and the beak hardens. On the fourteenth day, the claws are forming and the embryo is moving into position for hatching. **After twenty days**, the chick is in the hatching position, the beak has pierced the air cell, and pulmonary respiration has begun.

Air cell is the air-filled pocket between the white and shell at the large end of the egg.The air cell in an egg provides the chick with air when it is ready to start breathing on its own and hatch from the egg. As the chick starts breathing, there is a buildup of carbon dioxide in the egg, which prompts the chick to break through the egg to get fresh air. Twentieth day - yolk sac completely drawn into body cavity; embryo occupies practically all the space within the egg except the air cell.

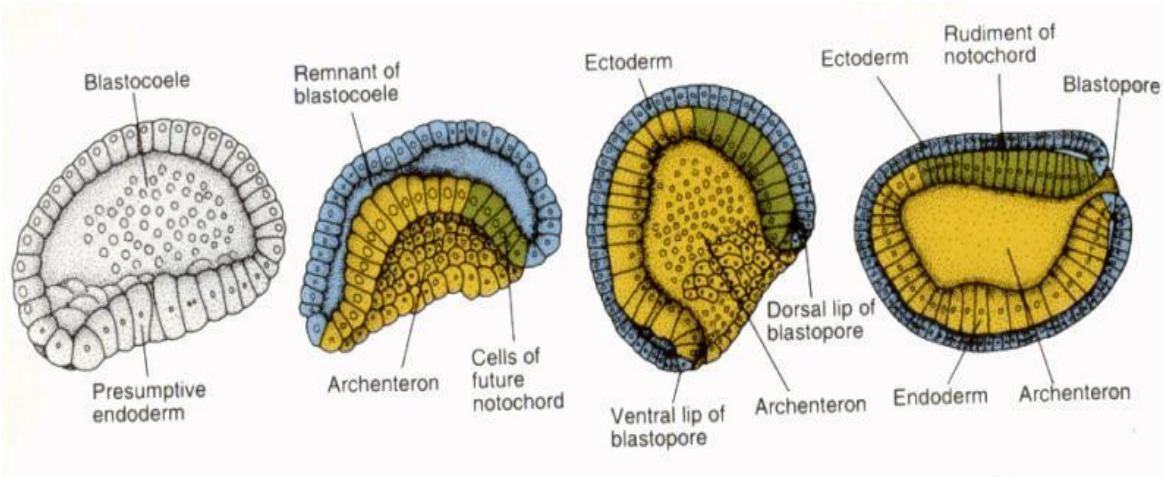
After 21 days of incubation, the chick finally begins its escape from the shell. The chick begins by pushing its beak through the air cell. The allantois, which has served as its lungs, begins to dry up as the chick uses its own lungs. The chick continues to push its head outward. The sharp horny structure on the upper beak (egg tooth) and the muscle on the back of the neck help cut the shell. The egg tooth makes the initial break in the shell.

Embryonic Development of Amphioxus

Gastrulation

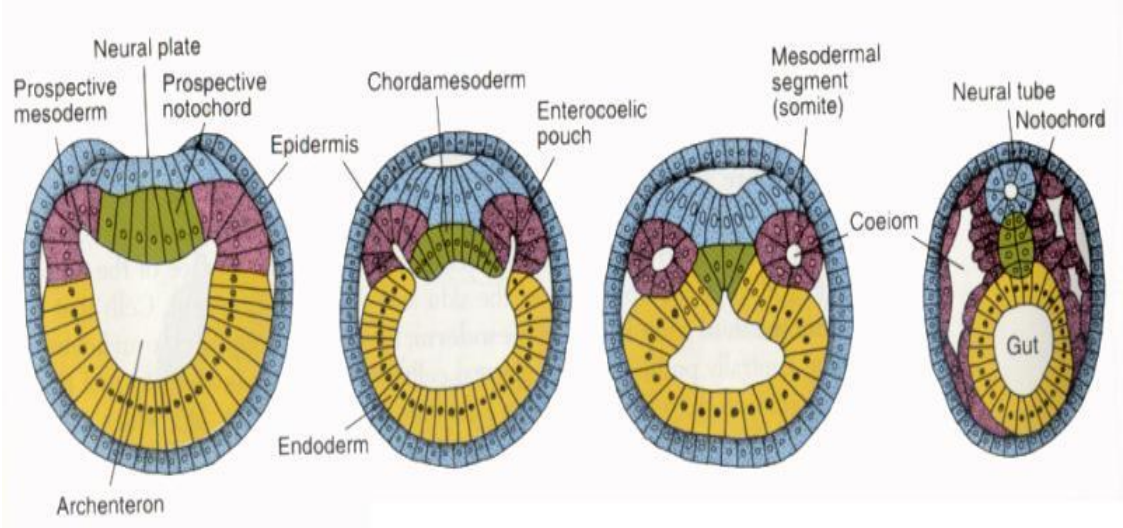
In Amphioxus, the gastrulation, by which a monoblastic blastula is converted into a diploblastic and stratified gastrula. The onset of gastrulation process is marked by flattening of blastoderm of vegetal pole, i.e., prospective endoderm. This endodermal plate then gradually invaginates, or folds inwardly, into the blastocoel. This invaginating layer of cells gradually eliminates that entire blastocoel and come to lie against the ectodermal micromeres. Thus, whole embryo, instead of being spherical, becomes converted into a cup-shaped structure, having a large cavity, the archenteron (gastrocoel), in open communication with the exterior by the blastopore. The cup has double walls, an external and internal epitheial layers, both of which remain continuous with each other over the rim of the cup-shaped embryo, the gastrula. The gatrula, at this stage, consists of two layers-an outer epiblast, consisting of neural and epidermal ectoderm, and an inner hypoblast encompassing prospective notochord mesoderm and endoderm. We now have an animal that is a tube within a tube.

The circular rim of the blastopore is termed the lip, the prospective mesoderm lies in the ventral lip of the blastopore and the prospective notochord lies in the dorsal lip of the blastopore.



Formation of the neural tube

With the completion of gastrulation, a strip of ectodermal cells in the region of midgut dorsal line enlarges to form the neural plate, which flattens and sinks inwards. The ectodermal on the sides of neural plate now rise up to form the neural folds is gradually extended round the lateral lips of blastopor. Then these folds start growing to meet each other over the neural plate, begining at the posterior end. These folds meet together in the mid-dorsal line. On the other hand, at the same time, the lateral edges of neural plate have grown towards each other, resulting the formation of the neural tube.



Formation of notochord

The chorda cells, in he gastrula are, present along the mid-dorsal wall of archenteron just below the neural plate. These chorda cells becomes in the form of strip due to a median groove. Later on, this groove deepens much resulting in coming together of the lateral sides of the strip of chorda cells. These sides finally meet each other restricting completely the cavity of the groove. In this way a solid rod-like notochord is formed just below central nervous systems.

Development of mesoderm and coelom

In gastrula the archenteron, is developed by invagination and is bounded by three types of cells namely chorda cells, mesodermal cells on the sides of the chorda cells and manly by endodermal cells. The chorda cells form the notochord. The mesodermal cells separate to form paired pouches or the mesodermal pouches. These pouches are in dorso-lateral position and ultimately develop into initial coelom. Each pouch is disconnected from archenteron and thus encloses a cavity. The remaining cavity with the archenteron becomes the cavity of the gut and persists as alimentary canal in the adult animal.

Formation of gut

The chorda cells and mesodermal cells of archenteron wall separate to form notochord and mesodermal pouches respectively and thus archenteron is left only with endodermal cells. The edges of the endoderm start growing towards each other (a rolling up process) and finally fuse with each other in mid-dorsal line just below the notochord, forming a tubular structure designated as mesenteron or gut.

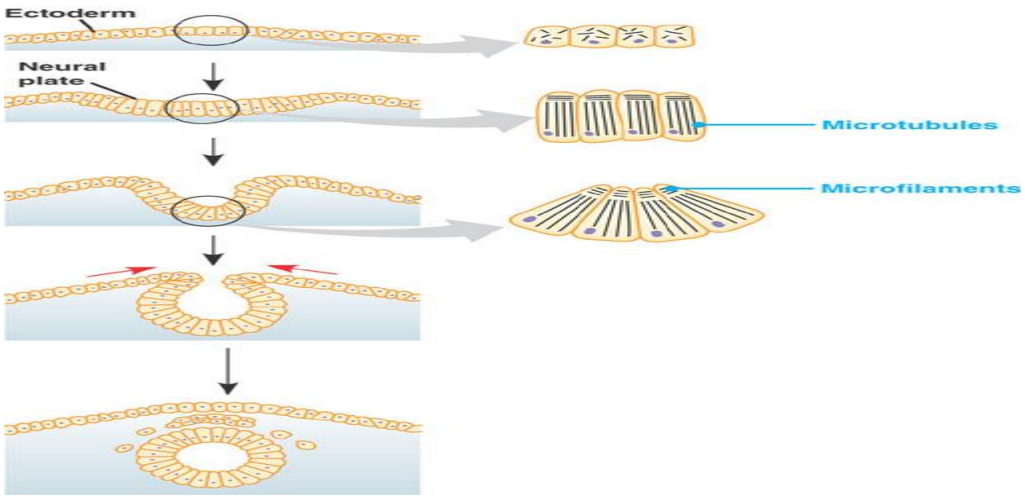
Embryonic Development of Toad

Organogenesis

Organogenesis concerns with the formation of and differentiation of various organs. Organogenesis converts an embryo into free swimming larva.

The formation of the neural tube

Neural tube is developed from prospective neurectoderm which during pregastrular processes takes its position some where in the mid dorsal region of the gastrula. Pear shaped neural plate is developed simply by the thickening of neurectodermal cells. The ectoderm on the sides of the ventral plate rises as a pair of neural folds. The edges of neural folds are developed by a process of differential growth and migration of cells called the convergence. The plate between the folds sinks down wards and form the neural groove. The elevation of neural folds increase dorsally and ultimately fuse over the neural groove to form the neural tube.



formation of the neural tube

Formation of notochord

The notochord develops from the chorda-mesoderm, lying in the mid dorsal line of the gastrula. Theses cells separate from mesoderm by a narrow cleft, by a process of delamination. Then these separated chorda cells very quickly expand and arrange themselves in the torm of a cylindrical rod.

Development of mesoderm

In the late gastrula after getting separation from chorda cells the mesodermal arrange themselves in such a precies manner that two mesodermal lateral sheets (several cell thick) are developed. These sheets are located at the right and left sides of the neural tube and notochord between the ectoderm and endoderm. Growing down toward the ventral side, the two mesodermal sheets unite in the mid ventral line. The dorso-lateral portion of the mesodermal sheets lying on each side of notochord forms the mesodermal somites or epimere. The remaining ventro-lateral portion of mesodermal sheets forms the lateral plate mesoderm.

Mesodermal somites which increase in number as the embryo grows larger, are arranged segmentally and from each somite three embryonic structure.

1- The dermatomes that portion of somite lying against the ectoderm from which the dermis of the skin is developed.

2- The myotomes from which the most of the body muscles are developed.

3- The sclerotomes lying against the notochord and neural tube, from which the axial skeleton is developed.

The lateral mesoderm is separated into two layers, an outer one of somatic mesoderm (somatopleure) which lines the ectoderm of the body and an inner of splanchnic mesoderm (splanchnopleure) which lines the gut.

Mesodermal derivatives

Development of heart

Heart is mesodermal in origin spechially from splanchnic mesoderm. A number of cells from splanchnic mesoderm are proliferated. Theses cells arrange themselves to form a tubular structure, the endocardial tube, which constitute the inner most layer of the heart. This tube is covered by epimyocardium. The epimyocardium form the middle layer the myocardium and the outermost layer the epicardium. The myocardium thickens to form the muscular wall of the

heart. The heart is suspended in the pericardial cavity. In the latter stage of development the heart becomes S shaped in the pericardial cavity. The lumen of the heart is divided into chambers by the development of valves. These champers are sinus venosus, atrium (receive the blood from the bodyorgans), ventricle, and conus arteriosus (distributed the blood to every part of the body.