مقرر

علم الأجنة Embryology

الفرقة الثالثة شعبة علم الكيمياء والحيوان (307 ح)

أستاذ المقرر

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قسم علم الحيوان – كلية العلوم بقنا

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	معمل	رسم قطاع عرضي في خصية الفأر وقطاع عرضي في مبيض القطة	
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الثالث	**محاضرة**	Pattern of cleavage and embryonic membranes of vertebrate species	
	معمل	أنواع ومستويات التفلج مع رسم أمثلة، مراحل التكوين الجنيني للرأس حبليات (جنين السهيم) حتى طور الجاسترولا	
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	معمل	مراحل التكوين الجنيني للرأس حبليات (جنين السهيم) أطوار ما بعد الجاسترولا	
الخامس	**محاضرة**	Embryonic development of vertebrates (amphioxus)	
	معمل	مراحل التكوين الجنيني للبرمائيات (جنين الضفدعة) حتى طور الجاسترولا	
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السابع	محاضرة	Midterm	
	معمل		
الثامن	محاضرة	Embryonic development of vertebrates (tadpole)	
	معمل	مراحل التكوين الجنيني للطيور (جنين الكتكوت) حتى طور الجاسترولا	
التاسع	محاضرة	Embryonic development of vertebrates (chicken)	
	معمل	منظر ظهري لجنين كتكوت عمر ٢٠ ساعة+ منظر ظهري لجنين كتكوت عمر ٢٤ ساعة	
العاشر	محاضرة	Embryonic development of vertebrates (chicken)	
	معمل	منظر ظهري لجنين كتكوت عمر ٣٣ ساعة	
الحادى عشر	محاضرة	Embryonic development of vertebrates (mammal)	
	معمل	منظر ظهري لجنين كتكوت عمر ٤٨ ساعة	
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الرابع عشر	محاضرة	placenta	
	معمل	**مراجعـــــــة عـــــــــــامة**	

استاذ المقرر **رئيس مجلس القسم** **وكيل الكلية لشئون التعليم و الطلاب** **عميد الكلية**

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Introduction

- Human development is a continuous process that begins when an oocyte (ovum) from a female is fertilized by a sperm (spermatozoon) from a male.
- Cell division, cell migration, programmed cell death (apoptosis), differentiation, growth, and cell rearrangement transform the fertilized oocyte, a highly specialized, totipotent cell, a zygote, into a multicellular human being.
- Most changes occur during the embryonic and fetal periods; however, important changes also occur during later periods of development.
- The field of study which includes investigations of the molecular, cellular, and structural factors contributing to the formation of an organism is called embryology.
- It is a branch of science that is related to the formation, growth, and development of an embryo.
- It mostly deals with the prenatal stage of development beginning from the formation of gametes, fertilization, the formation of a zygote, development of embryo and fetus to the birth of a new individual.

Definitions of Embryology

- Embryology is a branch of science that is related to the fertilization, formation, growth, and development of embryo. In mammals, it deals with the prenatal stage of development beginning from formation of gametes, fertilization, formation of zygote, development of embryo and fetus to the birth of a new individual.
- Embryology is the study of the early development of living organisms till it

reaches to adult form.

All animals and insects can reproduce new individuals to ensure the survival of their kind.

A Brief History of Embryology

The theory of preformationism

- ✓ Early embryology was proposed by Marcello Malpighi, and known as **preformationism**, a theory held that the generation of offspring occurs as a result of an unfolding and growth of preformed parts. There were two competing models of preformationism: **the ovism model**, in which the location of these preformed parts prior to gestation was the maternal egg, and the **spermism model**, in which a preformed individual or homunculus was thought to exist in the head of each sperm.
- ✓ Preformationism was the first theory of generation and development that applied to all organisms in the plant and animal kingdoms.
- ✓ The theory of preformation gained much traction before the invention of microscopes and more advanced imaging techniques.
- ✓ The theory also suggested women were simply vessels to carry the growing child, and that girls came from the left testicle, while boys came from the right.

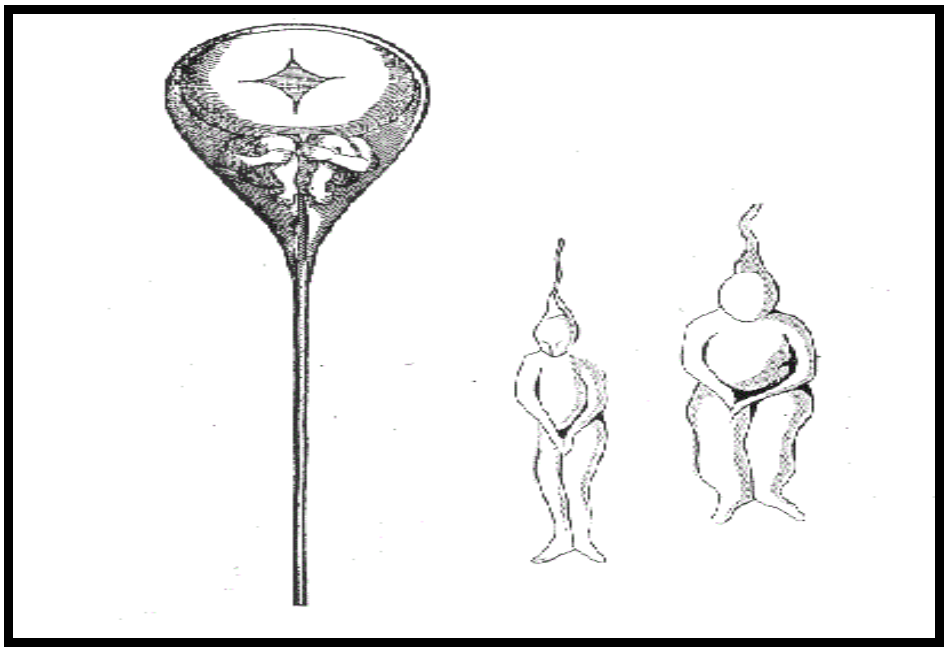
The theory of epigenesis

✓ Aristotle first proposed the correct mechanism for the development of an embryo, without having a microscope to observe his theory.

✓ He suggested that animals form through the process of epigenesis, in which a single cell divides and differentiates into the many tissues and organs of an animal.

✓ It wasn't until 1827 that clear evidence was obtained that female mammals also produce a sex cell, the ovum.

✓ The discovery of a female sex cell directly contradicted many aspects of the preformation theory and led to wider acceptance of the epigenesis theory.

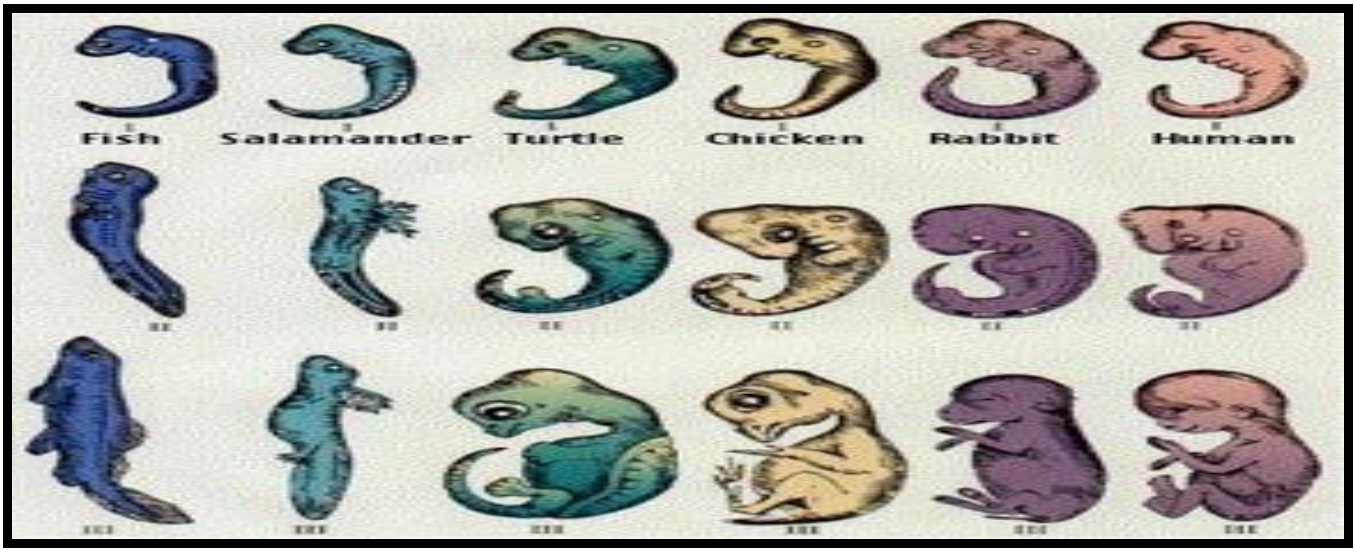


A tiny person (a *homunculus*) inside a sperm, as drawn by Nicolaas Hartsoeker in 1695

The theory of recaptiulation

✓ The embryonic forms of an animal resembled the adult organisms in its evolutionary ancestry.

✓ A historical hypothesis that the development of the embryo of an animal, from fertilization to gestation or hatching (ontogeny), goes through stages resembling or representing successive adult stages in the evolution of the animal's remote ancestors (phylogeny).



https://thebrain.mcgill.ca/flash/capsules/outil_bleu12.html

The Cell Theory

- The cell theory (proposed independently in 1838 and 1839) is a cornerstone of biology.
- All organisms are composed of one or more cells.
- Cells are the smallest living things.
- Cells arise only by division of previously existing cells.
- Ovum was discovered as a single cell and that fertilization is the union of the ovum and spermatozoon to form the zygote.

Importance of embryology

For example:

- Embryology is the basis for understanding the intimate relation between structures in different organ systems, such as the nervous system and muscle, and is primordial for understanding disorders of development that in the human may present as one of the congenital

myopathies.

- Provide knowledge essential for creating health care strategies for better reproductive outcomes

- A better understanding of embryology results in new techniques for prenatal diagnoses and treatments, therapeutic procedures to circumvent problems with infertility, and mechanisms to prevent birth defects, the leading cause of infant mortality.

- Supports the research and application of stem cells for the treatment of certain chronic diseases.

Subspecialties (Fields) of embryology

- **Descriptive embryology:** This field of embryology associated with the morphological description of different embryonic stages in the ontogenetic development of individuals of different species.

- **Comparative embryology:** the study of how anatomy changes during the development of different organisms.

- **Evolutionary embryology:** the study of how changes in development may cause evolutionary changes and of how an organism's ancestry may constrain the types of changes that are possible.

- **Experimental embryology:** It involves all those studies that attempt to understand the various fundamental mechanism in the development of different animals, like fertilization, cleavage, gastrulation, embryonic induction, determination, and differentiation.

- **Behavioral embryology:** the study of the early development of the

nervous system and behavior with a view toward understanding how the formative periods of neural and behavioral development affect later stages of neurobehavioral ontogeny.

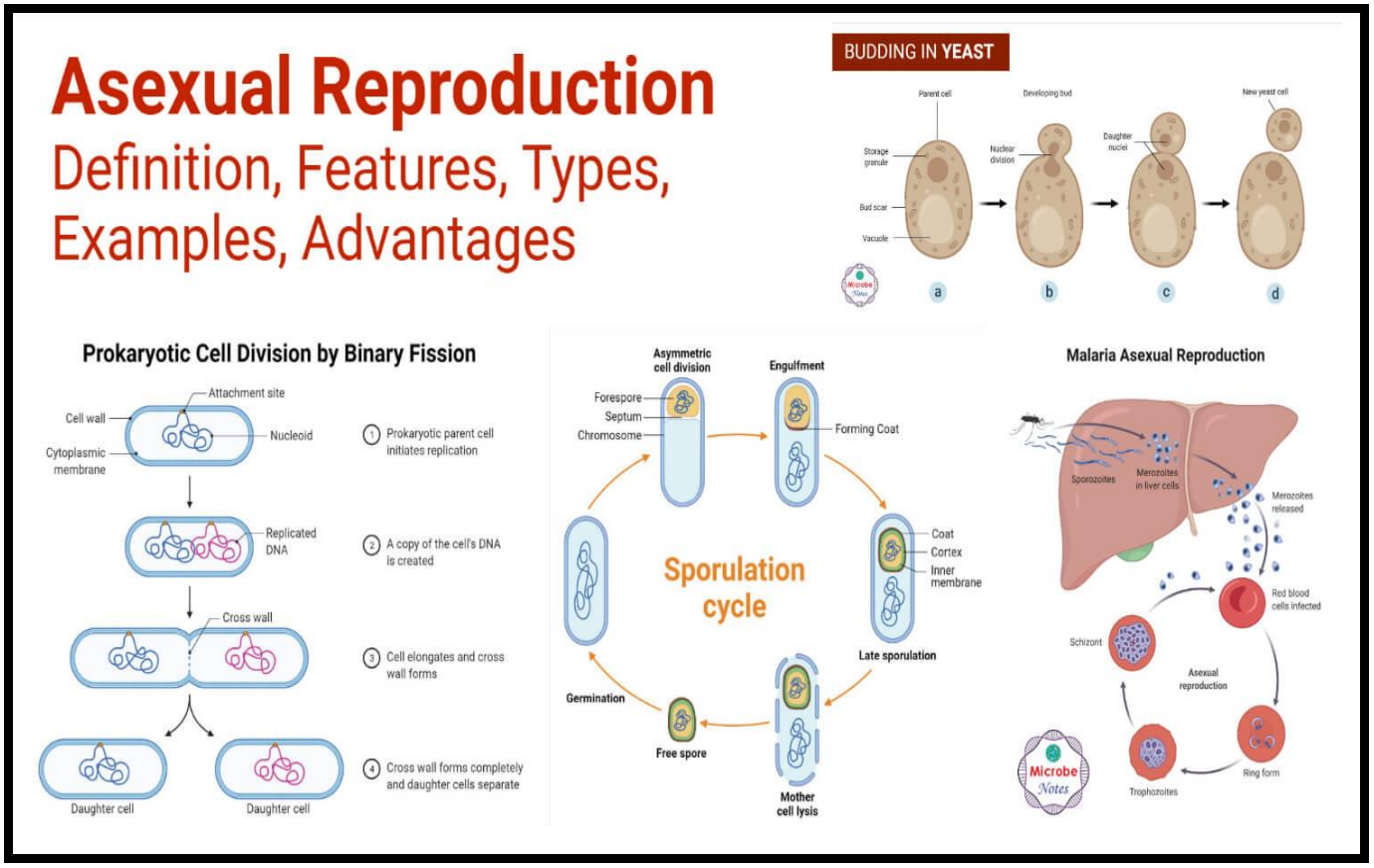
Chemical embryology: The branch of embryology includes all those studies which employ various biochemical, biophysical and physiological techniques for understanding embryological events at a molecular level.

Teratology: Teratology is the division of embryology and pathology that deals with abnormal development (birth defects). This branch of embryology is concerned with various genetic and/or environmental factors that disturb normal development and produce birth defects.

Reproduction

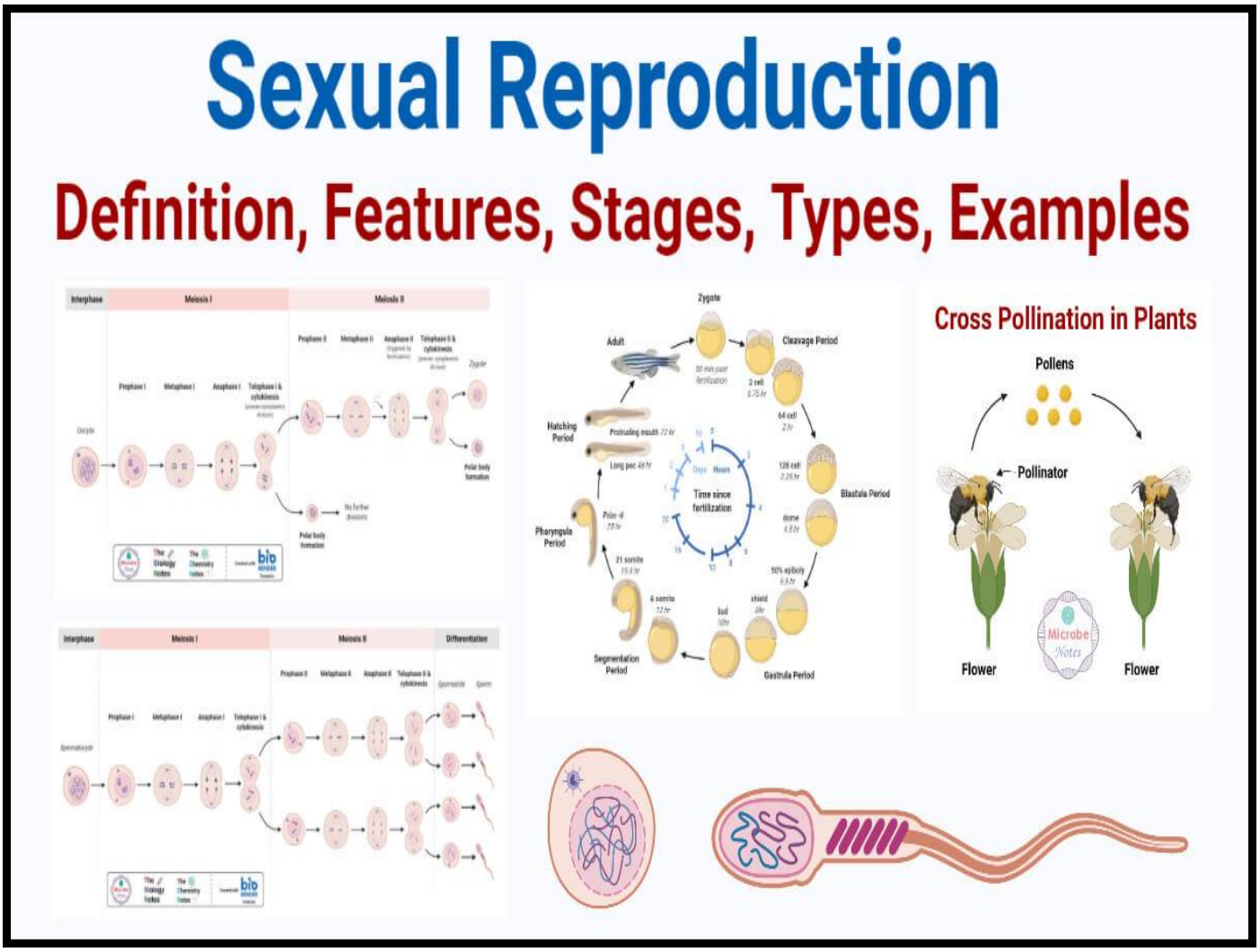
Reproduction may be defined as the biological process by which organisms give rise to their own kind. Reproduction may occur in two ways: **Asexual and Sexual reproduction**.

- Bacterial and protozoan offspring may be produced by single individuals. This is termed asexual reproduction. Lower animals and many plants reproduce asexually. When two individuals are involved in reproduction, it is termed sexual reproduction. Some methods of asexual reproduction are - fission, budding, fragmentation and spore formation.



Asexual Reproduction. Created with biorender.com

- In sexual reproduction, is a type of reproduction that involves a complex life cycle in which a gamete (such as a sperm or egg cell) with a single set of chromosomes (haploid) combines with another to produce a zygote that develops into an organism composed of cells with two sets of chromosomes (diploid). Sexual reproduction is the most common life cycle in multicellular eukaryotes, such as animals, fungi and plants. This is a more common mode of reproduction in plants and animals.



https://thebiologynotes.com/sexual-reproduction/

Basic Concepts of embryonic development include:

1. Gametogenesis
2. Fertilization
3. Cleavage
4. Blastulation
5. Gastrulation
6. Organization (Organogenesis)

Gametogenesis

Gametogenesis is the process by which male and female sex cells or gametes, i.e., sperms and ova are formed respectively in the male and female gonads (testes and ovaries). The gametes differ from all other cells (= somatic cells) of the body in that their nuclei contain only half the number of chromosomes found in the nuclei of somatic cells. Meiosis forms the most significant part of process of gametogenesis.

Gametogenesis for the formation of sperms is termed **spermatogenesis**, while that of ova is called **oogenesis**.

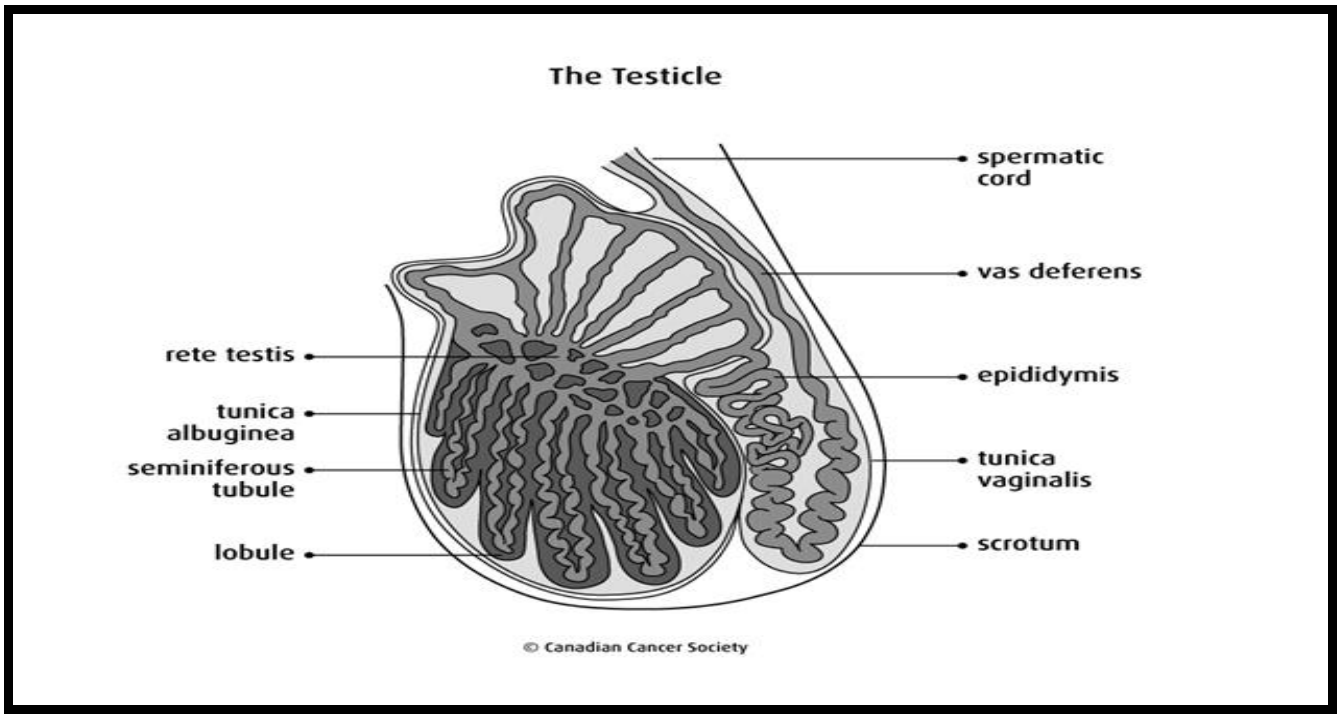
- Both spermatogenesis and oogenesis comprise similar phases of sequential changes as: **multiplication phase, growth and maturation phases**.

Spermatogenesis:

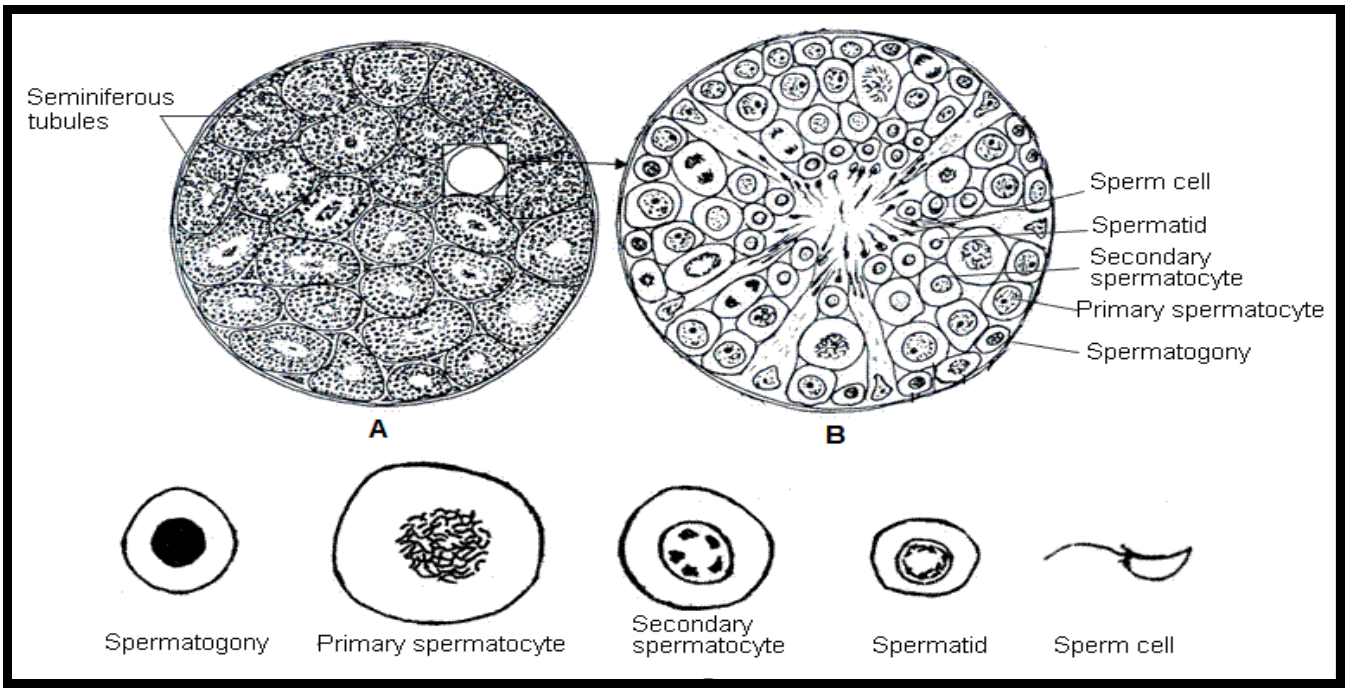
The process of formation of sperms is called spermatogenesis. It occurs in the seminiferous tubules of the testes. The seminiferous tubules are lined by germinal epithelium. The germinal epithelium consists largely of cuboidal primary or primordial germ cells (PGCs) and contains certain tall somatic cells called Sertoli cells (= nurse cells). Spermatogenesis includes formation of spermatids and formation of spermatozoa.

The testes structure

The testicles (testes) are part of a man's reproductive system. A man has 2 testicles. Each testicle is egg-shaped and about 5 cm long. The testicles are covered by a sac of skin called the scrotum. The scrotum hangs below the penis, between the legs. The testicles make sperm. They also make testosterone, which is a male sex hormone.



T.s. of rat testis



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- ✓ Each testicle is covered by tough, fibrous layers of tissue called the tunica. The outer layer is called the tunica vaginalis and the inner layer is called the tunica albuginea.

- ✓ The testicle is divided into parts called lobules. Each lobule contains tiny U-shaped tubes called seminiferous tubules. There are about 800 seminiferous tubules tightly coiled within each testicle.
- ✓ The seminiferous tubules open into a series of uncoiled, interconnected channels called the rete testis. Ducts, or tubes, connect the rete testis to a tightly coiled tube called the epididymis. The epididymis joins to a long, large duct called the vas deferens.
- ✓ Each testicle is held in the scrotum by a spermatic cord. Each spermatic cord is made of tough connective tissue and muscle. It contains the vas deferens, blood vessels, lymph vessels and nerves.
- ✓ Lymph fluid
- ✓ travels through vessels in the spermatic cord and drains from the testicles into several groups of lymph nodes at the back of the abdomen. These lymph nodes are called the retroperitoneal lymph nodes.
- ✓ Sertoli cells are the cells that are randomly scattered throughout the seminiferous tubules and provide nutrients to the developing spermatogonia.

Spermatogenesis: includes the following phases:

Multiplication Phase:

At sexual maturity, the undifferentiated primordial germ cells divide several times by mitosis to produce a large number of spermatogonia (Gr. sperma = seeds, gonos- generation). Spermatogonia (2N) are of two types: type A spermatogonia and type B spermatogonia. Type A spermatogonia serve as the stem cells which divide to form additional spermatogonia. Type B spermatogonia are the precursors of sperms.

Maturation Phase:

Each primary spermatocyte undergoes two successive divisions, called maturation divisions. The first maturation division is reductional or meiotic.

Hence, the primary spermatocyte divides into two haploid daughter cells called secondary spermatocytes. Both secondary spermatocytes now undergo second maturation division which is an ordinary mitotic division to form, four haploid spermatids, by each primary spermatocyte.

Growth Phase:

Each type B spermatogonium actively grows to a larger primary spermatocyte by obtaining nourishment from the nursing cells.

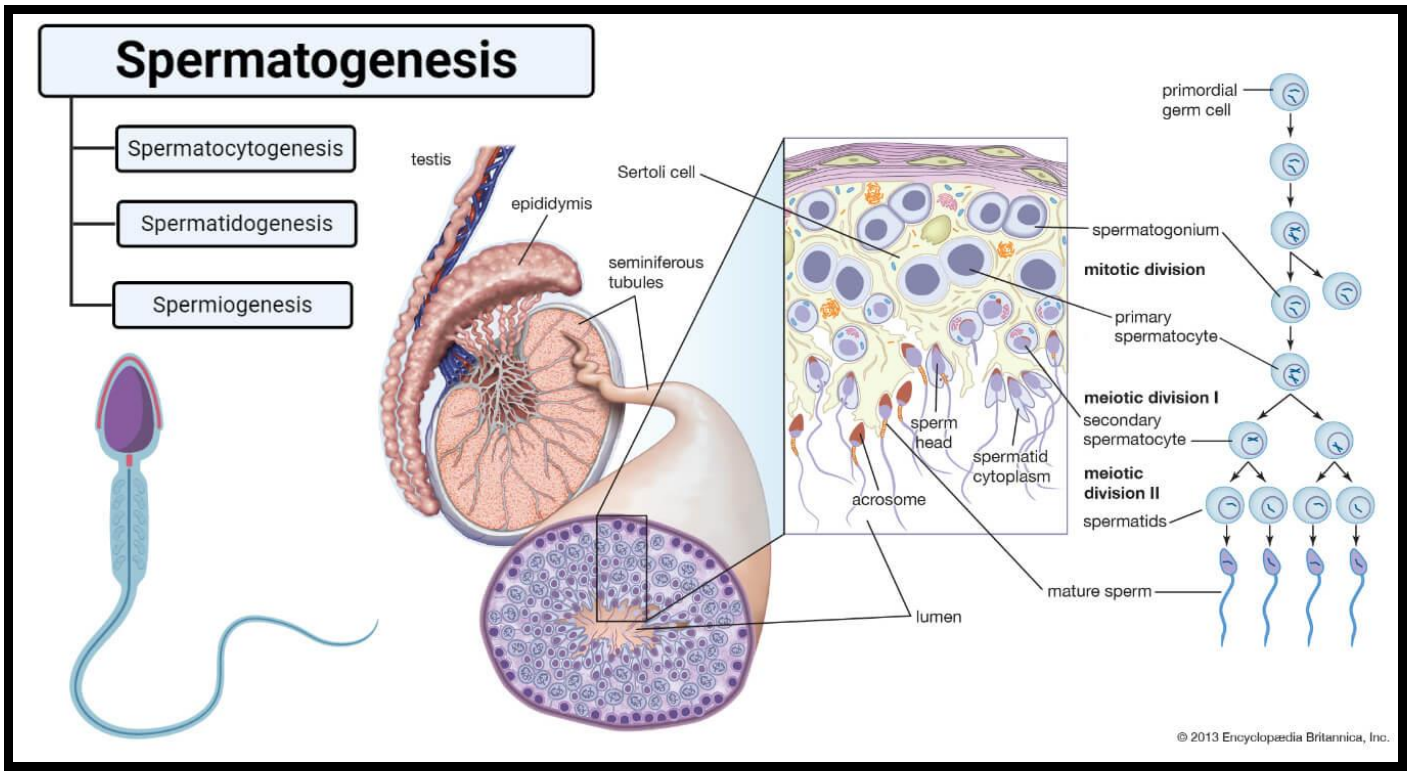
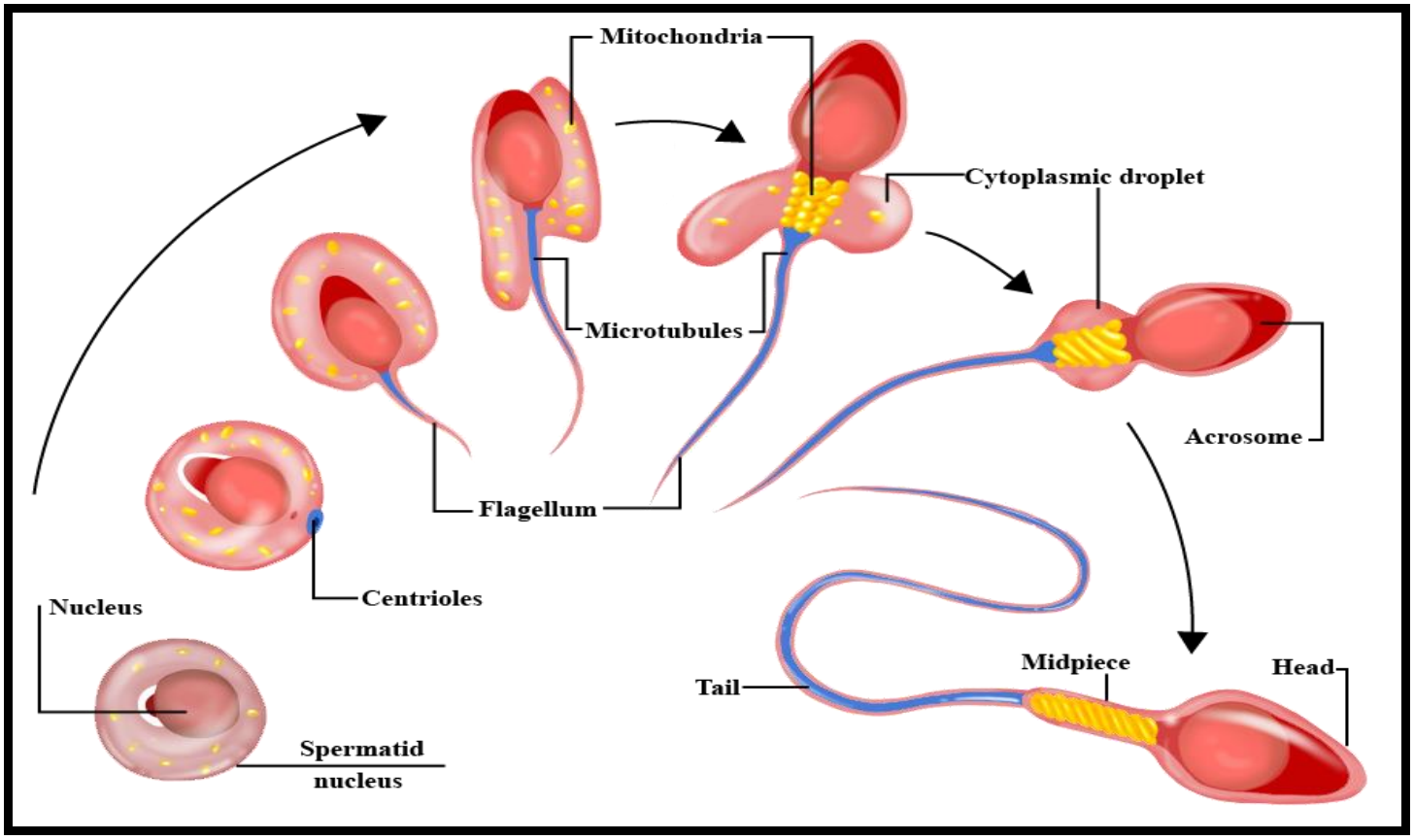


Image Source: Britannica, Created with BioRender.com.

Formation of Sperms from Spermatids (Spermiogenesis):

The transformation of spermatids into spermatozoa is called spermiogenesis. The spermatozoa are later on known as sperms. Thus, four sperms are formed from one spermatogonium. After spermiogenesis sperm heads become embedded in the Sertoli cells and are finally released from the seminiferous tubules by the process called spermiation.



https://byjus.com/question-answer/spermiogenesis-spermateleosis-is-formation-of-spermatozoa-from/

Spermatozoon (Sperm):

The sperms are microscopic and motile cells. Sperms remain alive and retain their ability to fertilize an ovum (egg) from 24 to 48 hours after having been released in the female genital tract. A typical mammalian sperm consists of a head, neck, middle piece and tail.

Head:

It contains anterior small acrosome and posterior large nucleus. Acrosome is formed from Golgi body of the spermatid. Acrosome contains hyaluronidase proteolytic enzymes which are popularly known as sperm lysins that are used to contact and penetrate the egg (ovum) at the time of fertilization.

Neck:

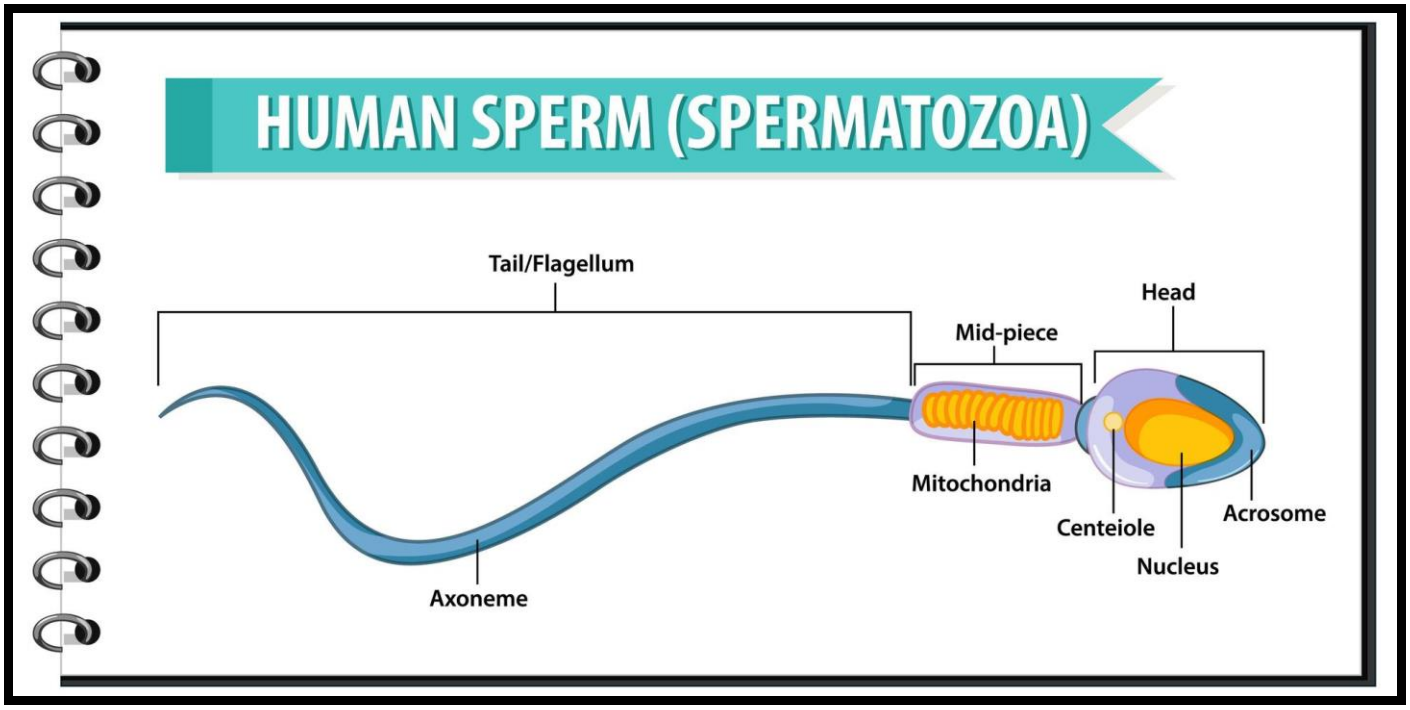
It is very short and is present between the head and middle piece. It contains the proximal centriole towards the nucleus which plays a role in the first cleavage of the zygote and the distal centriole which gives rise to the axial filament of the sperm.

Middle piece:

The middle piece of human sperm contains the mitochondria coiled around the axial filament called mitochondrial spiral. They provide energy for the movement of the sperm. So it is the "power house of the sperm". At the end of the middle piece there is a ring centriole (annulus) with unknown function. Posterior half of nucleus, neck and middle piece of sperm are covered by a sheath called manchette.

Tail:

The tail is several times longer than the head. In its most part called main piece, the axial filament is surrounded by a thin layer of cytoplasm. The part behind the main piece is called end piece which consists of naked filament alone. The sperm swims about by its tail in a fluid medium.



https://www.vecteezy.com/vector-art/1434164-human-sperm-or-spermatozoa-cell-structure

Different shape and size of sperm

Observe sperm of different animal species and compare the shape of sperm head, the size of acrosome (structure on the top of head containing enzymes important for penetrating the egg) and size and number of sperm tails.

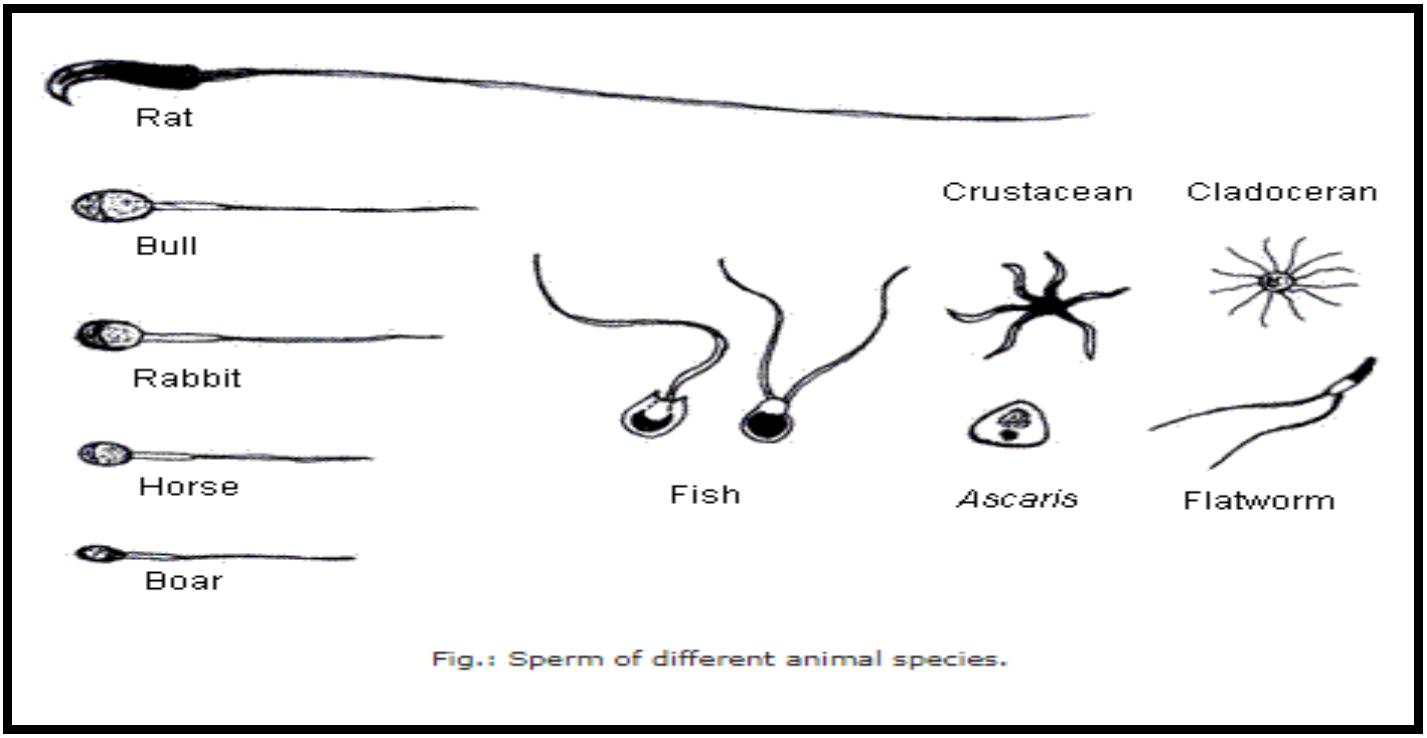


Fig.: Sperm of different animal species.

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Purpose of Spermatogenesis

The process of Spermatogenesis occurs to create mature male gametes, which then fertilize female gametes to create a zygote, a single-celled organism. This results in cell division and multiplication to create a fetus. For a healthy offspring, the number of chromosomes must be maintained properly across the body as failure can lead to some abnormalities.

Oogenesis

The process of formation of a mature female gamete (ovum) is called oogenesis. It occurs in the ovaries (female gonads).

Ovum structure:

The ovum is one of the largest cells that measures approximately 120 µm in diameter. The ovum has a large, centrally located nucleus which is covered by cytoplasm. This oocyte nucleus and nucleolus are termed **germinal vesicle** and **germinal disc** respectively. Likewise, the cytoplasm (yolk) of an ovum is termed **ooplasm**. It has less amount of yolk (in humans) and hence it is alecithal. This ooplasm is enclosed by a peripheral layer called the cortex which has many microvilli. These microvilli are tubular projections of the plasmalemma that aids in the transportation of substances in and out of the cytoplasm.

The human ovum is typically covered by 3 layers:

1. Inner thin vitelline membrane
2. Middle zona pellucida
3. Outer corona radiata

- ✓ The narrow space present between the vitelline membrane and zona pellucida is called the perivitelline space. The zona pellucida is often seen as a thick girdle that is surrounded by the corona radiata.
- ✓ For fertilization to occur, the hyaluronidase in the acrosome of the sperm has to scatter the outer corona radiata from the middle zona pellucida of an ovulated oocyte. This invariably allows contact between the oocyte's core and the sperm.

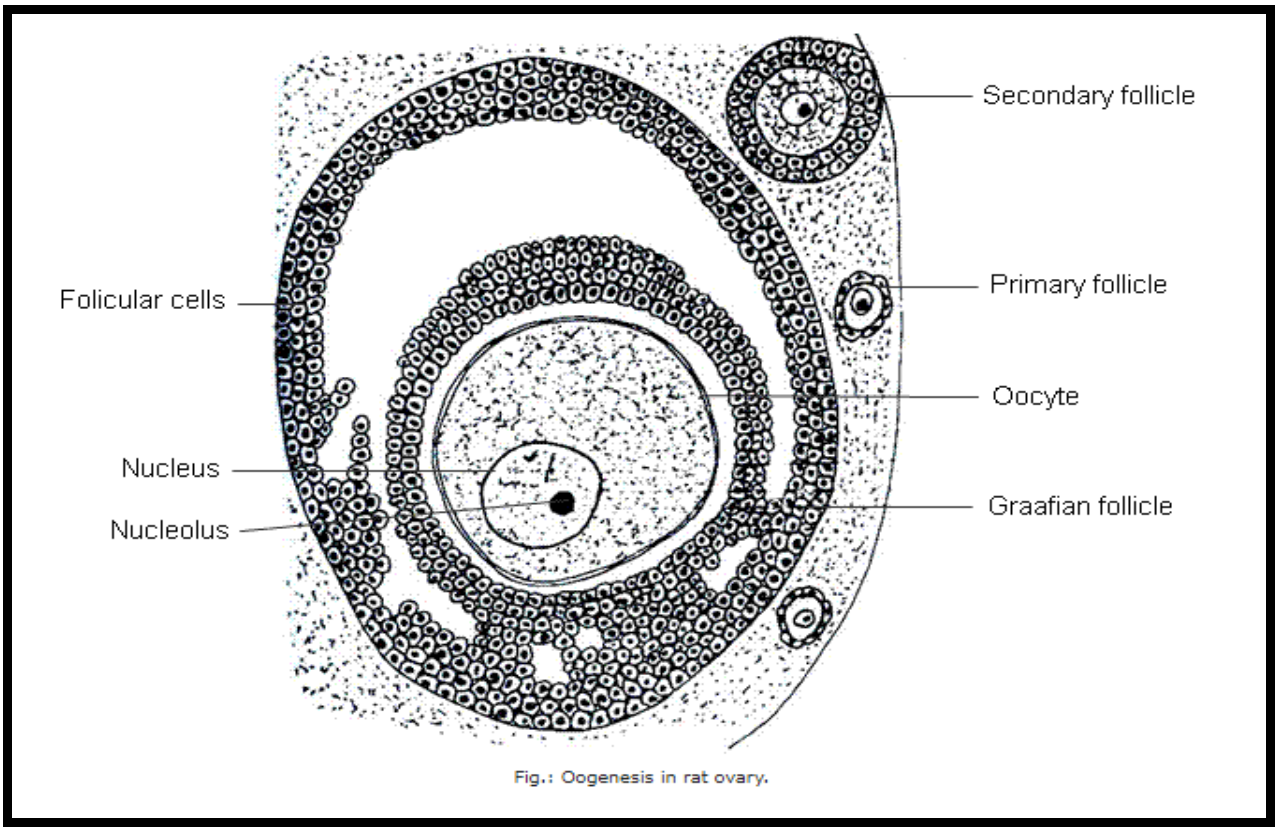

Fig.: Oogenesis in rat ovary.

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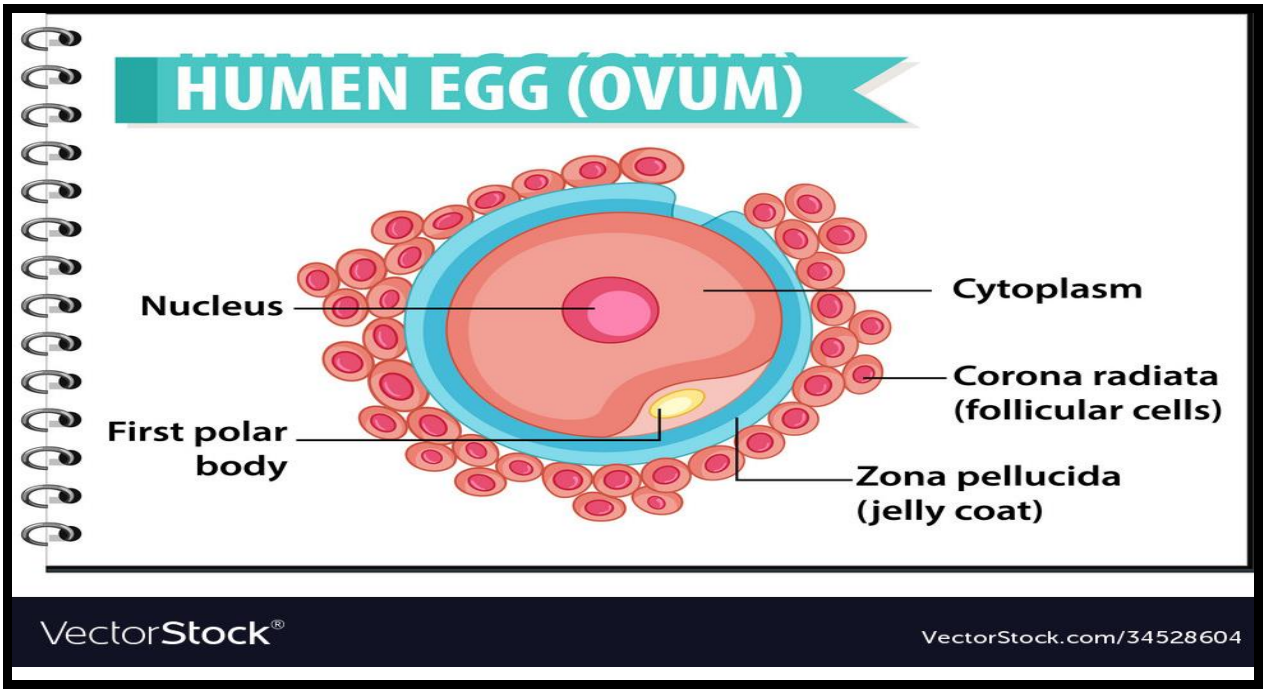


Types of Egg:

According to the proportion of the yolk to the cytoplasm of the ovum there are three types of egg:

[I] **Microlecithal egg:**

In microlecithal eggs the amount of yolk is much less than the amount of

cytoplasm. These eggs are very small in size. Some embryologists described microlecithal eggs as alecithal eggs or oligolecithal eggs or miolecithal (i.e. little yolk) eggs.

- ❖ The eggs of Amphioxus and mammals are of this type.
- ❖ The mammalian eggs contain so little yolk that they are sometimes called alecithal (without yolk) eggs.

[II] **Mesolecithal eggs:**

Here yolk is moderate in amount and such eggs are called mesolecithal or medialecithal (i.e. median yolk). The distribution of yolk is distinctly unequal.

- ❖ The eggs of sharks, fishes and many amphibians are of this type.

[III] **Macrolecithal or polylecithal eggs:**

Enormous amount of yolk is present in macrolecithal eggs and here yolk is several times greater than cytoplasm. These eggs may be small or big.

- ❖ The eggs of teleost fishes, reptiles, birds and monotremates (egg laying mammals) are of this type.

<u>According to distribution of yolk granules or platelets</u> in the cytoplasm of the ova or egg, the eggs are classified as follows:

1. **Homolecithal/Isolecithal:**

The yolk in these eggs is uniformly distributed through the cytoplasm.

- ❖ Examples are of Amphioxus, many invertebrates and mammals including man.

2. **Centrolecithal:**

Yolk is concentrated in the interior of the egg and the cytoplasm is distributed as a thin layer on the outside of the yolk.

- ❖ As in insects and many other arthropodes.

3. **Teleolecithal:**

Yolk becomes more abundant and tends to concentrate in one hemisphere of the egg. Because of the uneven distribution of yolk, such an egg is said to have

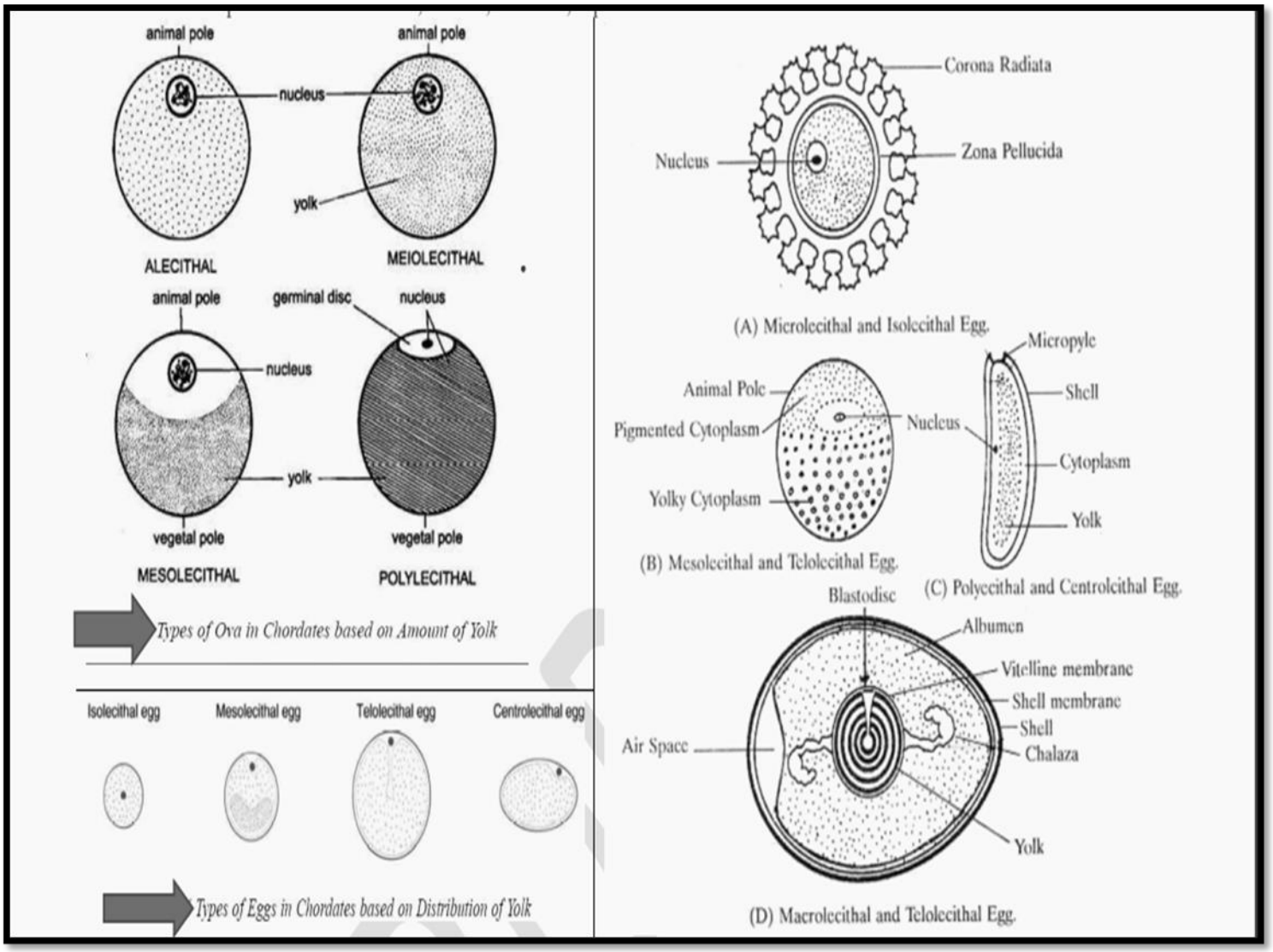
a vegetal pole, where the concentration of yolk is greatest and an animal pole, where the concentration of yolk is smallest.

In fact, in macrolecithal eggs, the amount of yolk is so massive that it occupies almost all the vegetal pole, and the active cytoplasm and germinal vesicles (nucleus) remain confined to a small cap at the animal pole.

- ❖ Examples are of fishes, amphibians, and reptiles, birds and monotremes eggs.

Functions of Yolk:

Although yolk of egg is used for two purposes—supply of energy and synthesis of the products required for elaboration of the embryonic body. The yolk also has important influence on—(i) the size of the ovum, (ii) differentiation of ooplasm, (iii) patterns of cleavage, (iv) morphogenetic movements of blastomeres during gastrulation, and (v) the type of development whether direct or indirect.



https://www.bajkulcollegeonlinestudy.in

Oogenesis: consists of three phases: multiplication, growth and maturation.

Multiplication phase:

In the foetal development, certain cells in the germinal epithelium of the ovary of the foetus are larger than others. These cells divide by mitosis, producing a couple of million egg mother cells or oogonia in each ovary of the foetus. No more oogonia are formed or added after birth. The oogonia multiply by mitotic divisions forming the primary oocytes.

Growth phase:

This phase of the primary oocyte is very long. It may extend over many years. The oogonium grows into a large primary oocyte. Each primary oocyte then gets surrounded by a layer of granulosa cells to form primary follicle. A large number of these follicles degenerate during the period from birth to puberty. So at puberty only 60,000- 80,000 primary follicles are left in each ovary.

Maturation phase:

Like a primary spermatocyte, each primary oocyte undergoes two maturation divisions, first meiotic and the second meiotic. The results of maturation divisions in oogenesis are, however, very different from those in spermatogenesis. In the first, meiotic division, the primary oocyte divides into two very unequal haploid daughter cells— a large secondary oocyte and a very small first polar body or polocyte. In the second maturation division, the first polar body may divide to form two second polar bodies. The secondary oocyte again divides into unequal daughter cells, a large ootid and a very small second polar body. The ootid grows into a functional haploid ovum. Thus, from one oogonium, one ovum and three polar bodies are formed. The ovum is the actual female gamete. The polar bodies take no part in reproduction and, hence, soon degenerate.

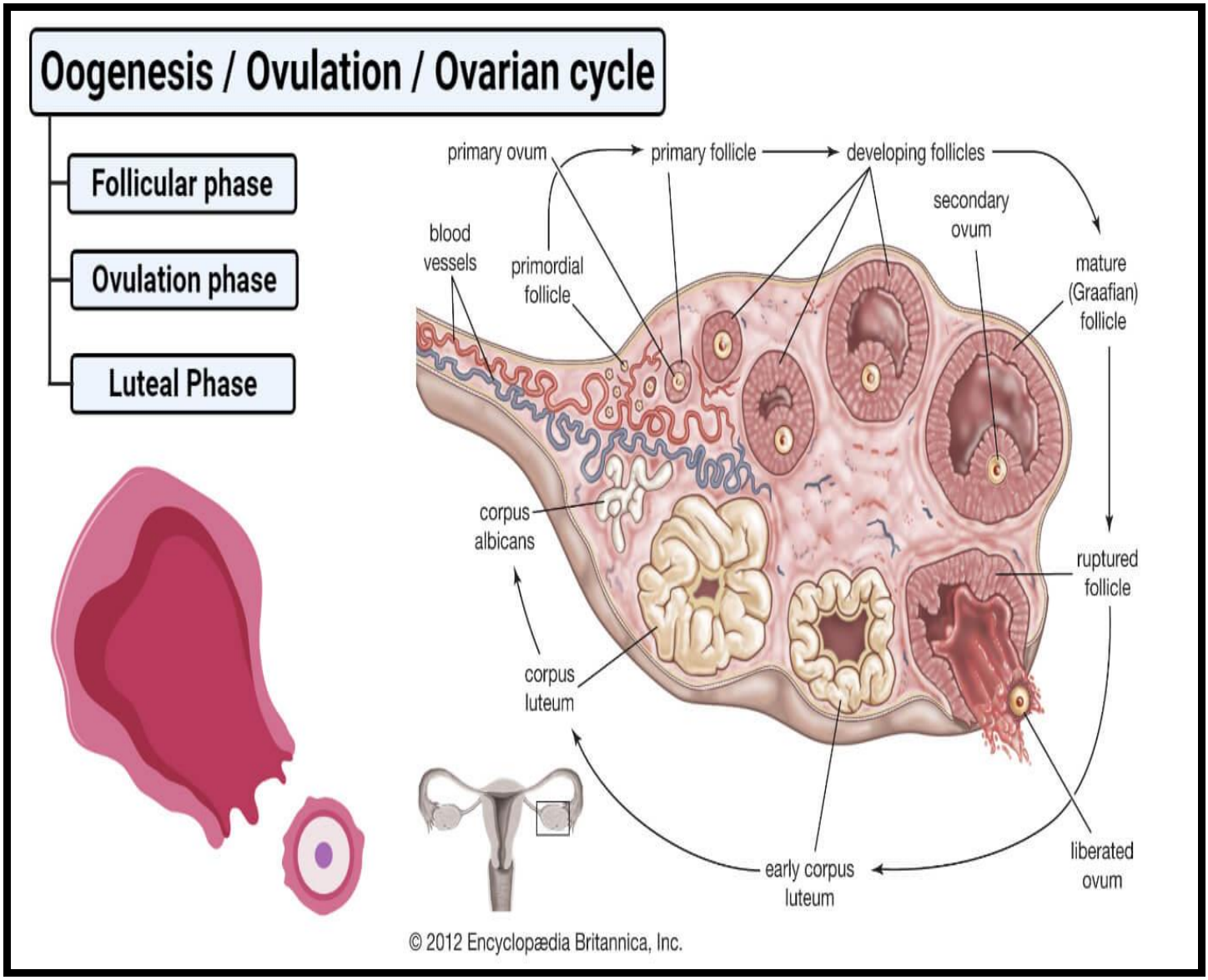


Image Source: Britannica, Created with BioRender.com.

The ovarian cycle

Of the roughly 500'000 follicles that are present in the two ovaries at the beginning of sexual maturity, only around 480 reach the graafian follicle stage and are thus able to release oocytes (ovulation). This number is simply derived by multiplying the number of cycles per year and the number of years in which a woman is fertile.

Ovulation represents an exceptional fate of a follicle.

- It is a series of cyclic changes occurring in the reproductive tract of female with the periodicity of 28 days
- It is also known as menstrual cycle,
- also known as endometrial cycle

- It occur From puberty to menopause
- It is characterized by loss of vaginal blood (breaking of endometrium wall of uterus)
- The cycle is under Influenced of hormones secreted by pituitary gland (FSH and LH), and ovary (progesterone and oesterogen).
- Menstrual phase
- Proliferative phase or follicular or ovulatory phase
- Luteal or secretory phase

Menstrual phase

- This phase is characterized by discharge of blood, connective tissues and mucus due to cast off of epithelial lining of endometrium wall
- It Lasts for **3-5 days**
- Ovum remain unfertilized,
- At this time level of oestrogen and progesterone is very low in blood resulting in Breaking of endometrium wall of uterus
- About 50-100 ml blood with mucus are discharges as menstrual flow.

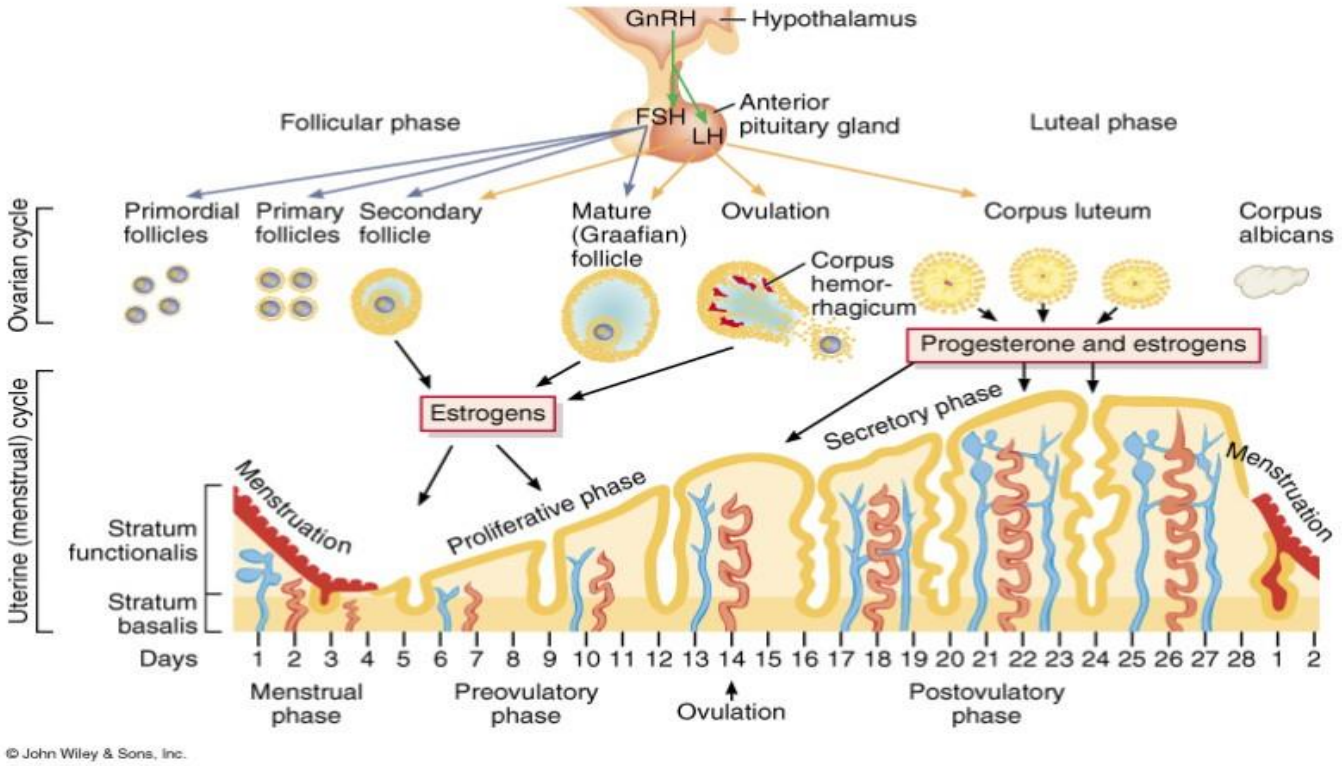
Proliferative phase

- This phase is characterized by rapid proliferation and repair of damaged endometrium wall
- It Lasts for **9-10 days** (5th – 14thdays)
- Anterior pituitary gland releases **Follicular stimulating Hormone (FSH)** which stimulates development and maturation of grafian follicle. So, it is also known as Follicular Phase.
- Mature grafian follicle secrete **oestrogen.** Its level gradually increases and maximize at 12thday
- Oestrogen stimulates endometrium repair and proliferation. It also stimulates Ovulation

- Endometrium become 2-3 mm thick and highly vascular

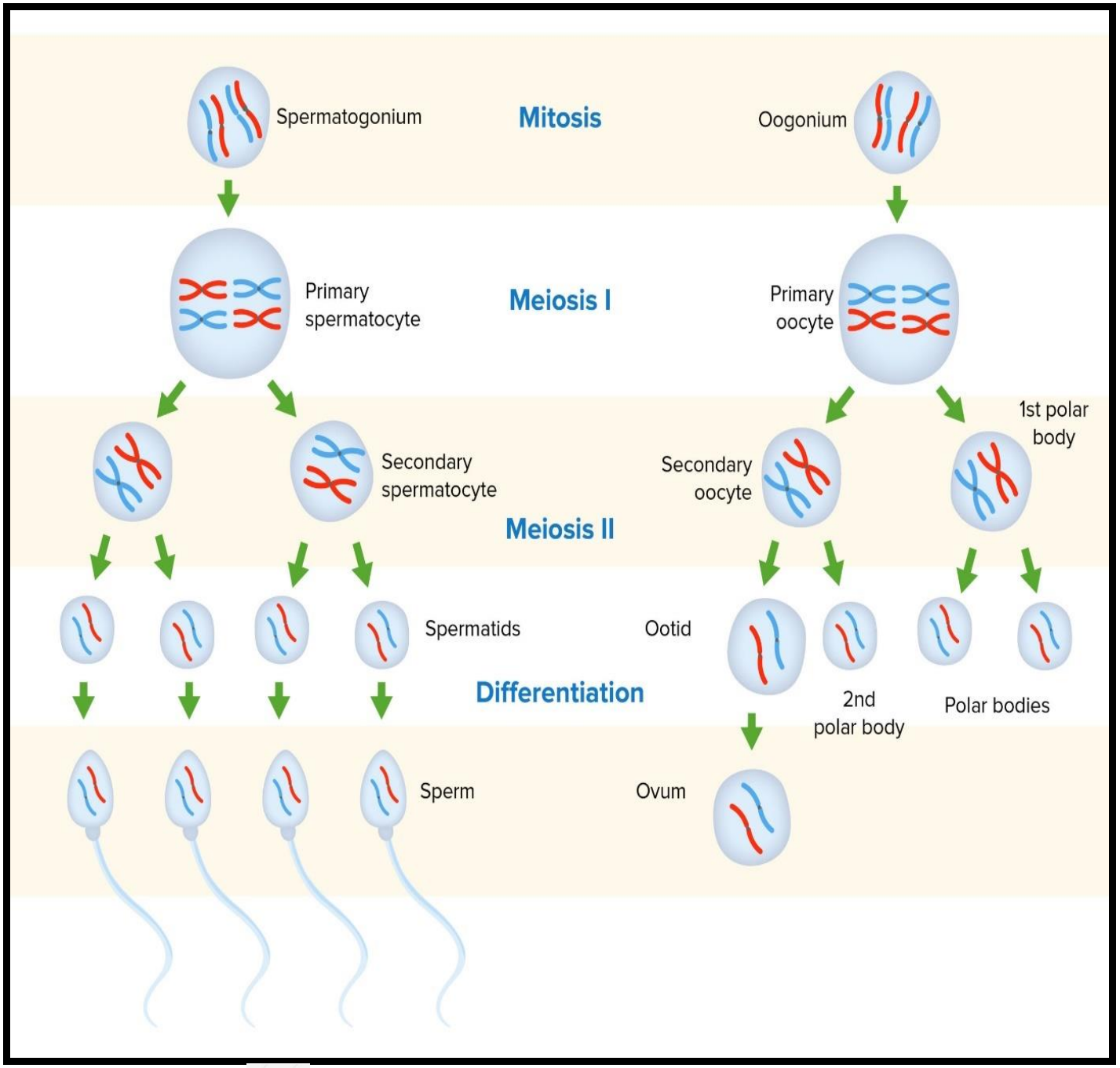
Luteal phase

- This phase is characterized by release of Ovum from mature graffian follicle which is stimulated by the secretion of **luteinizing hormone** (LH) by pituitary gland.
- It Lasts for **12-14 days** (14th-28th day)
- LH along with FSH stimulate ovulation.
- Mature graffian follicle release ovum and the rapture follicular cell form **corpus luteum**
- Corpus luteum secrete progesterone, high level of progesterone inhibits maturation of any other follicles
- Progesterone also stimulates thickening of endometrium wall
- When ovum remain unfertilized, corpus luteum degenerate; level of both hormone (progesterone and oestrogen) decreases, causing breaking of endometrium wall continuing the menstrual phase.



Purpose of Oogenesis

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



https://cdn.lecturio.com/assets/Gametogenesis-1200x956.jpg

	Spermatogenesis	Oogenesis
Process		
Location	Occurs *entirely* in testes	Occurs *mostly* in ovaries
Meiotic divisions	Equal division of cells	Unequal division of cytoplasm
Germ line epithelium	Is involved in gamete production	Is not involved in gamete production
Gametes		
Number produced	Four	One (plus 2 – 3 polar bodies)
Size of gametes	Sperm smaller than spermatocytes	Ova larger than oocytes
Timing		
Duration	Uninterrupted process	In arrested stages
Onset	Begins at puberty	Begins in foetus (pre-natal)
Release	Continuous	Monthly from puberty (menstrual cycle)
End	Lifelong (but reduces with age)	Terminates with menopause

http://ib.bioninja.com.au/higher-level/topic-11-animal-physiology/114-sexual- reproduction/gametogenesis.html

The timing of meiosis differs in females and males

In males

1- The spermatogonia enter meiosis and produce sperm from puberty until death.

2-The process of sperm production takes only a few weeks.

3- Four sperms result from spermatogenesis.

In females

1-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, 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.

2- All meiosis is ended in females at menopause.

The result is the egg cell and three polar bodies.

3- Only I egg produced A polar body consists of the chromosomes and nucleus resulting from meiotic division, but it receives almost no cytoplasm. All the cytoplasm is found in the secondary oocyte.

The cytoplasm will provide energy to the developing embryo until it implants.

In the mammalian ovary, the oocytes are closely associated with somatic cells called granulosa cells which aid oocyte maturation and ovulation.

Fertilization

Fertilization, the process by which male and female gametes nuclei fuses together to produce diploid zygote.

Types of Fertilization:

1. External:

Eggs are librated in water.

- Occurs outside the female genital system.
- Female laid a large number of eggs, them the male pour its sperms in the same region in water
- e.g. in fish and amphibian.

2. Internal:

- land-dwellers
- specialized structures for housing gametes.
- embryo more protected during development.
- Occurs in animals that have a well-developed reproductive system, animals may be:

a) **Oviparous:** zygote develops in a shell e.g., birds.

b) **Viviparous:** zygote develops inside uterus e.g., mammals.

The intrauterine life is about 21 days in the rat, 70 days in the in the Guinea pig while its about 280 days in human.

c) **Ovoviviparous: -** e.g. dog fish

It has 4 major steps:

1. Contact and recognition between sperm and egg. (Same species)
2. Regulation of sperm entry into the egg. (Only one and inhibiting the others)
3. Fusion of the genetic material of sperm and egg.
4. Activation of egg metabolism to start development.

Egg Maturation at Sperm Entry

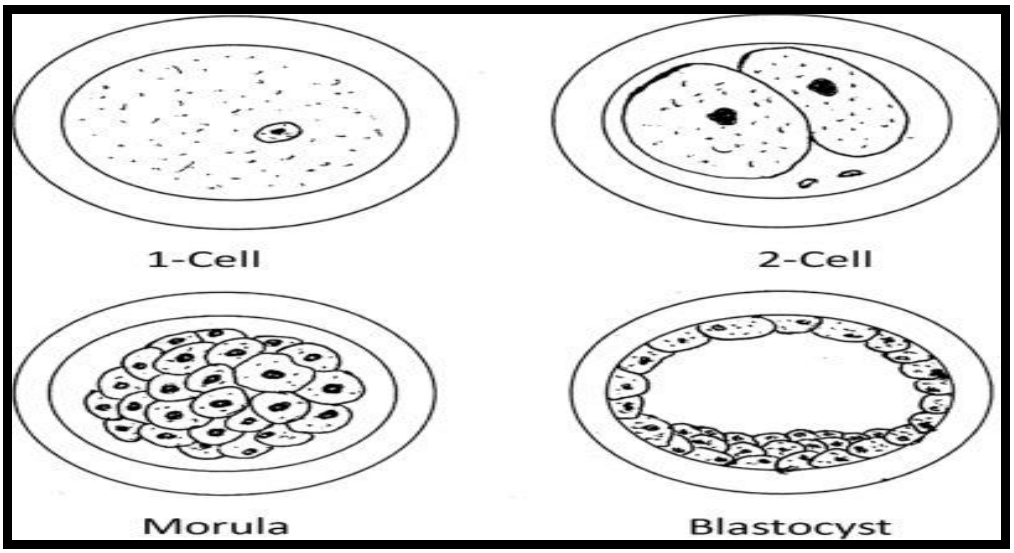
Most eggs are not fully mature at the time of fertilization. Sperm entry activates metabolism and relieves meiotic arrest.

Polar body formation results in egg maturation to be ready for actual fertilization (Pronucleus formation).

Cleavage and Blastula Formation

Meaning of Cleavage:

- Is the process of repeated rapid mitotic cell divisions of the zygote (unicellular structure) to form the Blastula (multicellular structure).
- The produced cells named Blastomeres.
- During this stage the size of the embryo does not change, the blastomeres become smaller with each division.
- The type & pattern of cleavage differ from species to species.
- continues divisions to form a ball of 32 cells called the morula.
- The morula continues divisions to form the hollow blastula with up to several hundred cells.
- The cavity of the blastula is the blastocoel.



https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/ova

Planes of Cleavage:

Considerable amount of reorganization occurs during the period of cleavage and the types of cleavage depend largely upon the cytoplasmic contents.

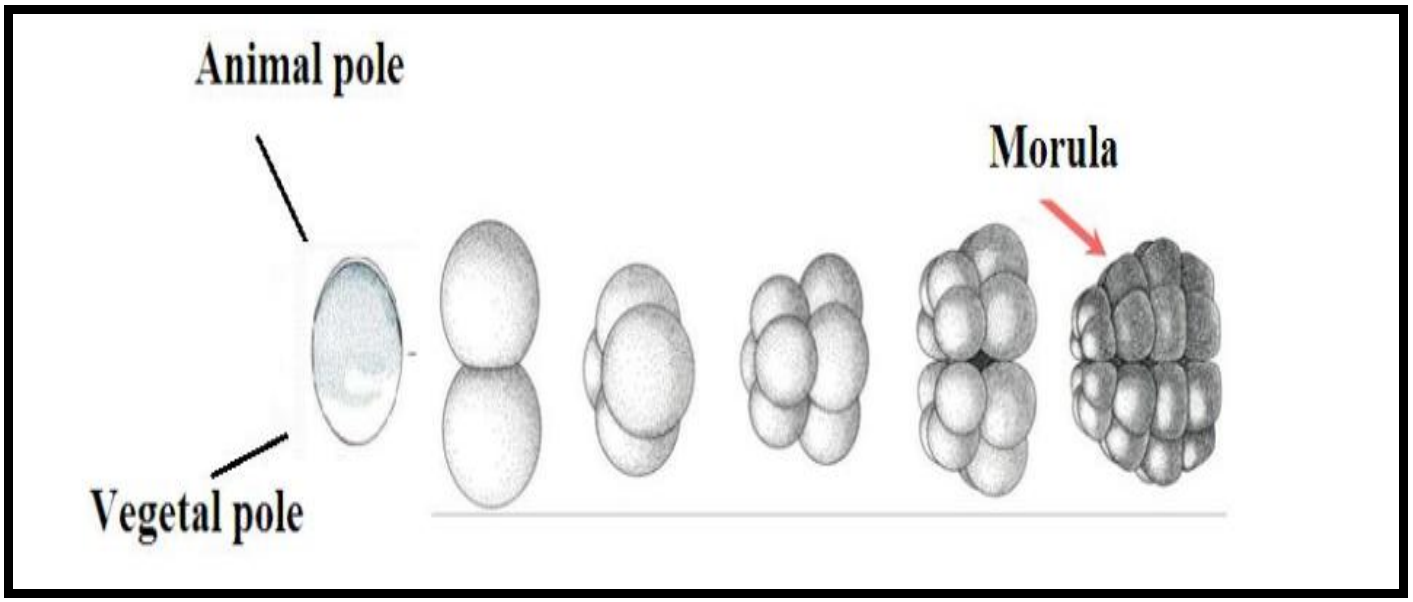
A: Holoblastic or total cleavage:

When the cleavage furrows divide the entire egg.

It may be:

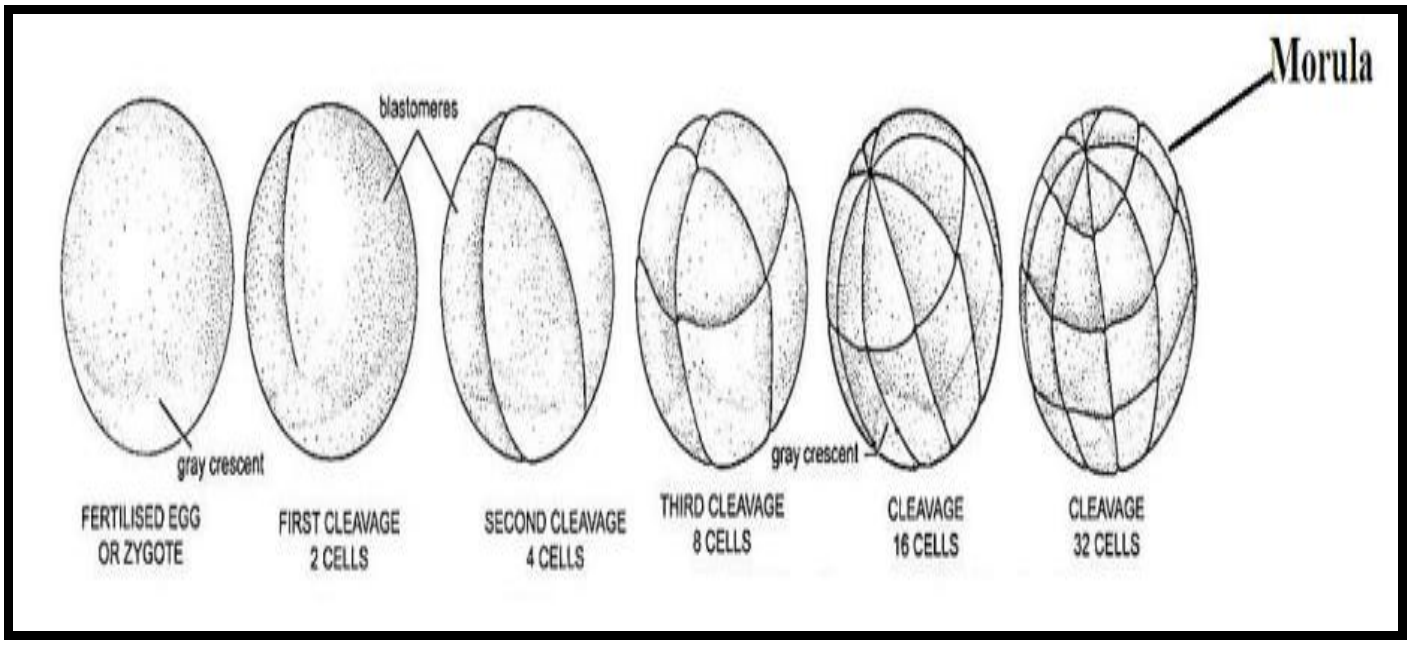
Equal:

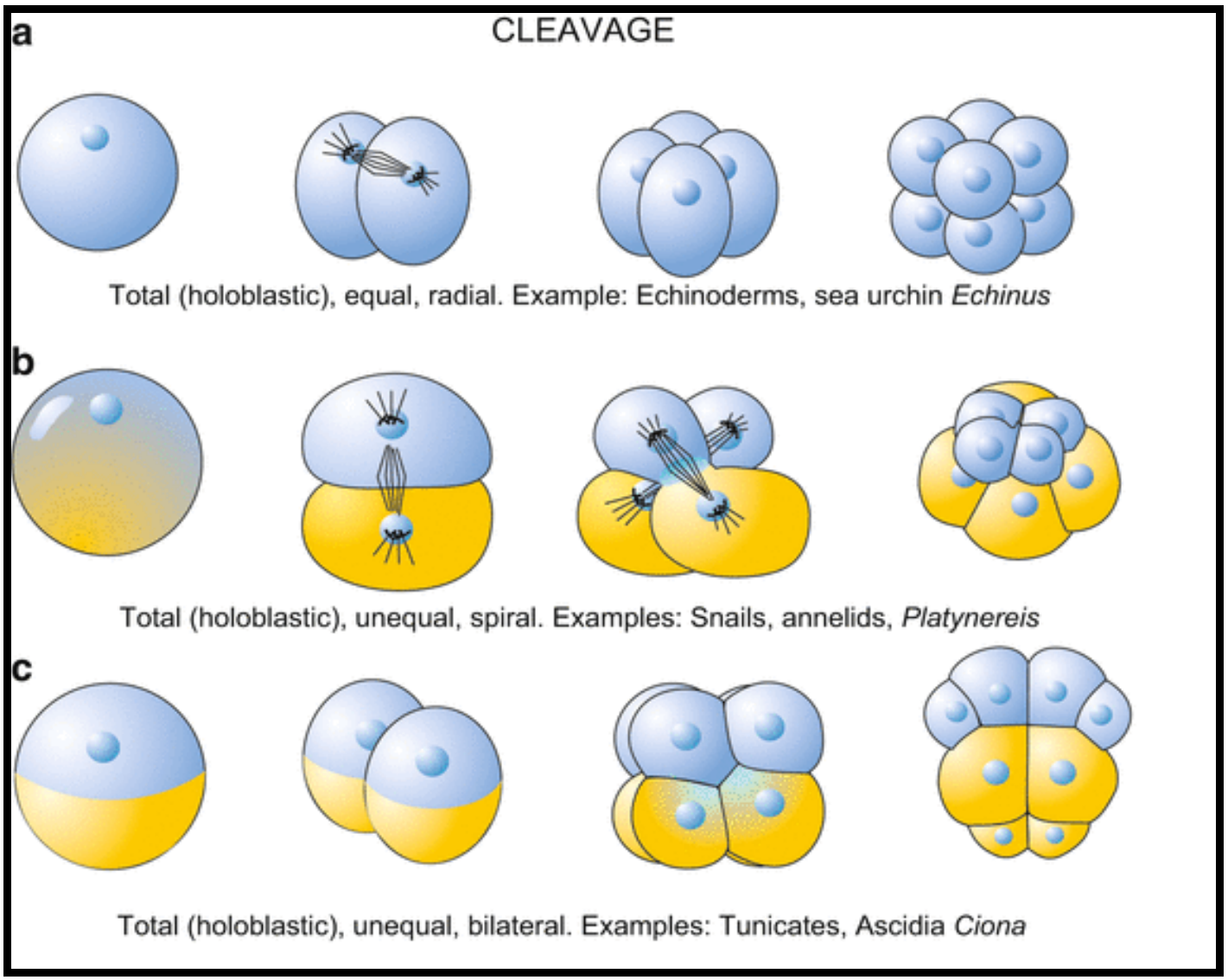
When the cleavage furrow cuts the egg into two equal cells. It may be radially symmetrical, bilaterally symmetrical, spirally symmetrical or irregular.



Unequal:

When the resultant blastomeres become unequal in size.





https://veteriankey.com/stages-and-principles-of-animal-development-terms-of-developmental-biology/

B. Meroblastic cleavage:

When segmentation takes place only in a small portion of the egg resulting in the formation of blastoderm, it is called meroblastic cleavage. Usually the blastoderm is present in the animal pole and the vegetal pole becomes laden with yolk which remains in an uncleaved state, i.e., the plane of division does not reach the periphery of blastoderm or blastodisc.

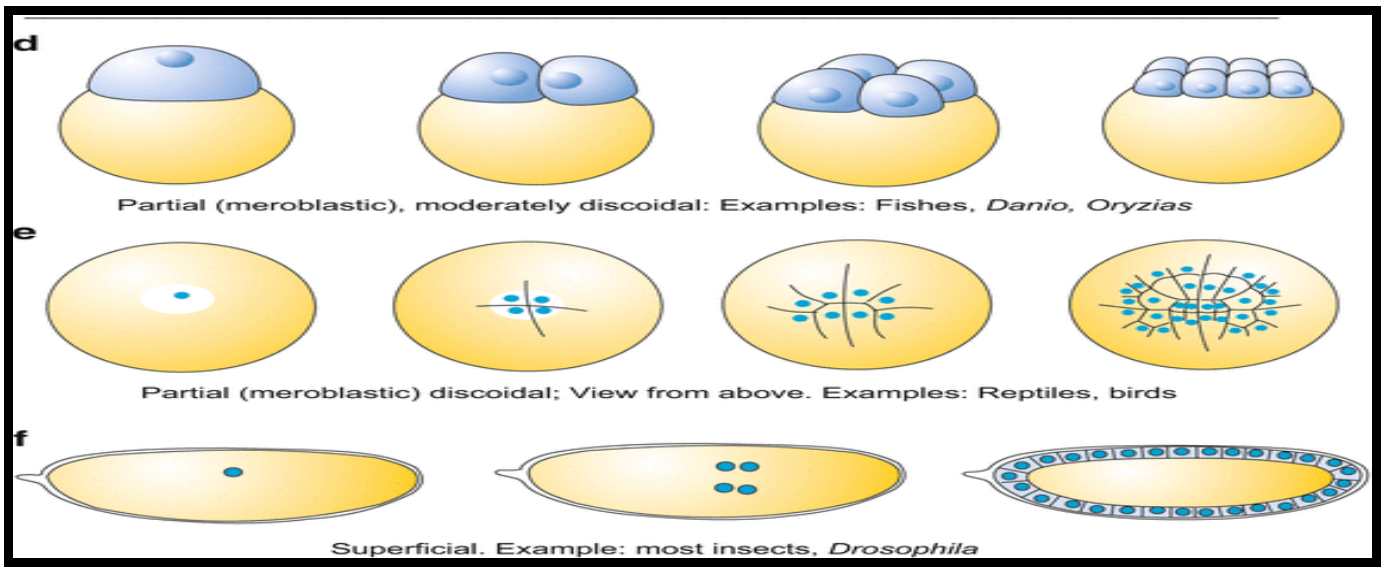
Two major types of meroblastic cleavage are discoidal and superficial:

1- Discoidal

In discoidal cleavage, the cleavage furrows do not penetrate the yolk. The embryo forms a disc of cells, called a blastodisc, on top of the yolk. Discoidal cleavage is commonly found in monotremes, birds, reptiles, and fish that have telolecithal egg cells (egg cells with the yolk concentrated at one end).

2-Superficial

In superficial cleavage, mitosis occurs but not cytokonesis, resulting in a polynuclear cell. With the yolk positioned in the center of the egg cell, the nuclei migrate to the periphery of the egg, and the plasma membrane grows inward, partitioning the cytoplasm into individual cells. Superficial cleavage occurs in arthropods that have centrolecithal eggs.



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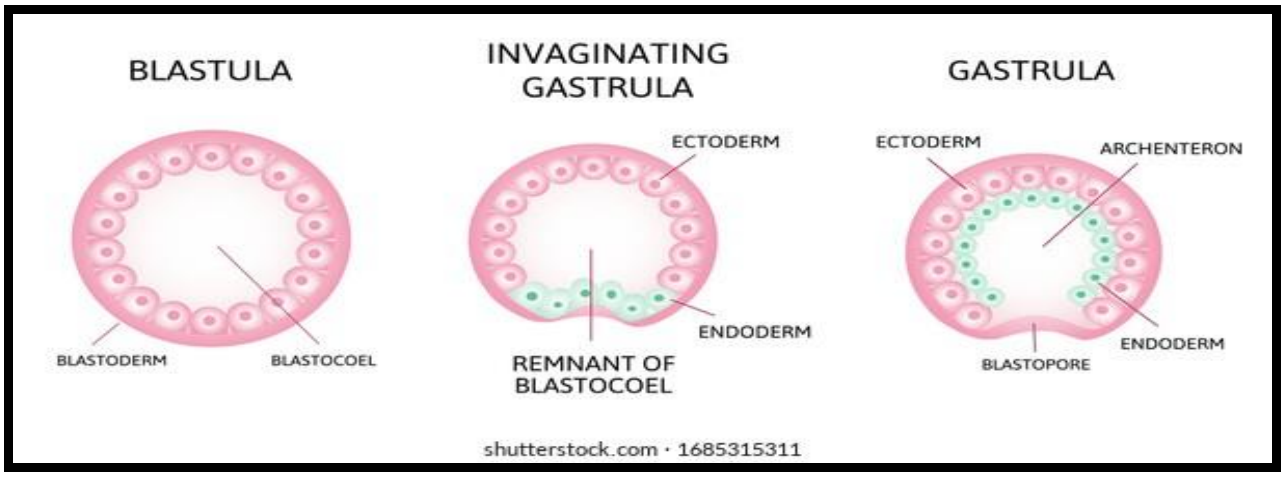
Gastrulation

The morphogenetic process called gastrulation rearranges the cells of a blastula into a three-layered (triploblastic) embryo, called a gastrula, that has a primitive gut. It means rearrangement of blastula cells that transforms the blastula into a gastrula. The blastula develops a hole in one end and cells start to migrate into the hole; this forms the gastrula which characterized by cell movement. Blastocoel is gradually disappeared and a new cavity is formed archenteron.



Germ Layer Patterns

Diploblastic gastrula = 2 germ layers

Endoderm (inner)

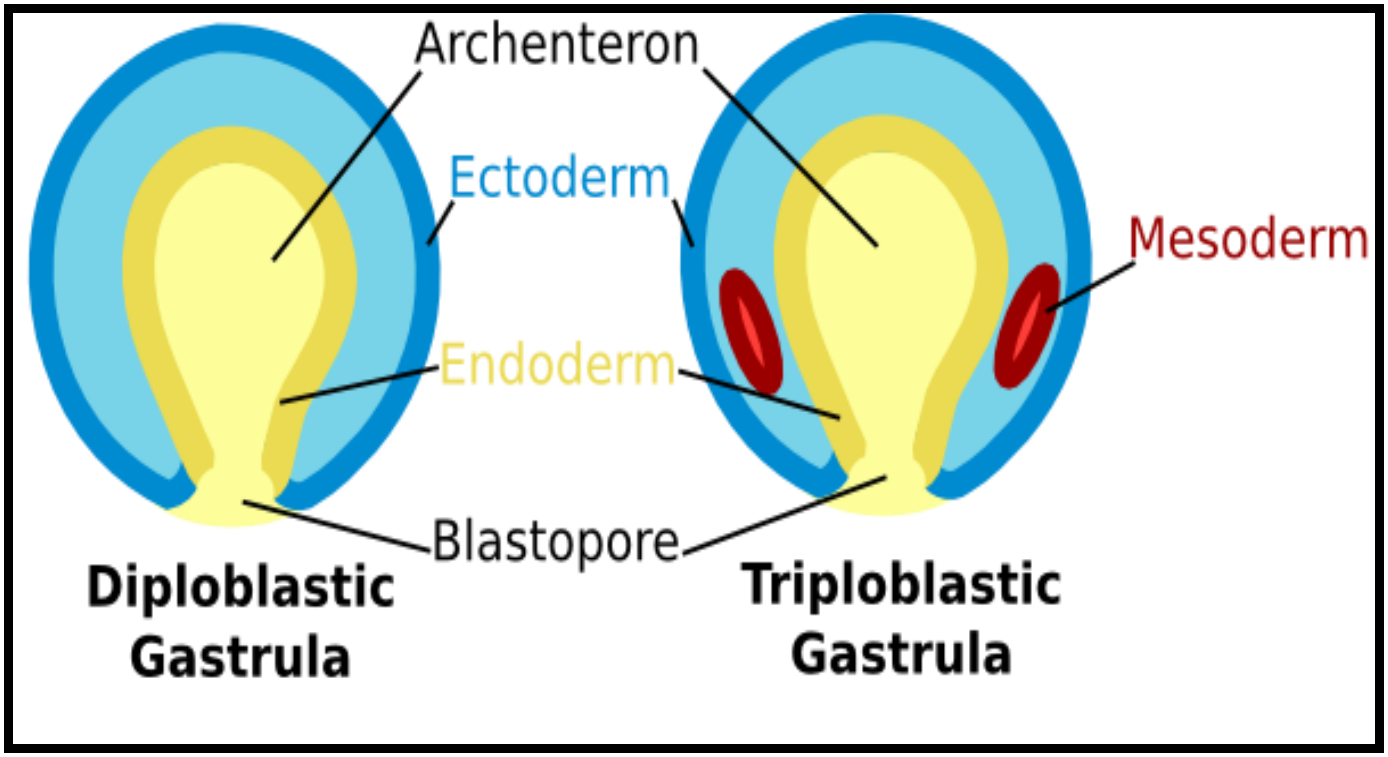
Ectoderm (outer)

Triploblastic = 3 germ layers

Endoderm (inner)

Mesoderm (middle)

Ectoderm (outer)



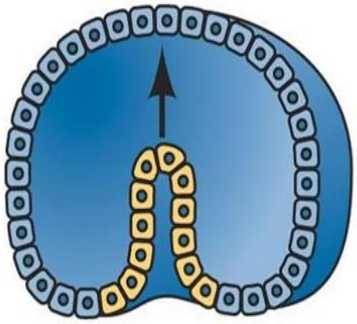
The pattern of gastrulation is affected by the amount of yolk. The cells at the vegetal pole invaginate, initiating gastrulation.

Gastrulation patterns

gastrulation patterns exhibit enormous variation throughout the animal kingdom, they are unified by the five basic types of cell movements that occur during gastrulation:

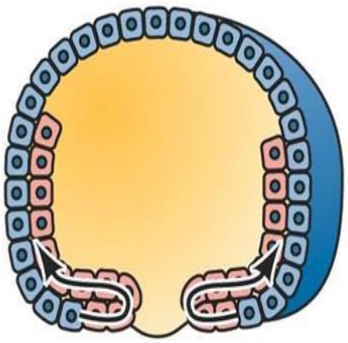
- Invagination.
- Involution.
- Ingression.
- Delamination.
- Epiboly

Invagination



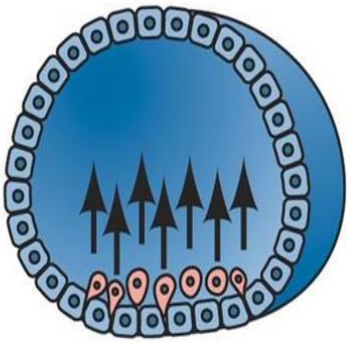
Local inward buckling of an epithelium

Involution



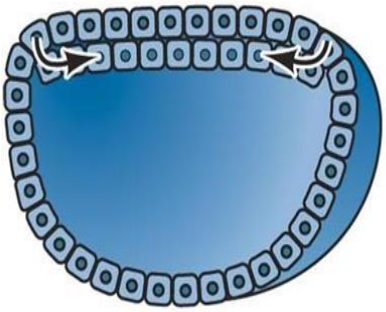
Inward movement of a cell layer around a point or edge

Ingression



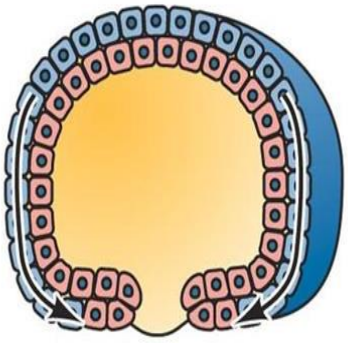
Movement of individual cells or small groups from an epithelium into a cavity

Delamination



Splitting layers of cells (sometimes used to describe coordinated ingression)

Epiboly

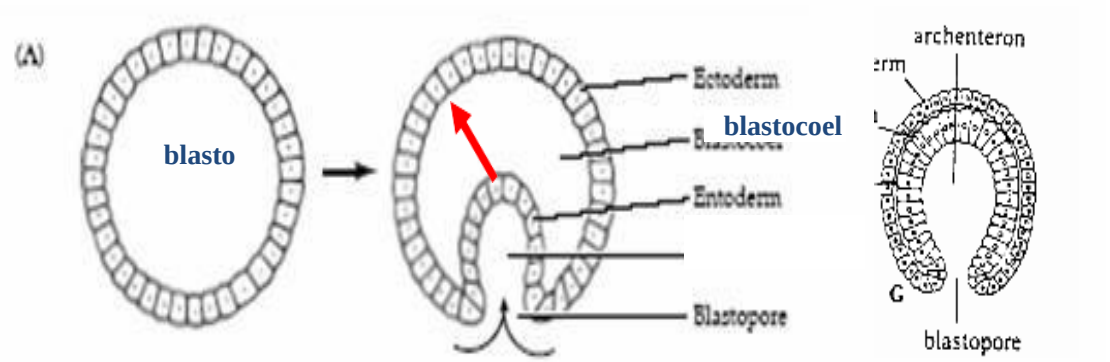


Spread of an outside cell layer (as a unit) to envelop a yolk mass or deeper layer

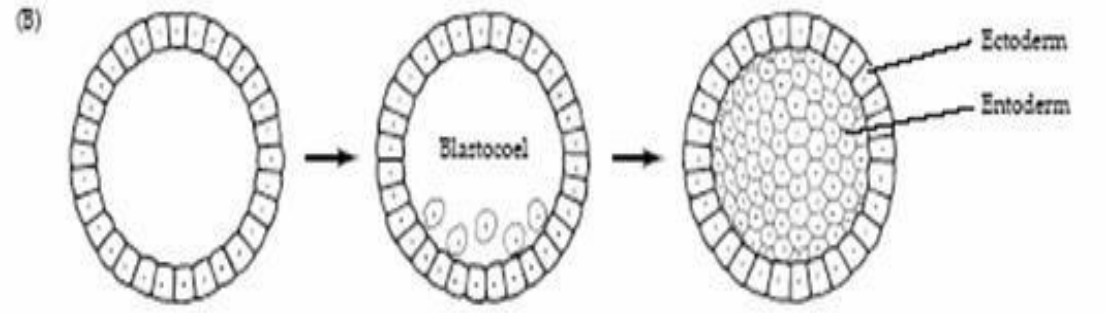
Migration

Movement of individual cells over other cells or matrix

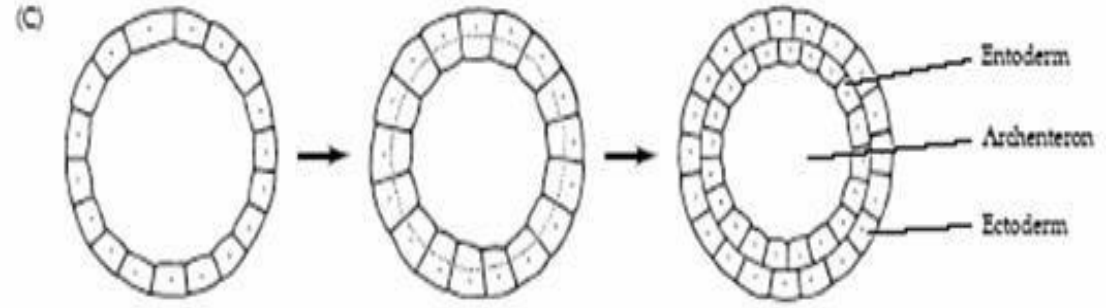
Invagination



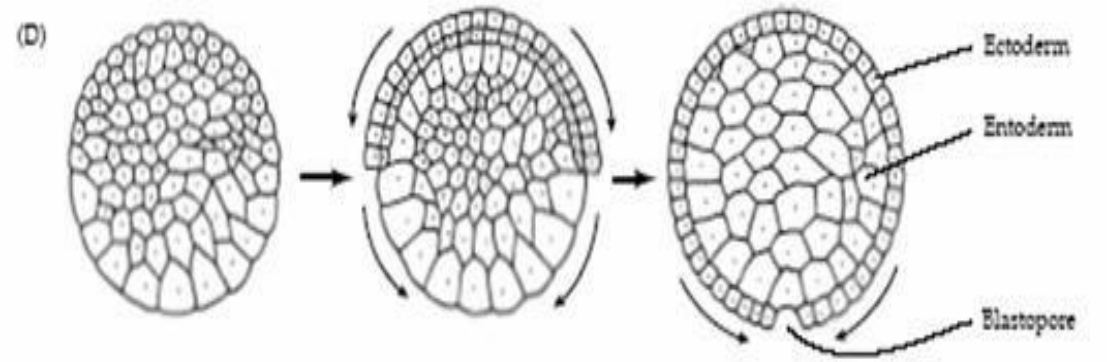
Delamination



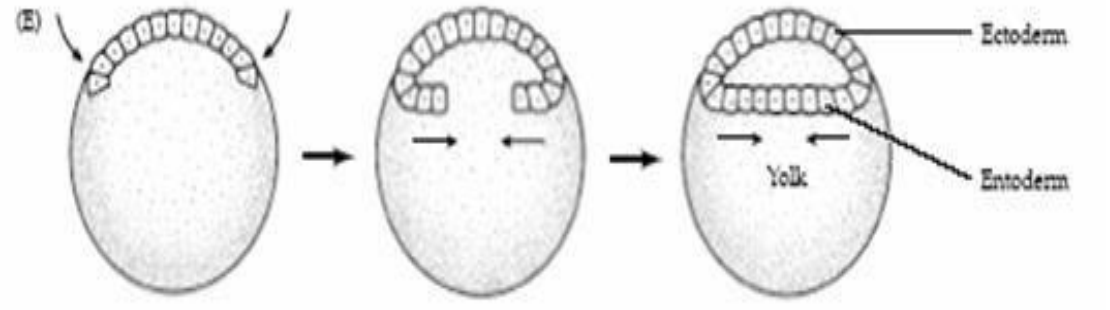
Ingression



Epiboly



Involution



Blastopore

Blastopore means a mouth-like opening of the archenteron on the surface of the embryo during the invagination of the archenteron. In many animals, the Blastopore becomes the anus.

The Blastopore is responsible for organizing and defining the germ layers. Through this layer, there is communication which takes place between the embryo and the outside environment in the womb. There is also a transfer of the necessary fluids until the gastrulation period lasts.

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

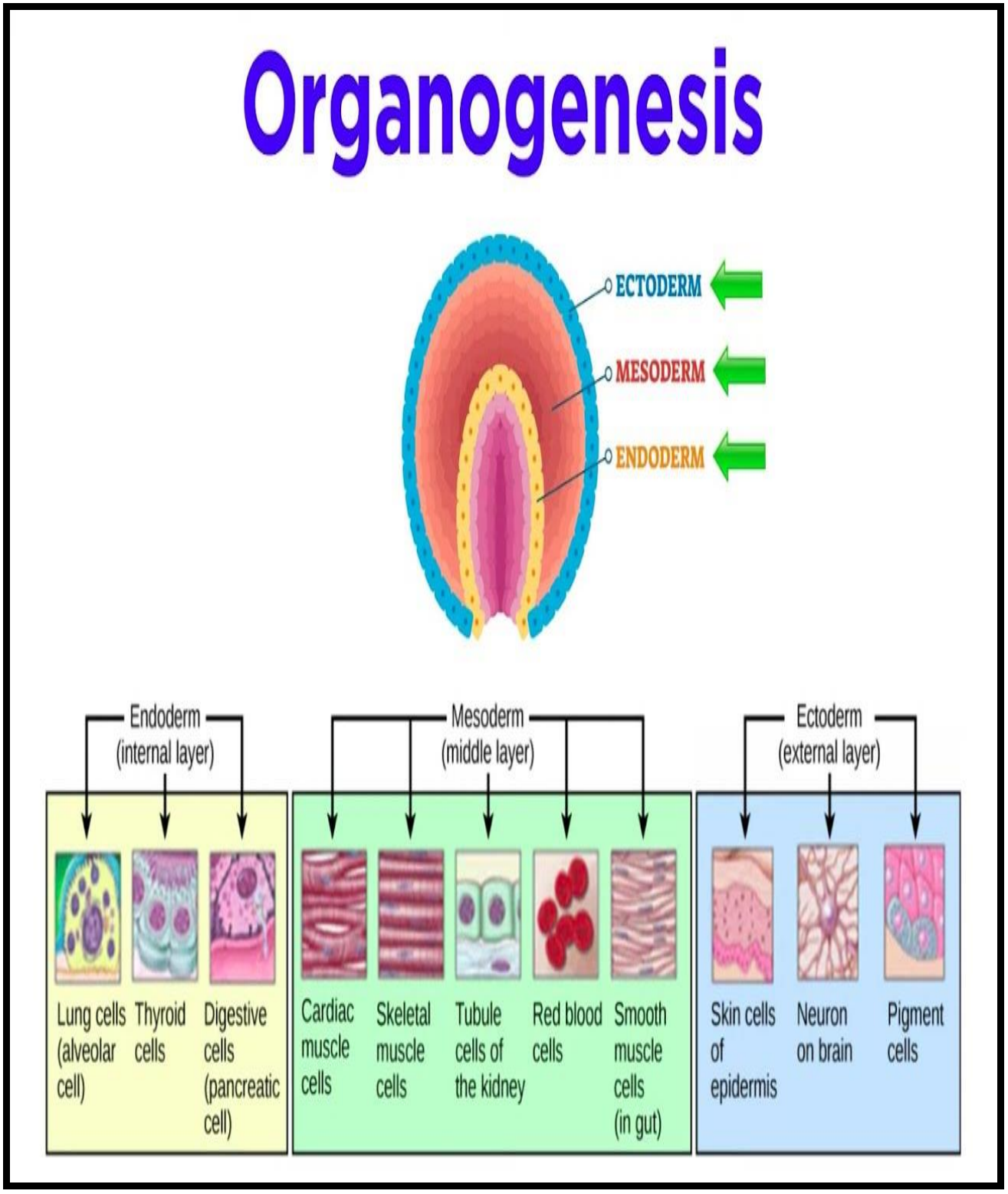
Organogenesis

- ✓ Organ formation it is basically cell differentiation. The embryois called “fetus”
- ✓ During the fifth phase of development, the *organogenesis* (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.

Germ layers

Embryonic Germ Layer	Vertebrate Adult Structures
Ectoderm (outer layer)	Epidermis of skin; epithelial lining of oral cavity and rectum; nervous system
Mesoderm (middle layer)	Skeleton; muscular system; dermis of skin; cardiovascular system; excretory system; reproductive system—including most epithelial linings; outer layers of respiratory and digestive systems
Endoderm (inner layer)	Epithelial lining of digestive tract and respiratory tract; associated glands of these systems; epithelial lining of urinary bladder

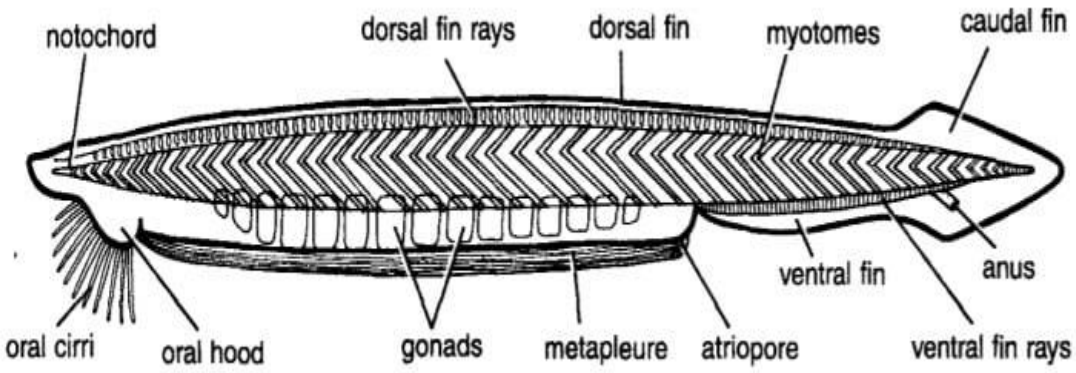
Differentiation of the Three Germ Layers



Early embryonic development of Amphioxus

Development of Branchiostoma (Amphioxus) is indirect involving a larval stage. Early embryology of Branchiostoma is simple. Therefore, the transformation of egg, which having less yolk, into a complex and differentiated animal is far easier to follow than in any other vertebrate.

The early development of Amphioxus is of great phylogenetic significance because it resembles with those of invertebrates like echinodermates on one hand and vertebrates on the other. Development of Amphioxus was described by many scientists such as Hatscheck (1882, 1888), Wilson (1883), Cerfontaine (1906), and Conklin (1932). The work of Conklin (1932) is the most recent and accepted one.



Egg:

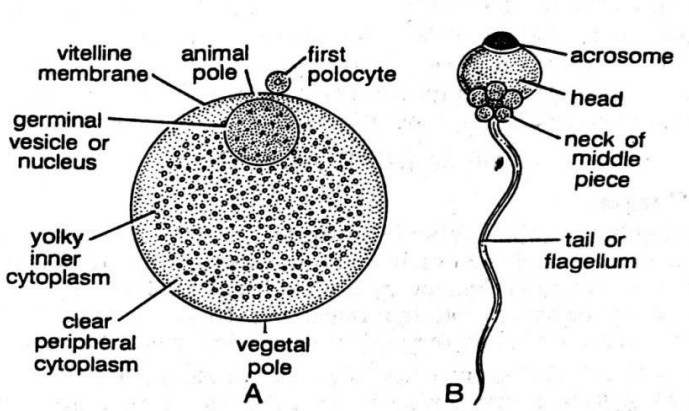
1 : The egg of Amphioxus is microlecithal and isolecithal type.

2 : The nucleus is almost centric because the yolk content is very less and does not affect the nucleus of the egg considerably.

3 : It can be differentiated into upper animal hemisphere and lower vegetal hemisphere containing animal pole and vegetable pole respectively.

Sperm:

1. The sperm of Amphioxus is extremely minute about 4μ in length and consist of a beak or acrosome, a head with a large compact nucleus, a neck or middle piece and a very long vibratile tail.



Amphioxus: A. Unfertilized egg. B. Sperm

FERTILIZATION:

Only one sperm can fuse with the egg. It is not yet known whether the entire sperm enters the egg or only the head enters. After the entry of sperm, the membrane becomes fibrous and is called fertilization membrane. A fluid filled space then appears between the fertilization membrane and the cell membrane. The fertilization membrane prevents the entry of more sperm. The chromosome of the egg and sperm come very close, develop a nuclear membrane around them and form a single nucleus- zygote nucleus. The egg is now called the zygote.

CLEAVAGE:

It is complete i.e., holoblastic which divides the egg completely into blastomeres.

1. First cleavage plane is maridional that is passing through the animal polel to vegetal pole axis forming two equal blastomeres.

2. Second plane of cleavage is also meridional but at right angle to the first one forming four equals sized blastomeres.

3. Third plane of cleavage is latitudinal which is slightly above the equatorial plane, The product is the 8-cell stage of which four upper are smaller cells called micro mere and four lower larger are called megameres

4. Fourth set of cleavage is meridionall forming 16 cell stage.

5. Fifth set of cleavage is latitudinal forming 32 cells in four tiers.

6. Sixth set of cleavage is meridiona forming 64 cell stage.

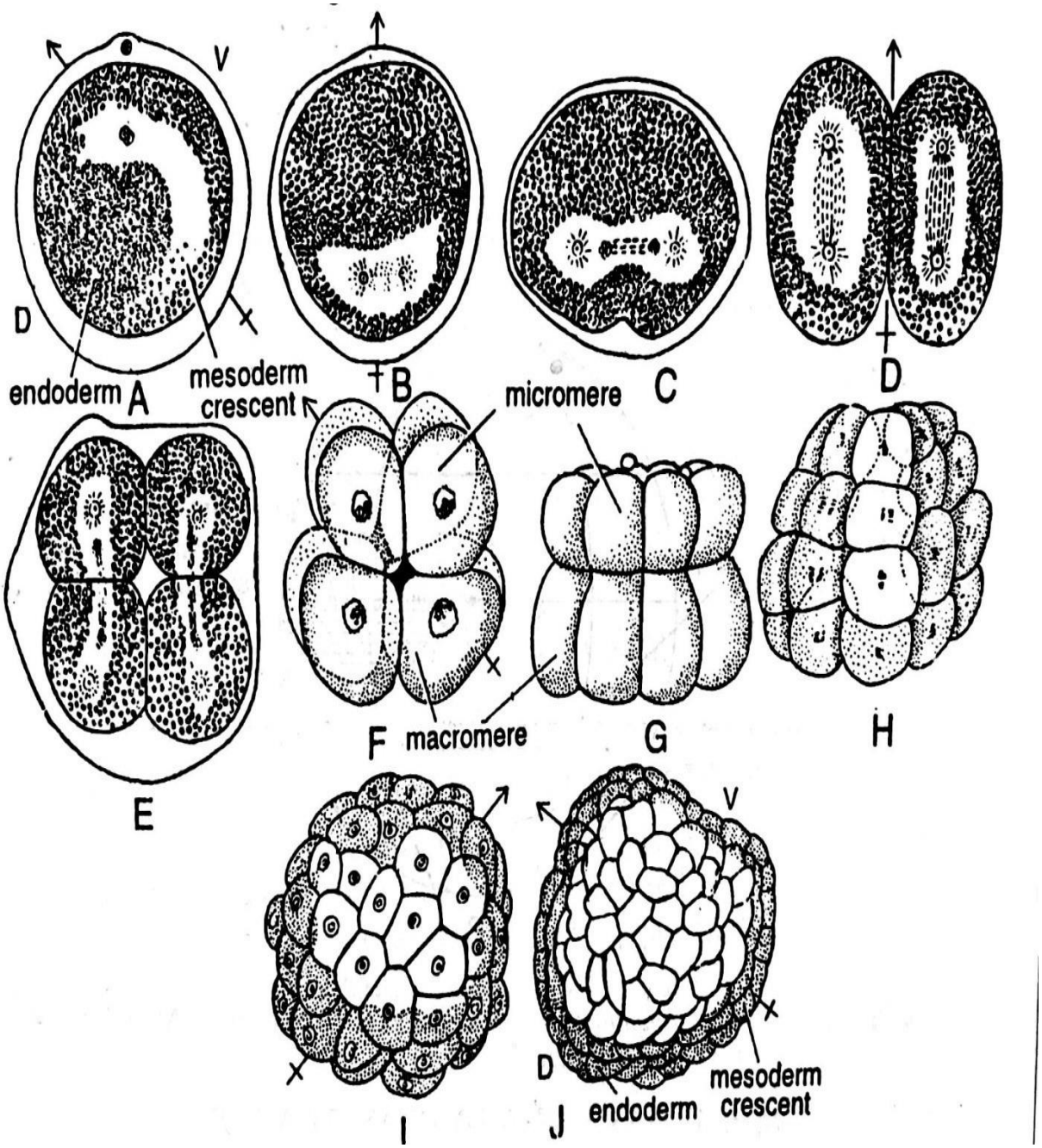
7. The cleavage till now is synchronous i.e., all cells at a particular cleavage divide at a time.

8. The cleavage plane on seventh cleavage onwards is asynchronous i.e., all cells at particular cleavage do not divide at a time.

9. As the division advances, the embryo is converted into a solid ball of cell called as morula.

10. Soon a small cavity appears in the interior of the embryo. it became fluid filled and expense gradually pushing the cells on

periphery and as a result a hollow ball of cells is formed having a spacious fluid filled cavity called blastocoel surrounded by a single layer of cells. This is called Blastula.



Cleavage and blastulation in Amphioxus- A-Fertilized egg, B.Mitosis of 1st cleavage .C- nuclear division. D-Two cell stage.E-Four cell stage.F-Eight cell stage. G-sixteen cell stage. H-Thirty cell stage. I-Morula stage J-Blastula stage

GASTRULATION:

Gastrulation is a process by which the monoblastic blastula is converted into a structure containing well-defined three germinal layer from which different organs can be formed. It can be dealt under following stages.

A. Invagination of the prospective endoderm and formation of the blastopore.

1. Invagination is a process in which the layer of cells itself goes into the interior of the developing embryo.
2. This process starts at vegetal pole.
3. Initially the investigating cavity is very small but gradually it depens into the blastocoel.
4. The new cavity is called as Archenteron. As the archenteron advances, the old cavity (blastocoel) starts Obliterating.
5. The archenteron communicates to outside by a pore called blastopore.
6. Initially the blastopore is a small pore but very is soon it becomes a well-developed structure and can be divided into three lips- one dorsal, two lateral and one ventral.

B. Involution of chord -mesoderm.

1. In the advance distance of invagination that that's the lip of the

blastopore is flanked by the prospect of notochord else while data when trailing by the prospective mesodermal cells.

2. Then auto chordal cells now move inside the process of involution to take the dorsal position in the developing embryo.

3. The mesodermal cells move inside by the process of involution through the ventral lip of the blaster pore and take the ventral position in the developing embryo.

Stretching of the embryo in the anterior posterior direction.

Now the embryo is stretched in the anterior posterior direction which causes the stretching of notochord in the axis of the body, and it occupies the roof of the archenteron from anterior to the posterior end. Mesodermal mass is also stretched so that it occupies the latero- dorsal position in the developing embryo.

Closing of the blastopore.

After the completion of the invagination and involution the blastopore starts diminishing and finally left a narrow crevice.

Structure of a fully formed gastrula:

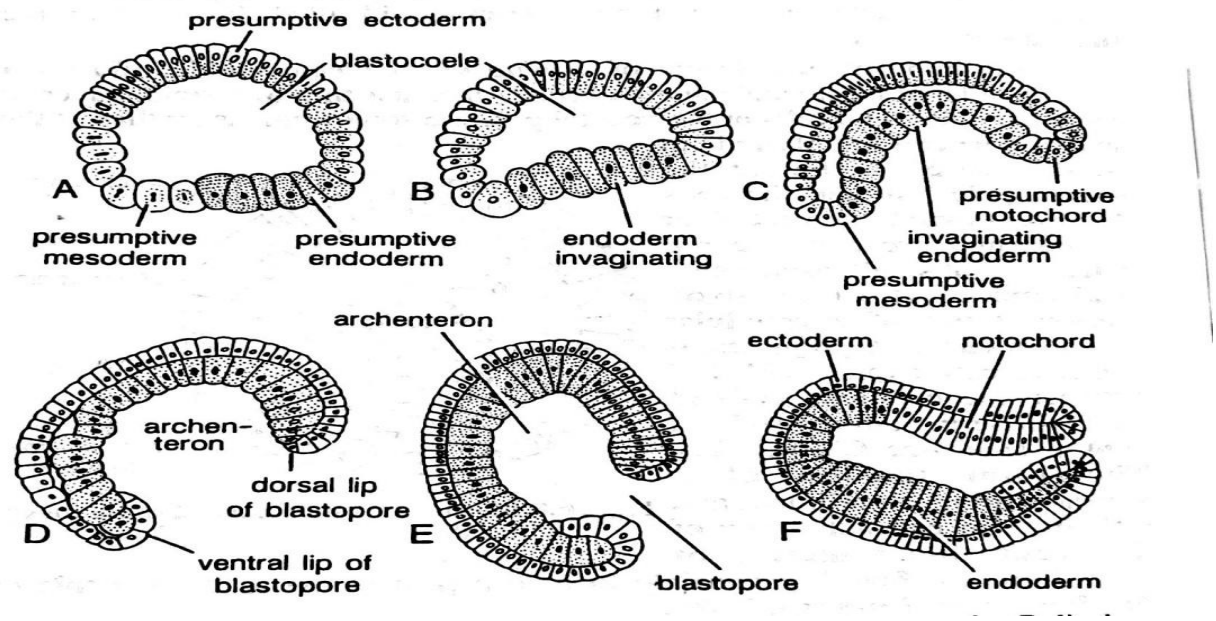
A fully formed gastrula of Amphioxus contain well-defined three terminal layers, the ectoderm, mesoderm and endoderm. The upper portion is covered by neural ectoderm and all sides by the epidermal ectoderm. A spacious cavity called archenteron is present in the interior of the embryo which contain various cell type at various portions:

a. Roof is formed of notochordal cells.

b. Sides contain mesodermal cells.

c. Rest is endodermal.

So, in this way we can say that a single layered blastula is converted into a double layered structure having distinguished three germ layers.



Gastrulation of Amphioxus: A series of consecutive stages.

TUBULATION:

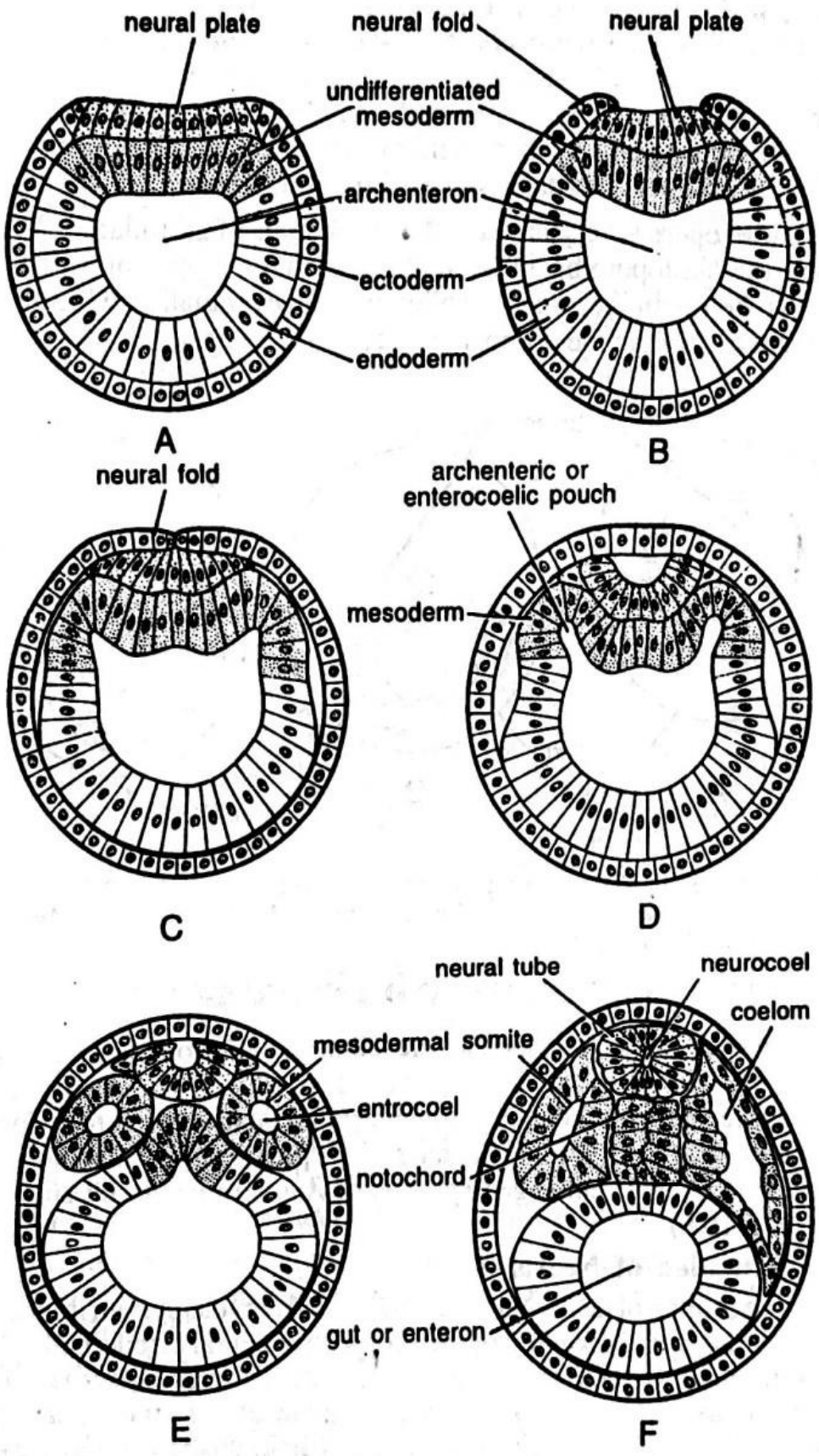
It is the formation of organ rudiments from three germinal layers, so that organ can develop from them.

a. Neurulation- formation of neural tube

b. Notogenesis- formation of notochord.

c. Mesogenesis- formation of mesoderm.

d. Development of endoderm and formation of alimentary canal.



Neurulation in Amphioxus: Transverse section of Amphioxus embryo to show the formation of neural tube, notochord, coelom and gut.

1. The upper surface of the embryo which is the 1 to 10 starts thickening due to the change in cell shape called as neural plate.

2. The neural plate invaginates to form a neural groove flanked by neural folds.

3. Soon the groove is closed into a tube from anterior to posterior end of the embryo.

4. Anteriorly the neural tube opens outside by a neuropore.

5. Posteriorly also there is a canal covered by upcoming epidermal ectoderm called the neuro centric canal.

Later the anterior portion of the tube makes brain, and the posterior makes the spinal cord.

NOTOGENESIS

The roof of the Archenteron is invaginated to form a closed structure called notochordal cord. Later on it develops into a notochord just below the neural tube and above the alimentary canal.

MESOGENESIS

The lateral portions on both sides are evaginated to form a cord of cells from anterior to posterior end containing a space derived from the archenteron called as Coelom.

Letter on the cord is cut off and different segments to form somites.

Development of endoderm and alimentary canal:

After the cutting of cellular masses of notochord and mesoderm the remaining portion of inner layer of embryo flanks the cavity and called as endoderm, while the cavity later on develops into alimentary canal.

The study of the development of Branchiostoma (Amphioxus) is significant from the following point of view:

1. The study of embryology (development) provides an insight into the evolutionary history of chordates.

2. The position and the way of the formation of blastopore in developing embryos divide bilaterally symmetrical animal into two groups, viz., Protostomia (where blastopore marks the area of mouth) and Deuterostomia (where blastopore marks the anus). The Branchiostoma falls in the later together with other chordates and echinodermates.

3. The way of formation of coelom in Branchiostoma (Amphioxus) brings it closer to echinodermates.

Based on the fate of blastopore, manner of mesoderm formation, muscle chemistry and similarity in sera proteins, it is believed that coelenterates onwards two stocks of invertebrates evolved. Branchiostoma (Amphioxus) is supposed to be a representative of primitive chordate and links chordates with invertebrates and shows the evolutionary steps followed by vertebrates.

Summary

✓Phylum: Chordata – Class: Cephalochordata

✓ Sexes are separate

✓ The gonads which are in the form of hollow sacs enclosed in coelomic pouches- twenty-six in number on each side

- genital ducts are lacking

✓ On maturity of gonads the sperms and ova are liberated into the atrium and from where they are discharged outside through the atriopore in breeding season

✓ The spermatozoa contain spherical head, very short mid-piece and tail

✓ The ovum of is 0.10 mm to 0.12 mm in diameter

✓ Type of Egg: According to amount of yolk oligolecithal or microlecithal

According to distribution of yolk isolecithal

✓ Fertilization: External

✓ **Type of cleavage:** holoblastic cleavage

The first is holoblastic and meridional passes through the egg axis from pole to pole. Result in two identical blastomeres.

The second in a vertical plane, at right angles to the first plane, forming four cells.

The third is horizontal (latitudinal) nearer the animal pole. Each of the four blastomeres dividing into a smaller micromere at the animal pole and a larger macromere at the vegetal pole. Eight blastomeres are produced.

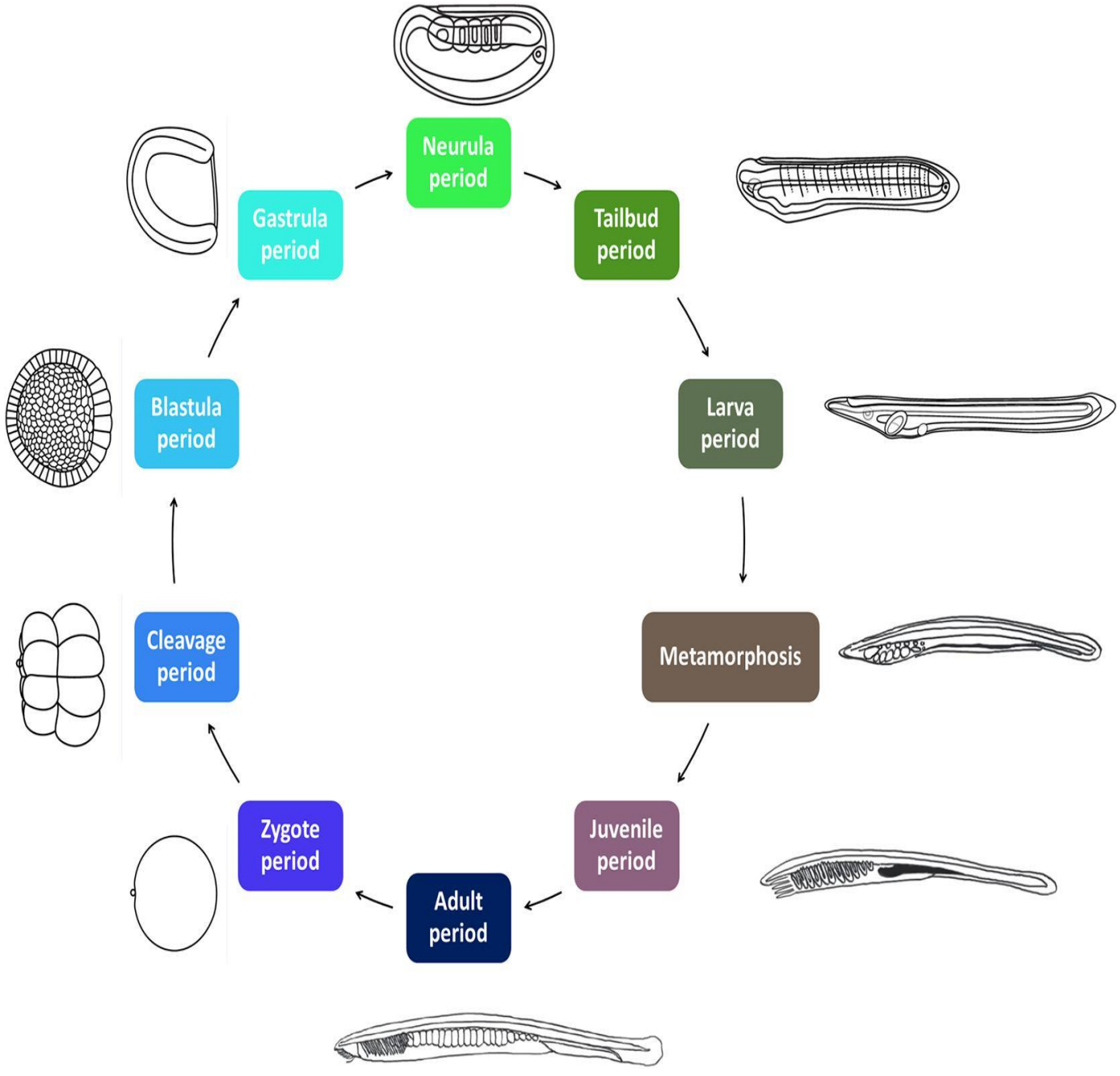
The Fourth cleavage is double plane each one oriented from animal to vegetal pole. Results in eight animal micromeres and eight vegetal macromeres.

The Fifth is latitudinal and double parallel to plane three – one occurring in the animal, the other in the vegetal hemisphere. They result in 32-cells, arranged in four tiers.

The sixth cleavage are approximately meridional, producing 64-blastomeres

The cleavages pattern beyond this is irregular and difficult to follow.

The blastomeres remain loosely packed and form the embryonic stage, called morula.



Early embryonic development of Frog

Xenopus laevis

There are three groups of present-day amphibians:

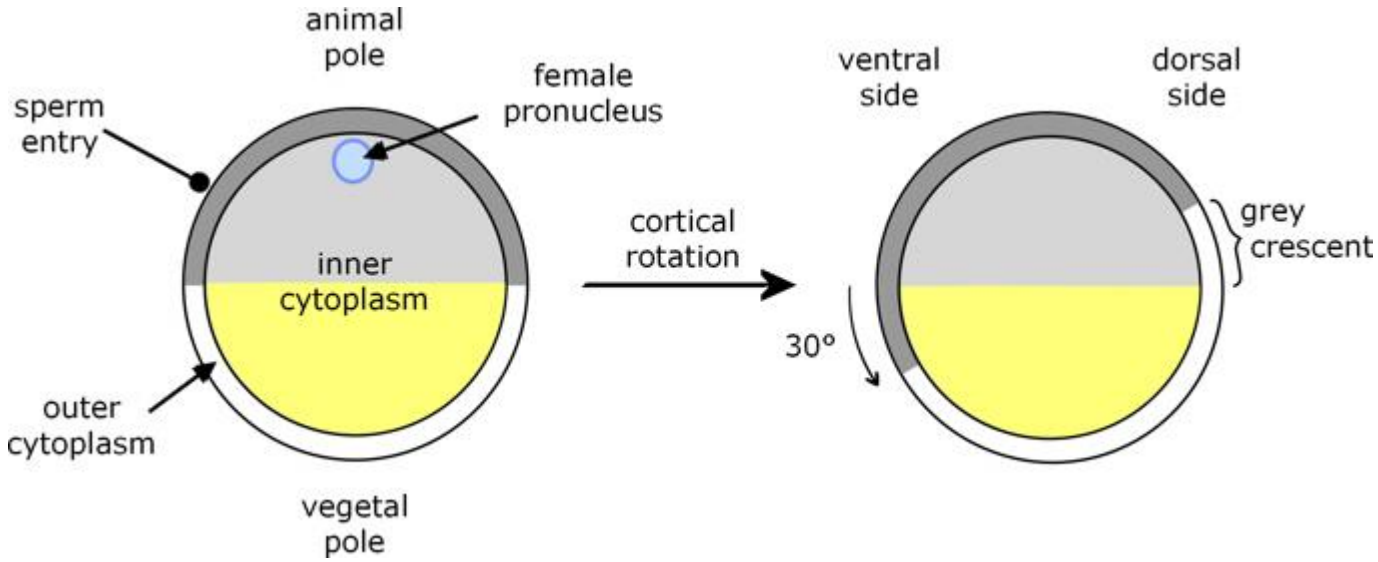
- urodeles (having a tail) e.g., salamanders;
- anurans (without a tail) e.g., frogs and toads; and
- caecilians (without limbs) so resemble worms or snakes.

Most embryological studies have been on frogs because their development can be observed easily, especially the African clawed frog (Xenopus laevis) because it is easy to stimulate egg laying, and the following description is based mainly on this species.

Egg and fertilisation

Amphibian eggs are generally large, with a substantial quantity of yolk. In Xenopus the cytoplasm is in two distinct parts, inner and outer (or cortical). The inner cytoplasm of the animal hemisphere is darker than that of the vegetal hemisphere; and, corresponding with this, the animal cortical cytoplasm is pigmented, whereas the vegetal cortical cytoplasm is not. In the haploid egg

meiosis is halted at metaphase II, and on fertilisation meiosis completes to yield the diploid zygote.



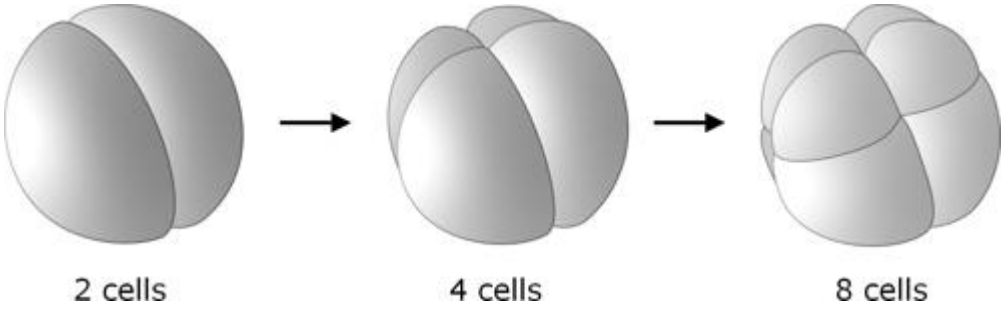
Xenopus fertilisation

Sperm entry and completion of meiosis prompts the cortical cytoplasm to rotate by about 30° relative to the deep cytoplasm, such that part of the underlying animal hemisphere becomes visible as a 'grey crescent'. Due to this rotation, sperm entry (which always occurs in the animal hemisphere) specifies the dorsal-ventral (back-front) axis of the embryo, because gastrulation begins opposite sperm entry, on the same side as the grey crescent.

Cleavage and Blastula

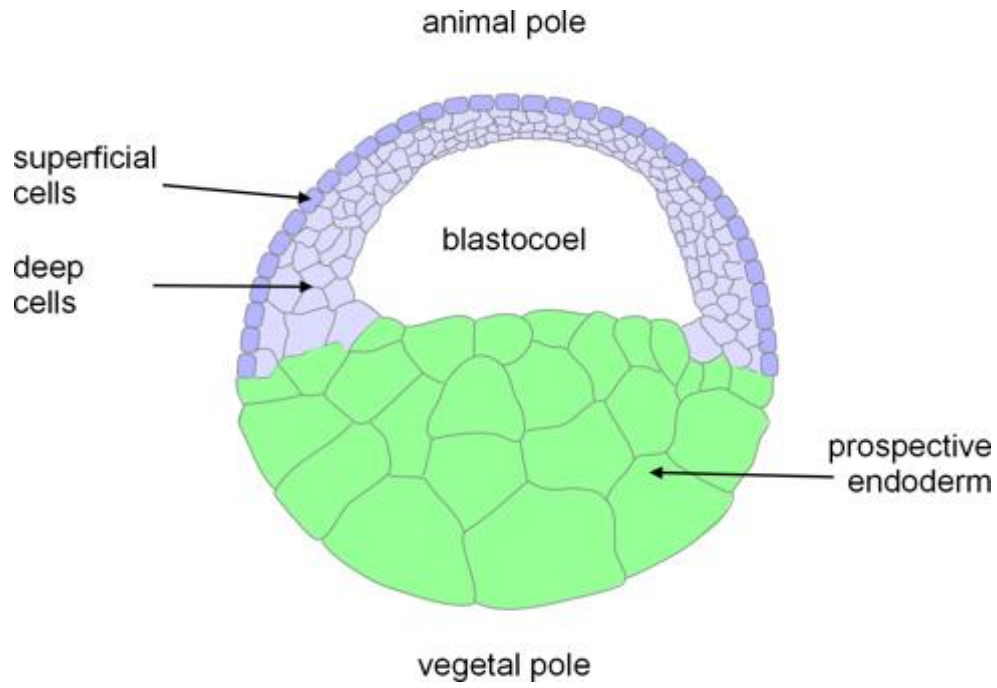
Cleavage is holoblastic: the first divisions extend right through the zygote. The first cell division goes through the poles of the zygote (meridional), as does the second but at right angles to the first, to produce four approximately symmetrical cells. The third division is at right angles to the first two (latitudinal), and approximately equatorial except that it is somewhat towards the animal pole. This occurs because, although cleavage is holoblastic, division is slower through the yolky vegetal hemisphere; and this pattern continues with subsequent

divisions being more frequent in the animal hemisphere, which leads to cells there being smaller than in the vegetal hemisphere.



Xenopus cleavage: the first 3 cell divisions.

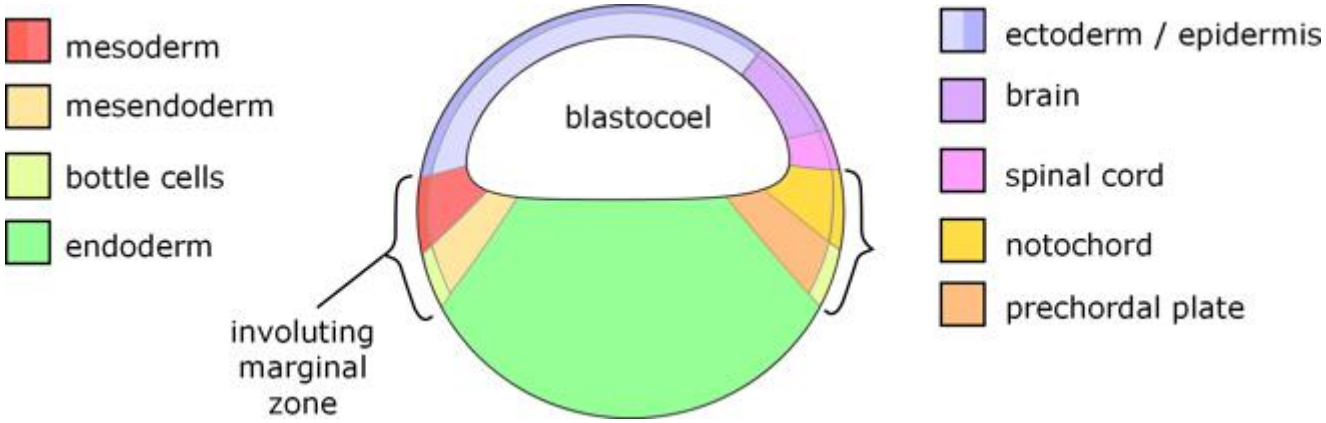
A blastocoel begins to develop from the first cell division and is evident from the 8-cell stage. Eventually it occupies a large part of the animal half of the blastula. Its dome-like roof is formed by numerous small, pigmented micromeres, whilst the vegetal half is composed of large yolk-laden, pale macromeres. Also, the cells of the animal hemisphere and upper part of the vegetal hemisphere form an outer epithelial layer and an inner or deep layer whose cells are more mesenchymal in nature.



Section through *Xenopus* blastula.

Gastrulation

Before describing the cell movements that occur during gastrulation it's probably helpful to summarise the fates of different parts of the blastula.



Section through *Xenopus* blastula section, showing prospective fates following gastrulation.

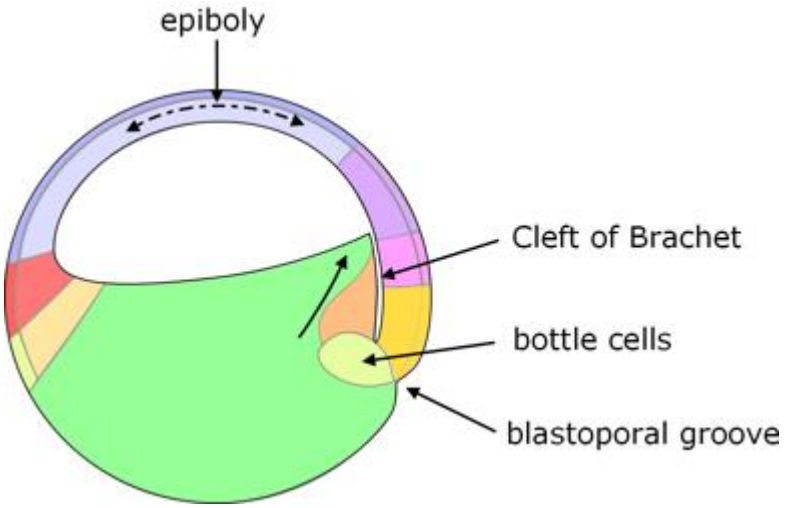
The cells of the animal hemisphere spread (epiboly) to cover the whole of the embryo, to form the ectoderm. Cells along the dorsal centerline form the neural plate, which produces the neural tube and then reforms the epidermis above the neural tube.

- A band of cells (the involuting marginal zone, IMZ) around the equator of the blastula moves inwards and then upwards. Mainly, these form mesoderm, the most dorsal part of which is the notochord.
- Most of the cells of the vegetal hemisphere are enveloped by the expanding ectoderm, are incorporated within the body of the embryo, and develop into endoderm.

The first external sign of gastrulation is when cells just below the equator, called bottle cells, on the dorsal side invaginate to form a crescent-shaped groove, which is the beginning of the blastopore.

However, before this, some deep cells (presumptive prechordal plate) of the dorsal side of the vegetal hemisphere begin to move toward the animal pole. They move close to the inside of the animal dome but separated from it by a small gap known as the Cleft of Brachet.

Bottle cells. Bottle cells occur on the outer surface of the embryo where invagination occurs. Their outer surface constricts, and this constriction creates a local depression which develops into the invagination through which cells involute. They are called 'bottle cells' because the constriction makes them somewhat bottle shaped.

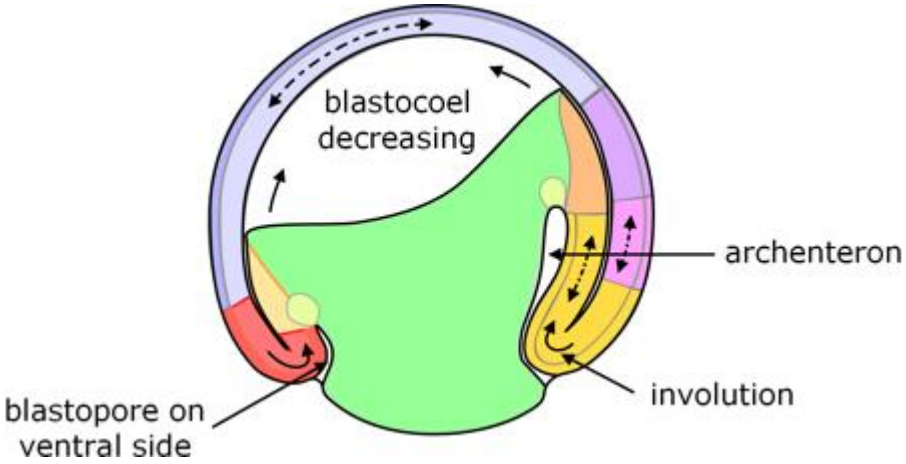


Start of gastrulation

At the same time, the animal hemisphere begins epiboly (partly by flattening of its cells, and partly by intercalation of cells from different layers) and, as it does so, its cells along the upper edge (dorsal lip) of the blastopore start to roll over the lip (involute) into the blastopore. These cells, which are predominantly presumptive notochord, move towards the animal pole, close to the overlying outer layer of cells, behind the presumptive prechordal plate.

The dorsal part of the blastopore deepens to form a pouch known as the archenteron which gets progressively larger, gradually displacing the blastocoel which in due course almost disappears.

The blastoporal groove progressively extends laterally on both sides until the two ends of the groove meet on the ventral side of the blastula, and the resulting blastoporal groove completely encircles the vegetal pole of the blastula. At the ventral side of the blastopore, cells of the expanding animal hemisphere involute and move towards the animal pole. What were part of the outer layer of cells becomes endoderm, and the deep cells become predominantly mesoderm.



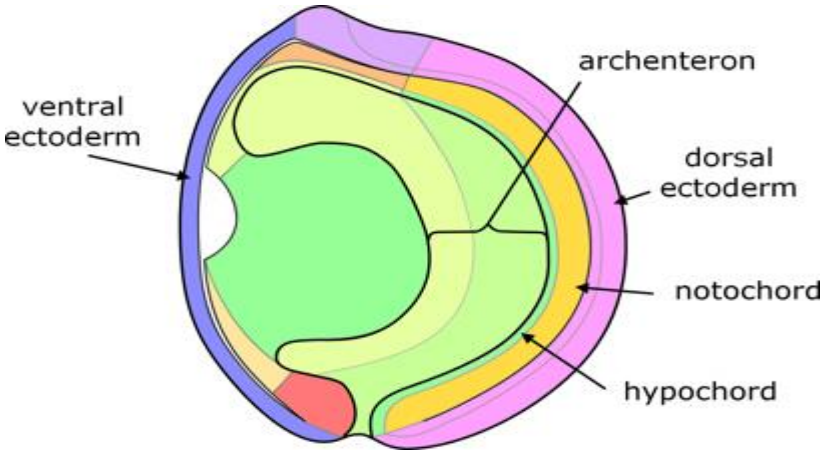
Mid-gastrulation: the archenteron has formed, the blastopore encircles the vegetal pole, and involution is taking place all around the lip of the blastopore.

It will be apparent from the foregoing that involution begins at the dorsal side before the ventral side. Consistent with this, the involuted cells on the dorsal side move further than those on the ventral side, and there is an overall rotation of the inner cells with respect to the outer cell layers.

Endoderm and gut

As epiboly of the animal hemisphere continues, the blastopore becomes smaller, and the cells of the vegetal hemisphere are progressively incorporated into the

gastrula where they develop into endoderm. There is a consequent constriction of the blastopore, and reduction of the exposed cells of the vegetal hemisphere until only a small blastopore remains, called the yolk plug. Eventually, the archenteron becomes the digestive tract, with the blastopore as the anus.



End of gastrulation.

Mesoderm

Notochord

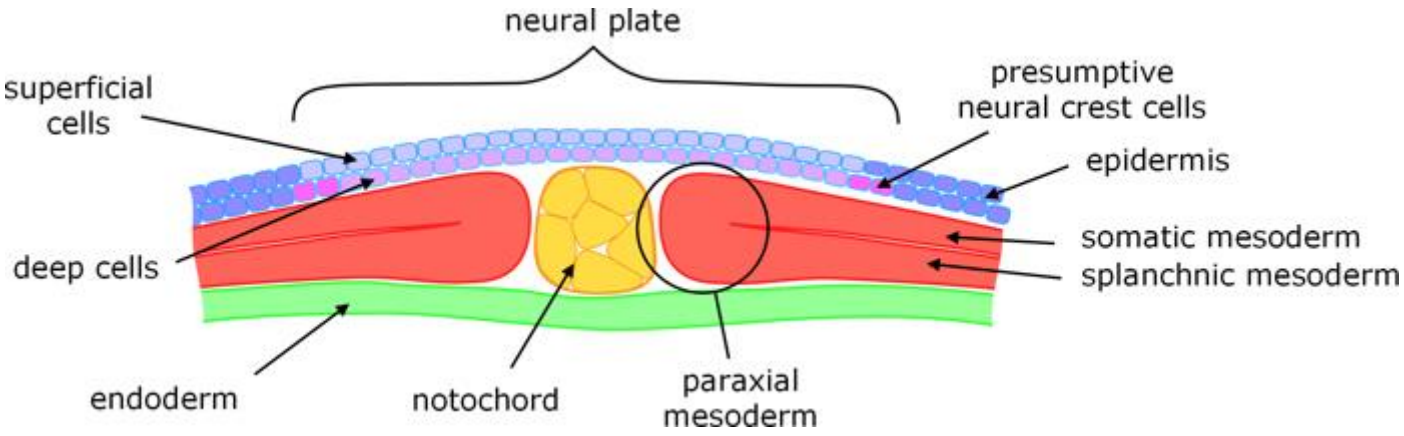
Most of the involuting cells (IMZ) become mesoderm, extending around the embryo between the ectoderm and endoderm. Those along the dorsal midline become notochord.

Coelum

The remaining ‘paraxial’ mesoderm on each side of the notochord forms into a double layer:

An outer ‘somatic mesoderm’ which lies within the ectoderm (and subsequently contributes to connective tissue), and an inner ‘splanchnic mesoderm’ which overlies the endoderm (and subsequently forms the circulatory system).

The space between them extends all around the embryo to form the body cavity or coelum.

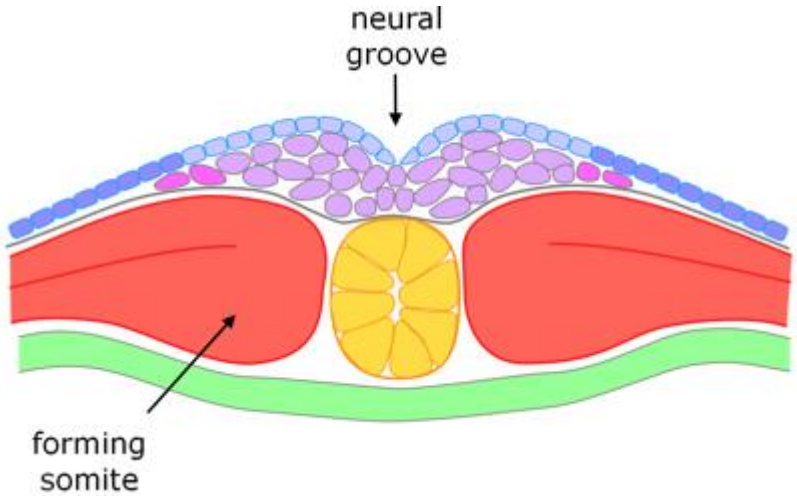


Transverse section through the dorsal side after gastrulation.

Somites

This is significantly different from the way somites usually form, which is by segmentation of both layers of mesoderm.

Close to the notochord the two layers of mesoderm are called dermatome and myotome, which are joined immediately alongside the notochord (the split that forms the coelum does not extend right up to the notochord). The (inner) myotome segments into somites, which arise in pairs either side of the notochord, developing in a regular sequence, in the anterior to posterior direction. The somites arise from the myotome; and in the course of segmentation, the cells of the myotome rotate through 90° which separates them from the dermatome which remains as a sheet between the newly formed somites and overlying ectoderm.



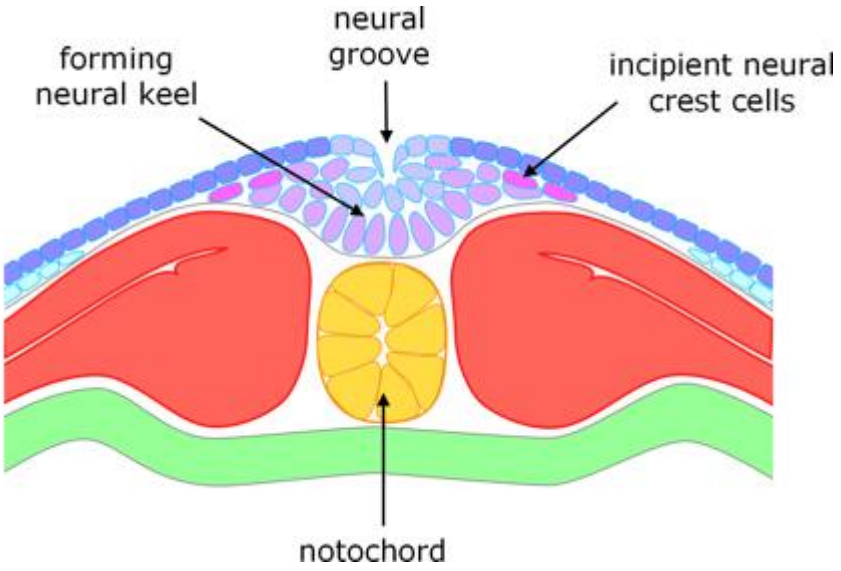
Transverse section through the dorsal side at the beginning of somitogenesis and neurulation.

Neural tube

The neural tube forms during the time when the somites are developing.

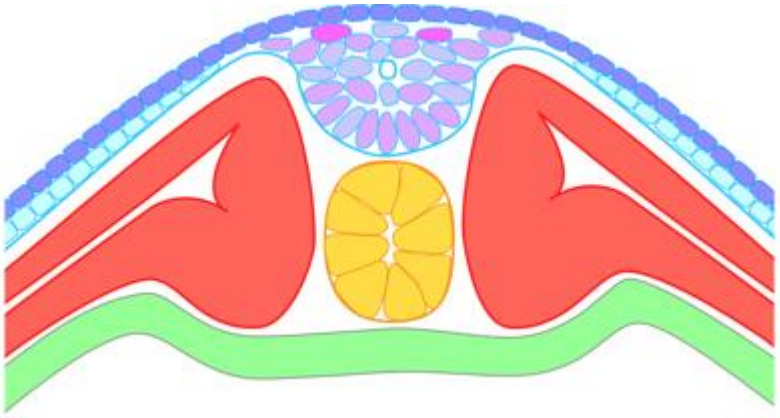
On completion of gastrulation, the dorsal surface (ectoderm) comprises a double layer of cells – deep and superficial. This includes the neural plate, although at first there is no clear morphological boundary between the neural plate (which will be internalised as the neural tube) and the presumptive epidermis (which remains on the exterior).

The neural plate narrows and lengthens (through what is called convergent extension) such that both layers of cells converge towards the midline – cells of the upper layer intercalating with the lower cells – to produce a bulge of cells between the notochord and neural groove.



Transverse section through the dorsal side shortly before the sides of the neural groove fuse.

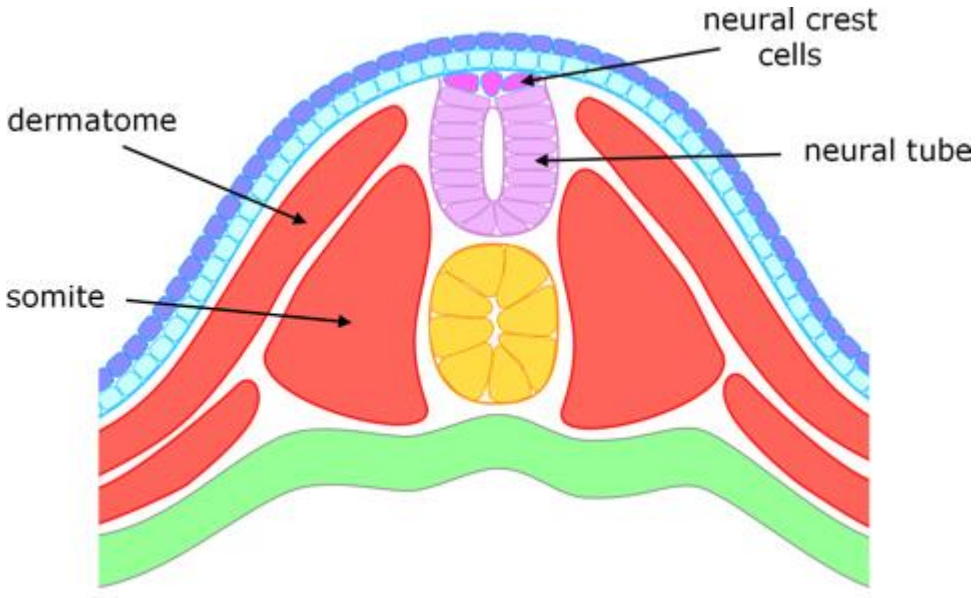
The sides of the groove fuse, almost simultaneously along the full length of the neural groove, usually enclosing a small lumen, although its surrounding cells are mesenchymal rather than epithelial.



Transverse section through the dorsal side after the neural groove has fused to form the neural keel, and the somites have almost developed from myotome.

Immediately after this fusion, the cells between the notochord and overlying ectoderm appear disorganised. However, they gradually rearrange /organise into a clearly defined neural tube, involving intercalation and a change from mesenchymal to epithelial cells, this process starting at the ventral (lower) side of the tube, and progressing to the dorsal (upper) side.

As the neural tube forms, a deep layer of dorsal epidermis reforms over the neural tube (and below the superficial epidermis).



Transverse section through the dorsal side after the neural tube and somites have formed.

Neural crest cells

The presumptive neural crest cells arise in the lower layer of cells near the lateral boundary of the neural plate. At the time of fusion of the two sides of the neural groove, the forming neural crest cells are not near the point of fusion but in the deep layer, somewhat distant from the midline. That is, although there are neural folds, neural crest cells do not originate from the fusion points (which might be thought of as crests) of these folds, either in terms of depth or distance from the midline. These cells migrate (through the tissue, not by gross movement of cells) toward the midline as the neural tube forms and become associated with the dorsal side of the neural tube, before migrating elsewhere.

Metamorphosis:

Metamorphosis (Gk., metamorphoun = to transform) is the abrupt transition from larval to adult form. It includes morphological, anatomical, physiological

and behavioural, hormonally regulated changes in the larval form to transform it into the adult form.

In frog, metamorphosis is of progressive type. In frog, it is associated with a transition from an aquatic to a terrestrial mode of life and from an herbivorous to carnivorous mode of feeding. The metamorphosis involves numerous structural, biochemical and physiological changes.

These changes include the degeneration of existing structure, construction of new structures and modification of larval structures. Metamorphosis is controlled by hormones such as thyroxine of thyroid gland.

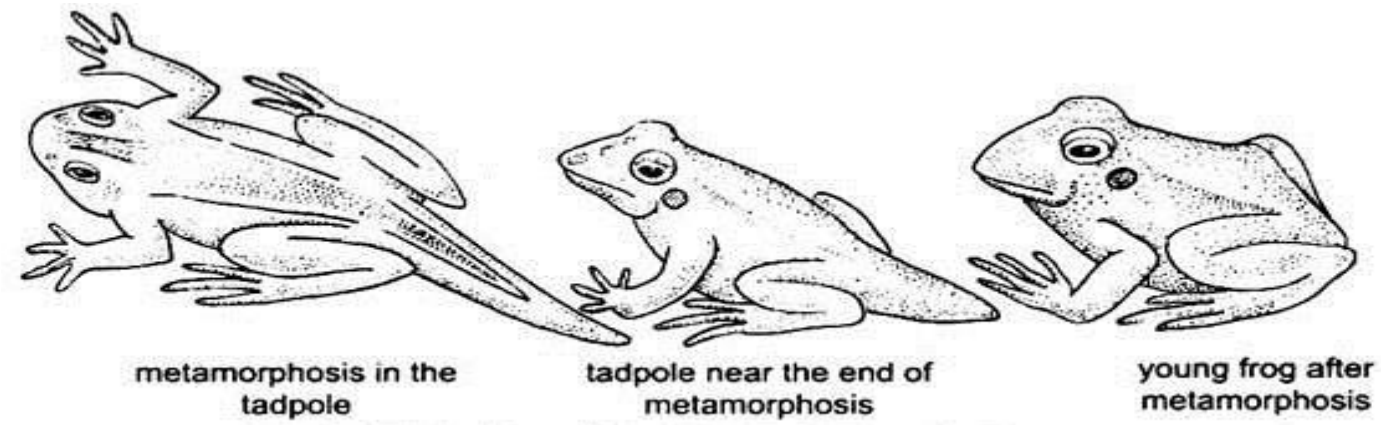


Fig. 37.13. Frog. Stages in metamorphosis.

The study of embryology of frog is practically useful to us in a variety of ways:

1. It helps in interpretation of avian and mammalian development.

2. It explains the evolutionary transition of lower chordates into higher chordates.

3. It explains the evolution of lung-breathing animals from gill-breathing animals.

4. It also explains the evolution of various physiological requirements present in air-breathing and land-living animals.

Summary

✓Phylum: Chordata – Class: Amphibia

✓Fertilization: External.

✓Type of Egg: According to amount of yolk mesolecithal. According to distribution of yolk telolecithal.

Spawning:

The mesolecithal eggs of frog enclosed in a protective gelatinous albumen are laid in water. The cluster or masses of eggs which remain stick together is called spawn. A spawn of *Rana tigrina* may have 3000 to 4000 ova. The spawn is laid during pseudocopulation or amplexus.

✓Type of cleavage: Unequal holoblastic cleavage.

✓Adult toads live on land most of the time and rely on water for hydration, breeding, and temperature regulation, Mating.

✓Cleavage and blastulation the period of cleavage and blastula formation completed within 24 hours.

✓The cleavage furrow elongates at a rate of about 1mm/minute in the animal hemisphere but slows to 0.03mm/minute in the vegetal pole.

The first is meridional. It cuts the egg through its median animals-vegetal polar axis and result in two equals sized blastomeres.

The second at the right angles to the first plane.

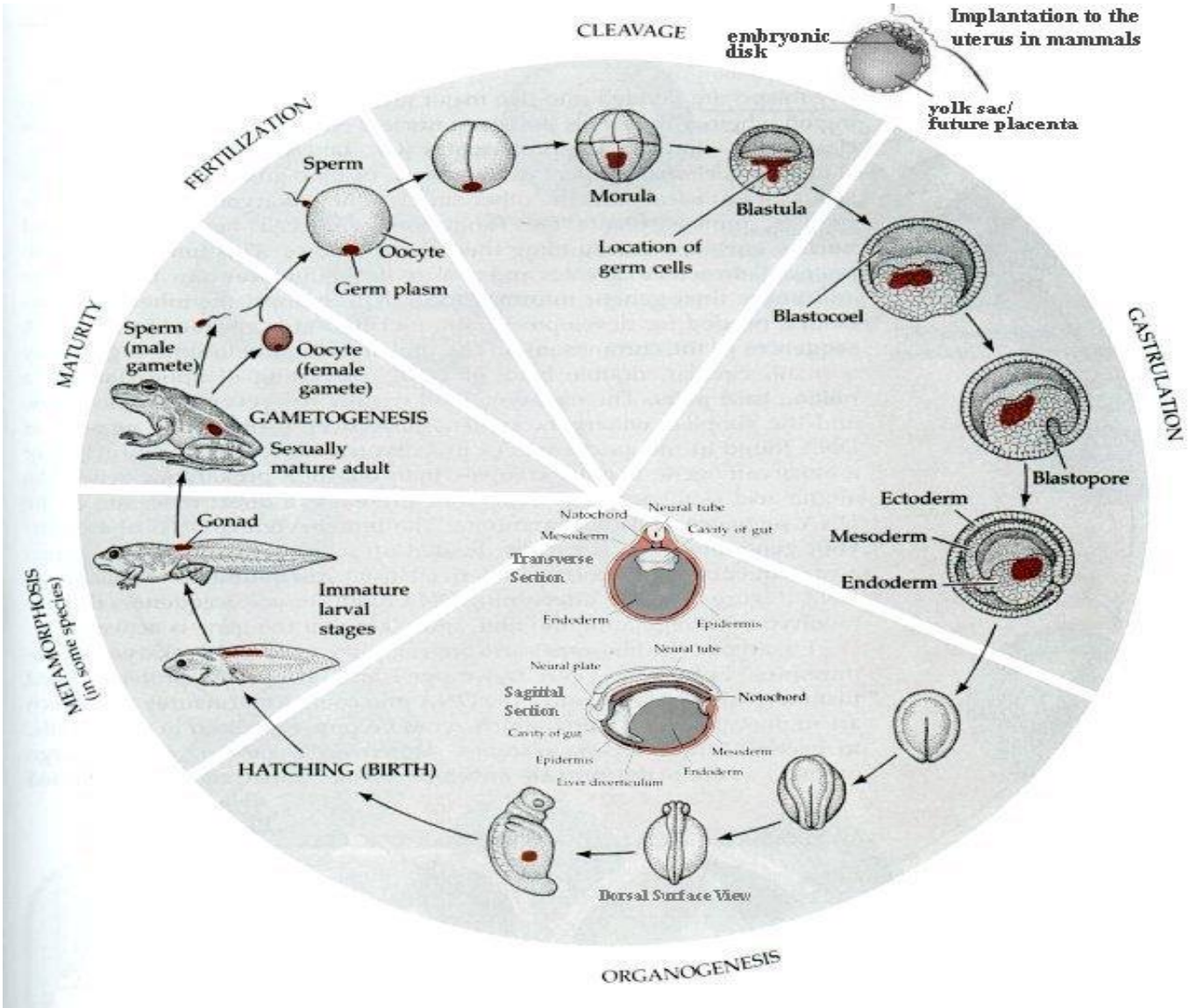
The third orient parallel to the polar axis and displaced near the animal pole. The eight blastomeres stage consists of four large-sized, yolk rich, vegetal cells (macromeres) and four small-sized, yolk poor, animal cells (micromeres).

The fourth cleavage is double plane each one oriented from animal to vegetal

pole result in 16-cell stage.

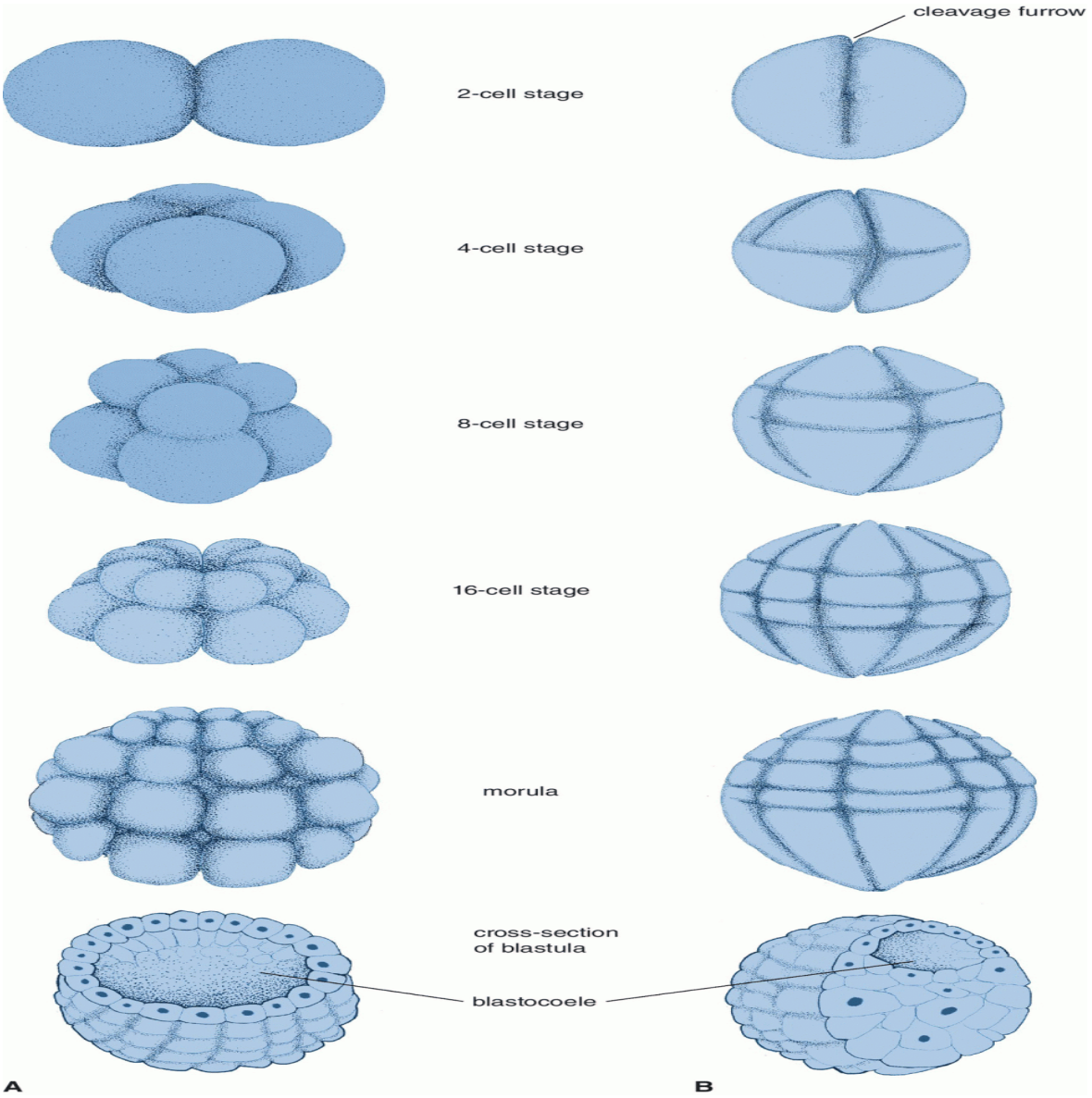
In amphibians, an embryo between the 16-and 64-cell stages is commonly called a morula. A cavity (blastocoel) appears in the animals hemisphere above the mass of yolk. The blastula is a hollow spherical embryonic stage. The blastoderm remains two-cell thick towards the animal pole of the egg, the sides and floor of the blastocoel are multilayered blastoderm of large yolky blastomeres. -The blastoderm encloses eccentric (peripheral) blastocoel.

-The blastocoel becomes infiltered by water and albuminous fluid secreted by the surrounding blastomeres.



Quick comparative review between Amphioxus and Frog early development

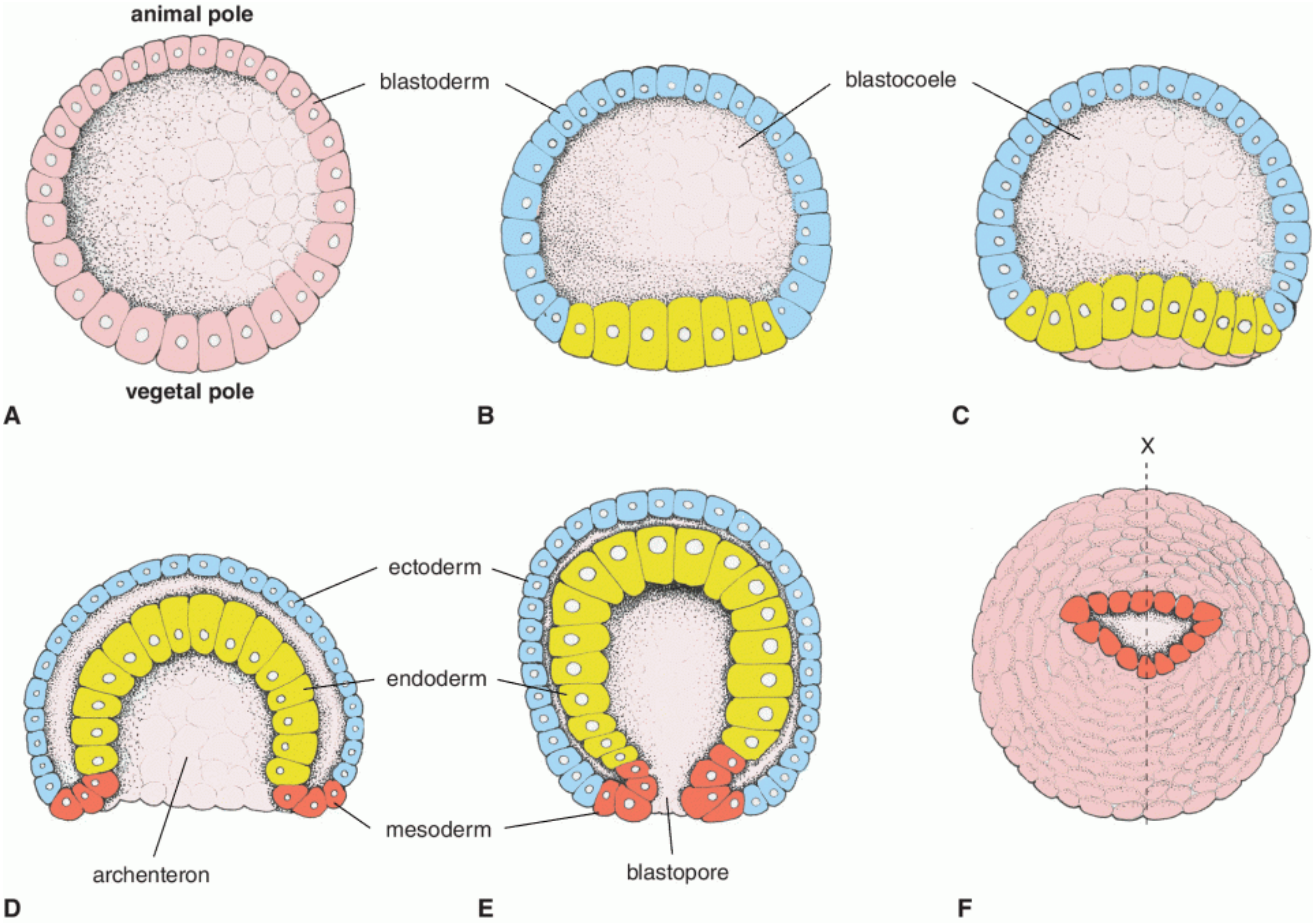
1- Stages of cleavage from the 2-cell stage to the early blastula stage in Amphioxus, A, and amphibians, B.



2- Sections showing sequential stages of gastrulation in Amphioxus from the blastula stage A to the gastrula stage E. The section shown in E is at the level indicated in the embryo at the gastrula stage in F.

The pattern of gastrulation in Amphioxus represents a comparatively simple model for illustrating the major cellular events in germ layer formation observed in more evolutionarily advanced species. Gastrulation in Amphioxus begins when the blastoderm at the vegetal pole flattens and invaginates. The embryo

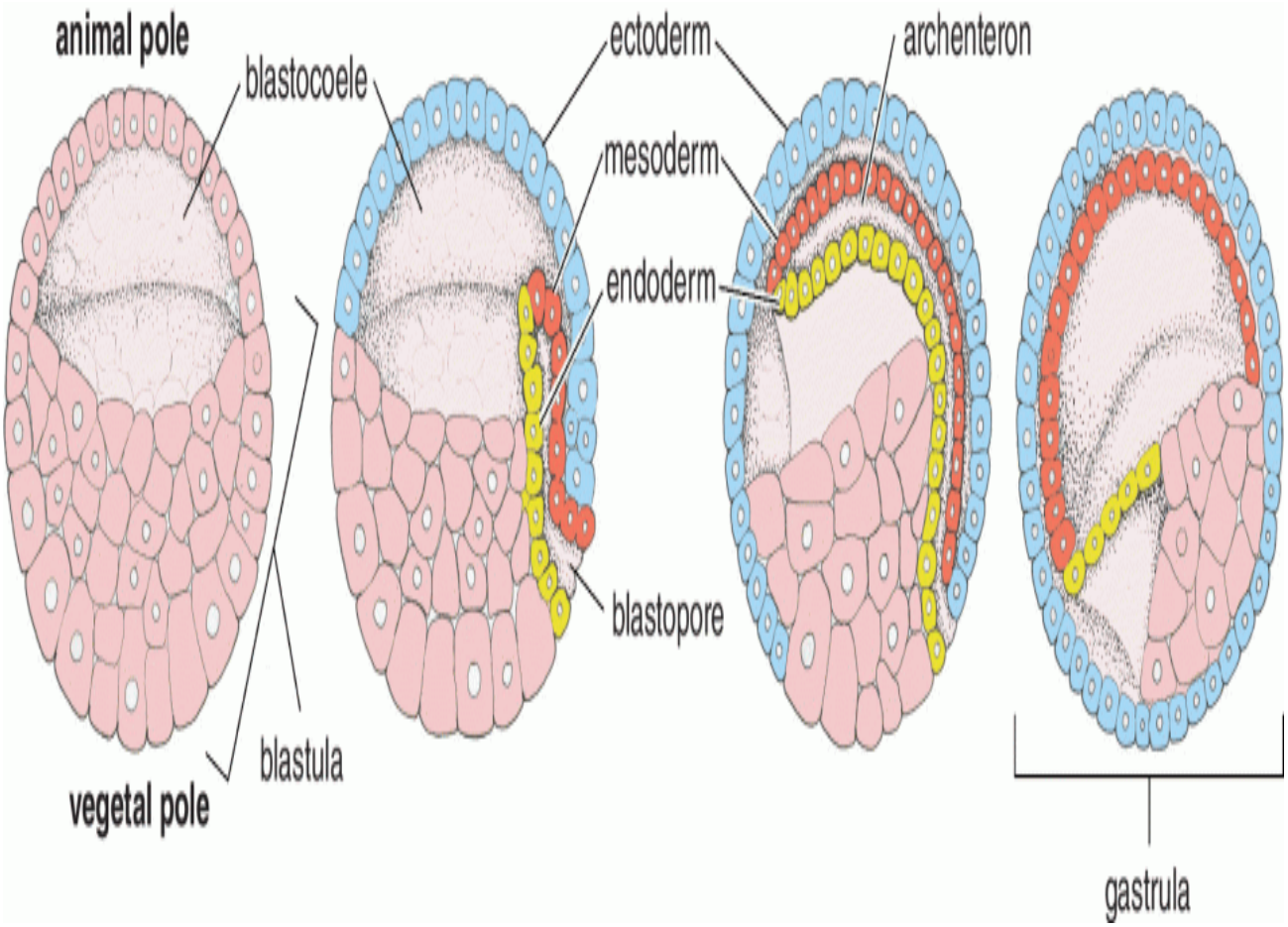
then undergoes a series of morphological changes. As cells at the vegetal pole invaginate, the spherical shape of the embryo changes with the sequential formation of a cavity referred to as the archenteron or primitive gut. The opening of the archenteron to the exterior is known as the blastopore. The outer layer of cells forms the ectoderm, and the inner layer the endoderm. Cells responsible for the formation of the notochord and other mesodermal structures originally occupy a position at the edge of the blastopore. Later, these cells migrate to a position between the ectoderm and endoderm. Thus, the endodermal and mesodermal structures relocate from the surface of the embryo to its interior, forming a trilaminar embryo referred to as a gastrula.



3- Sequential stages of gastrulation in amphibians from the blastula stage to the gastrula stage.

Because of the presence of yolk filled cells in the vegetal hemisphere of the

amphibian blastula, invagination, as observed in Amphioxus, cannot occur. At the junction of the animal and vegetal hemispheres, cells from the surface move to the interior forming a cleft, the forerunner of the primitive gut. Following an influx of endodermal cells from below the cleft and mesodermal cells from above, the cleft deepens. With the constant movement of cells from the surface to the interior, a circular blastopore is formed. The blastocoele becomes obliterated and the yolk-laden cells at the vegetal pole move to the interior. Finally, a trilaminar embryo, similar to that observed in Amphioxus, is formed.



Early embryonic development of Birds

Egg and fertilization

Testes

The male bird or rooster, possess a pair of testes, each testis is an oval body, cream white in colour and. From its inner border, a vas deferens emerges to run backwards, lateral to the ureter to open into the cloaca. Just before its opening, it dilates forming a small vesicular seminalis.

Ovaries

In the adult of most flying birds only one ovary of the left side, the right one degenerates.

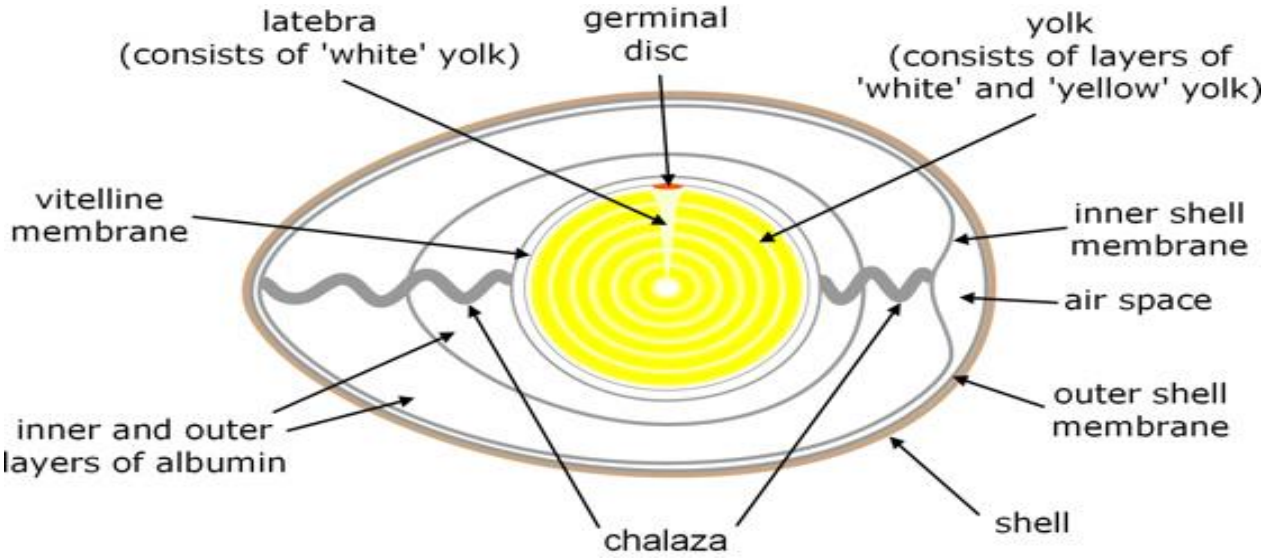
The structure of ovum:

The oocyte grows due to the accumulation of yolk in it, the cytoplasm localized at the animal pole in which the nucleus embedded.

The mature oocyte migrates towards the periphery and finally bulged out from the ovary, connected with the ovary only by means of stalk. The fully formed egg contains a large amount of yolk. The cytoplasm is very little and is in the form of a small disc (the blastodisc or germinal disc).

After fertilization the ovum is surround by various envelopes added to the delicate vitelline membrane.

The cleavage starts immediately in the germinal disc. The fully formed and laid egg is surrounded on the outer side by a calcareous shell. The shell consisting chiefly of calcium carbonate.



Section through domestic hen's egg.

Fertilisation of the egg occurs in the oviduct before the albumen and shell are added to it. The egg is laid about 24 hours after fertilisation, by which time the development has reached the blastula stage.

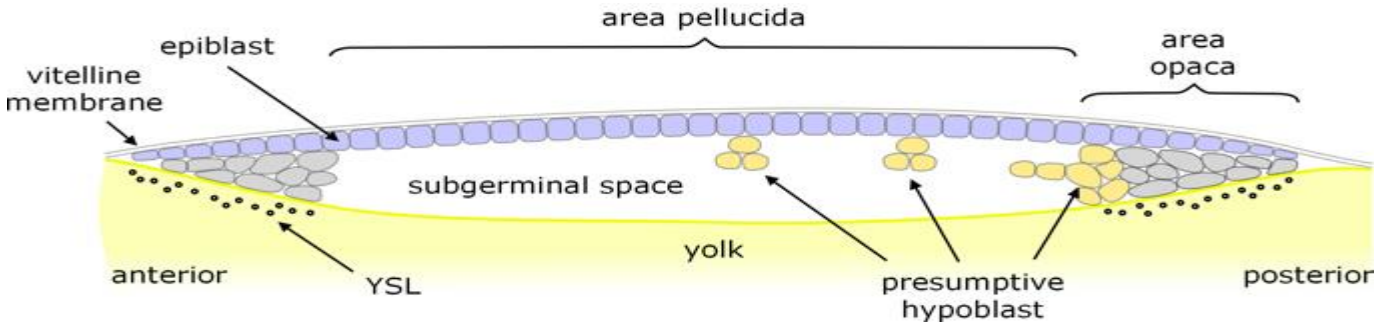
Cleavage and blastula

Consistent with having a large yolk, cleavage is meroblastic and is restricted to the germinal disc, and cell divisions do not extend into the yolk at all. The first division passes near the centre of the germinal disc and the next few divisions are at right angles to the preceding one, but then divisions becomes more irregular and asymmetric.

View from above of the germinal disc after the first few cleavages.

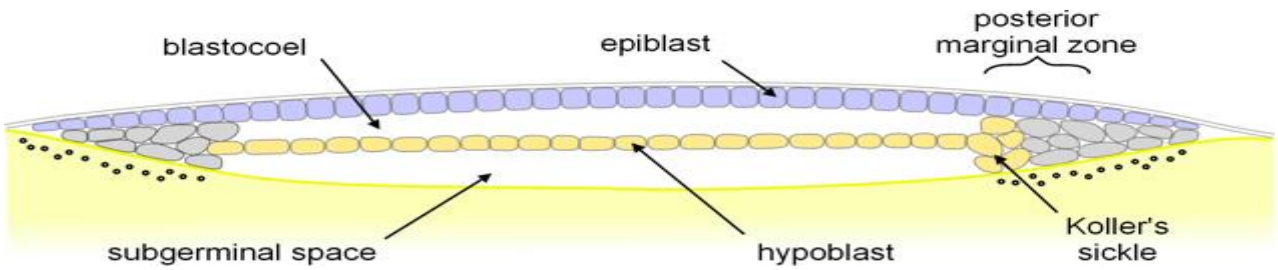
Hence, the early divisions give rise to a disc of cells (blastoderm), several layers thick, sitting on top of the yolk, with a subgerminal cavity in-between. Cells on the periphery of the disc are open to the cytoplasm of the germinal disc, i.e. they form a yolk syncytial layer (YSL).

Across most of the disc, the cells thin to a substantially single layer (but see below) of epithelial cells called the epiblast. This thinning appears to be mainly through cells of the deeper layers being shed, and possibly through some of the lower layer cells being intercalated with the uppermost layer. The central area is relatively translucent and is called the area pellucida, and beneath this is a substantially cell-free subgerminal space. Around the margins of the germinal disc, the cells remain several layers thick, and this relatively opaque peripheral ring is called the area opaca.



Longitudinal section through the blastoderm.

The hypoblast (sometimes called the primary hypoblast) then forms. Some of its cells arise as separate ‘islands’ beneath the epiblast; it is not known to what extent these are left overs from the preceding thinning process or arise by delamination (ingression) from the overlying epiblast. Most of the hypoblast cells arise from the posterior marginal zone (especially the area known as Koller’s sickle, named because it is crescent shaped when viewed from above) by some of its underlying cells spreading anteriorly and incorporating the ‘islands’. The space between the epiblast and hypoblast is the blastocoel.

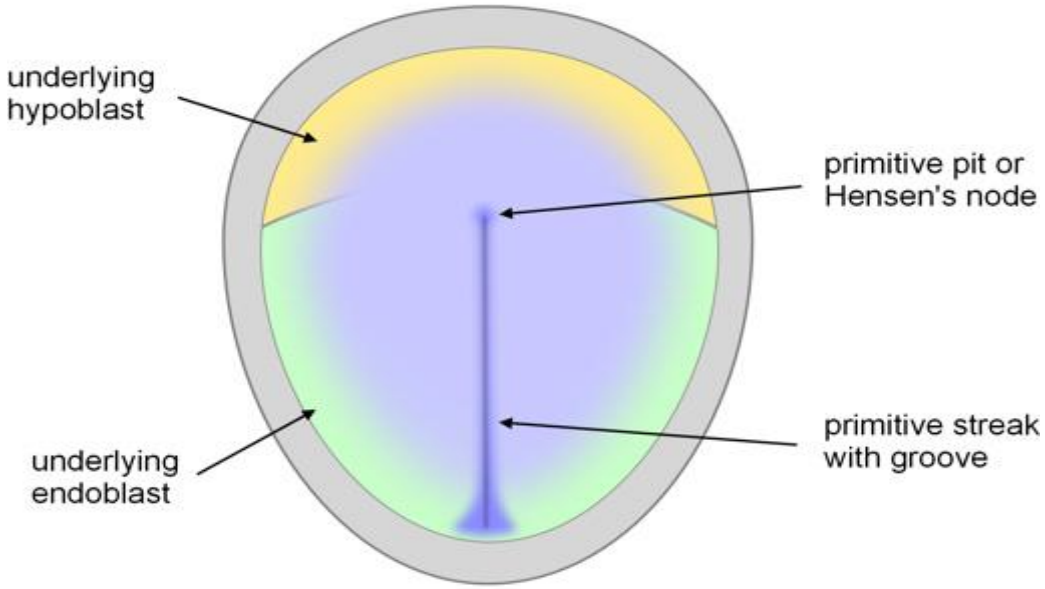


Longitudinal section through the blastula.

Gastrulation

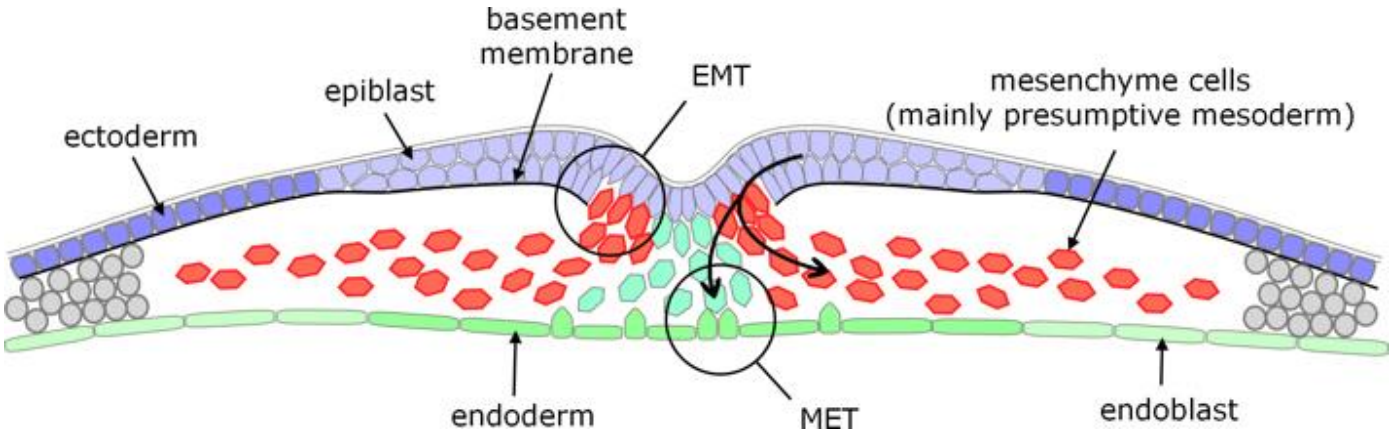
The key feature of gastrulation in birds is the primitive streak.

Initially this is a thickening of the epiblast along its midline, originating close to its posterior end (just forward of Koller’s sickle) and then extending anteriorly until it reaches a maximum extent of about 2/3 across the area pellucida. As these thickening progresses along the epiblast, in tandem with it, a lower layer of cells spreads from the posterior margin. This endoblast (or secondary hypoblast) displaces the (primary) hypoblast anteriorly (figure 5). When the primitive streak reaches its maximum length, a groove develops on its dorsal (upper) surface along its length, culminating in a funnel-shaped depression at its anterior end, known as the primitive pit or Hensen’s node.



Early primitive streak, at its maximum extent, viewed from above, with the epiblast faded at the margin to view the underlying hypoblast and endoblast.

The epiblast spreads (epiboly); and it is through the primitive groove and pit that epiblast cells now ingress between the epiblast and endoblast. This translocation involves a change from an epithelial nature of the epiblast cells to a mesenchymal nature (epithelial-to-mesenchymal transition, EMT) such that the cells can migrate.



Transverse section through the primitive streak.

Some cells entering the primitive groove move across the intervening space and enter the endoblast to become endoderm (progressively displacing the endoblast

to the sides of the embryo). Because the endoderm is an epithelial tissue, these migrating cells must revert to an epithelial nature i.e., undergo a mesenchymal-to-endothelial transition (MET).

Other cells spread out to form mesoderm between the overlying epiblast (ectoderm) and underlying endoderm.

In general, early cells entering the primitive streak become endoderm and later ones become mesoderm; but at any particular time, some cells entering the streak are presumptive endoderm and some presumptive mesoderm.

Epiblast cells that do not enter the primitive streak remain as the ectoderm.

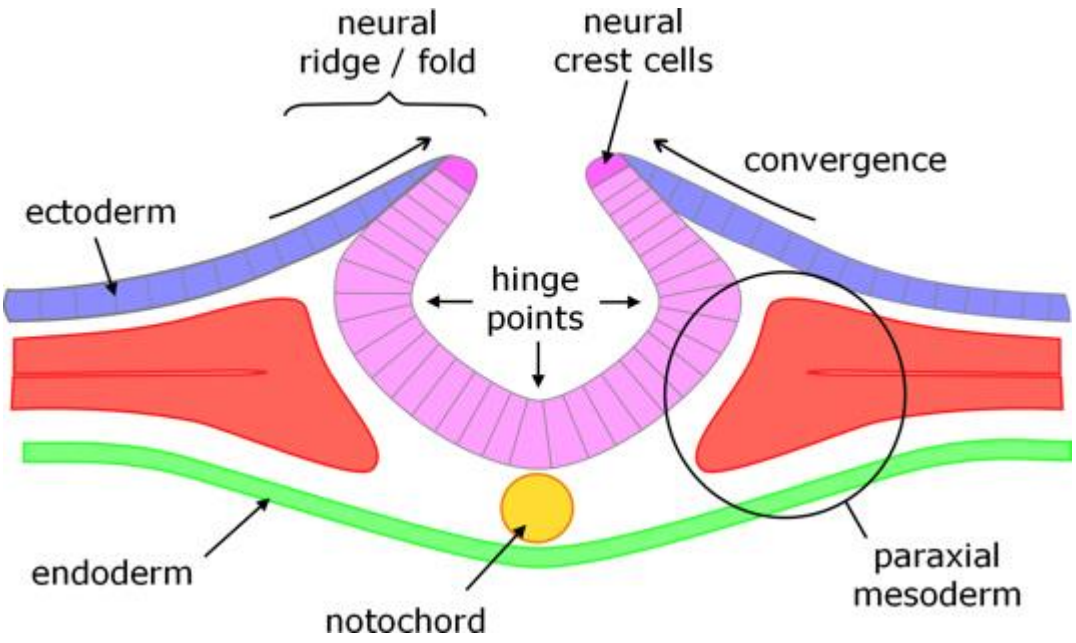
Early cells entering the primitive pit (Hensen's node) move anteriorly, enter the endoblast and become the endoderm of the presumptive foregut. Cells following these become head mesenchyme, prechordal plate mesoderm, and then chordamesoderm which becomes the most anterior part of the notochord, i.e. starting at the most anterior, progressively more posterior parts of the mesoderm are laid down. When the posterior-ward growth of the chordamesoderm reaches the primitive pit, the pit itself starts to retreat posteriorly; and, as it moves progressively further posteriorly, cells entering the node become progressively more posterior parts of the chordamesoderm (and subsequently notochord).

While gastrulation is proceeding, the cells of the marginal zone start to spread outwards, beginning the extraembryonic membranes.

Neural tube

The cells of the dorsal ectoderm (anterior to the retreating primitive streak) converge towards the midline and extend along the anterior-posterior axis

(convergent extension). Those cells near the midline also thicken by changing from cuboidal to columnar to form the neural plate. The lateral edges of the neural plate begin to rise, on each side forming neural ridges and then folds, which fuse to form the neural tube and re-form the overlying ectoderm.



Transverse section to show formation of the neural tube and somites.

Closure of the neural folds starts at two points:

At the level of the future midbrain, and

At the hindbrain-cervical boundary; and progresses in both directions (anteriorly and posteriorly) from each of these. The neural tube has closed in the anterior part of the embryo before the primitive streak has completely regressed posteriorly.

Neural crest cells

Neural crest cells arise at the edges or crests of the neural folds just before the neural tube closes (i.e., are archetypal neural crest cells) and then disperse laterally.

Mesoderm

Notochord

As indicated above, chordamesoderm along the midline forms the notochord (forming anteriorly before the most posterior chordamesoderm has entered through the primitive streak).

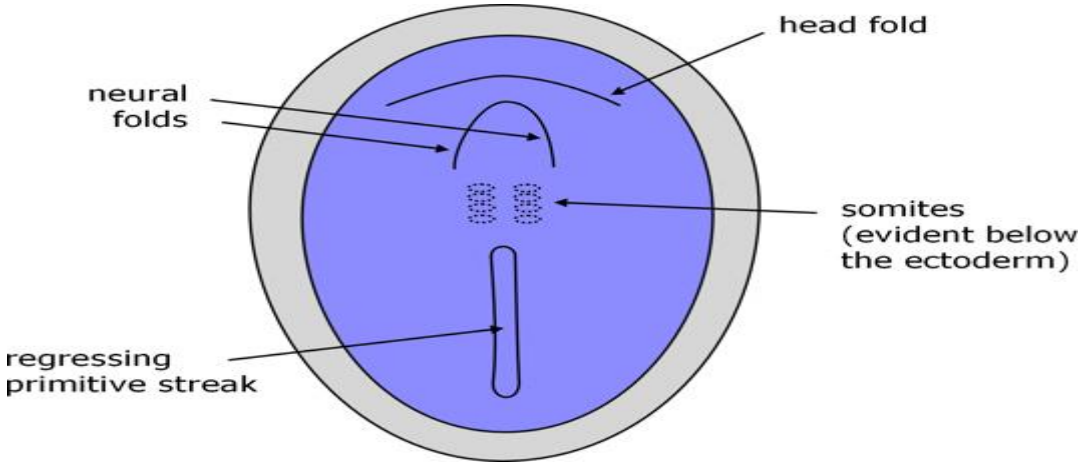
Somites

Either side of the notochord the mesoderm splits into a double layer:

an outer ‘somatic mesoderm’ which lies within the ectoderm (and subsequently contributes to connective tissue), and

an inner ‘splanchnic mesoderm’ which overlies the endoderm (and subsequently forms the circulatory system).

Immediately either side of the notochord, what is known as the paraxial mesoderm segments into somites which form as pairs either side of the notochord. These form in tandem with the neural tube; and, as with the notochord and neural tube, because of the rearward progression of the primitive pit, the somites at the anterior of the embryo develop well before those at the posterior e.g., the anterior somites are visible before gastrulation completes.



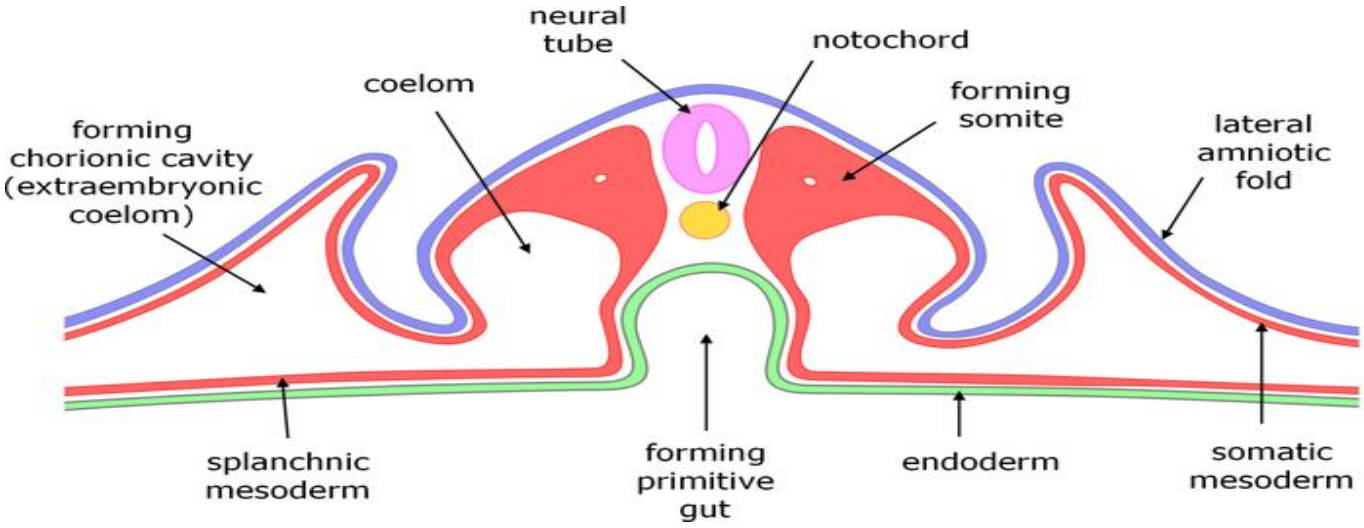
Beginnings of the neural ridges and somites, viewed from above.

Coelom

The remaining space between the two layers of mesoderm extends all around the embryo to form the body cavity or coelom, and beyond the embryo itself it forms the chorionic cavity, bounded by extraembryonic membranes.

Endoderm / gut

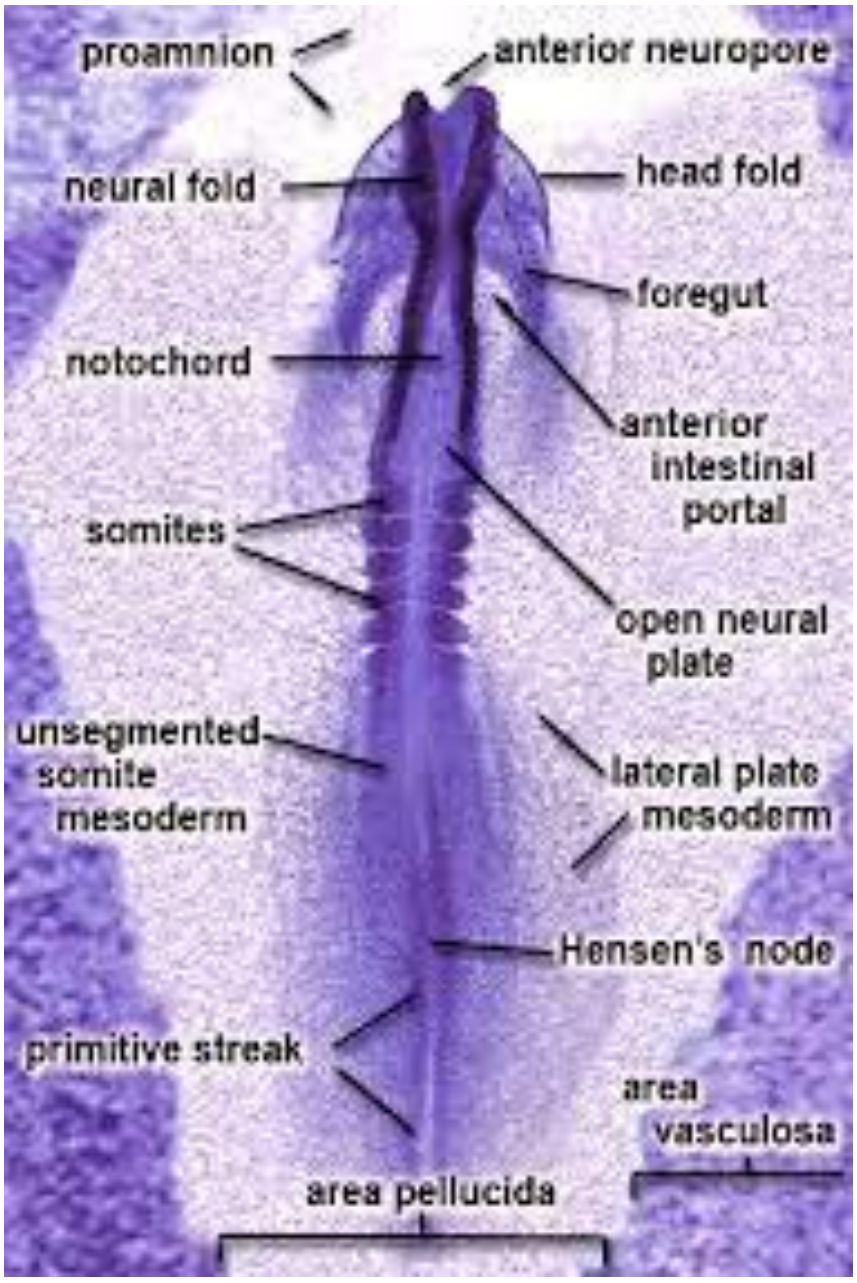
As part of the formation of the extraembryonic membranes the ventral edges of the embryo grow laterally. These folds include the endoderm, and part of this fuses to form the primitive gut.



Transverse section to show early embryonic folds.

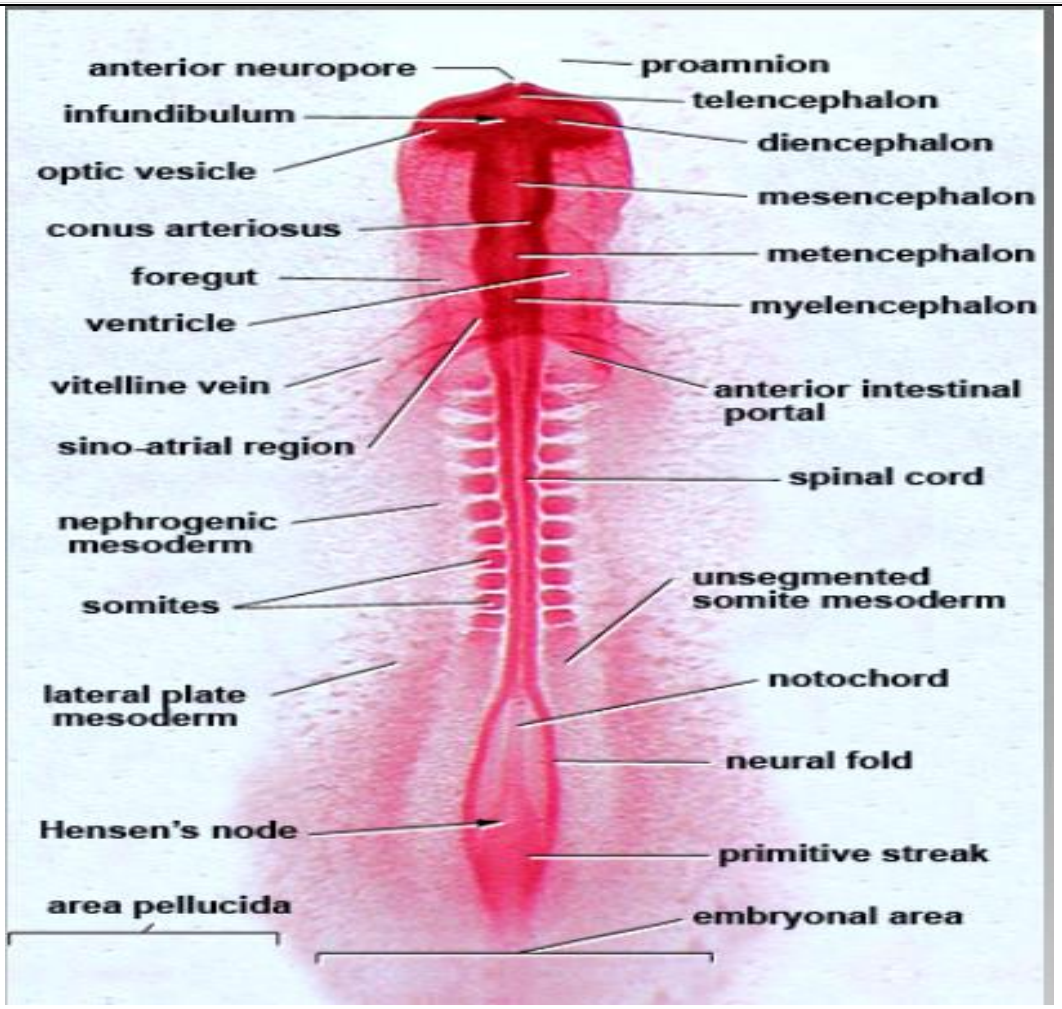
Chick 24 hour

The somites are formed in the mesoderm at the left and right side of the neural walls. In this stage, they are visible as 4 to 5 segmented paired blocks. Afterwards these structures will differentiate into the vertebrae, the ribs, a part of the skin and the dorsal muscles. Only this head region elevates above the underlying area pellucida. In this preparation, one can see the chorda (notochord) in the region of the differentiating foregut.



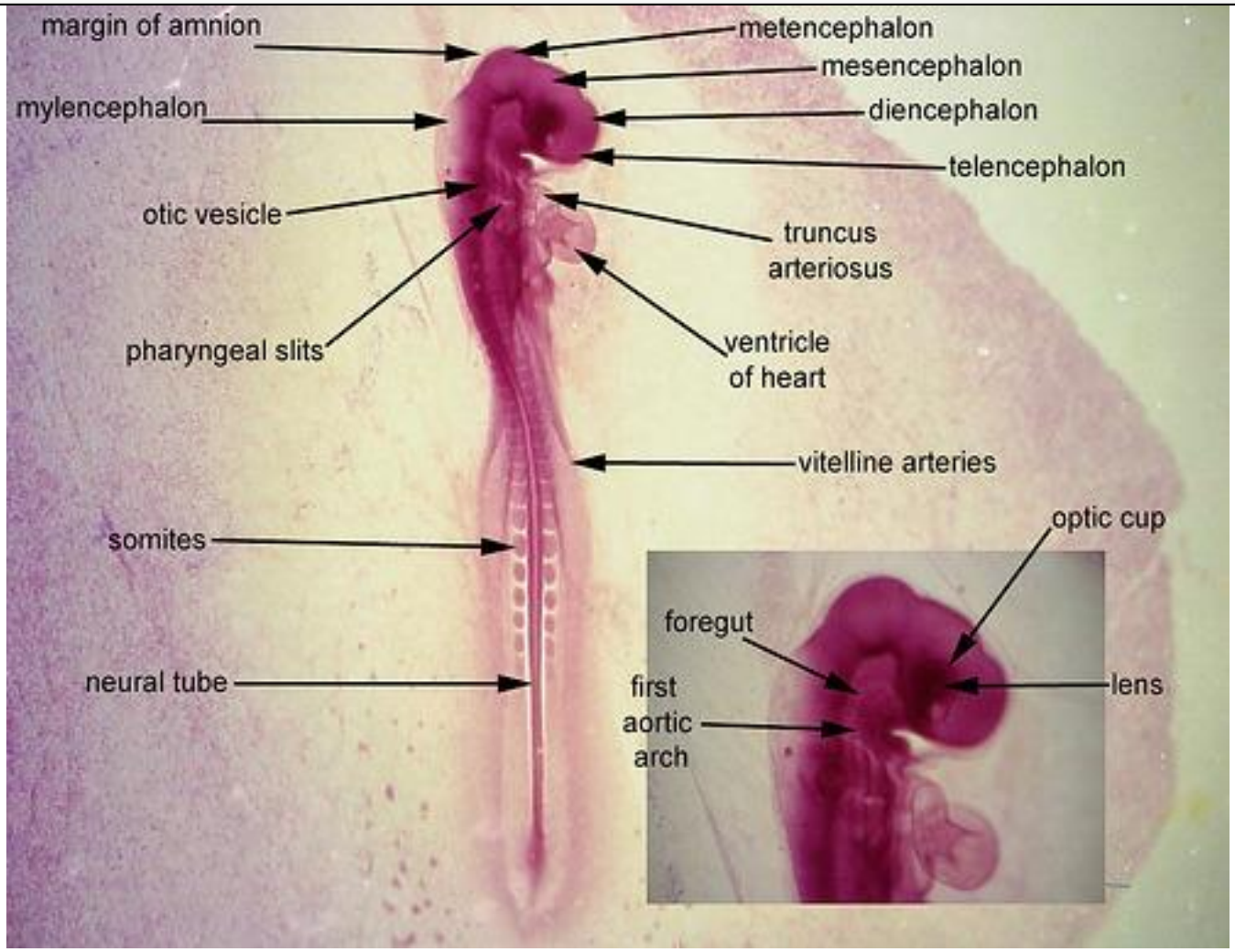
Chick 33 hour

At about 33 hours after fertilization, the embryo is about 4 mm long and the first flexion of the originally straight embryo starts in the head region and the cranial flexure will be visible a few hours later. At this stage 12 to 13 somite are formed. The eye vesicles are rather large. The forebrain vesicle or prosencephalon will divide, the midbrain vesicle or mesencephalon remains undivided while the hindbrain vesicle or rhombencephalon will form a series of smaller neuromeres. The sinus rhomboidalis (diamond-shaped???) is still present as the only opening of the neural tube and the primitive streak is only rudimentary. The infundibulum (= derived from the diencephalon) appears as a half circular structure at the ventral side of caudal part of the forebrain. The notochord or chorda dorsalis ends just behind this venral vesicle.



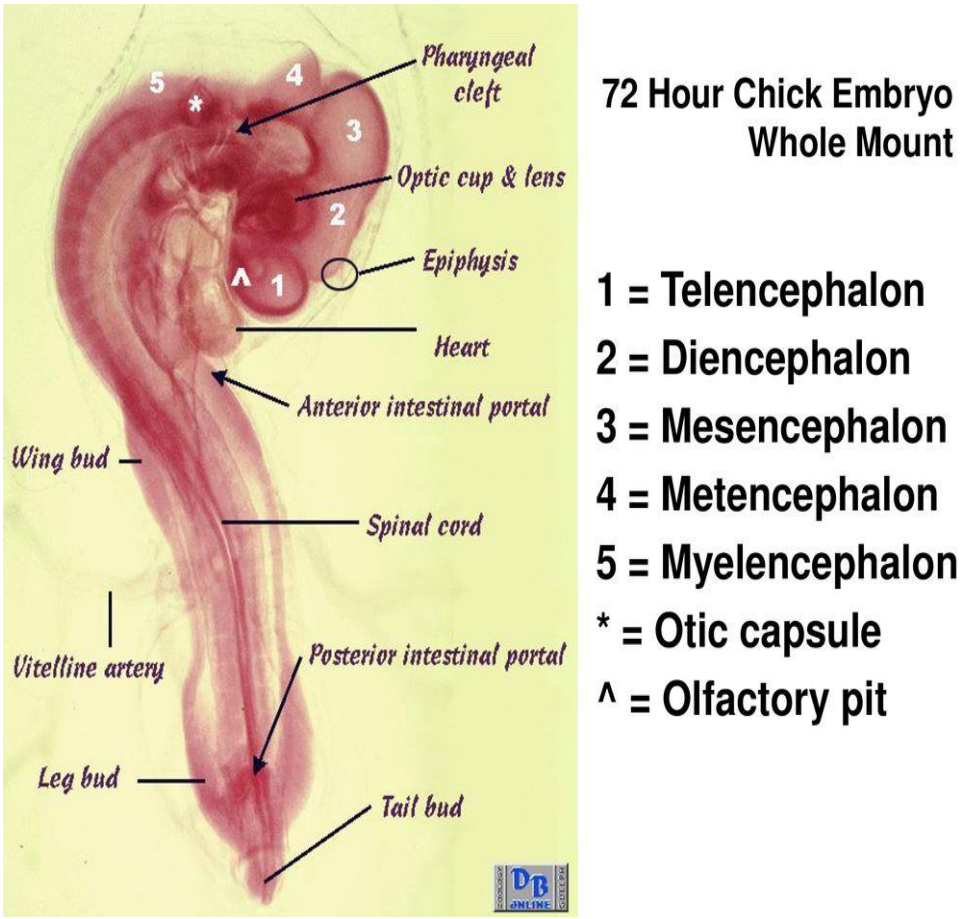
Chick 48 hour

The position of the embryo with respect to the yolk changes strongly about 48 hours after fertilization. In addition to the head fold of the amnion, also the lateral and caudal amniotic folds begin to form. The outgrowth of the cranial flexure is so strong that the forebrain and hindbrain vesicles become almost located to each other. The cephalic region of the embryo is twisted in such a manner that the left side comes to lie next to the yolk. A second flexure appears at the transition of the head and the body just behind the heart region. The embryo takes now the shape of a C. The head becomes covered by a double fold. These folds definitely establish the first extra embryonic membrane (=outside of the embryo): the amnion membrane. The vitelline (yolk rich) arteries and veins become connected with the extra embryonic circulatory vessels. A few branchial grooves are already visible. The brain divides in to 5 vesicles: telencephalon and diencephalon (both formed by the division of the forebrain vesicle), mesencephalon, metencephalon and myencephalon (both formed by the division of the hindbrain vesicle). The lens placode (placode=plate) will form the lens vesicle, the optic vesicle will become the optic cup and the auditory placode the auditory pit. The heart differentiates in to 4 compartiments: the sinus venosus, connected with the veins, the atrium, the U-shaped ventricle and the bulbus cordis. The atrium and ventricle are well distinguishable in the figure.

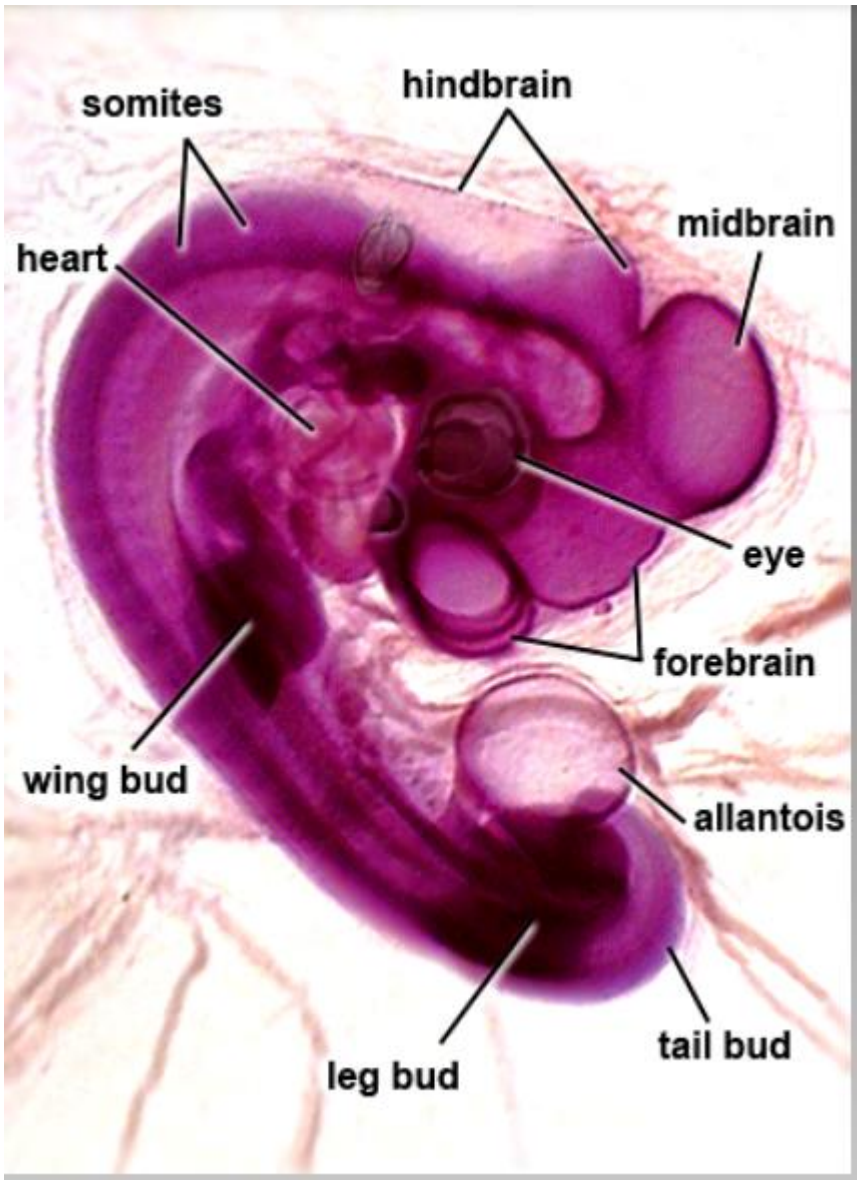


Chick 72 hour

72 Hours after fertilization, the rotation of the embryo to the left is arrived such behind the region of the heart and only the caudal part of the embryo must twist 90 degrees. The two flexures in the head region are almost completed. The fourth pharyngeal groove develops, and the pharyngeal arches are thicker. Due to the cranial flexure, the pharyngeal region (= region of the trachea) is now located at the ventral side of the head. The fore and hind limbs at the level of the 16th to the 20th respectively the 27th to the 32nd somite pairs are visible as small buds at an incubation time of about 3 days.

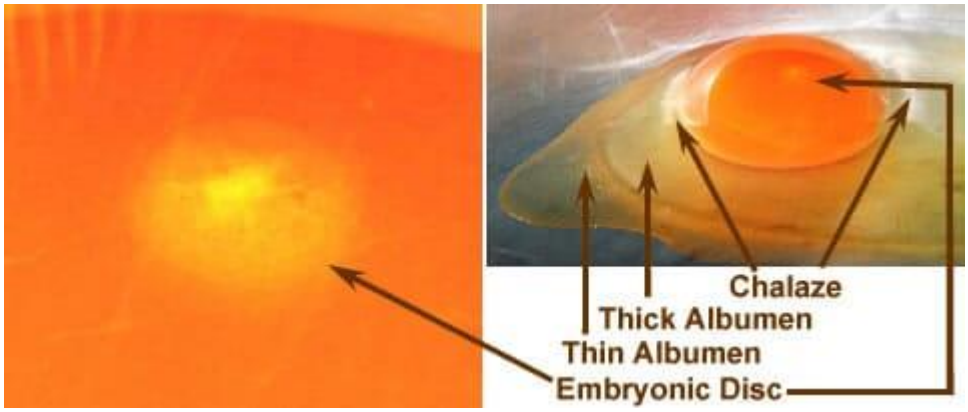


Chick 96 hour



Embryonic Development of Chick, Day by Day

Unfertilized egg: The embryonic disc of a sterile egg bears an accumulation of white material at its center

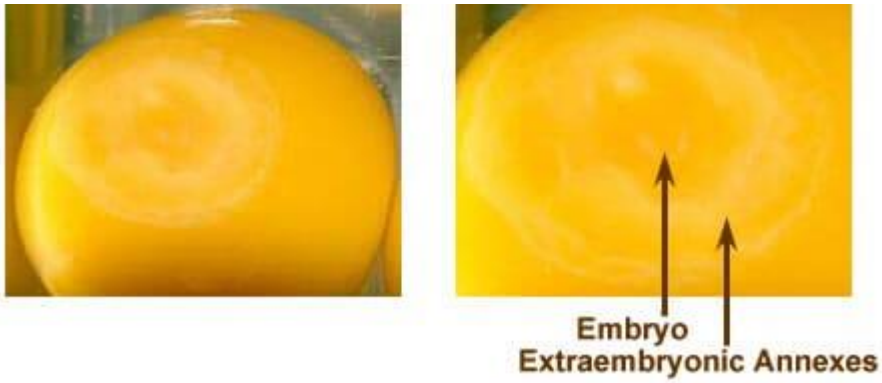


Fertilized egg: The fertilized embryonic disc looks like a ring: it has a central area, lighter in color, which is to house the embryo.

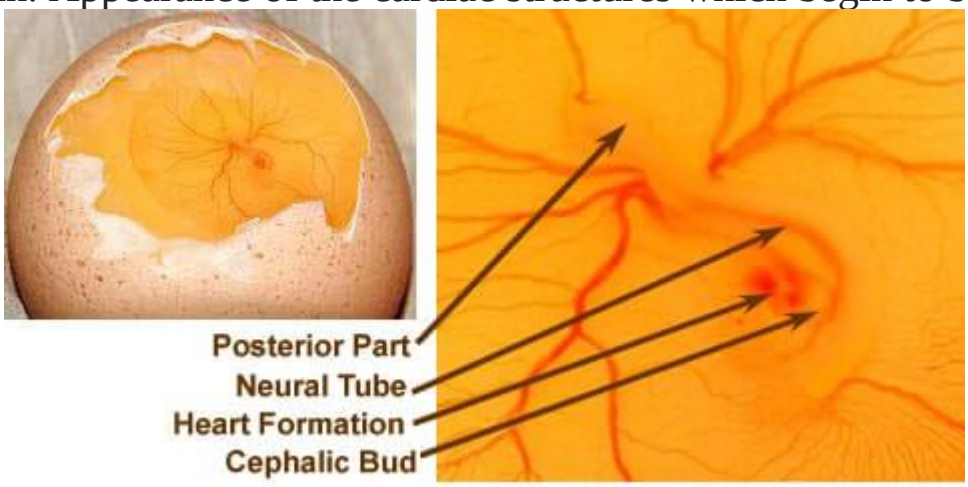
Day 1: The germinal disc is at the blastodermal stage. The segmentation cavity, under the area pellucida, takes on the shape of a dark ring.

Day 2: Appearance of the first groove at the center of the blastoderm. Among extraembryonic annexes, appearance of the

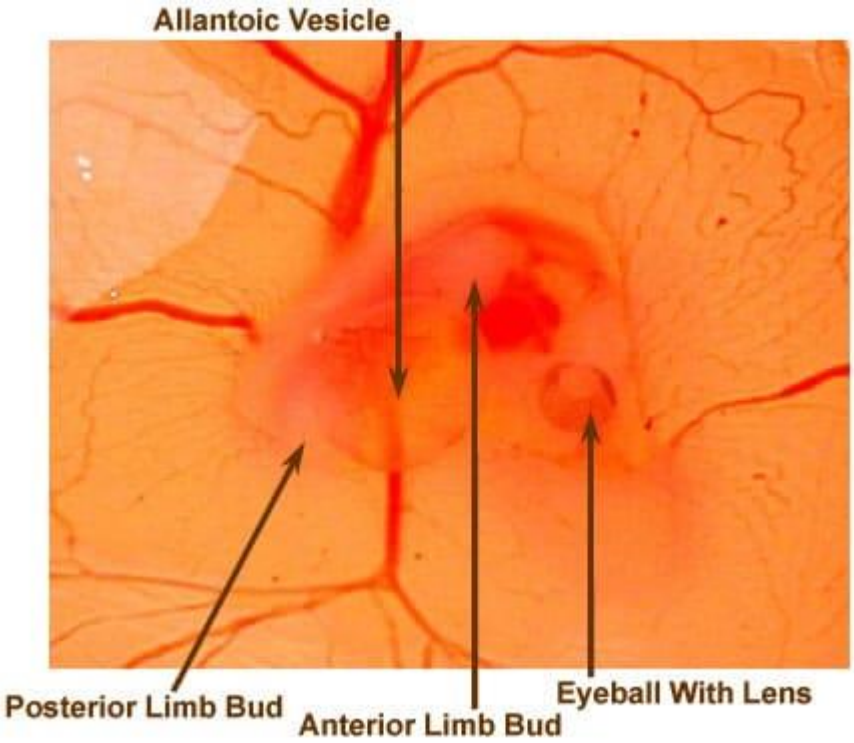
vitelline membrane which is going to play a major role in embryo nutrition.



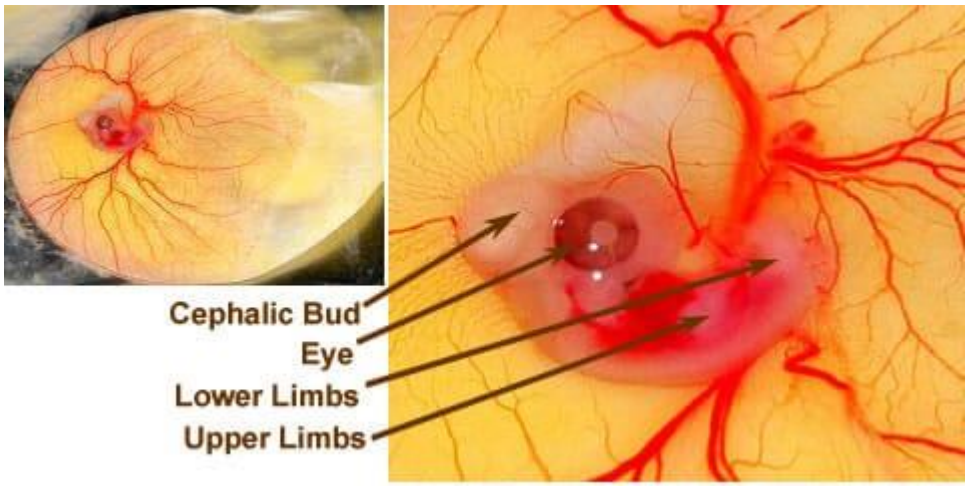
Day 3: The embryo is lying on its left side. Onset of blood circulation. The vitelline membrane spreads over the yolk surface. The head and trunk can be discerned, as well as the brain. Appearance of the cardiac structures which begin to beat.



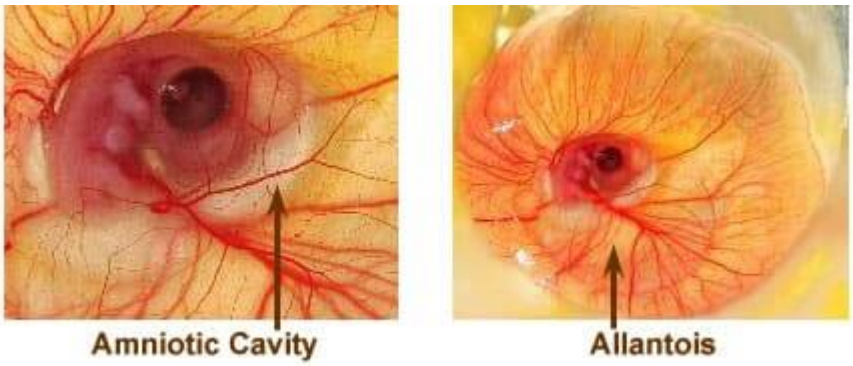
Day 4: Development of the amniotic cavity, which will surround the embryo: filled with amniotic fluid, it protects the embryo and allows it to move. Appearance of the allantoic vesicle: it plays a major role in calcium resorption, respiration and waste storage.



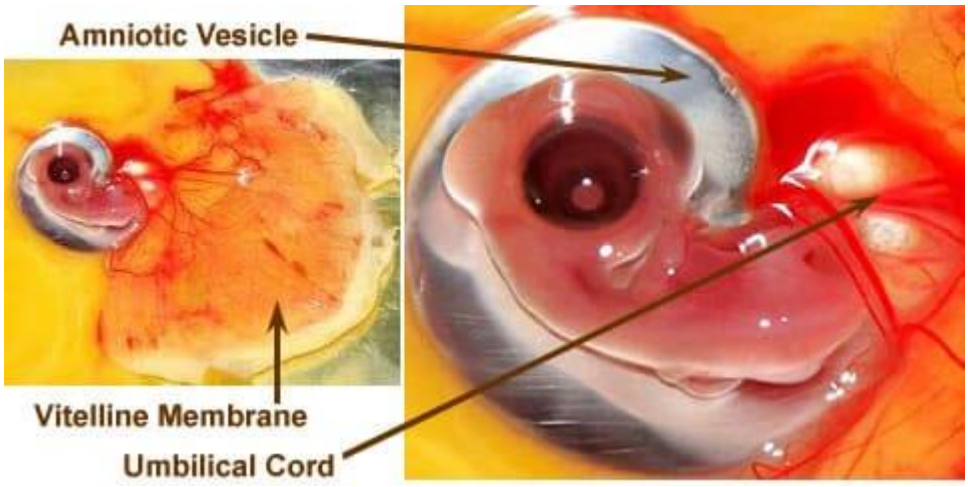
Day 5: Sensible increase in the embryo's size; the embryo takes a C shape: the head moves closer to the tail. Extension of limbs. Differentiation of the fingers of the inferior limbs.



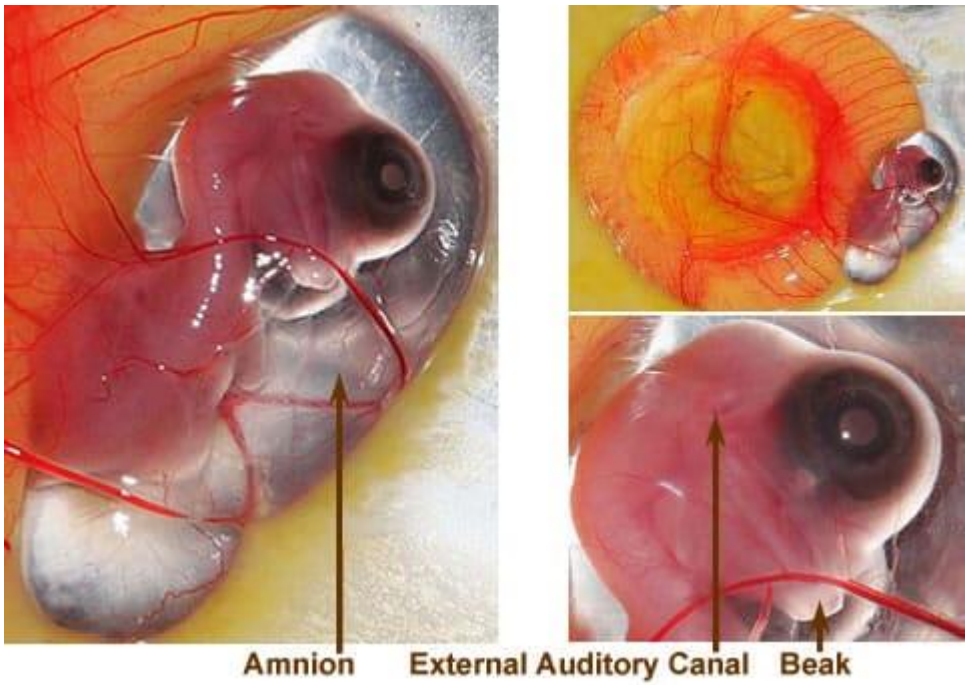
Day 6: The vitelline membrane continues to grow and now surrounds more than half the yolk. Fissura between the first, second and third fingers of the upper limbs, and between the second and third fingers of the lower limbs. The second finger is longer than the others.



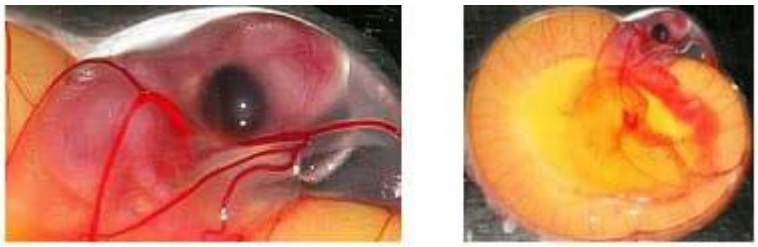
Day 7: Thinning of the neck which now clearly separates the head from the body. Formation of the beak. The brain progressively enters the cephalic region: it progressively grows smaller proportionally to the embryo's size.



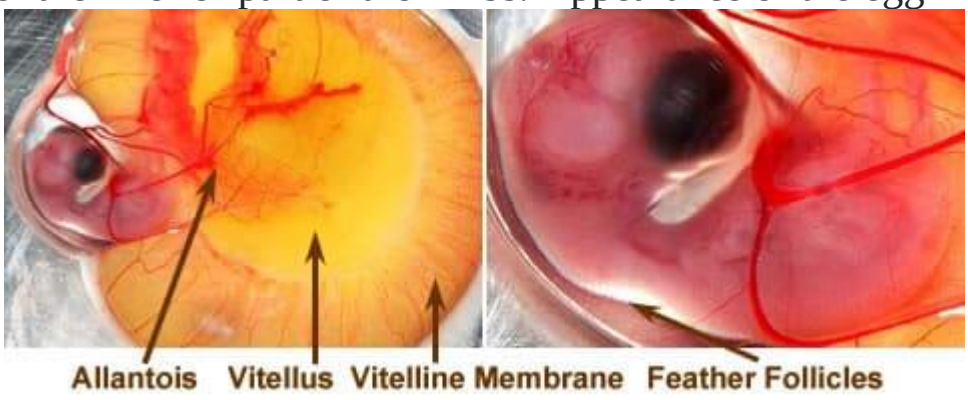
Day 8: The vitelline membrane covers almost the whole yolk. Eye pigmentation is readily visible. The beak's upper and lower parts are differentiated, as well as the wings and legs. The neck stretches and the brain is completely settled in its cavity. Opening of the external auditory canal.



Day 9: Appearance of claws. Budding of the first feather follicles. Growth of the allantois and increased vascularization of the vitellus.

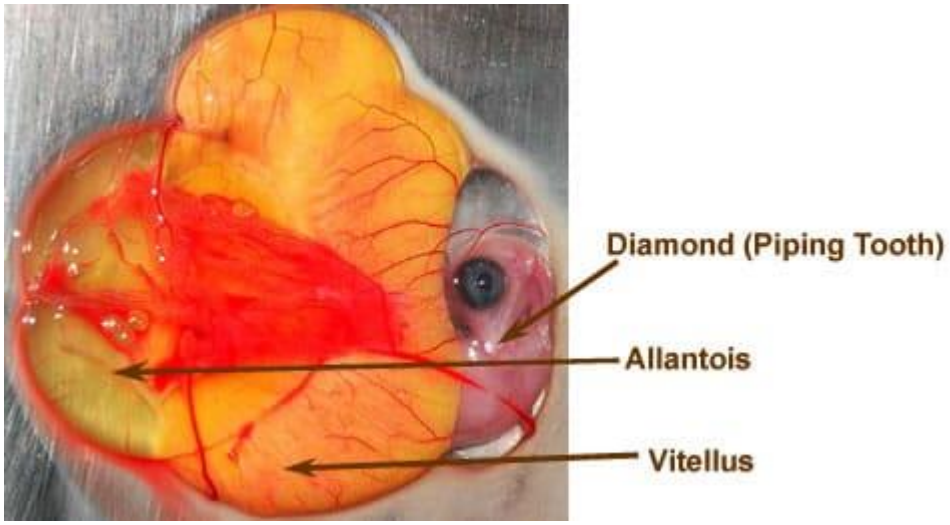


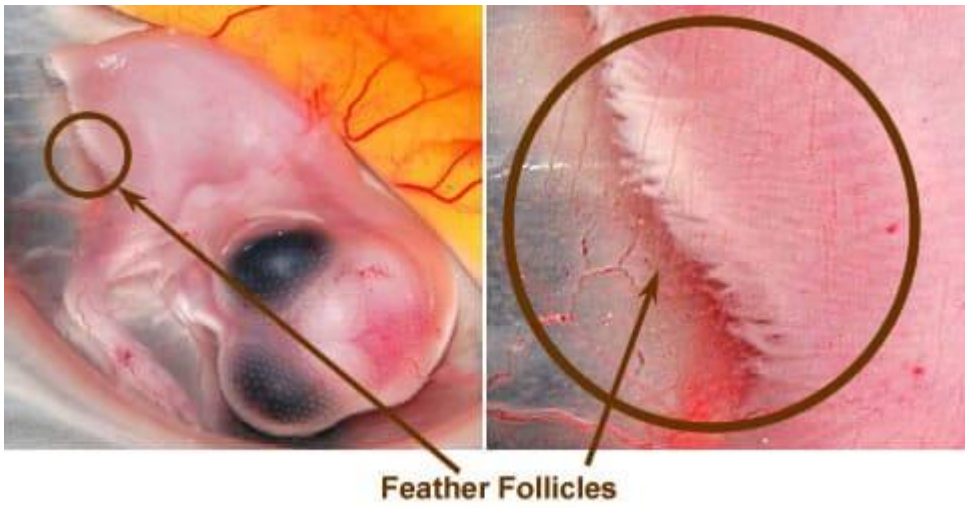
Day 10: The nostrils are present as narrow apertures. Growth of eyelids. Extension of the distal portion of the limbs. The vitelline membrane completely surrounds the yolk. Feather follicles now cover the inferior part of the limbs. Appearance of the egg-tooth.



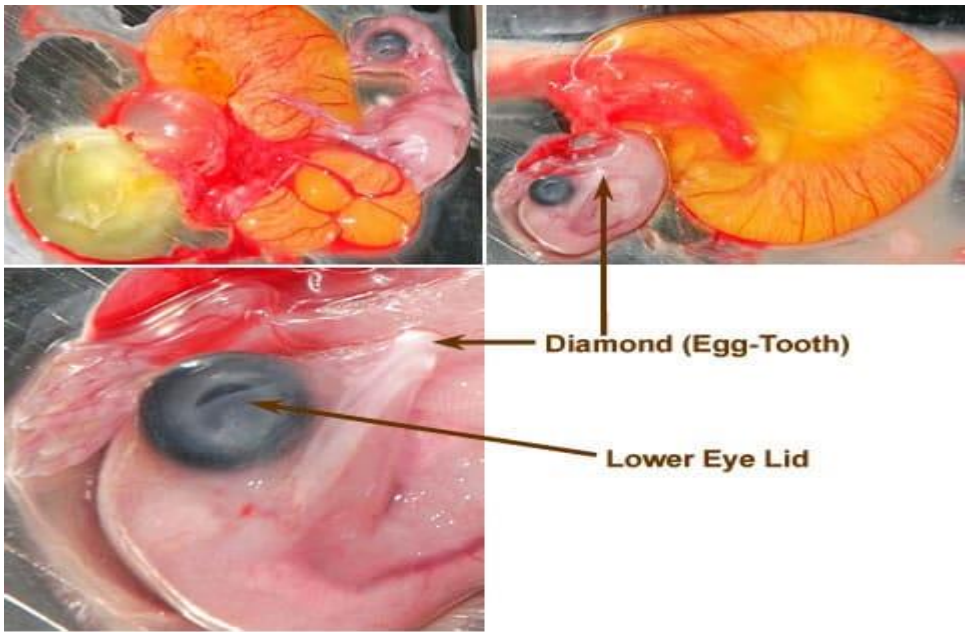
Day 11: The palpebral aperture has an elliptic shape that tends to become thinner. The allantois reaches its maximum size while the

vitellus begins to shrink. The embryo now has the aspect of a chick.

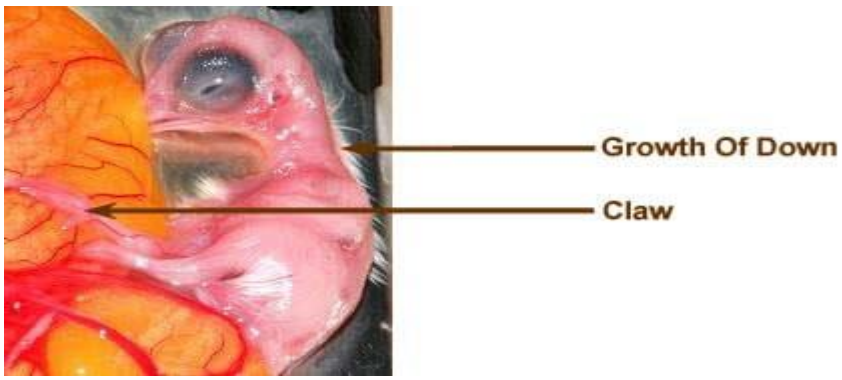




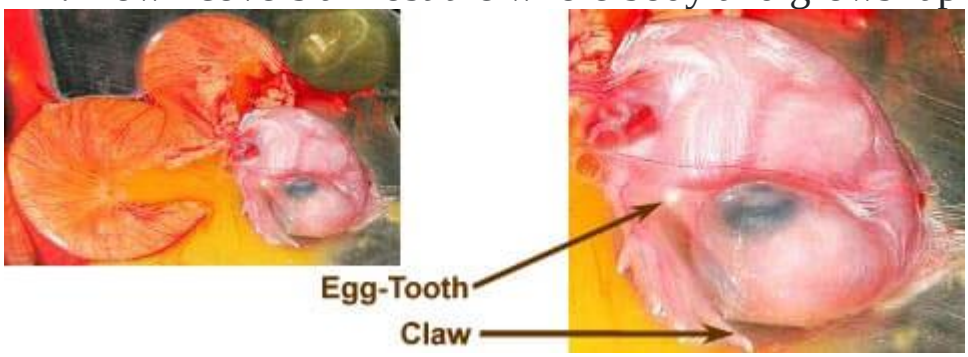
Day 12: Feather follicles surround the external auditory meatus and cover the upper eyelid. The lower eyelid covers two thirds, or even three quarters, of the cornea.



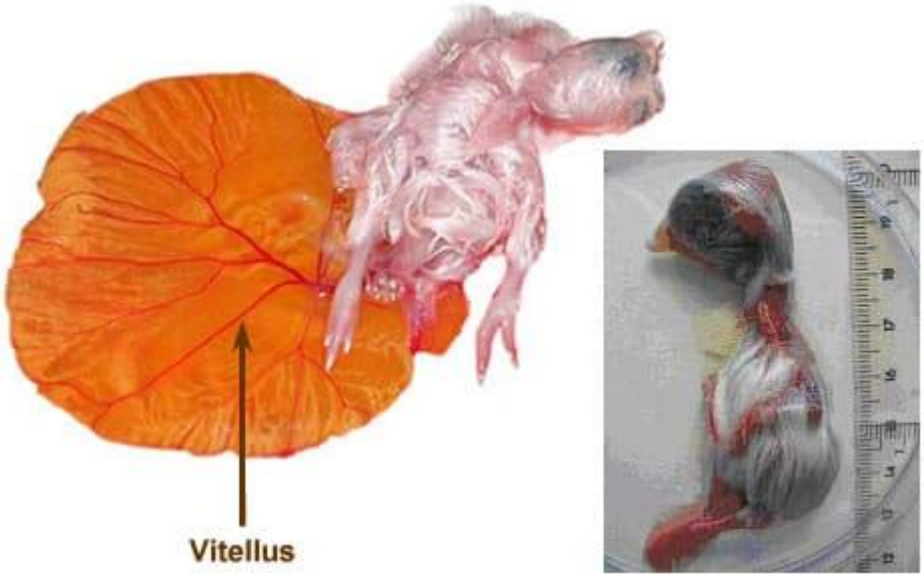
Day 13: The allantois shrinks to become the chorioallantoic membrane. Appearance of claws and leg scales.



Day 14: Down covers almost the whole body and grows rapidly.

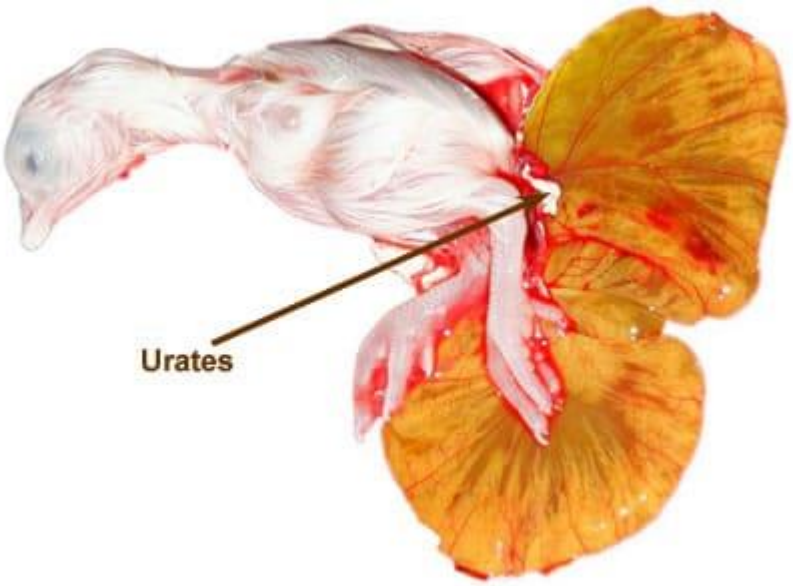


Day 15 & 16: Few morphological changes: chick and down continue to grow. Vitellus shrinking accelerates. Progressive disappearance of the egg white. The head moves toward pipping position, under the right wing.



Day 17: The embryo's renal system produces urates. The beak, which is under the right wing, points to the air cell. The egg white is fully resorbed.

Day 18: Onset of vitellus internalization. Reduction in the amount of amniotic fluid. This is the time for transfer from incubator to hatcher, and also perhaps in ovo vaccination.



Day 19: Acceleration of vitellus resorption. The beak is against the inner shell membrane, ready to pierce it.

Day 20: Vitellus fully resorbed; closing of the umbilicus. The chick pierces the inner shell membrane and breathes in the air cell. Gas exchanges occur through the shell, which is porous. The chick is ready to hatch. Piercing of the shell begins.

Day 21: The chick uses its wing as a guide and its legs to turn around and pierce the shell in a circular way by means of its egg-tooth.

It extricates itself from the shell in 12 to 18 hours and lets its down dry off.

Embryonic development of mammals (humans)

Humans are classified within the group of mammals called eutherians which (with a few exceptions) use a placenta to nourish the developing embryo within the mother.

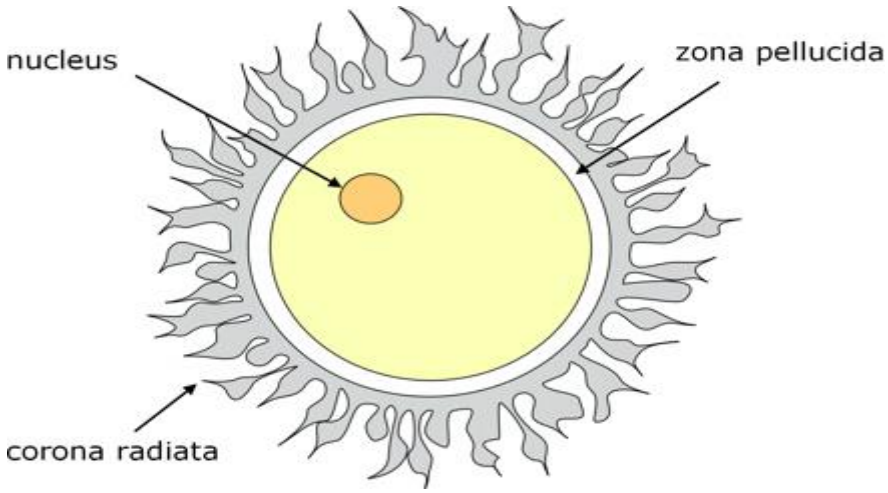
The other main groups of present-day mammals are:

marsupials (pouched), and

monotremes (egg-laying).

Egg and fertilisation

The human ovum comprises a single cell, about 0.1 mm in size, containing the haploid nucleus. It is enveloped by a clear jelly-like coat called the zona pellucida; and the whole is surrounded by a population of follicular cells (originating from the ovary) which form the corona radiata.

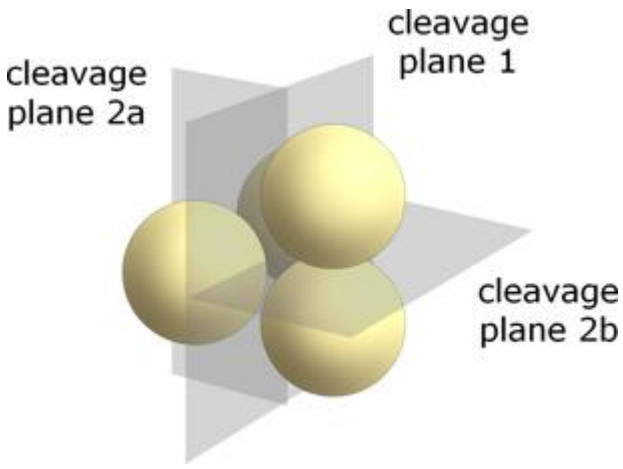


Section through human ovum.

Fertilisation takes place in the upper region of the oviduct (Fallopian tube) and the early stages of development unfold as the embryo travels along the oviduct. During its passage along the oviduct, the embryo loses some of the cells of the corona radiata, but the zona pelludica remains intact. Implantation in the uterus occurs when development has reached the blastocyst (blastula) stage.

Cleavage to blastocyst

Consistent with the absence of a significant yolk, cleavage in mammals is holoblastic, meaning that the first division extends right through the egg cell. The first division is typical of other organisms having holoblastic cleavage, with the division being meridional – extending from one pole to the other. However, in mammals the second cleavage is unusual: one cell divides meridionally, but the other divides equatorially; which is called rotational cleavage.



Rotational cleavage: cleavage 2a is meridonal, 2b is equatorial.

In most other organisms (having holoblastic cleavage) both of the second divisions are meridional, and the third or subsequent divisions are equatorial.

Also, whereas in other vertebrates the early cell divisions tend to be synchronous, this is often not the case with mammals, such that there is an odd number of cells instead of the usual geometric increase 2, 4, 8 … .

Early cell divisions also tend to be slower than for other animals.

The cell divisions up to just before implantation take place within the zona pellucida, so there is no overall increase in size of the embryo but its cells become smaller as they proliferate.

Compaction and morula

Up to 8 – 16 cells, they form a loose association within the zona pellucida, but then they compact, with tight junctions forming between the outer cells. This is called the morula stage.

It is about now that the embryonic genome is activated, and this is followed by the first clear differentiation of cells, with further cell divisions resulting in inner cells being distinct from the peripheral ones, and the beginning of a fluid-filled cavity, the blastocoel.

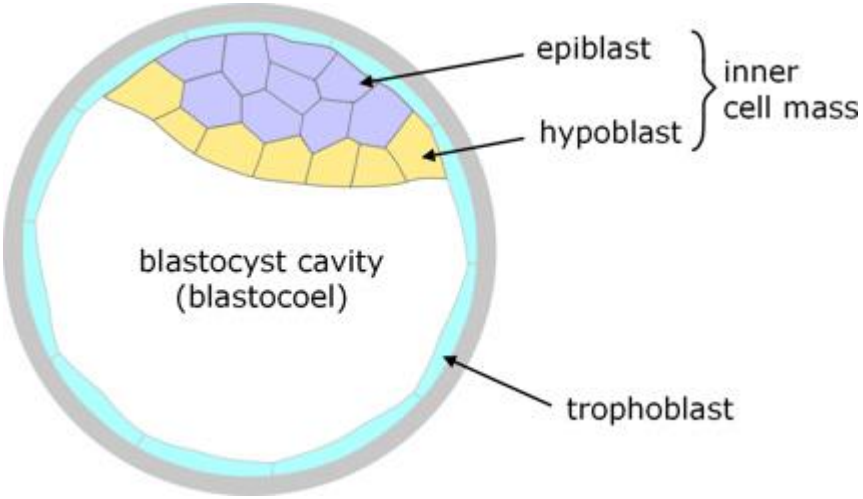
Blastocyst

The blastocyst is the mammalian equivalent of the blastula in other vertebrates. It comprises three populations of cells:

an outer cell layer (trophoblast) which develops into the placenta; and

an inner cell mass:

most of which is the epiblast, which is the source of embryonic tissues, and the amnion, although the layer of cells in contact with the blastocoel is the hypoblast, most of which forms extraembryonic tissues.



Human blastocyst.

Implantation and embryonic disc

About 7 days after fertilisation the embryo loses the zona pellucida, and implants into the lining of the uterus, by which time it comprises about 200 cells.

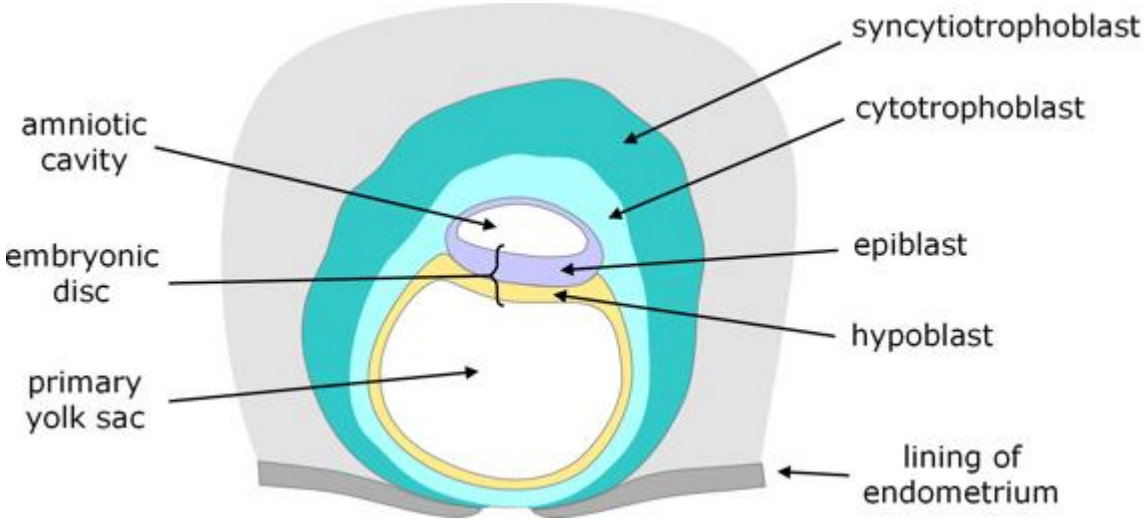
Around the time of implantation:

- the amniotic cavity arises within the epiblast,
- the blastocyst cavity becomes the primary yolk sac, which is lined by cells that spread from the hypoblast.

In addition, cells from the epiblast and hypoblast organise into a two-layered structure known as the embryonic disc, positioned between the primary yolk sac and amniotic cavity. Previously these two layers

had been thought to correspond with the first two germ layers, the ectoderm and endoderm, but see below.

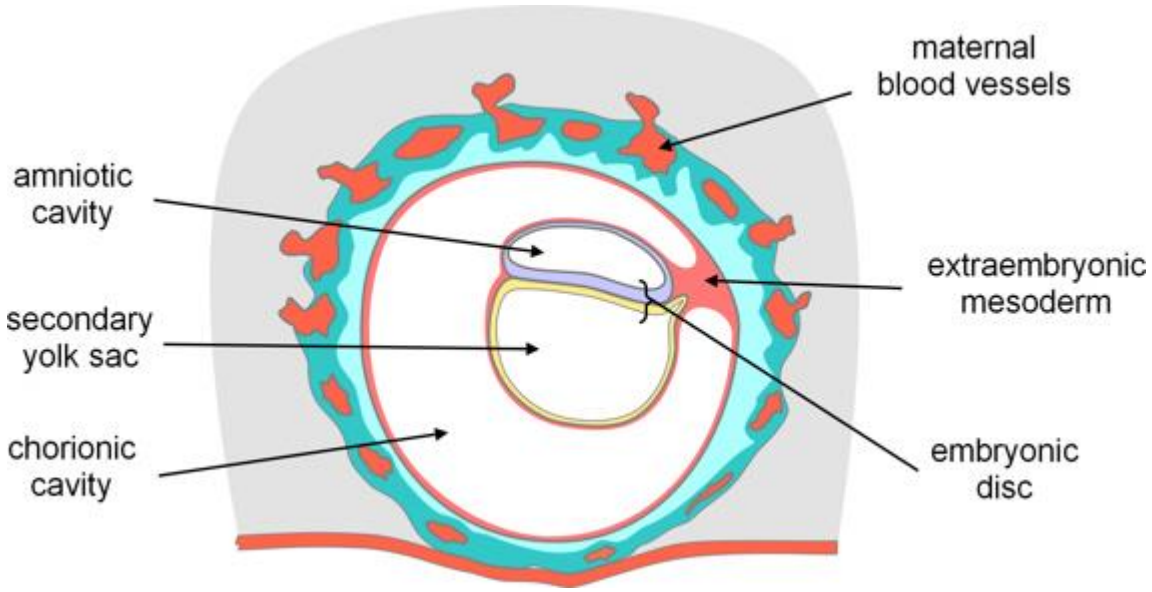
The trophoblast penetrates the uterine wall and begins to form the placenta; at an early stage it differentiates into two distinct layers, known as the cytotrophoblast and the syncytiotrophoblast.



Embryo shortly after implantation, with embryonic disc.

Extraembryonic mesoderm

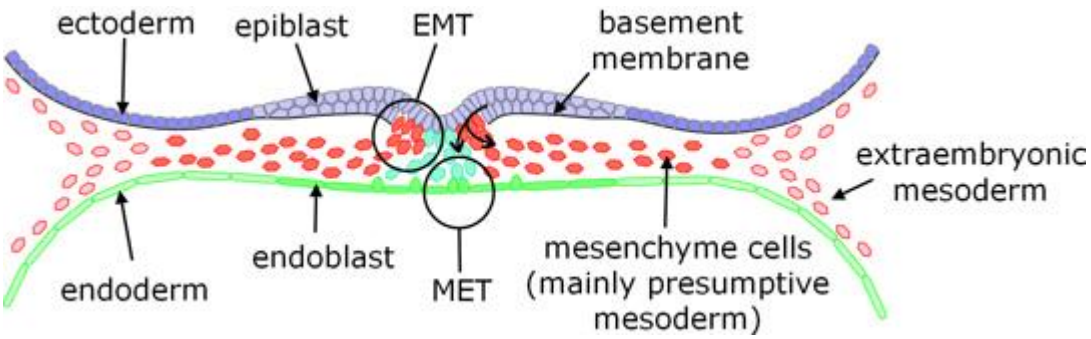
Extraembryonic mesoderm is a layer of tissue that arises between the lining of the primary yolk sac and the cytotrophoblast, and spreads to cover the amniotic cavity as well. As this tissue thickens, cavities form within it, and coalesce to form the chorionic cavity which is lined with extraembryonic mesoderm (figure 5). (Note that this is different from the germ-layer mesoderm which forms later, see below.) In this process some of the primary yolk sac is lost, and what remains is called the secondary yolk sac. The embryo remains attached to the internal lining of the chorion by a connecting stalk of extraembryonic mesoderm which becomes the umbilical cord.



Longitudinal section pre-gastrulation (approx. day 14).

Gastrulation

From about day 14 after fertilisation, a groove appears near the caudal end of the epiblast, it extends about two-thirds of the way along the midline towards the cranial end, terminating in a widening with a depression at its centre. This primitive groove and primitive pit are where gastrulation occurs. As gastrulation proceeds, the primitive node recedes caudally, with a corresponding shortening of the primitive streak.



Transverse section (perpendicular to figure 5) through the embryonic disc, showing gastrulation.

In the course of gastrulation, cells of the epiblast proliferate and move towards the groove where they transition from epithelial to mesenchymal in character, and ingress below the surface. In the early phase, these ingressing cells enter the hypoblast, reverting to epithelial cells (mesenchymal to epithelial transition) to become the definitive endoderm; at the same time displacing the hypoblast cells from the embryonic disc to line the yolk sac. As this stage proceeds, further cells ingressing from the epiblast move into the space between the epiblast and endoderm to form a middle layer of cells called mesoderm. (At the edges of the embryonic disc this embryonic mesoderm merges with the previously formed extraembryonic mesoderm.) Once the mesoderm is formed, the remaining epiblast is called ectoderm, and the three germ layers are complete.

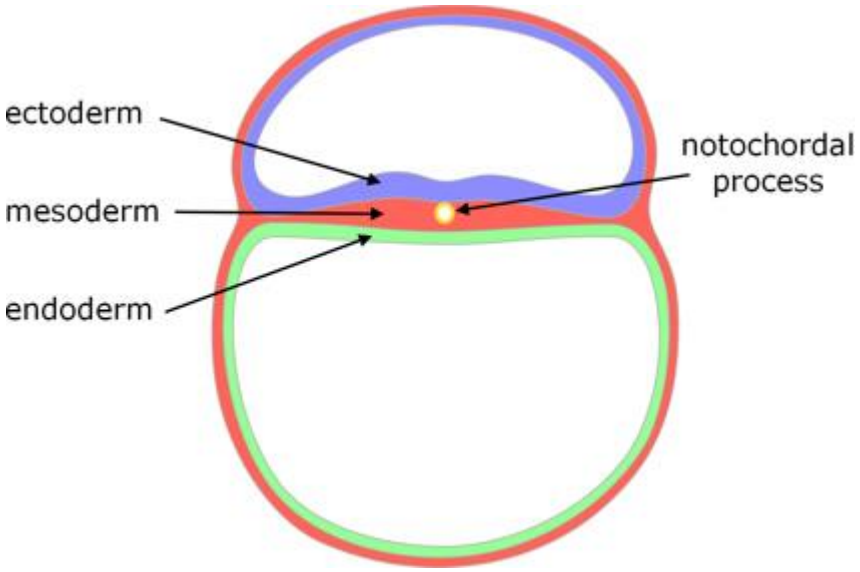
Notochord

The notochord forms within the mesoderm in three stages:

1. First, the primitive pit extends into the mesoderm, below the epiblast / ectoderm, towards the cranial end of the embryonic disc, resulting in a hollow tube called the notochordal process (or canal).
2. This process merges with the underlying endoderm, to form the notochordal plate (during the early stages of this process, there is therefore a connection from the overlying amniotic cavity through to the underlying yolk sac via the lumen of the notochordal process, this connection being called the neuroenteric canal although in other contexts this term generally refers to a connection via the forming neural tube and the forming gut).

3. Then, after about a day, the definitive notochord (which is a solid rod, rather than a tube) emerges from the notochordal plate.

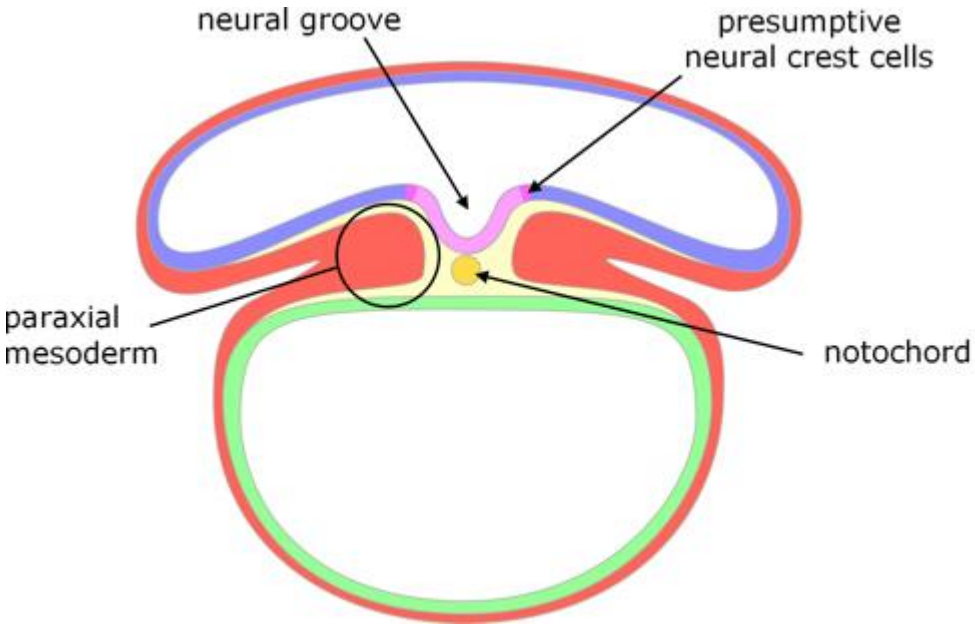
Throughout this development, cells of the presumptive or definitive notochord are in contact with the overlying epiblast / ectoderm and stimulate it to develop the neural tube.



Transverse section following gastrulation, approximately through the middle of the embryonic disc, showing prenotochordal process /canal, and the beginning of the neural ridges.

Neural tube

An early role for the notochord, including its precursors, is to induce formation of the neural tube. As gastrulation completes, ectoderm converges towards and thickens along the midline to form the neural plate. The lateral edges of the neural plate rise to form ridges (with the neural groove in-between) which meet and fuse to enclose the neural tube.



Transverse section showing formation of the neural tube.

Neural crest cells

Cells of the ectoderm that line the edges of the neural groove are called neural crest cells. When the neural tube closes these cells become separated from both the ectoderm and the neural tube, initially located between them, but subsequently migrate to form various tissues.

Mesoderm

Either side of the notochord the (embryonic) mesoderm splits into a double layer:

the ‘somatic mesoderm’ which underlies the ectoderm (and subsequently contributes to connective tissue), and

the ‘splanchnic mesoderm’ which overlies the endoderm (and subsequently forms the circulatory system).

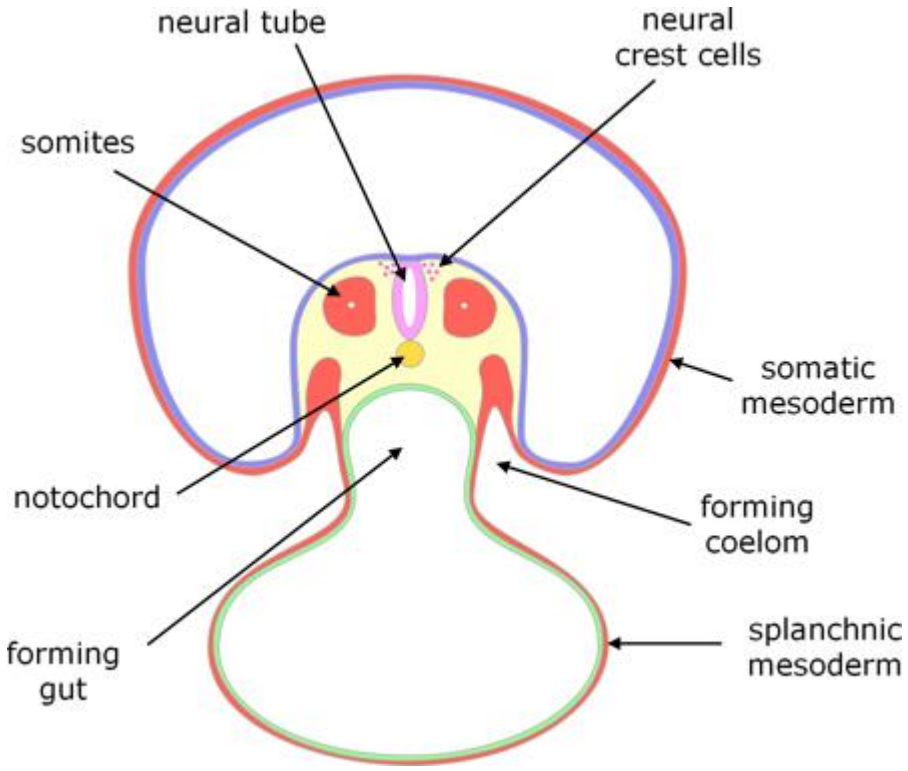
At the edges of the embryonic disc, these layers of embryonic mesoderm merge respectively with:

the extraembryonic mesoderm of the amnion; and

the extraembryonic mesoderm that lines the yolk sac.

Somites

Immediately either side of the notochord, what is known as the paraxial mesoderm segments into somites which form as pairs either side of the notochord.



Transverse section showing formation of the gut.

Coelom and gut

While the neural tube and somites are forming, the amnion begins to spread ventrally around the embryo. When the folds of membranes meet and fuse:

- they pinch off part of the yolk sac, which becomes the primitive gut, having an internal layer of endoderm.
- the spaces between the two layers of mesoderm coalesce to form the spaces between the two layers of mesoderm coalesce to form the coelom or body cavity; and
- The embryo is enveloped by the amniotic cavity.

Four extraembryonic membranes (or embryonic membranes or foetal membranes):

Formed in amniotes (reptiles, birds, and mammals) outside the body of embryo by the cells of presumptive ectoderm, mesoderm and endoderm. These are:

- Chorion
- Amnion
- Allantois
- Yolk sac

1- Chorion (serosa): The outermost covering, formed by ectoderm and mesoderm as a protective layer head fold and tail fold of ectoderm and mesoderm emerge from respective parts of embryo,

start growing and folding upon the dorsal side where both fuse (= sero-amniotic connection) to form outer chorion and inner amnion.

✓ The site of exchange between the embryo and the environment around it.

✓ **In reptiles and birds**, the principal 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.

2- Amnion: It forms private (closest) chamber of embryo filled with amniotic fluid, isotonic to the body fluid. The aquatic medium for embryo to float and grow, denotes the aquatic origin of life. This fluid having cells of embryo is used (amniocentesis) to test its sex and genetic disorders.

✓ 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 an amniotes.

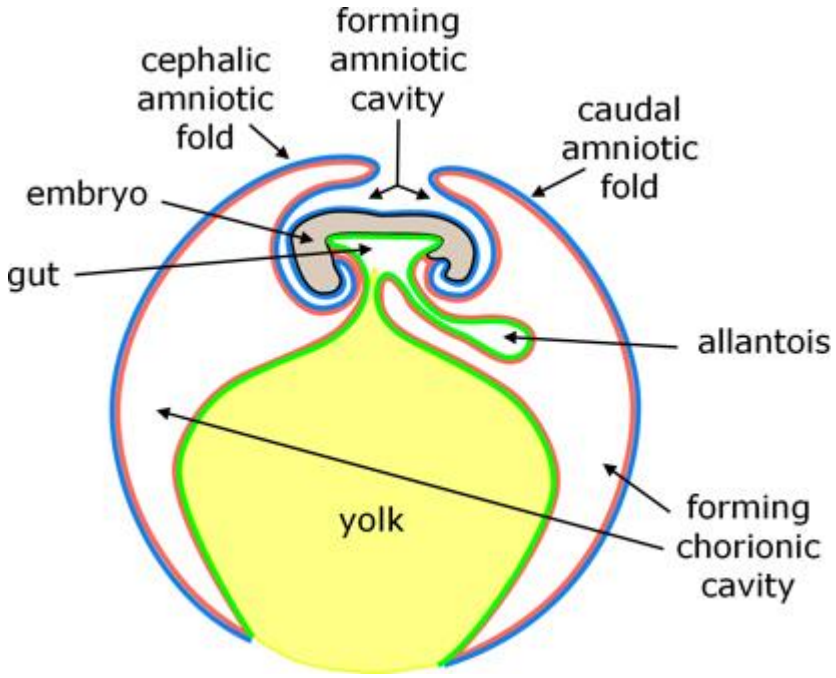
3- Allantois: It develops from the inner endoderm and outer mesoderm. Its principal functions are to act as a reservoir for storing

or removing urinary wastes and to mediate gas exchange between the embryo and its surroundings.

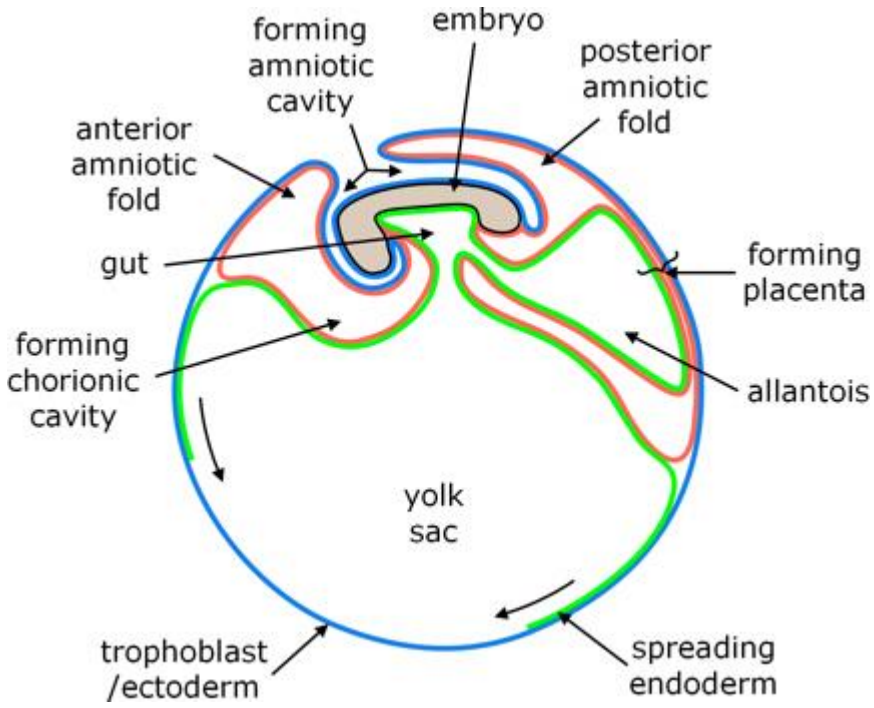
✓ **In reptiles and birds,** the allantois is a large sac, and because the egg is a closed system with respect to urinary wastes, the allantois must sequester nitrogenous by-product so that they do not subject the embryo to osmotic stress or toxic effects.

✓ **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.

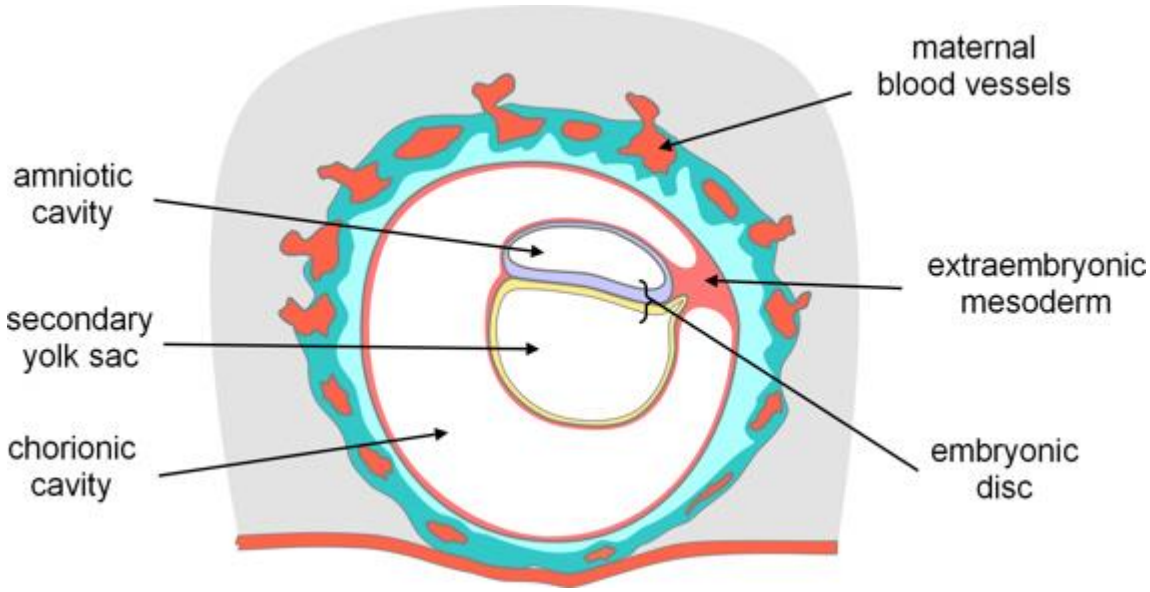
4- The yolk sac: The endodermal yolk sac is intimately involved with nutrition of the embryo in large-yolked forms such as reptiles and birds. Despite the lack of stored in mammalian eggs, the yolk sac has been preserved, possibly because other important secondary functions are associated with it. For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



Chick extraembryonic membranes



Rabbit extraembryonic membranes

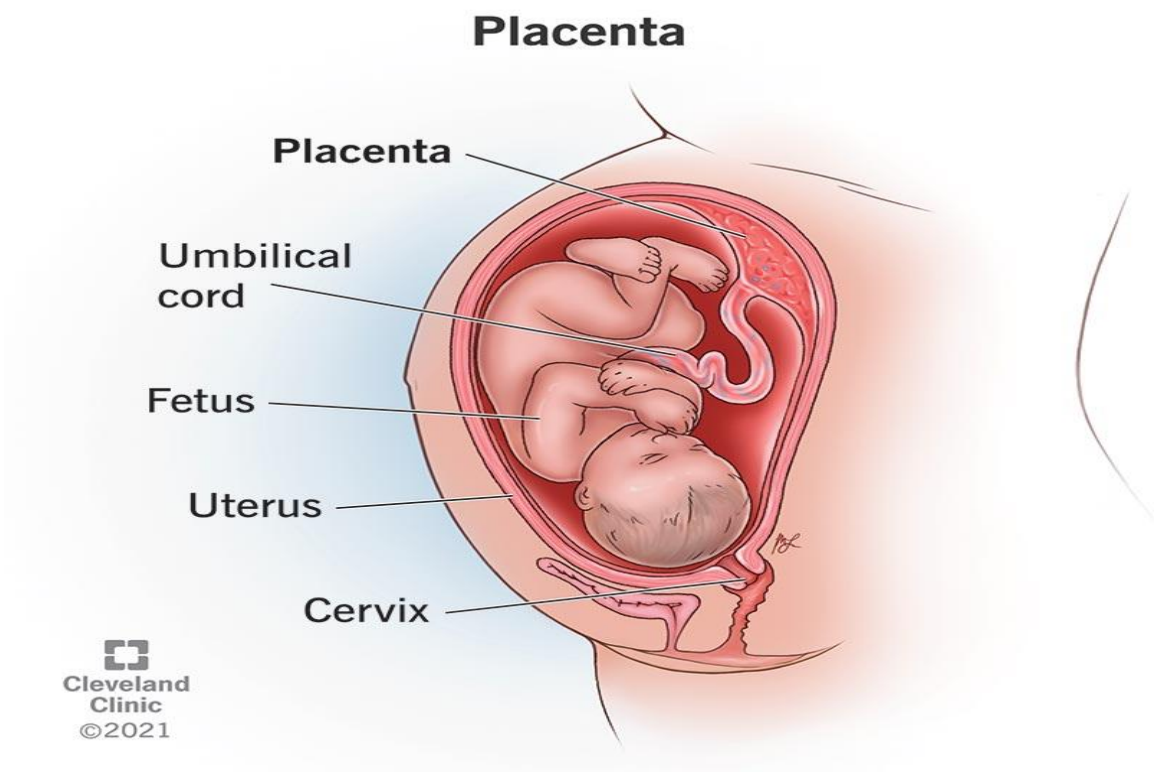


Human extraembryonic membranes

Placenta

What is the placenta?

The placenta is a temporary organ that forms in your uterus during pregnancy. It attaches to your uterine wall and provides nutrients and oxygen to your baby through the umbilical cord. Certain conditions of the placenta can cause pregnancy complications.



The placenta is a temporary organ that connects your baby to your uterus during pregnancy. The placenta develops shortly after conception and attaches to the wall of your uterus. Your baby is connected to the placenta by the umbilical cord. Together, the placenta and umbilical cord act as your baby's lifeline while in the uterus. Functions of the placenta include:

- Provides your baby with oxygen and nutrients.
- Removes harmful waste and carbon dioxide from your baby.
- Produces hormones that help your baby grow.
- Passes immunity from you to your baby.
- Helps protect your baby.

When does the placenta form?

- The placenta begins to form after a fertilized egg implants in your uterus around seven to 10 days after conception. It

continues to grow throughout your pregnancy to support your baby. The placenta starts as a few cells and grows to be several inches long.

When does the placenta take over?

- The placenta takes over hormone production by the end of the first trimester (12 weeks of pregnancy). Up until this time, the corpus luteum handles most of the hormone production. Many people's first-trimester symptoms of nausea and fatigue go away once the placenta takes over in the second trimester.

What does the placenta do?

- The placenta helps to keep your baby alive and healthy during pregnancy. Your blood passes through the placenta and provides oxygen, glucose and nutrients to your baby through the umbilical cord. The placenta can also filter out harmful waste and carbon dioxide from your baby's blood. The placenta enables the exchange of oxygen and nutrients between the bloodstreams of you and your baby without ever mixing them. It acts as your baby's lungs, kidneys and liver until birth.
- As you get closer to delivery, the placenta passes antibodies to your baby to jumpstart its immunity. This immunity sticks with your baby for the first several months of life.
- The placenta produces several important hormones like lactogen, estrogen and progesterone during pregnancy. These pregnancy hormones are beneficial to both you and your baby. For example, the placenta produces a hormone that suppresses milk production during pregnancy.

Does the placenta move?

- The placenta appears to move only because the uterus expands as the pregnancy and fetus grow. Your healthcare provider will look at the location of your placenta during your 20-week anatomy ultrasound and determine if its position may cause complications. Most placentas move to the top or side of the uterus by 32 weeks of pregnancy.

Where does the placenta form?

The placenta can form anywhere in your uterus. It develops wherever the fertilized egg implants into your uterine wall. Some of the positions of the placenta are:

- Posterior placenta: The placenta grows on the back wall of your uterus.
- Anterior placenta: The placenta grows on the front wall of your uterus closest to your abdomen.
- Fundal placenta: The placenta grows at the top of your uterus.
- Lateral placenta: The placenta grows on the right or left wall of your uterus.

The placenta can move up until about 32 weeks of pregnancy. It's common to have a placenta that moves upwards and away from your cervix as your baby gets bigger.

What does the placenta look like?

The placenta looks like a disc of bumpy tissue rich in blood vessels, making it appear dark red at term. Most of the mature placental tissue

is made up of blood vessels. They connect with the baby through the umbilical cord and branch throughout the placenta disc like the limbs of a tree.

What color is the placenta?

The placenta has two sides: the side attached to your uterus and the side closest to your baby. The side attached to your uterine wall is a deep reddish blue color, while the side facing your baby is gray.

How big is a normal placenta?

The placenta is about 10 inches long and 1 inch thick at its center. It weighs around 16 ounces (1 pound) by the time your baby is born.

What is the placenta made of?

The placenta begins to develop when the fertilized egg implants into your uterine wall. The placenta contains mostly blood vessels contained within structures called “villi.” The blood vessels connect with the baby’s bloodstream through the umbilical cord. The rest of the placental tissues mainly connect the villi to the umbilical cord and allow your blood to bathe the villi, supplying the baby with oxygen and nutrients.

What types of substances are bad for the placenta?

Medicine, drugs, alcohol and nicotine can all transfer from your bloodstream to your baby through the placenta. Talk to your healthcare provider before taking any prescription or over-the-counter medications (including vitamins and supplements) during

pregnancy. Drinking alcohol or smoking cigarettes is not recommended during pregnancy.

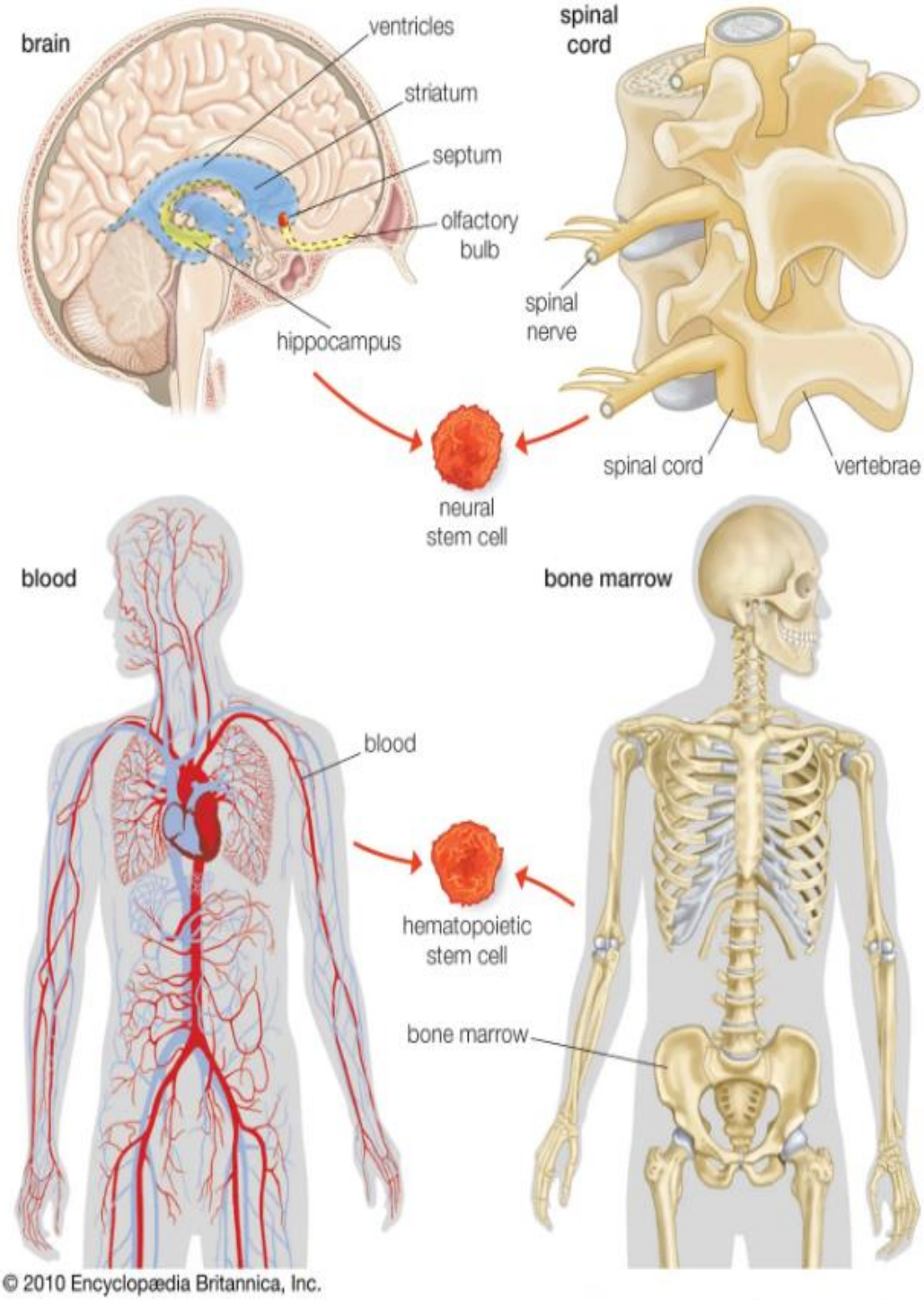
How is the placenta delivered?

The placenta is delivered shortly after your baby is born (usually between five and 30 minutes after). This is called the afterbirth or the third stage of labor. If you've delivered your baby vaginally, your uterus will continue to contract to expel the placenta. Your healthcare provider may push on your belly or ask you for one final push. If your baby was born via C-section, your healthcare provider removes the placenta through the incision used to deliver your baby. In rare cases, parts of the placenta stay in your uterus after delivery. This can cause bleeding, pain and infection.

Stem cells

Stem cell, an undifferentiated cell that can divide to produce some offspring cells that continue as stem cells and some cells that are destined to differentiate (become specialized). Stem cells are an ongoing source of the differentiated cells that make up the tissues and organs of animals and plants. There is great interest in stem cells because they have potential in the development of therapies for replacing defective or damaged cells resulting from a variety of disorders and injuries, such as Parkinson disease, heart disease, and diabetes. There are two major types of stem cells: embryonic stem cells and adult stem cells, which are also called tissue stem cells.

Anatomical sources of neural and hematopoietic stem cells



Embryonic stem cells

Embryonic stem cells (often referred to as ES cells) are stem cells that are derived from the inner cell mass of a mammalian embryo at a very early stage of development, when it is composed of a hollow sphere of dividing cells (a blastocyst). Embryonic stem cells from human embryos and from embryos of certain other mammalian species can be grown in tissue culture.

Human embryonic stem cells

Extensive experience with mouse embryonic stem cells made it possible for scientists to grow human embryonic stem cells from early human embryos, and the first human stem cell line was created in 1998. Human embryonic stem cells are in many respects similar to mouse embryonic stem cells, but they do not require LIF for their maintenance. The human embryonic stem cells form a wide variety of differentiated tissues in vitro, and they form teratomas when grafted into immunosuppressed mice. It is not known whether the cells can colonize all the tissues of a human embryo, but it is presumed from their other properties that they are indeed pluripotent cells, and they therefore are regarded as a possible source of differentiated cells for cell therapy—the replacement of a patient's defective cell type with healthy cells. Large quantities of cells, such as dopamine-secreting neurons for the treatment of Parkinson disease and insulin-secreting pancreatic beta cells for the treatment of diabetes, could be produced from embryonic stem cells for cell transplantation. Cells for this purpose have previously been obtainable only from sources in very limited supply, such as the pancreatic beta cells obtained from the cadavers of human organ donors.

The use of human embryonic stem cells evokes ethical concerns, because the blastocyst-stage embryos are destroyed in the process of obtaining the stem cells. The embryos from which stem cells have been obtained are produced through in vitro fertilization, and people who consider preimplantation human embryos to be human beings generally believe that such work is morally wrong. Others accept it because they regard the blastocysts to be simply balls of cells, and human cells used in laboratories have not previously been accorded any special moral or legal status. Moreover, it is known that none of the cells of the inner cell mass are exclusively destined to become part of the embryo itself—all of the cells contribute some or all of their cell offspring to the placenta, which also has not been accorded any special legal status. The divergence of views on this issue is illustrated by the fact that the use of human embryonic stem cells is allowed in some countries and prohibited in others.

In 2009 the U.S. Food and Drug Administration approved the first clinical trial designed to test a human embryonic stem cell-based therapy, but the trial was halted in late 2011 because of a lack of funding and a change in lead American biotech company Geron's business directives. The therapy to be tested was known as GRNOPC1, which consisted of progenitor cells (partially differentiated cells) that, once inside the body, matured into neural cells known as oligodendrocytes. The oligodendrocyte progenitors of GRNOPC1 were derived from human embryonic stem cells. The therapy was designed for the restoration of nerve function in persons suffering from acute spinal cord injury.

Embryonic germ cells

Embryonic germ (EG) cells, derived from primordial germ cells found in the gonadal ridge of a late embryo, have many of the properties of embryonic stem cells. The primordial germ cells in an embryo develop into stem cells that in an adult generate the reproductive gametes (sperm or eggs). In mice and humans it is possible to grow embryonic germ cells in tissue culture with the appropriate growth factors—namely, LIF and another cytokine called fibroblast growth factor.

Adult stem cells

Some tissues in the adult body, such as the epidermis of the skin, the lining of the small intestine, and bone marrow, undergo continuous cellular turnover. They contain stem cells, which persist indefinitely, and a much larger number of "transit amplifying cells," which arise from the stem cells and divide a finite number of times until they become differentiated. The stem cells exist in niches formed by other cells, which secrete substances that keep the stem cells alive and active. Some types of tissue, such as liver tissue, show minimal cell division or undergo cell division only when injured. In such tissues there is probably no special stem-cell population, and any cell can participate in tissue regeneration when required.

Epithelial stem cells

The epidermis of the skin contains layers of cells called keratinocytes. Only the basal layer, next to the dermis, contains cells that divide. A number of these cells are stem cells, but the majority are transit amplifying cells. The keratinocytes slowly move outward through the epidermis as they mature, and they eventually die and are sloughed

off at the surface of the skin. The epithelium of the small intestine forms projections called villi, which are interspersed with small pits called crypts. The dividing cells are located in the crypts, with the stem cells lying near the base of each crypt. Cells are continuously produced in the crypts, migrate onto the villi, and are eventually shed into the lumen of the intestine. As they migrate, they differentiate into the cell types of characteristic of the intestinal epithelium.

Bone marrow and hematopoietic stem cells

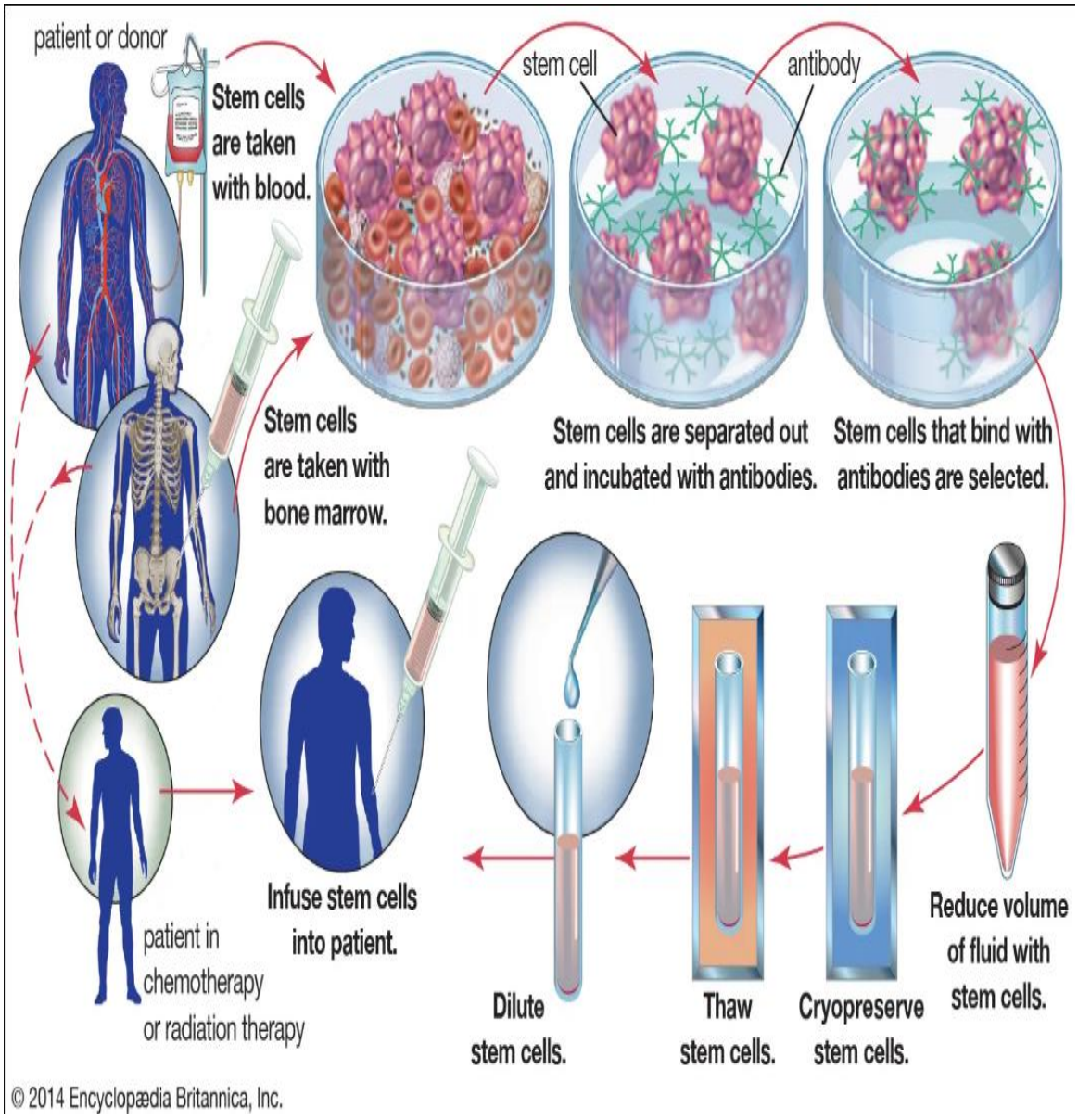
Bone marrow contains cells called hematopoietic stem cells, which generate all the cell types of the blood and the immune system. Hematopoietic stem cells are also found in small numbers in peripheral blood and in larger numbers in umbilical cord blood. In bone marrow, hematopoietic stem cells are anchored to osteoblasts of the trabecular bone and to blood vessels. They generate progeny that can become lymphocytes, granulocytes, red blood cells, and certain other cell types, depending on the balance of growth factors in their immediate environment.

Work with experimental animals has shown that transplants of hematopoietic stem cells can occasionally colonize other tissues, with the transplanted cells becoming neurons, muscle cells, or epithelia. The degree to which transplanted hematopoietic stem cells are able to colonize other tissues is exceedingly small. Despite this, the use of hematopoietic stem cell transplants is being explored for conditions such as heart disease or autoimmune disorders. It is an especially attractive option for those opposed to the use of embryonic stem cells.

Bone marrow transplants (also known as bone marrow grafts) represent a type of stem cell therapy that is in common use. They are used to allow cancer patients to survive otherwise lethal doses of radiation therapy or chemotherapy that destroy the stem cells in bone marrow. For this procedure, the patient's own marrow is harvested before the cancer treatment and is then reinfused into the body after treatment. The hematopoietic stem cells of the transplant colonize the damaged marrow and eventually repopulate the blood and the immune system with functional cells. Bone marrow transplants are also often carried out between individuals (allograft). In this case the grafted marrow has some beneficial antitumour effect. Risks associated with bone marrow allografts include rejection of the graft by the patient's immune system and reaction of immune cells of the graft against the patient's tissues (graft-versus-host disease).

Bone marrow is a source for mesenchymal stem cells (sometimes called marrow stromal cells, or MSCs), which are precursors to non-hematopoietic stem cells that have the potential to differentiate into several different types of cells, including cells that form bone, muscle, and connective tissue. In cell cultures, bone-marrow-derived mesenchymal stem cells demonstrate pluripotency when exposed to substances that influence cell differentiation. Harnessing these pluripotent properties has become highly valuable in the generation of transplantable tissues and organs. In 2008 scientists used mesenchymal stem cells to bioengineer a section of trachea that was transplanted into a woman whose upper airway had been severely damaged by tuberculosis. The stem cells were derived from the woman's bone marrow, cultured in a laboratory, and used for tissue

engineering. In the engineering process, a donor trachea was stripped of its interior and exterior cell linings, leaving behind a trachea "scaffold" of connective tissue. The stem cells derived from the recipient were then used to recolonize the interior of the scaffold, and normal epithelial cells, also isolated from the recipient, were used to recolonize the exterior of the trachea. The use of the recipient's own cells to populate the trachea scaffold prevented immune rejection and eliminated the need for immunosuppression therapy. The transplant, which was successful, was the first of its kind.



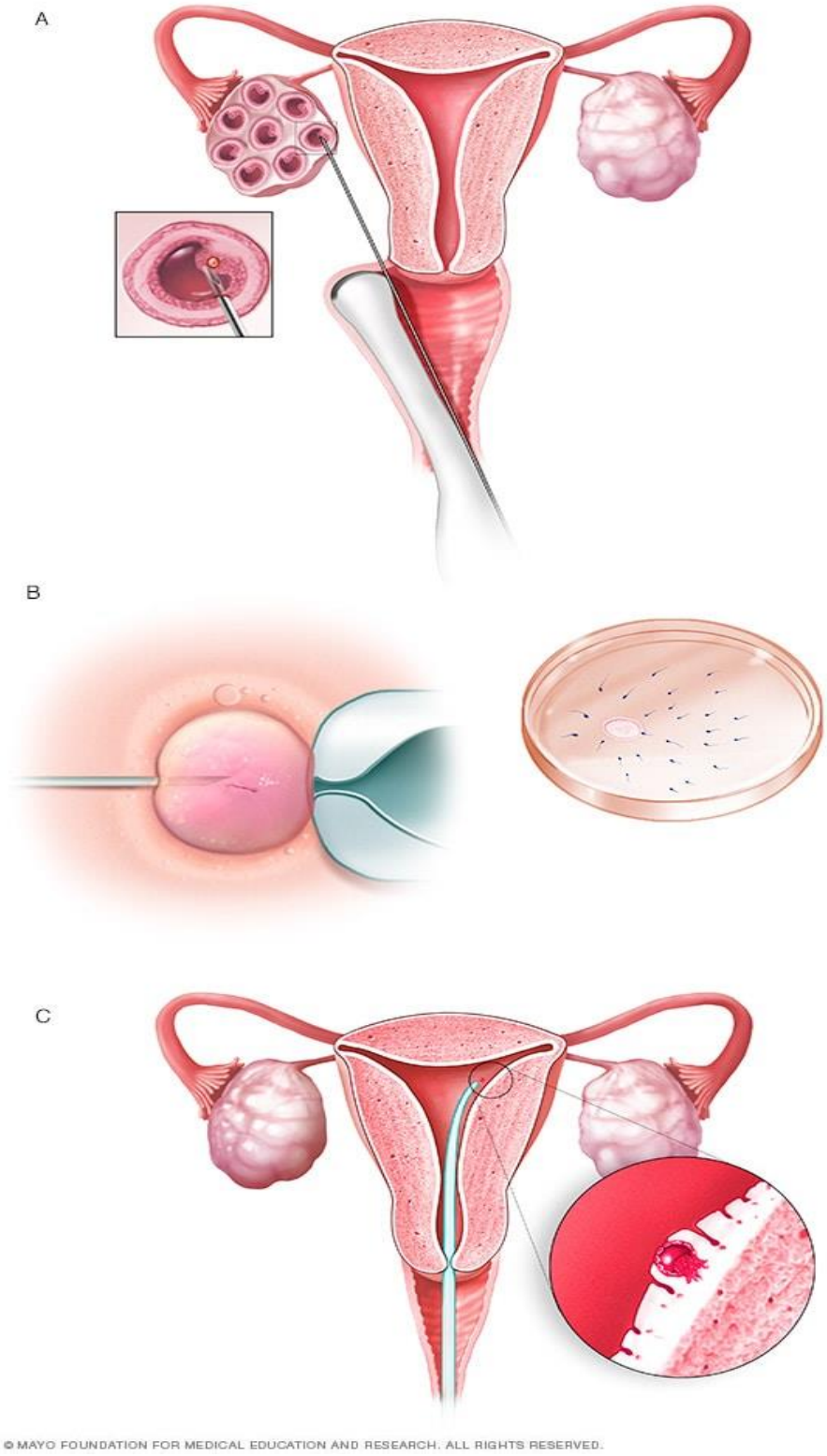
In vitro fertilization (IVF)

In vitro fertilization (IVF) is a complex series of procedures used to help with fertility or prevent genetic problems and assist with the conception of a child.

During IVF, mature eggs are collected (retrieved) from ovaries and fertilized by sperm in a lab. Then the fertilized egg (embryo) or eggs (embryos) are transferred to a uterus. One full cycle of IVF takes about three weeks. Sometimes these steps are split into different parts and the process can take longer.

IVF is the most effective form of assisted reproductive technology. The procedure can be done using a couple's own eggs and sperm. Or IVF may involve eggs, sperm or embryos from a known or anonymous donor. In some cases, a gestational carrier — someone who has an embryo implanted in the uterus — might be used.

Your chances of having a healthy baby using IVF depend on many factors, such as your age and the cause of infertility. In addition, IVF can be time-consuming, expensive and invasive. If more than one embryo is transferred to the uterus, IVF can result in a pregnancy with more than one fetus (multiple pregnancy).



During in vitro fertilization, eggs are removed from mature follicles within an ovary (A). An egg is fertilized by injecting a single sperm into the egg or mixing the egg with sperm in a petri dish (B). The fertilized egg (embryo) is transferred into the uterus (C).

Why it's done

In vitro fertilization (IVF) is a treatment for infertility or genetic problems. If IVF is performed to treat infertility, you and your partner might be able to try less-invasive treatment options before attempting IVF, including fertility drugs to increase production of eggs or intrauterine insemination — a procedure in which sperm are placed directly in the uterus near the time of ovulation.

Sometimes, IVF is offered as a primary treatment for infertility in women over age 40. IVF can also be done if you have certain health conditions. For example, IVF may be an option if you or your partner has:

- **Fallopian tube damage or blockage.** Fallopian tube damage or blockage makes it difficult for an egg to be fertilized or for an embryo to travel to the uterus.
- **Ovulation disorders.** If ovulation is infrequent or absent, fewer eggs are available for fertilization.
- **Endometriosis.** Endometriosis occurs when tissue similar to the lining of the uterus implants and grows outside of the uterus — often affecting the function of the ovaries, uterus and fallopian tubes.
- **Uterine fibroids.** Fibroids are benign tumors in the uterus. They are common in women in their 30s and 40s. Fibroids can interfere with implantation of the fertilized egg.
- **Previous tubal sterilization or removal.** Tubal ligation is a type of sterilization in which the fallopian tubes are cut or blocked to

permanently prevent pregnancy. If you wish to conceive after tubal ligation, IVF may be an alternative to tubal ligation reversal surgery.

- **Impaired sperm production or function.** Below-average sperm concentration, weak movement of sperm (poor mobility), or abnormalities in sperm size and shape can make it difficult for sperm to fertilize an egg. If semen abnormalities are found, a visit to an infertility specialist might be needed to see if there are correctable problems or underlying health concerns.

- **Unexplained infertility.** Unexplained infertility means no cause of infertility has been found despite evaluation for common causes.

- **A genetic disorder.** If you or your partner is at risk of passing on a genetic disorder to your child, you may be candidates for preimplantation genetic testing — a procedure that involves IVF. After the eggs are harvested and fertilized, they're screened for certain genetic problems, although not all genetic problems can be found. Embryos that don't contain identified problems can be transferred to the uterus.

- **Fertility preservation for cancer or other health conditions.** If you're about to start cancer treatment — such as radiation or chemotherapy — that could harm your fertility, IVF for fertility preservation may be an option. Women can have eggs harvested from their ovaries and frozen in an unfertilized state for later use. Or the eggs can be fertilized and frozen as embryos for future use.

Women who don't have a functional uterus or for whom pregnancy poses a serious health risk might choose IVF using another person to carry the pregnancy (gestational carrier). In this case, the woman's eggs are fertilized with sperm, but the resulting embryos are placed in the gestational carrier's uterus.

Risks of IVF include:

- **Multiple births.** IVF increases the risk of multiple births if more than one embryo is transferred to your uterus. A pregnancy with multiple fetuses carries a higher risk of early labor and low birth weight than pregnancy with a single fetus does.

- **Premature delivery and low birth weight.** Research suggests that IVF slightly increases the risk that the baby will be born early or with a low birth weight.

- **Ovarian hyperstimulation syndrome.** Use of injectable fertility drugs, such as human chorionic gonadotropin (HCG), to induce ovulation can cause ovarian hyperstimulation syndrome, in which your ovaries become swollen and painful.

Symptoms typically last a week and include mild abdominal pain, bloating, nausea, vomiting and diarrhea. If you become pregnant, however, your symptoms might last several weeks. Rarely, it's possible to develop a more severe form of ovarian hyperstimulation syndrome that can also cause rapid weight gain and shortness of breath.

- **Miscarriage.** The rate of miscarriage for women who conceive using IVF with fresh embryos is similar to that of women who

conceive naturally — about 15% to 25% — but the rate increases with maternal age.

- **Egg-retrieval procedure complications.** Use of an aspirating needle to collect eggs could possibly cause bleeding, infection or damage to the bowel, bladder or a blood vessel. Risks are also associated with sedation and general anesthesia, if used.

- **Ectopic pregnancy.** About 2% to 5% of women who use IVF will have an ectopic pregnancy — when the fertilized egg implants outside the uterus, usually in a fallopian tube. The fertilized egg can't survive outside the uterus, and there's no way to continue the pregnancy.

- **Birth defects.** The age of the mother is the primary risk factor in the development of birth defects, no matter how the child is conceived. More research is needed to determine whether babies conceived using IVF might be at increased risk of certain birth defects.

- **Cancer.** Although some early studies suggested there may be a link between certain medications used to stimulate egg growth and the development of a specific type of ovarian tumor, more-recent studies do not support these findings. There does not appear to be a significantly increased risk of breast, endometrial, cervical, or ovarian cancer after IVF.

- **Stress.** Use of IVF can be financially, physically, and emotionally draining. Support from counselors, family and friends can help you and your partner through the ups and downs of infertility treatment.

How you prepare

The Centers for Disease Control and Prevention and the Society for Assisted Reproductive Technology provide information online about U.S. clinics' individual pregnancy and live birth rates.

A clinic's success rate depends on many factors. These include patients' ages and medical issues, as well as the clinic's treatment population and treatment approaches. Ask for detailed information about the costs associated with each step of the procedure.

Before beginning a cycle of IVF using your own eggs and sperm, you and your partner will likely need various screenings, including:

- **Ovarian reserve testing.** To determine the quantity and quality of your eggs, your doctor might test the concentration of follicle-stimulating hormone (FSH), estradiol (estrogen) and anti-mullerian hormone in your blood during the first few days of your menstrual cycle. Test results, often used together with an ultrasound of your ovaries, can help predict how your ovaries will respond to fertility medication.
- **Semen analysis.** If not done as part of your initial fertility evaluation, your doctor will conduct a semen analysis shortly before the start of an IVF treatment cycle.
- **Infectious disease screening.** You and your partner will both be screened for infectious diseases, including HIV.

- **Practice (mock) embryo transfer.** Your doctor might conduct a mock embryo transfer to determine the depth of your uterine cavity and the technique most likely to successfully place the embryos into your uterus.

- **Uterine exam.** Your doctor will examine the inside lining of the uterus before you start IVF. This might involve a sonohysterography — in which fluid is injected through the cervix into your uterus — and an ultrasound to create images of your uterine cavity. Or it might include a hysteroscopy — in which a thin, flexible, lighted telescope (hysteroscope) is inserted through your vagina and cervix into your uterus.

Before beginning a cycle of IVF, consider important questions, including:

- **How many embryos will be transferred?** The number of embryos transferred is typically based on age and number of eggs retrieved. Since the rate of implantation is lower for older women, more embryos are usually transferred — except for women using donor eggs or genetically tested embryos.

Most doctors follow specific guidelines to prevent a higher order multiple pregnancy, such as triplets or more. In some countries, legislation limits the number of embryos that can be transferred. Make sure you and your doctor agree on the number of embryos that will be transferred before the transfer procedure.

- **What will you do with any extra embryos?** Extra embryos can be frozen and stored for future use for several years. Not all

embryos will survive the freezing and thawing process, although most will.

Having frozen embryos can make future cycles of IVF less expensive and less invasive. Or, you might be able to donate unused frozen embryos to another couple or a research facility. You might also choose to discard unused embryos.

- **How will you handle a multiple pregnancy?** If more than one embryo is transferred to your uterus, IVF can result in a multiple pregnancy — which poses health risks for you and your babies. In some cases, fetal reduction can be used to help a woman deliver fewer babies with lower health risks. Pursuing fetal reduction, however, is a major decision with ethical, emotional, and psychological consequences.

- **Have you considered the potential complications associated with using donor eggs, sperm or embryos, or a gestational carrier?** A trained counselor with expertise in donor issues can help you understand the concerns, such as the legal rights of the donor. You may also need an attorney to file court papers to help you become legal parents of an implanted embryo.

What you can expect

IVF involves several steps — ovarian stimulation, egg retrieval, sperm retrieval, fertilization, and embryo transfer. One cycle of IVF can take about two to three weeks. More than one cycle may be needed.

Ovulation induction

The start of an IVF cycle begins by using synthetic hormones to stimulate the ovaries to produce multiple eggs — rather than the single egg that typically develops each month. Multiple eggs are needed because some eggs won't fertilize or develop normally after fertilization.

Several different medications may be used, such as:

- **Medications for ovarian stimulation.** To stimulate your ovaries, you might receive an injectable medication containing a follicle-stimulating hormone (FSH), a luteinizing hormone (LH) or a combination of both. These medications stimulate more than one egg to develop at a time.
- **Medications for oocyte maturation.** When the follicles are ready for egg retrieval — generally after eight to 14 days — you will take human chorionic gonadotropin (HCG) or other medications to help the eggs mature.
- **Medications to prevent premature ovulation.** These medications prevent your body from releasing the developing eggs too soon.
- **Medications to prepare the lining of your uterus.** On the day of egg retrieval or at the time of embryo transfer, your doctor might recommend that you begin taking progesterone supplements to make the lining of your uterus more receptive to implantation.

Your doctor will work with you to determine which medications to use and when to use them.

Typically, you'll need one to two weeks of ovarian stimulation before your eggs are ready for retrieval. To determine when the eggs are ready for collection, you may have:

- **Vaginal ultrasound,** an imaging exam of your ovaries to monitor the development of follicles — fluid-filled ovarian sacs where eggs mature
- **Blood tests,** to measure your response to ovarian stimulation medications — estrogen levels typically increase as follicles develop, and progesterone levels remain low until after ovulation

Sometimes IVF cycles need to be canceled before egg retrieval for one of these reasons:

- Inadequate number of follicles developing
- Premature ovulation
- Too many follicles developing, creating a risk of ovarian hyperstimulation syndrome
- Other medical issues

If your cycle is canceled, your doctor might recommend changing medications or their doses to promote a better response during future IVF cycles. Or you may be advised that you need an egg donor.

Egg retrieval

Egg retrieval can be done in your doctor's office or a clinic 34 to 36 hours after the final injection and before ovulation.

- During egg retrieval, you'll be sedated and given pain medication.
- Transvaginal ultrasound aspiration is the usual retrieval method. An ultrasound probe is inserted into your vagina to identify follicles. Then a thin needle is inserted into an ultrasound guide to go through the vagina and into the follicles to retrieve the eggs.
- If your ovaries aren't accessible through transvaginal ultrasound, an abdominal ultrasound may be used to guide the needle.
- The eggs are removed from the follicles through a needle connected to a suction device. Multiple eggs can be removed in about 20 minutes.
- After egg retrieval, you may experience cramping and feelings of fullness or pressure.
- Mature eggs are placed in a nutritive liquid (culture medium) and incubated. Eggs that appear healthy and mature will be mixed with sperm to attempt to create embryos. However, not all eggs may be successfully fertilized.

Sperm retrieval

If you're using your partner's sperm, a semen sample needs to be provided at your doctor's office or clinic the morning of egg retrieval.

Typically, the semen sample is collected through masturbation. Other methods, such as testicular aspiration — the use of a needle or surgical procedure to extract sperm directly from the testicle — are sometimes required. Donor sperm also can be used. Sperm are separated from the semen fluid in the lab.

Fertilization

Fertilization can be attempted using two common methods:

- **Conventional insemination.** During conventional insemination, healthy sperm and mature eggs are mixed and incubated overnight.
- **Intracytoplasmic sperm injection (ICSI).** In ICSI, a single healthy sperm is injected directly into each mature egg. ICSI is often used when semen quality or number is a problem or if fertilization attempts during prior IVF cycles failed.

In certain situations, your doctor may recommend other procedures before embryo transfer.

- **Assisted hatching.** About five to six days after fertilization, an embryo "hatches" from its surrounding membrane (zona pellucida), allowing it to implant into the lining of the uterus. If you're an older woman, or if you have had multiple failed IVF attempts, your doctor might recommend assisted hatching — a technique in which a hole is made in the zona pellucida just before transfer to help the embryo hatch and implant. Assisted hatching is also useful for eggs or

embryos that have been previously frozen as the process can harden the zona pellucida.

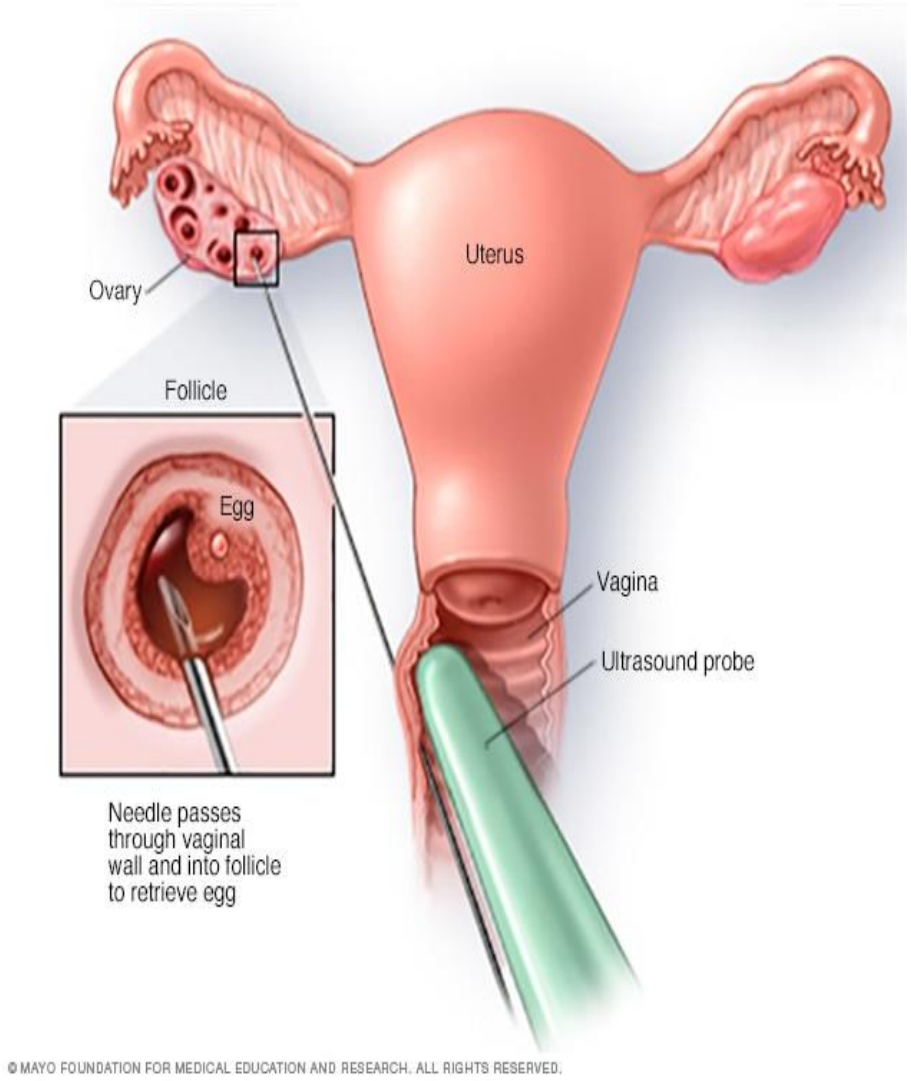
- **Preimplantation genetic testing.** Embryos are allowed to develop in the incubator until they reach a stage where a small sample can be removed and tested for specific genetic diseases or the correct number of chromosomes, typically after five to six days of development. Embryos that don't contain affected genes or chromosomes can be transferred to your uterus. While preimplantation genetic testing can reduce the likelihood that a parent will pass on a genetic problem, it can't eliminate the risk. Prenatal testing may still be recommended.

Embryo transfer

Embryo transfer is done at your doctor's office or a clinic and usually takes place two to five days after egg retrieval.

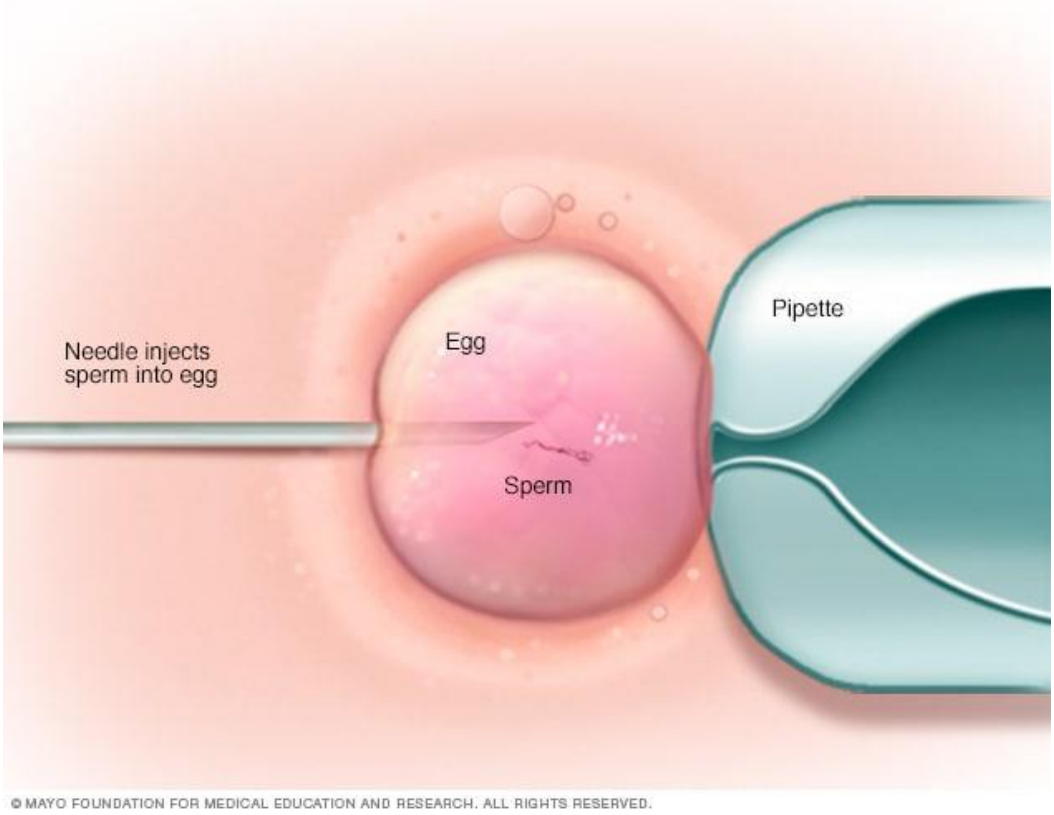
- You might be given a mild sedative. The procedure is usually painless, although you might experience mild cramping.
- The doctor will insert a long, thin, flexible tube called a catheter into your vagina, through your cervix and into your uterus.
- A syringe containing one or more embryos suspended in a small amount of fluid is attached to the end of the catheter.
- Using the syringe, the doctor places the embryo or embryos into your uterus.

If successful, an embryo will implant in the lining of your uterus about six to 10 days after egg retrieval.



Egg-retrieval technique

Typically, transvaginal ultrasound aspiration is used to retrieve eggs. During this procedure, an ultrasound probe is inserted into your vagina to identify follicles, and a needle is guided through the vagina and into the follicles. The eggs are removed from the follicles through the needle, which is connected to a suction device.



ICSI

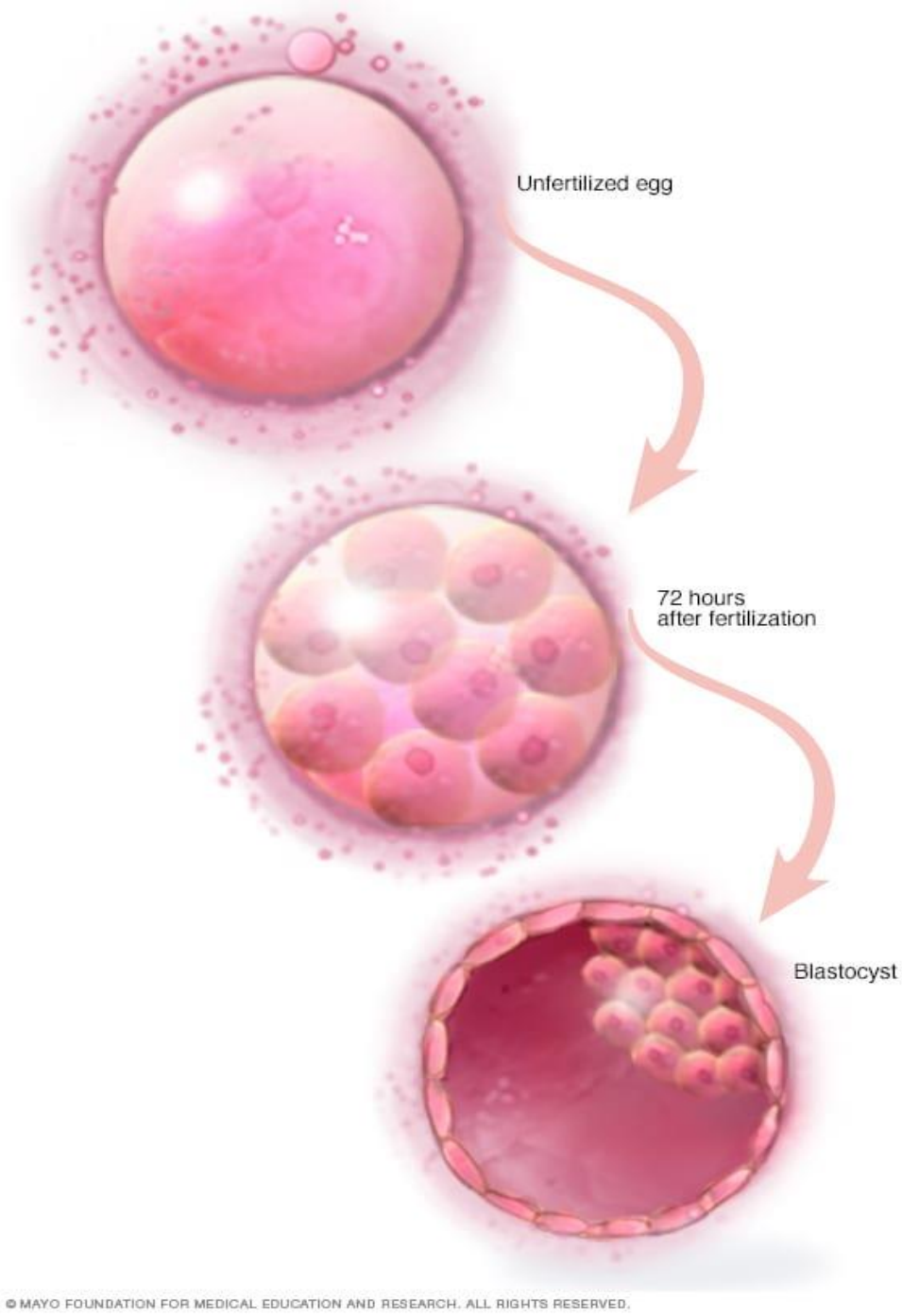
In intracytoplasmic sperm injection (ICSI), a single healthy sperm is injected directly into each mature egg. ICSI is often used when semen quality or number is a problem or if fertilization attempts during prior in vitro fertilization cycles failed.

After the procedure

After the embryo transfer, you can resume your usual daily activities. However, your ovaries may still be enlarged. Consider avoiding vigorous activity, which could cause discomfort.

Typical side effects include:

- Passing a small amount of clear or bloody fluid shortly after the procedure — due to the swabbing of the cervix before the embryo transfer
- Breast tenderness due to high estrogen levels
- Mild bloating
- Mild cramping
- Constipation



Blastocyst

Three days after fertilization, a normally developing embryo will contain about six to 10 cells. By the fifth or sixth day, the fertilized egg is known as a blastocyst — a rapidly dividing ball of cells. The inner group of cells will become the embryo. The outer group will become the cells that nourish and protect it.

If you develop moderate or severe pain after the embryo transfer, contact your doctor. He or she will evaluate you for complications such as infection, twisting of an ovary (ovarian torsion) and severe ovarian hyperstimulation syndrome.

Results

About 12 days to two weeks after egg retrieval, your doctor will test a sample of your blood to detect whether you're pregnant.

- **If you're pregnant,** your doctor will refer you to an obstetrician or other pregnancy specialist for prenatal care.
- **If you're not pregnant,** you'll stop taking progesterone and likely get your period within a week. If you don't get your period or you have unusual bleeding, contact your doctor. If you're interested in attempting another cycle of in vitro fertilization (IVF), your doctor might suggest steps you can take to improve your chances of getting pregnant through IVF.

The chances of giving birth to a healthy baby after using IVF depend on various factors, including:

- **Maternal age.** The younger you are, the more likely you are to get pregnant and give birth to a healthy baby using your own eggs during IVF. Women age 41 and older are often counseled to consider using donor eggs during IVF to increase the chances of success.
- **Embryo status.** Transfer of embryos that are more developed is associated with higher pregnancy rates compared with less-developed

embryos (day two or three). However, not all embryos survive the development process. Talk with your doctor or other care provider about your specific situation.

- **Reproductive history.** Women who've previously given birth are more likely to be able to get pregnant using IVF than are women who've never given birth. Success rates are lower for women who've previously used IVF multiple times but didn't get pregnant.

- **Cause of infertility.** Having a normal supply of eggs increases your chances of being able to get pregnant using IVF. Women who have severe endometriosis are less likely to be able to get pregnant using IVF than are women who have unexplained infertility.

- **Lifestyle factors.** Women who smoke typically have fewer eggs retrieved during IVF and may miscarry more often. Smoking can lower a woman's chance of success using IVF by 50%. Obesity can decrease your chances of getting pregnant and having a baby. Use of alcohol, recreational drugs, excessive caffeine and certain medications also can be harmful.

The End

Glossary of embryological terms

Gametes

gamete

Reproductive cell: e.g. ovum or sperm.

meiosis

The process where a single cell divides twice to give four cells containing half of the original genetic material; typically produces sperm or ovum.

haploid

Sperm and egg cells result from meiosis and are haploid: they have only half of the number of chromosomes of somatic (body) cells, e.g. in humans, haploid cells have 23 chromosomes, whereas somatic cells have 46 chromosomes.

polar body

Production of an ovum involves 2 rounds of cell division, giving rise to 4 (sometimes only 3) nuclei, only one of which is incorporated within an ovum. The resulting 3 (or 2) nuclei are small polar bodies which eventually degrade. One polar body may remain associated with the ovum for a while. [check]

animal pole and **vegetal pole**

In most ova, the nucleus is not in the centre but displaced to one end - this is called the animal pole, and the opposite end is the vegetal pole. In general there is more yolk towards the vegetal pole.

germinal disc

The embryo-forming part of the egg, e.g. excluding the body of the yolk.

zona pellucida

A clear layer surrounding the cell of the mammalian ovum (c.f. area pellucida of bird and reptile blastula).

corona radiata

The outermost layer of the mammalian ovum.

Zygote

zygote

Fertilised egg.

pronucleus

A pronucleus is the male or female polar body or ‘nucleus’ within the zygote, at the start of fertilisation.

Cleavage

cleavage

The first few cell divisions of the zygote, during which there is an increase in number of cells, but not in overall size or mass, so the cells get smaller.

holoblastic cleavage

The cell divisions pass right through the zygote.

meroblastic cleavage

The cell divisions do not extend right through the zygote (generally there is a large amount of yolk)

discoidal cleavage

A form of meroblastic cleavage where the cell divisions are restricted to the germinal disc.

rotational cleavage

A form of holoblastic cleavage where the two second cell divisions are in different planes, one meridional and one equatorial.

morula

An early stage of embryonic development, especially in mammals, when the cells are in the form of a loose clump.

compaction

A stage of embryonic development when the loose clump of cells becomes more compact, usually involving the formation of tight junctions between peripheral cells and the formation of a central blastocoel.

blastomere

One of the cells resulting from cleavage; or one of the cells of the blastoderm.

blastodisc

The germinal disc during and after cleavage, up to the stage of the blastula.

Blastula

blastula

The early embryo, after cleavage and the first differentiation of cells, just before gastrulation.

blastocyst

The name for the blastula in mammals.

blastoderm

A surface layer of cells of the blastula.

blastocoel

A space within the body of cells of the blastula, generally arising during cleavage.

subgerminal space / cavity

A space between the cells of the blastula and the underlying yolk.

yolk syncytial layer (YSL)

A layer at the surface of the yolk containing nuclei, but the cytoplasm of the cells is continuous with the yolk, i.e. the cell membranes are incomplete.

mid blastula transition (MBT)

Generally refers to the stage of the blastula when the embryonic genome becomes active and/or the cells begin to differentiate.

epiblast

In amniotes: the upper, epithelial layer of the blastula, i.e. before gastrulation, which in most cases is the source of all of the germ layers.

In anamniotes: sometimes used to refer to the upper, epithelial layer of the gastrula, i.e. after gastrulation, which usually becomes the ectoderm.

hypoblast

In amniotes: a layer of cells below the epiblast, which is substantially displaced in the course of gastrulation and does not become part of the embryo.

In anamniotes: sometimes used to refer to a lower layer of cells that have involuted in the course of gastrulation, and usually becomes mesoderm and endoderm (except amphibians).

trophoblast

The outer layer of cells of the mammalian blastocyst.

inner cell mass

Generally refers to mammals where the blastocyst comprises an outer layer of cells (the trophoblast), an inner cell mass (generally containing epiblast and hypoblast) and a blastocoel.

area pellucida

Central part of the reptile or bird blastula, that is over the blastocoel and is relatively translucent (c.f. zona pellucida of the mammalian ovum).

area opaca

Area of the reptile or bird blastula, that is around the area pellucida and above the marginal cells, and is relatively opaque.

enveloping layer (EVL)

A thin outer layer of cells of the teleost blastula, which persists through early embryonic development, but is shed at hatching.

Gastrulation

gastrulation

The overall term for the various processes through which the blastula develops into the gastrula in which all three germ layers - ectoderm, mesoderm and endoderm - are formed.

presumptive and **definitive**

Presumptive refers to cells which are still undifferentiated, or partly differentiated, but destined to become the final or definitive tissue.

epithelial

Surface cells are generally epithelal in nature, and move as a sheet of cells.

mesenchymal

Mesenchymal cells are usually below the surface, and migrate individually through tissues.

EMT and **MET**

When cells transition between epithelial and mesenchymal in nature by 'epithelail-to-mesenchymal transition' or 'mesenchymal-to-epithelial transition'.

epiboly

Spreading of a layer of cells in the course of gastrulation. This can be achieved by thinning of individual cells, and/or intercalation of cells from within the same or adjacent cell layer.

invagination

The process whereby a layer of cells indents and forms a cavity or pouch.

involution

Movement of cells from the outside to the inside, the cells remaining epithelial in nature and moving as a layer of cells.

ingression

Movement of cells, typically from the outside to the inside, the cells being (or transitioning to) mesenchymal in nature, and moving individually.

blastopore

A sac-like cavity in the outer surface of the blastula through which cells are internalised, usually by involution.

primitive streak

A depression in the epiblast of birds and mammals through which cells are internalised by ingression.

ectoderm

The outer germ layer; generally produces the outer layer of the embryo, and central nervous system via the neural tube.

mesoderm

The middle germ layer; from it forms the notochord, somites, some of the skeleton and musculature.

endoderm

The inner germ layer; it forms most of the digestive tract and associated organs.

extraembryonic membranes

These are membranes that develop along with the embryo but do not form part of the final embryo.

Usually these are the amniote amnion, chorion, and membranes of the yolk sac and allantois.

The yolk sac of teleosts is part of the embryo, and the yolk sac of chondrichthyans is reabsorbed, so these are not strictly extraembryonic.

Although the teleost enveloping layer (EVL) does not become part of the embryo, it is not usually regarded as an extraembryonic membrane.

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عملي مقرر الأجنة للفرقة الثالثة علم الكيمياء والحيوان

د/ سهام علي مبارك- المدرس بقسم علم الحيوان

Embryology

Embryology is a branch of science that is related to the fertilization, formation, growth, and development of embryo. In mammals, it deals with the prenatal stage of development beginning from formation of gametes, fertilization, formation of zygote, development of embryo and fetus to the birth of a new individual.

A Brief History of Embryology

- The theory of preformationism
- The theory of epigenesis
- The theory of recaptiulation
- The Cell Theory

Reproduction

Reproduction may be defined as the biological process by which organisms give rise to their own kind. Reproduction may occur in two ways: **Asexual and Sexual reproduction.**

Basic Concepts of embryonic development include:

1. Gametogenesis
2. Fertilization
3. Cleavage
4. Blastulation
5. Gastrulation
6. Organization (Organogenesis)

Gametogenesis

Gametogenesis for the formation of sperms is termed **spermatogenesis**, while that of ova is called **oogenesis**.

- Both spermatogenesis and oogenesis comprise similar phases of sequential changes as: **multiplication phase, growth and maturation phases**.

Spermatogenesis:

The testes structure

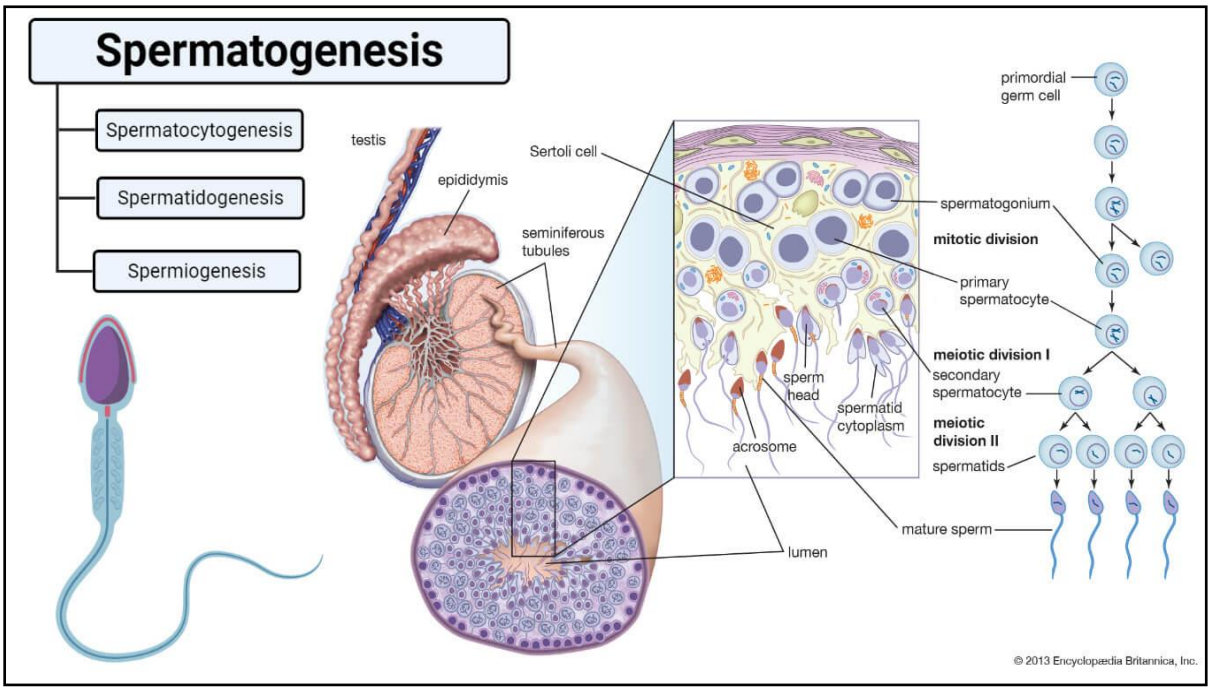
The testicles (testes) are part of a man's reproductive system. A man has 2 testicles.

- ✓ **Spermatogenesis:** includes the following phases:

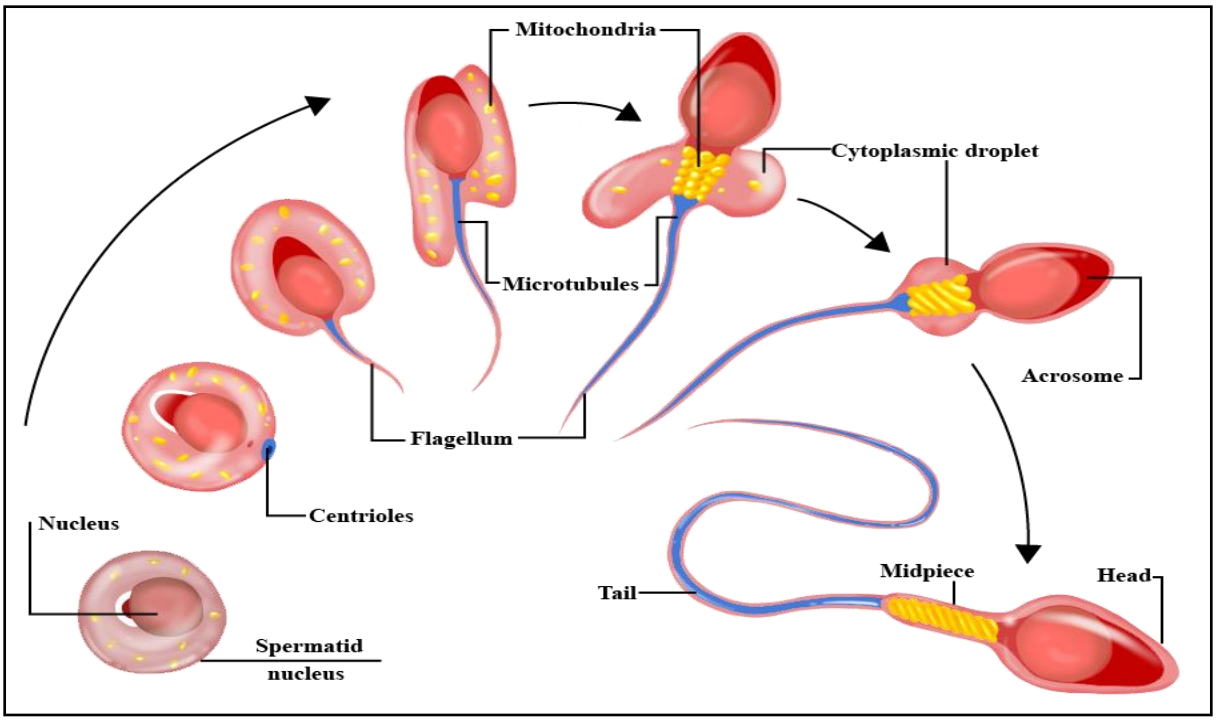
Multiplication Phase

Maturation Phase

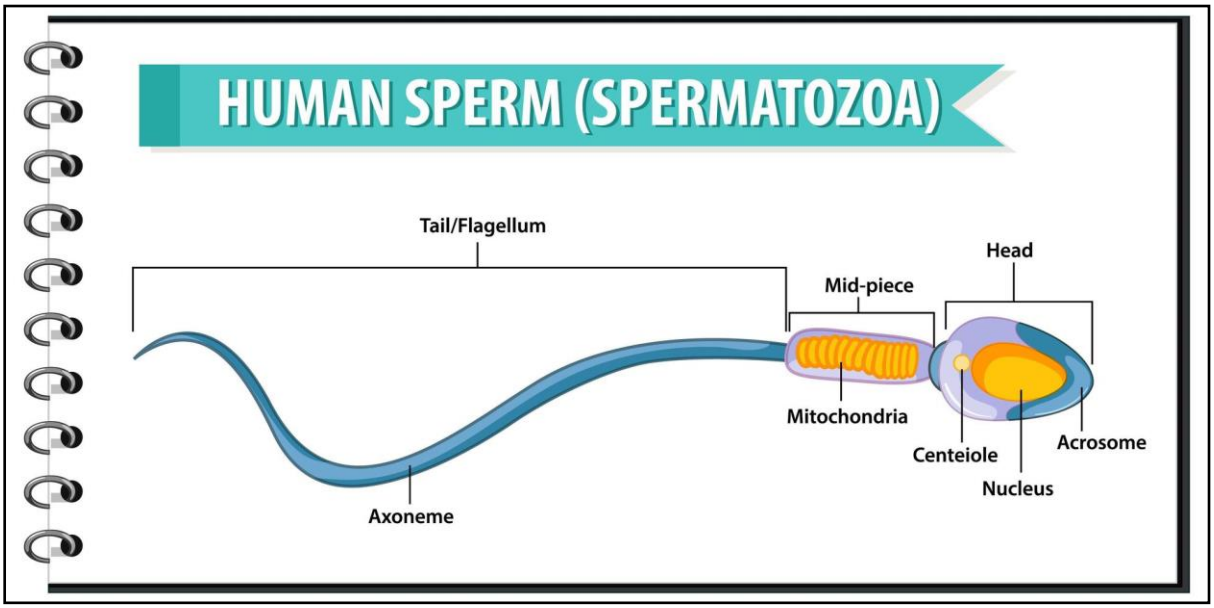
Growth Phase



Formation of Sperms from Spermatids (Spermiogenesis):



Spermatozoon (Sperm):



Different shape and size of sperm

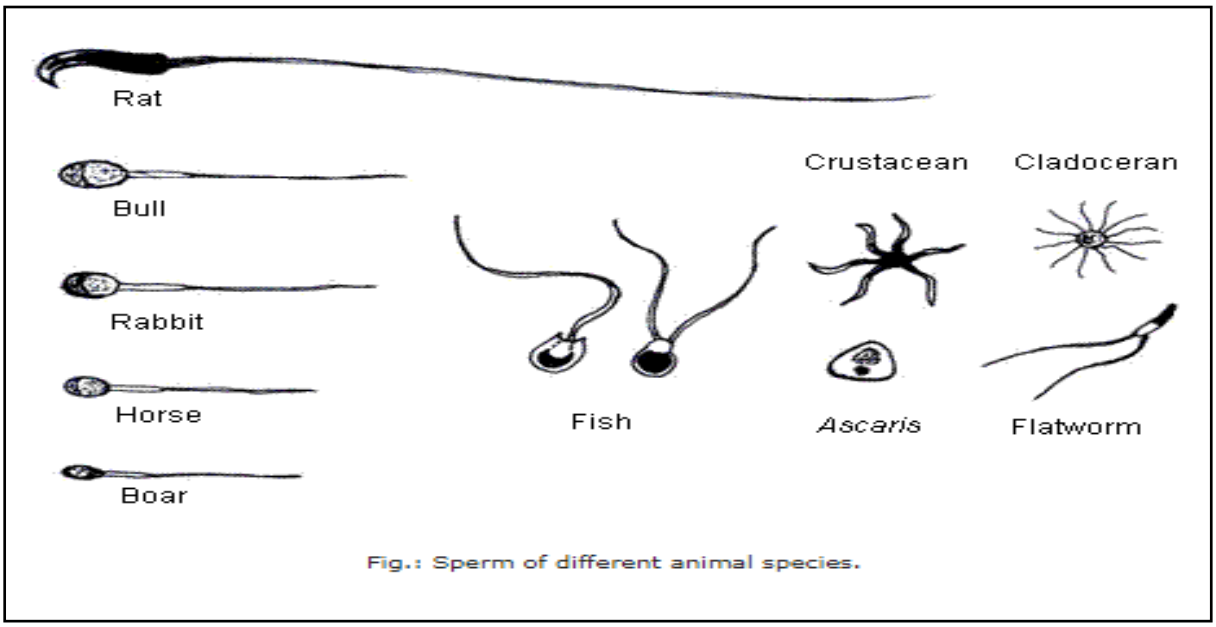


Fig.: Sperm of different animal species.

Oogenesis

Ovum structure:

The ovum is one of the largest cells that measures approximately 120 µm in diameter. The ovum has a large, centrally located nucleus which is covered by cytoplasm. This oocyte nucleus and nucleolus are termed **germinal vesicle** and **germinal disc** respectively. Likewise, the cytoplasm (yolk) of an ovum is termed **ooplasm**. It has less amount of yolk (in humans) and hence it is alecithal. This ooplasm is enclosed by a peripheral layer called the cortex which has many microvilli. These microvilli are tubular projections of the plasmalemma that aids in the transportation of substances in and out of the cytoplasm.

The human ovum is typically covered by 3 layers:

1. Inner thin vitelline membrane
2. Middle zona pellucida
3. Outer corona radiata

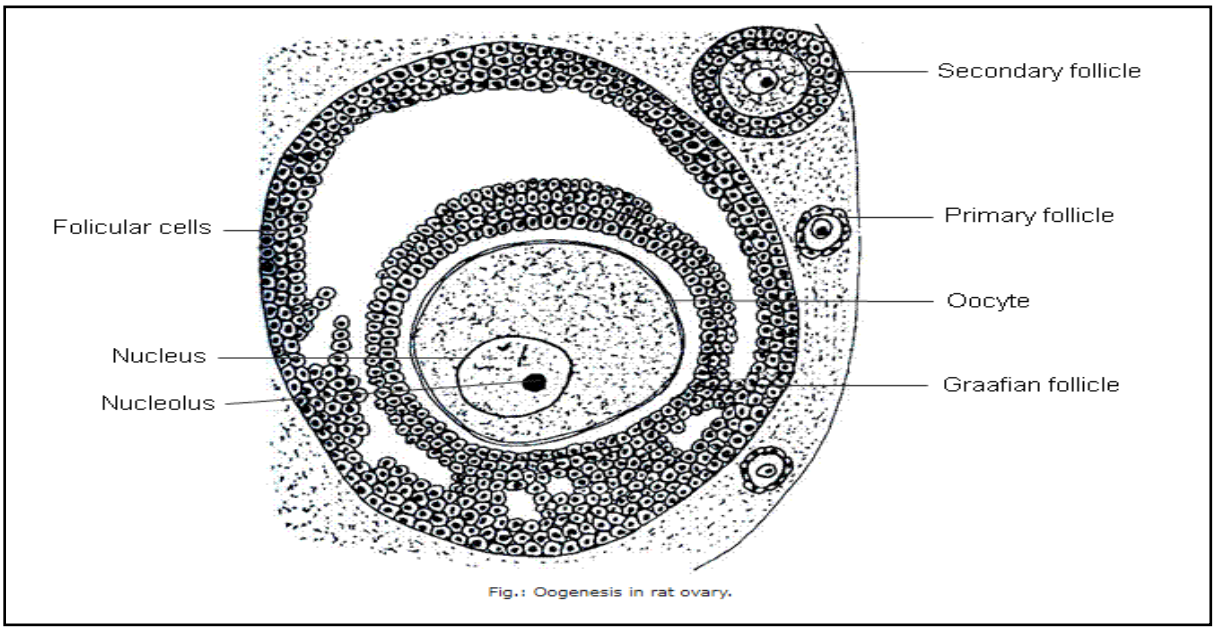
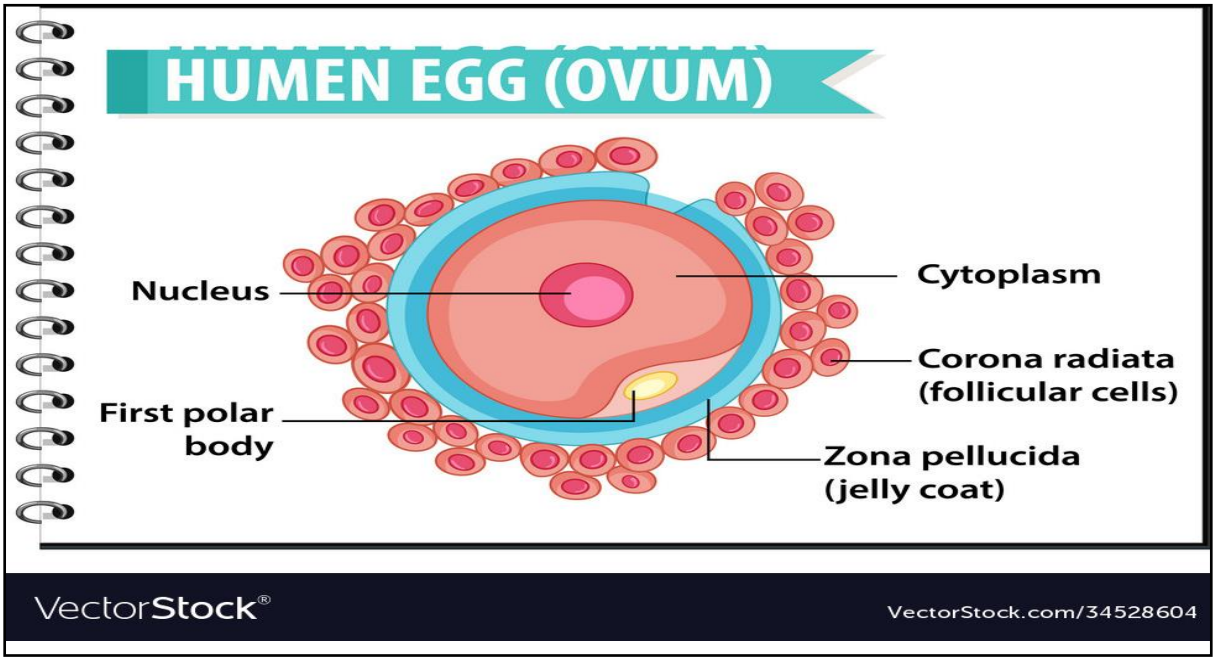


Fig.: Oogenesis in rat ovary.

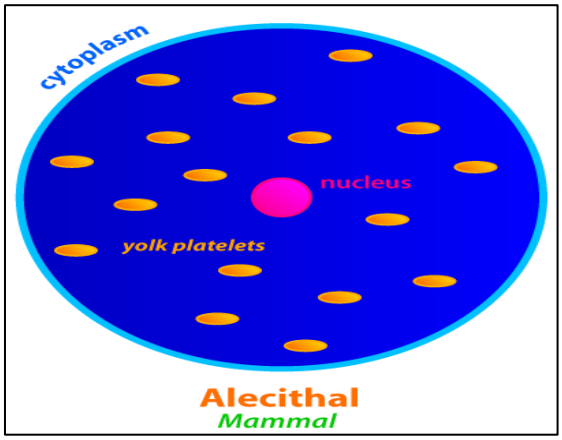


Types of Egg:

According to the proportion of the yolk to the cytoplasm of the ovum there are three types of egg:

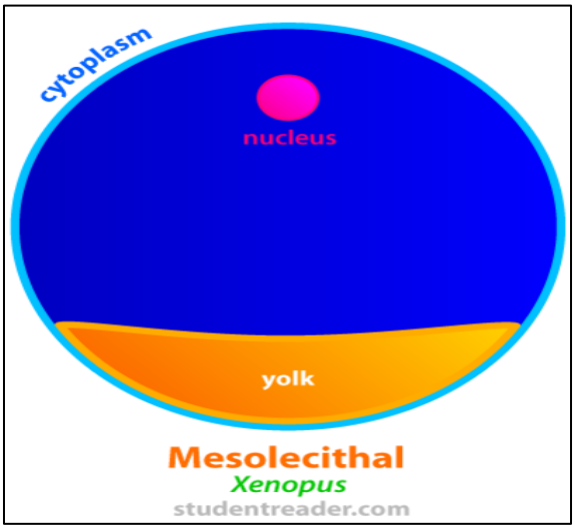
[I] **Microlecithal egg**

- ✓ The eggs of Amphioxus and mammals are of this type.
- ✓ The mammalian eggs contain so little yolk that they are sometimes called alecithal (without yolk) eggs.



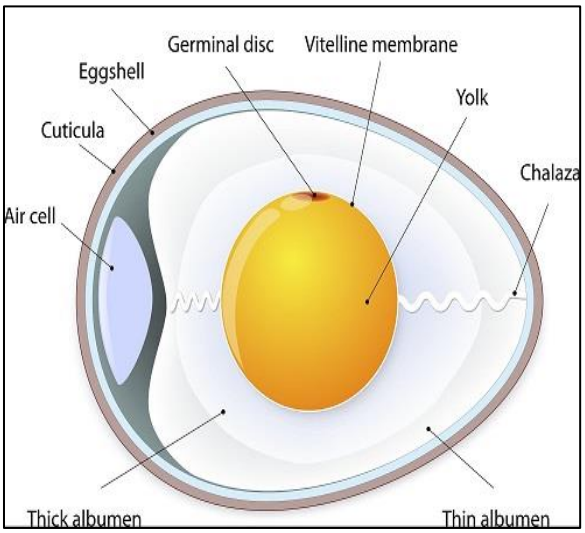
[II] **Mesolecithal eggs**

The eggs of sharks, fishes and many amphibians are of this type.



[III] **Macrolecithal or polylecithal eggs**

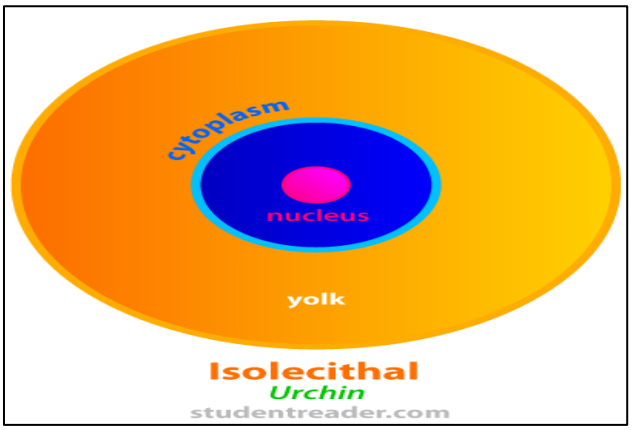
The eggs of teleost fishes, reptiles, birds and monotremates (egg laying mammals) are of this type.



According to distribution of yolk granules or platelets in the cytoplasm of the ova or egg, the eggs are classified as follows:

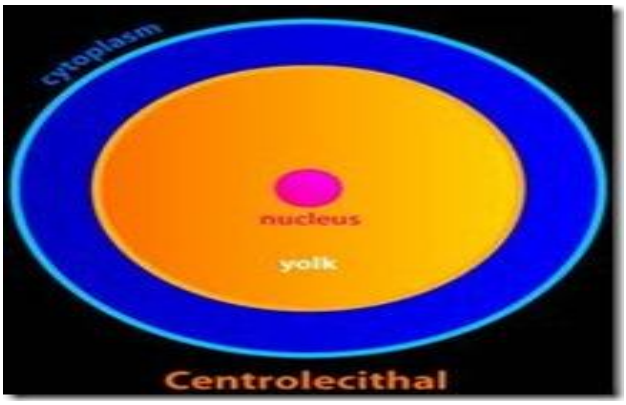
1. Homolecithal/Isolecithal

Examples are of Amphioxus, many invertebrates and mammals including man.



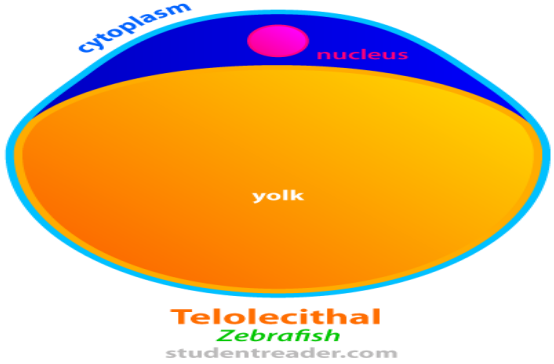
2. Centrolecithal

As in insects and many other arthropodes.

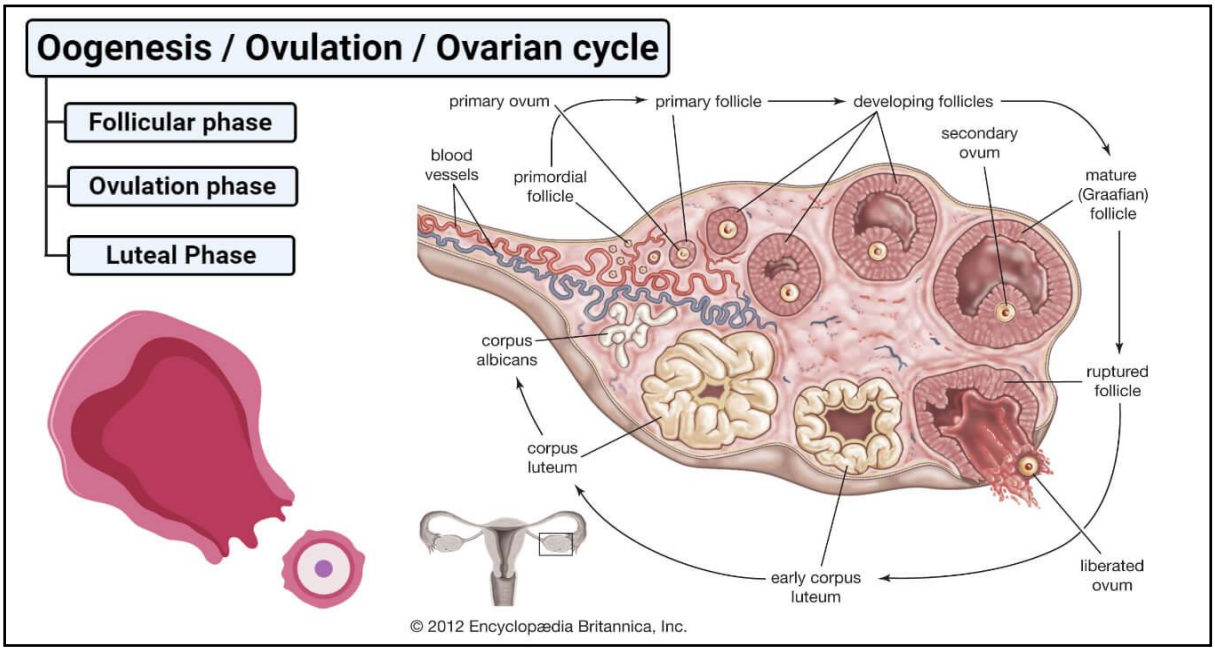


3. Teleolecithal

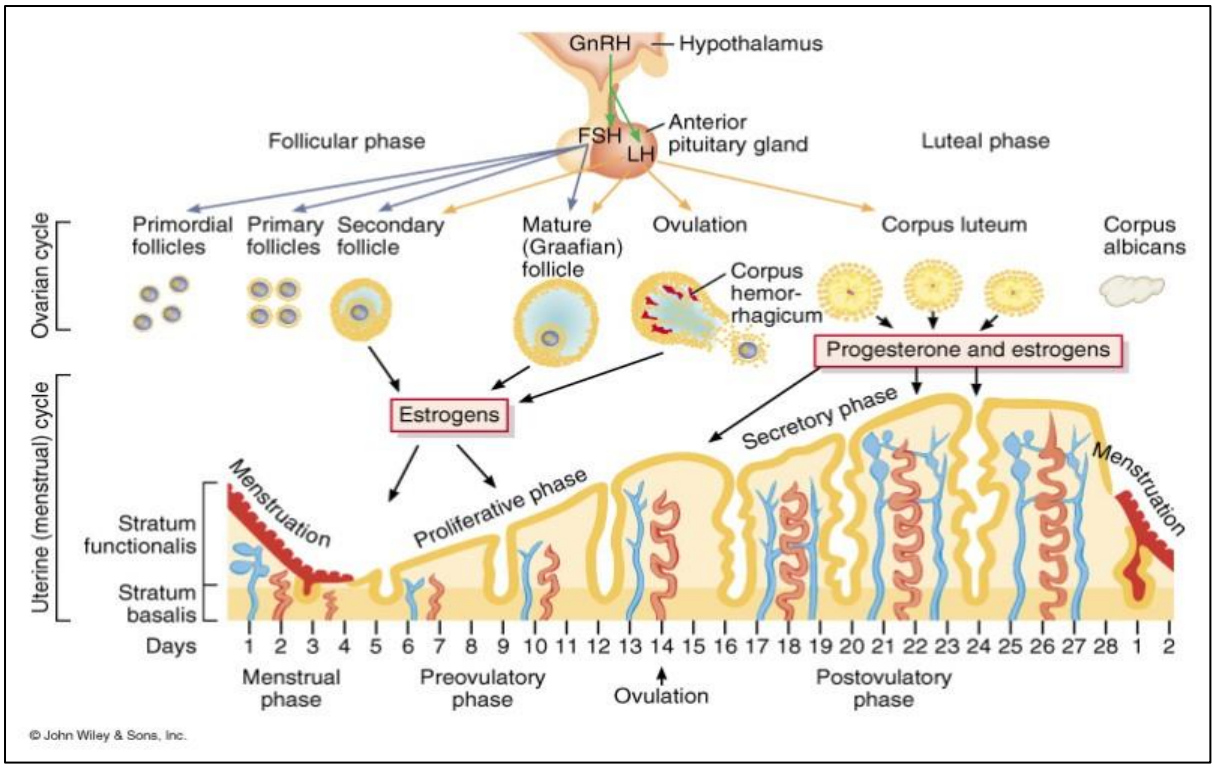
Examples are of fishes, amphibians, and reptiles, birds and monotremes eggs.



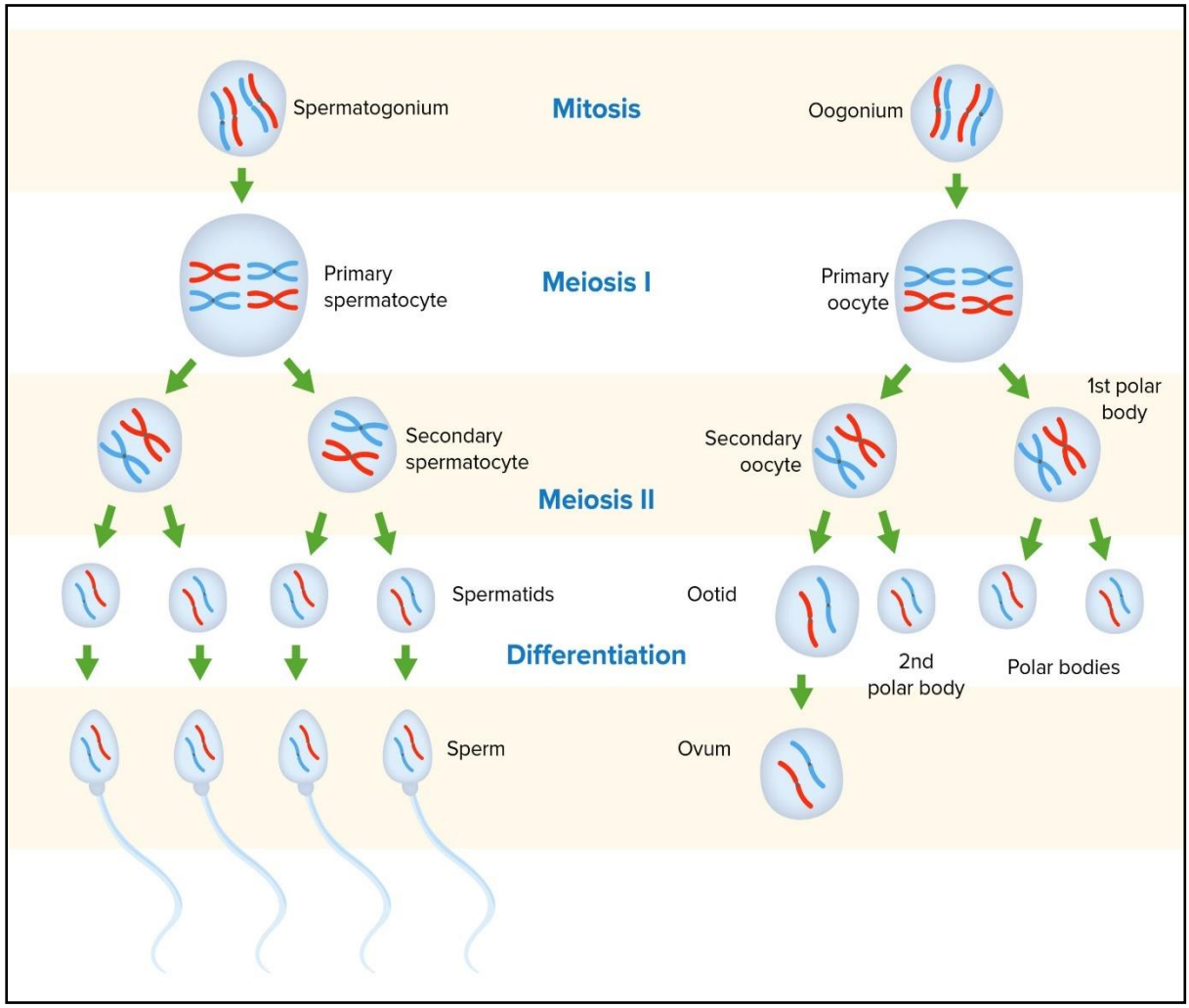
Oogenesis: consists of three phases: multiplication, growth and maturation.



The ovarian cycle

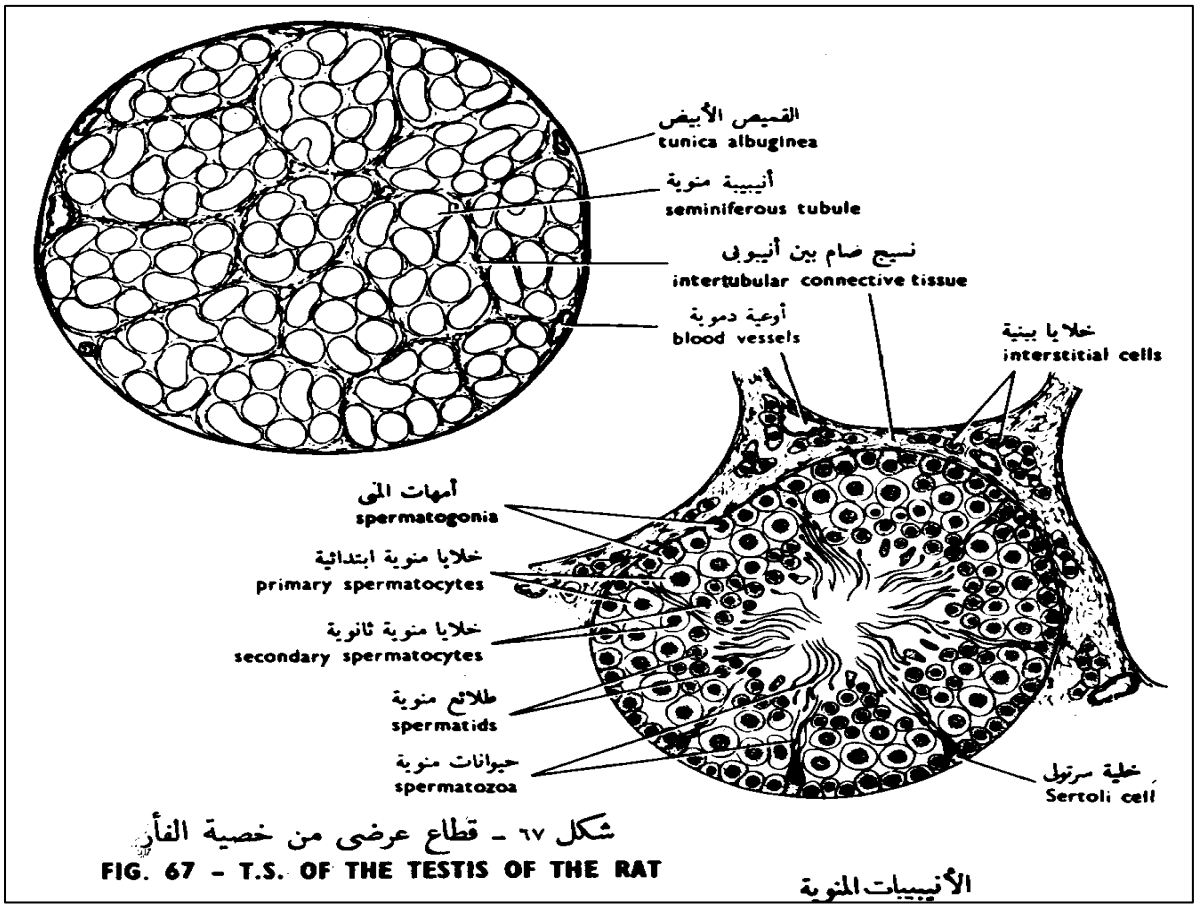


Draw

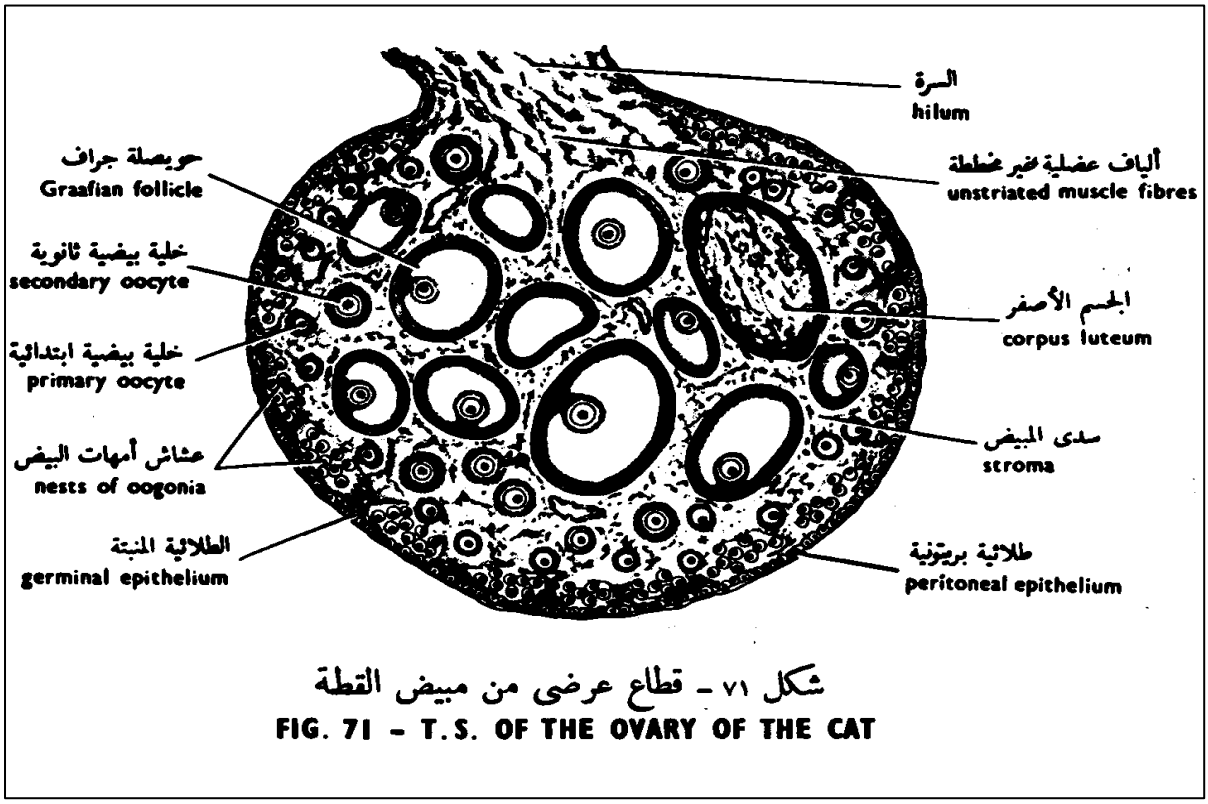


	Spermatogenesis	Oogenesis
Process		
Location	Occurs *entirely* in testes	Occurs *mostly* in ovaries
Meiotic divisions	Equal division of cells	Unequal division of cytoplasm
Germ line epithelium	Is involved in gamete production	Is not involved in gamete production
Gametes		
Number produced	Four	One (plus 2 – 3 polar bodies)
Size of gametes	Sperm smaller than spermatocytes	Ova larger than oocytes
Timing		
Duration	Uninterrupted process	In arrested stages
Onset	Begins at puberty	Begins in foetus (pre-natal)
Release	Continuous	Monthly from puberty (menstrual cycle)
End	Lifelong (but reduces with age)	Terminates with menopause

Draw



شكل ٦٧ ـ قطاع عرضى من خصية الفأر
FIG. 67 – T.S. OF THE TESTIS OF THE RAT



شكل ٧١ ـ قطاع عرضى من مبيض القطة
FIG. 71 – T.S. OF THE OVARY OF THE CAT

Fertilization

Fertilization, the process by which male and female gametes nuclei fuses together to produce diploid zygote.

Types of Fertilization:

1. External:

Eggs are librated in water.

- Occurs outside the female genital system.
- Female laid a large number of eggs, them the male pour its sperms in the same region in water
- e.g. in fish and amphibian.

2. Internal:

- Land-dwellers
- Specialized structures for housing gametes.
- Embryo more protected during development.
- Occurs in animals that have a well-developed reproductive system, animals may be:

a) **Oviparous:** zygote develops in a shell e.g. birds.

b) **Viviparous:** zygote develops inside uterus e.g. mammals.

The intrauterine life is about 21 days in the rat, 70 days in the in the Guinea pig while it's about 280 days in human.

c) **Ovoviviparous:-** e.g. dog fish

It has 4 major steps:

1. Contact and recognition between sperm and egg. (same species)
2. Regulation of sperm entry into the egg. (only one and inhibiting the others)
3. Fusion of the genetic material of sperm and egg.
4. Activation of egg metabolism to start development.

Cleavage and Blastula Formation

Planes of Cleavage:

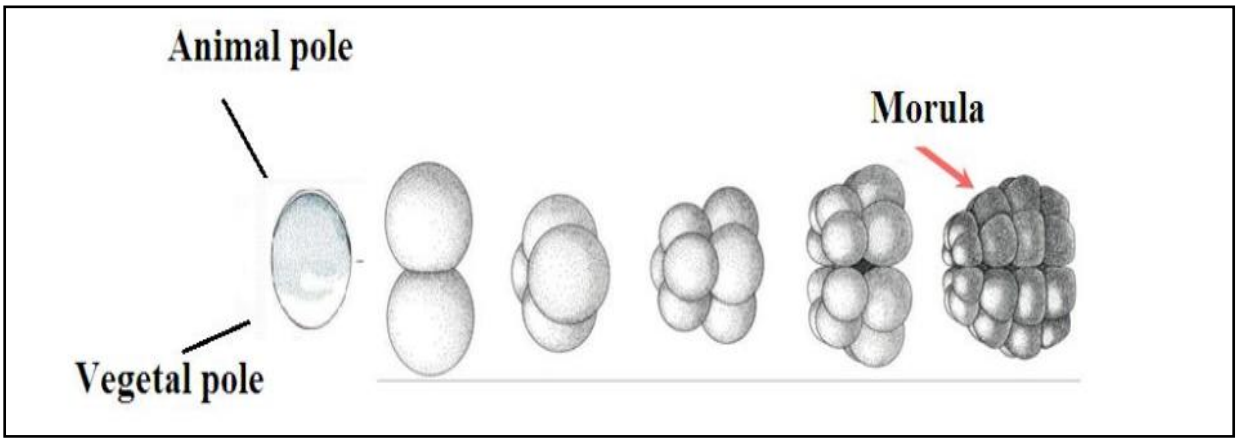
A: Holoblastic or total cleavage:

When the cleavage furrows divide the entire egg.

It may be:

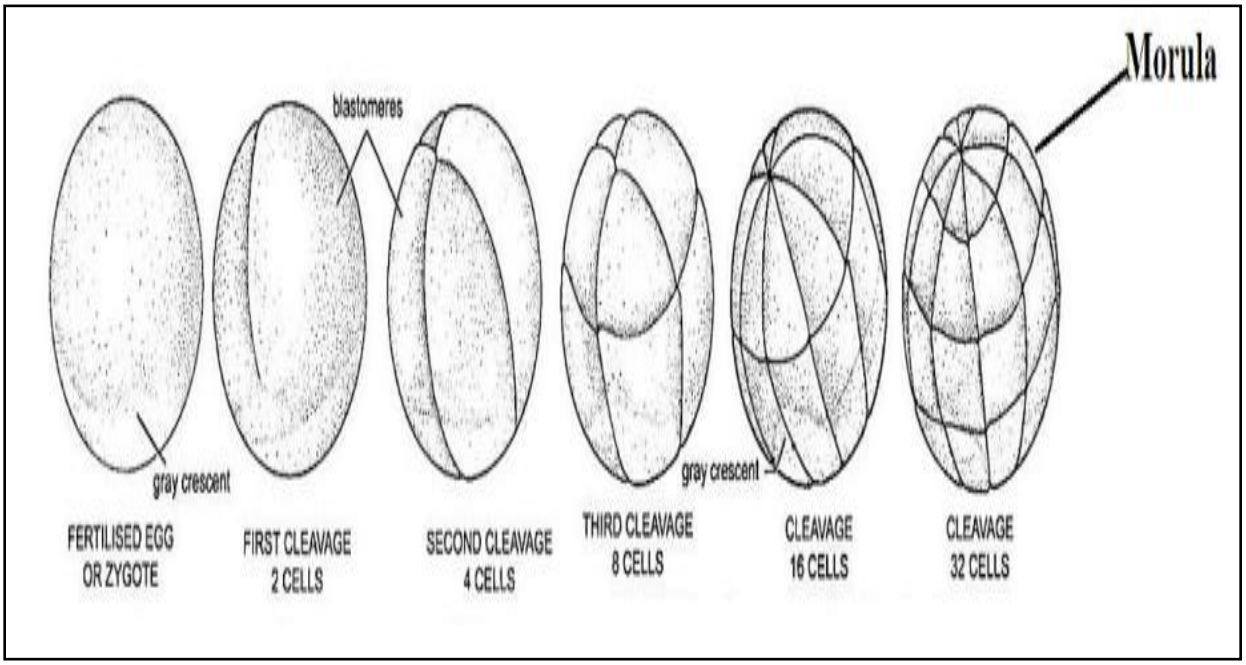
Equal:

When the cleavage furrow cuts the egg into two equal cells. It may be radially symmetrical, bilaterally symmetrical, spirally symmetrical or irregular.



Unequal:

When the resultant blastomeres become unequal in size.



B. Meroblastic cleavage:

When segmentation takes place only in a small portion of the egg resulting in the formation of blastoderm, it is called meroblastic cleavage. Usually the blastoderm is present in the animal pole and the vegetal pole becomes laden with yolk which remains in an uncleaved state, i.e., the plane of division does not reach the periphery of blastoderm or blastodisc.

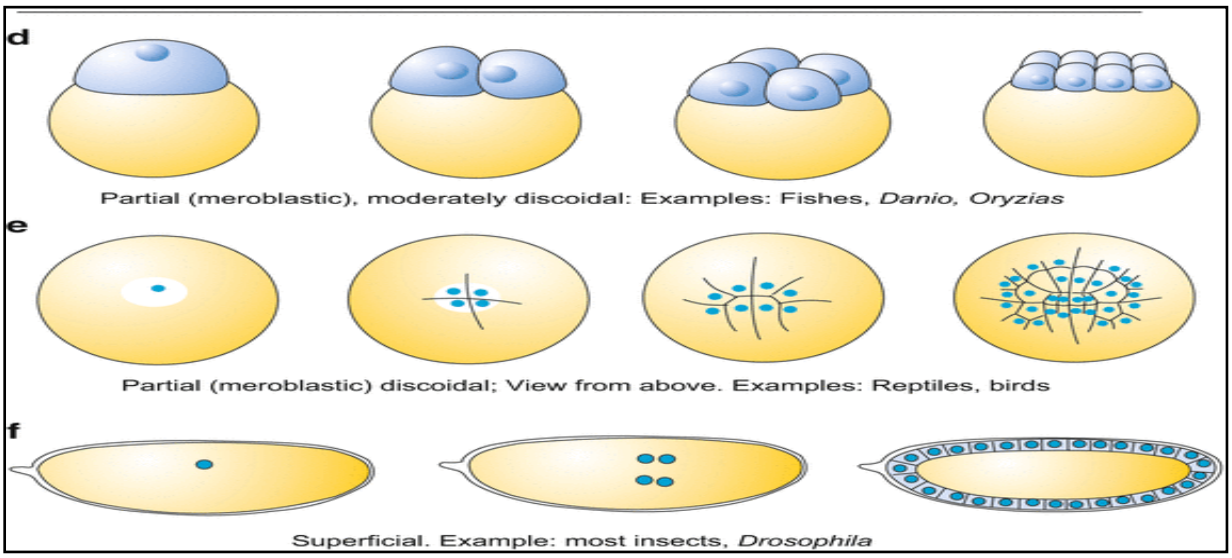
Two major types of meroblastic cleavage are discoidal and superficial:

1- Discoidal

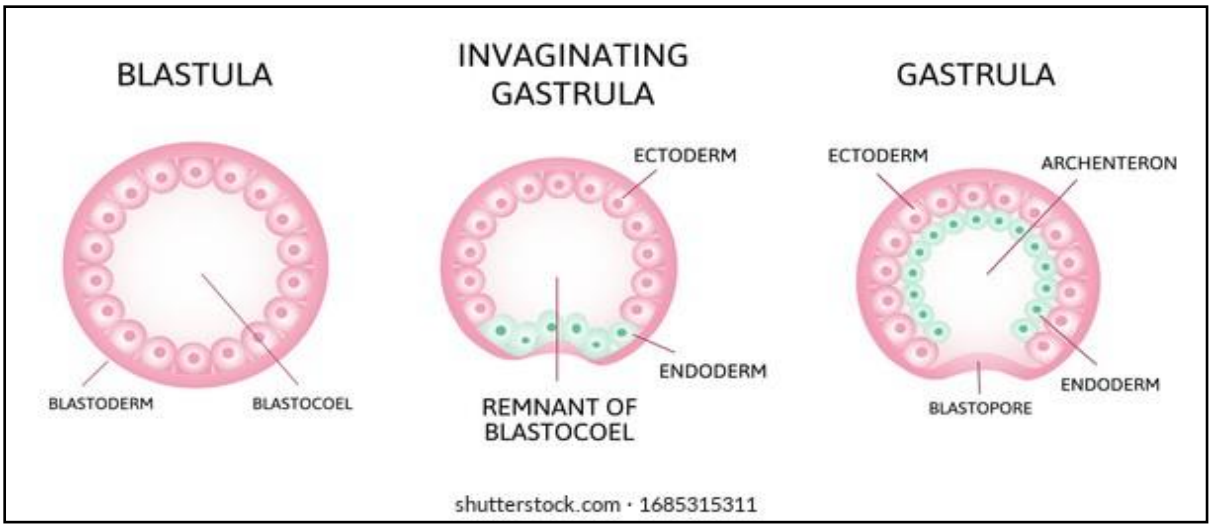
In discoidal cleavage, the cleavage furrows do not penetrate the yolk. The embryo forms a disc of cells, called a blastodisc, on top of the yolk. Discoidal cleavage is commonly found in monotremes, birds, reptiles, and fish that have telolecithal egg cells (egg cells with the yolk concentrated at one end).

2- Superficial

In superficial cleavage, mitosis occurs but not cytokonesis, resulting in a polynuclear cell. With the yolk positioned in the center of the egg cell, the nuclei migrate to the periphery of the egg, and the plasma membrane grows inward, partitioning the cytoplasm into individual cells. Superficial cleavage occurs in arthropods that have centrolecithal eggs.



Gastrulation

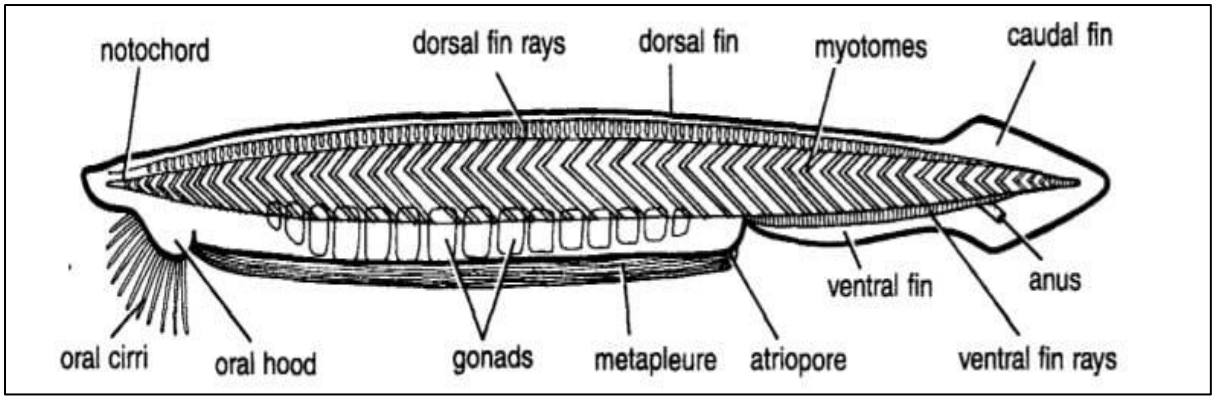


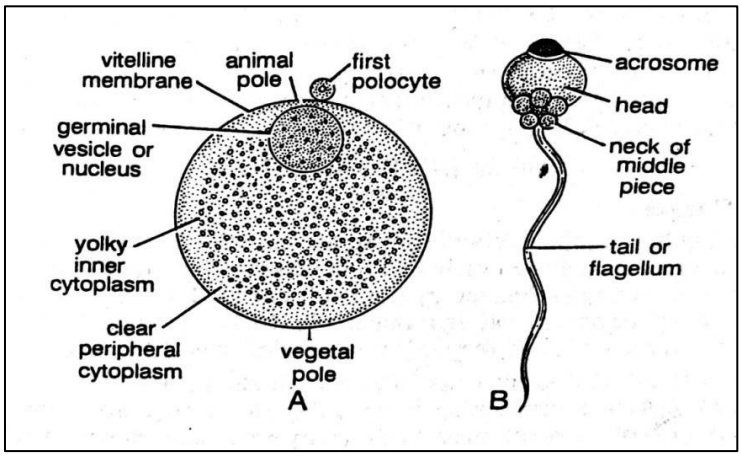
Organogenesis

Germ layers

Embryonic Germ Layer	Vertebrate Adult Structures
Ectoderm (outer layer)	Epidermis of skin; epithelial lining of oral cavity and rectum; nervous system
Mesoderm (middle layer)	Skeleton; muscular system; dermis of skin; cardiovascular system; excretory system; reproductive system—including most epithelial linings; outer layers of respiratory and digestive systems
Endoderm (inner layer)	Epithelial lining of digestive tract and respiratory tract; associated glands of these systems; epithelial lining of urinary bladder

Early embryonic development of Amphioxus





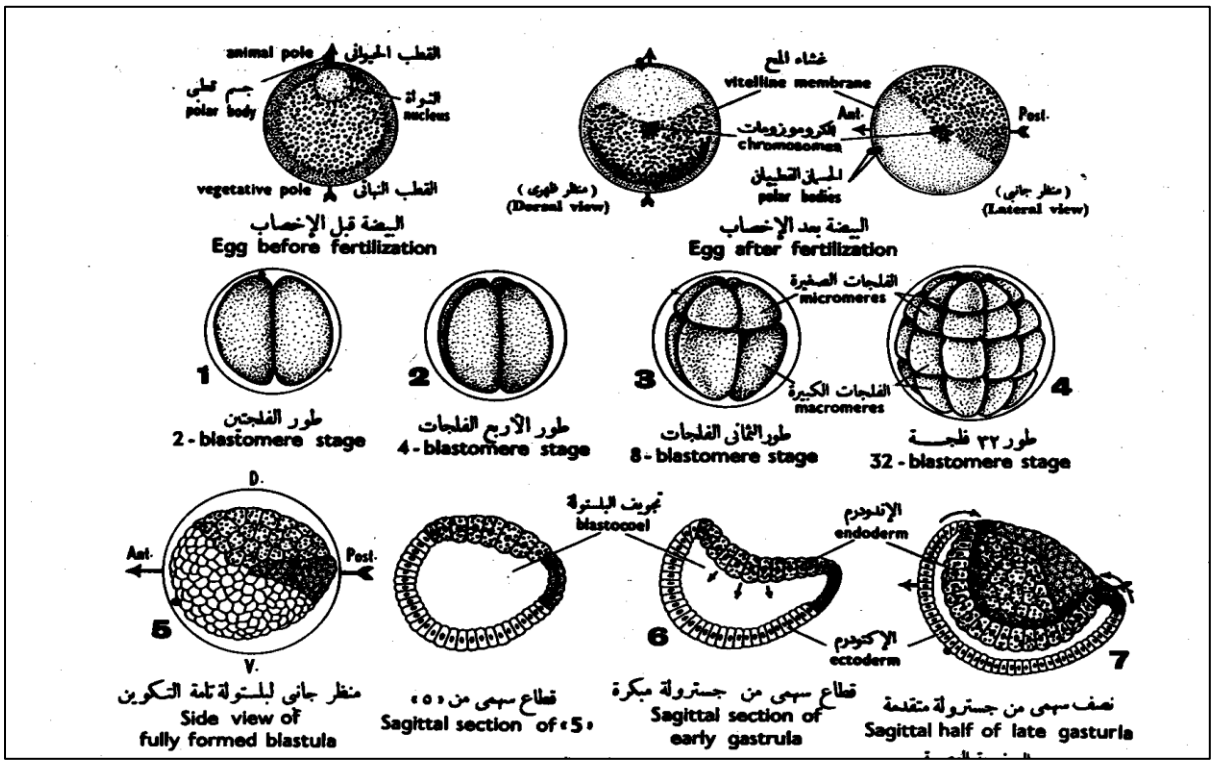
Amphioxus: A. Unfertilized egg. B. Sperm

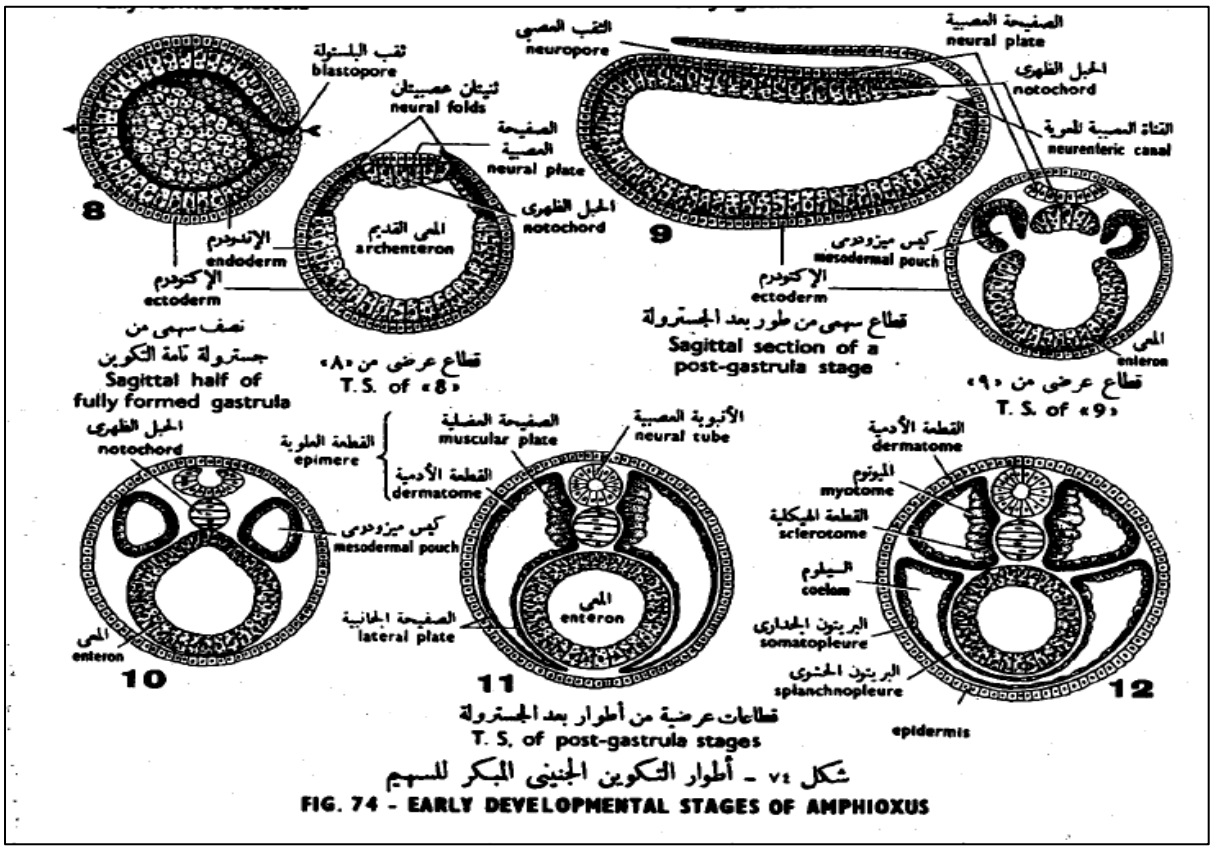
- ✓ Phylum: Chordata – Class: Cephalochordata
- ✓ Sexes are separate
- ✓ The gonads which are in the form of hollow sacs enclosed in coelomic pouches- twenty six in number on each side
  - genital ducts are lacking
- ✓ On maturity of gonads the sperms and ova are liberated into the atrium and from where they are discharged outside through the atriopore in breeding season
- ✓ The spermatozoa contain spherical head, very short mid-piece and tail
- ✓ The ovum of is 0.10 mm to 0.12 mm in diameter
- ✓ Type of Egg: According to amount of yolk oligolecithal or microlecithal

According to distribution of yolk isolecithal

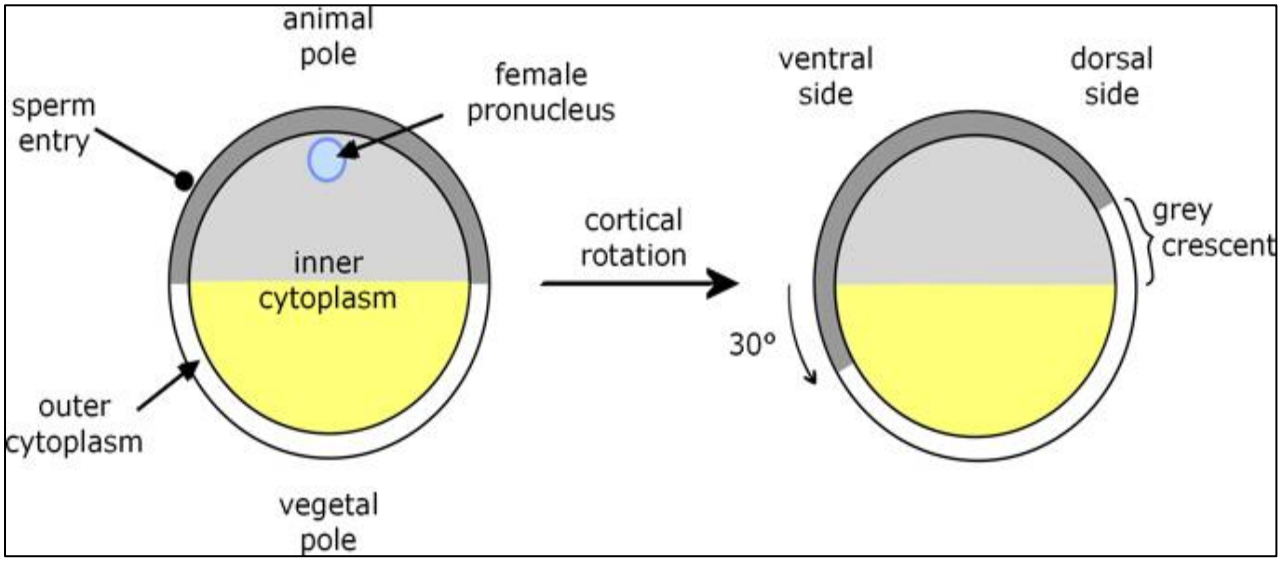
- ✓ Fertilization : External
- ✓ **Type of cleavage:** holoblastic cleavage

Draw

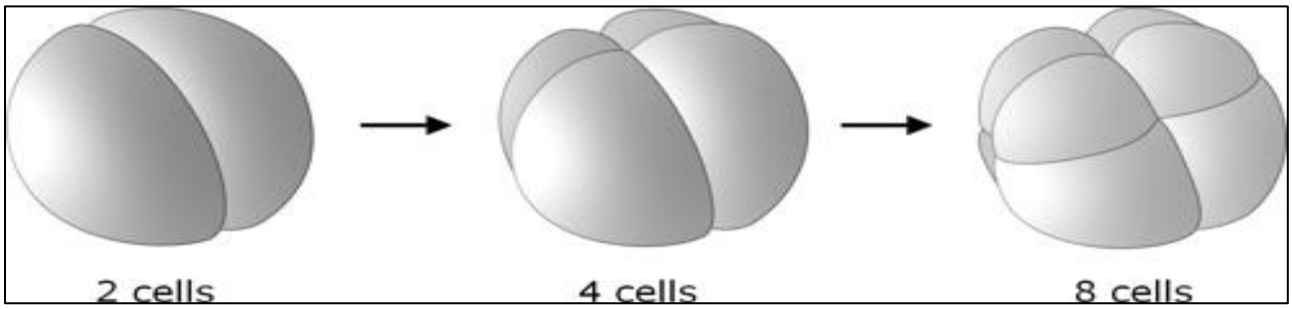




1. Early embryonic development of Frog



Xenopus fertilisation



Xenopus cleavage: the first 3 cell divisions.

✓ Phylum: Chordata – Class: Amphibia

✓ Fertilization: External.

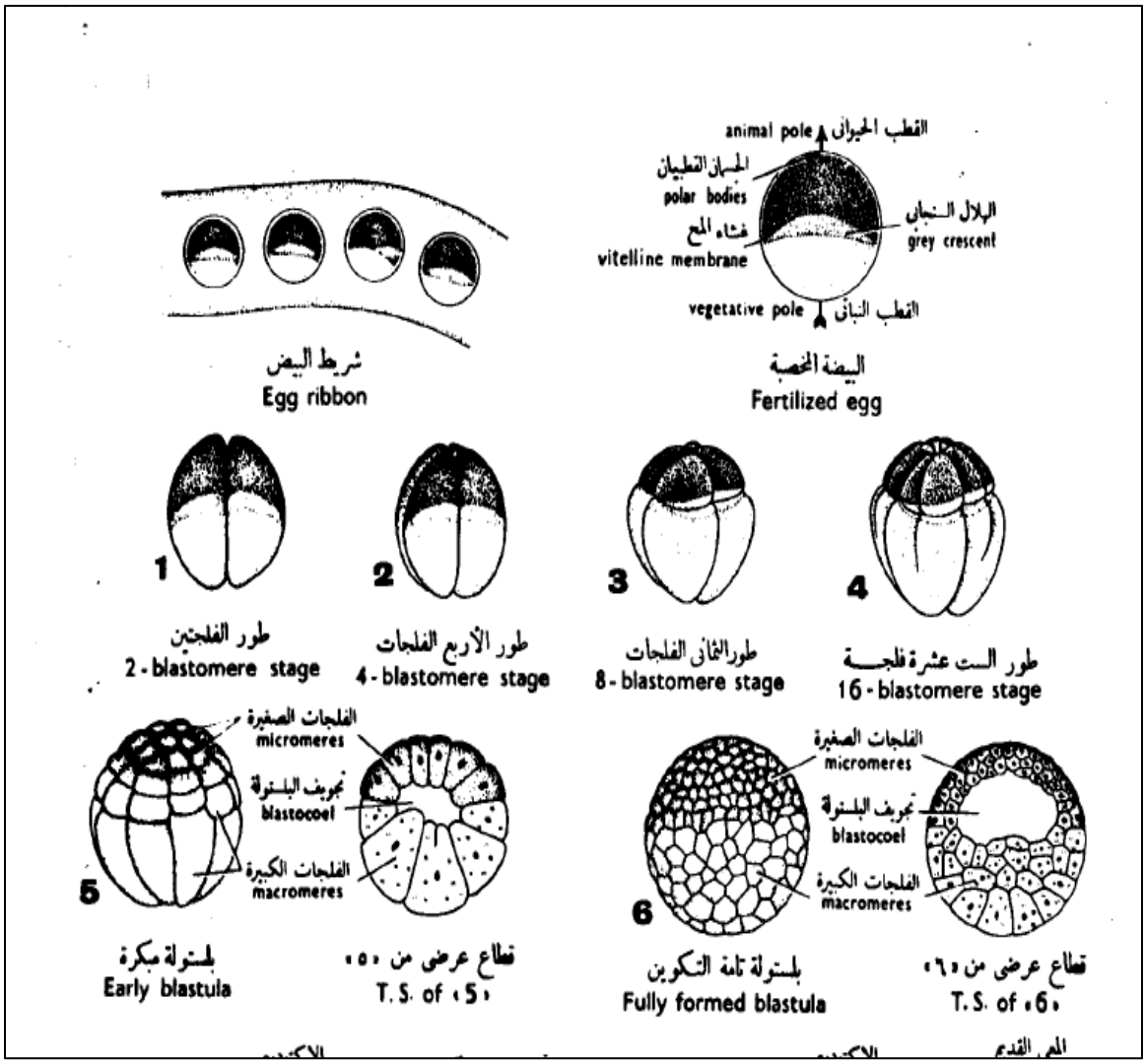
✓ Type of Egg: According to amount of yolk mesolecithal. According to distribution of yolk telolecithal.

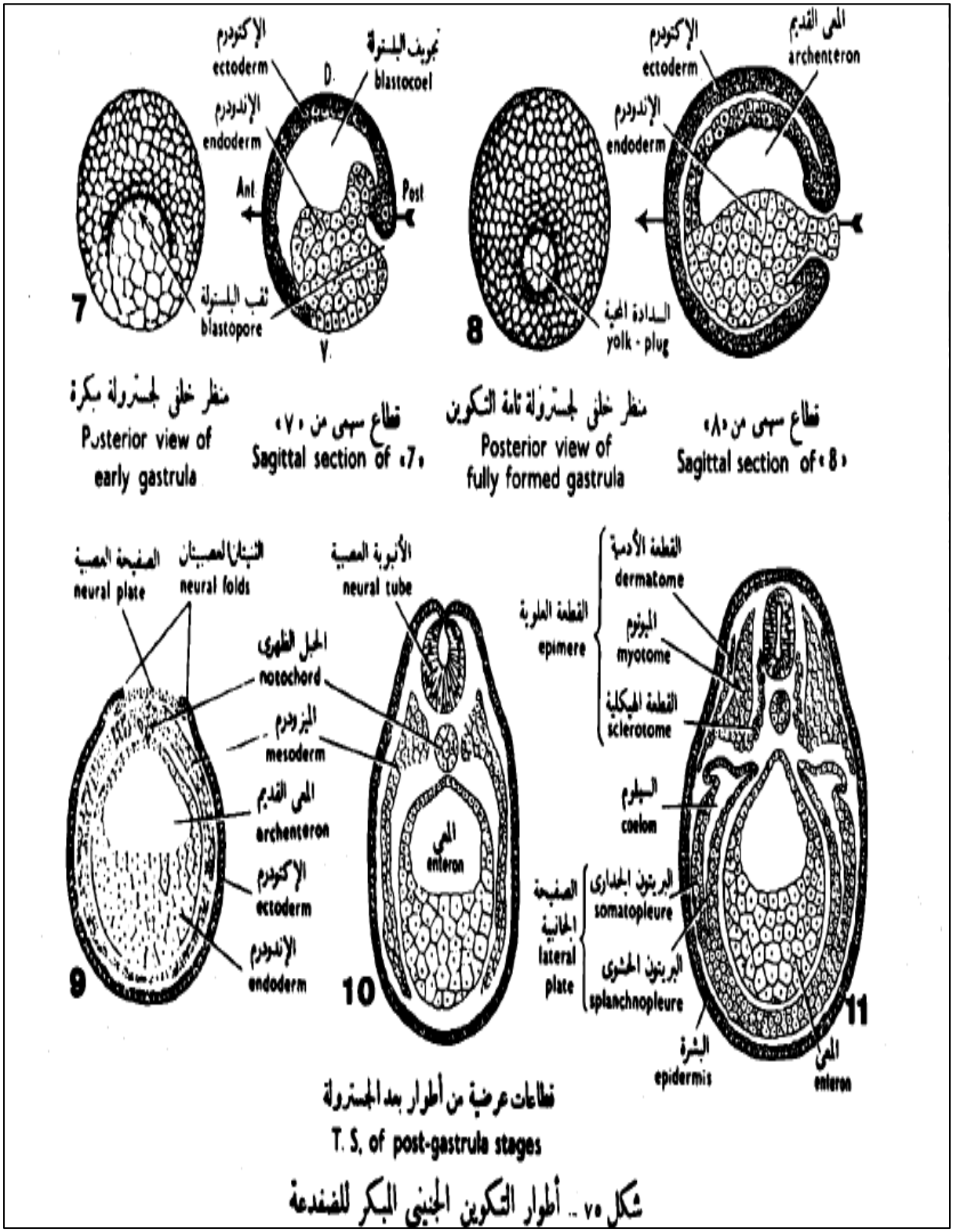
Spawning:

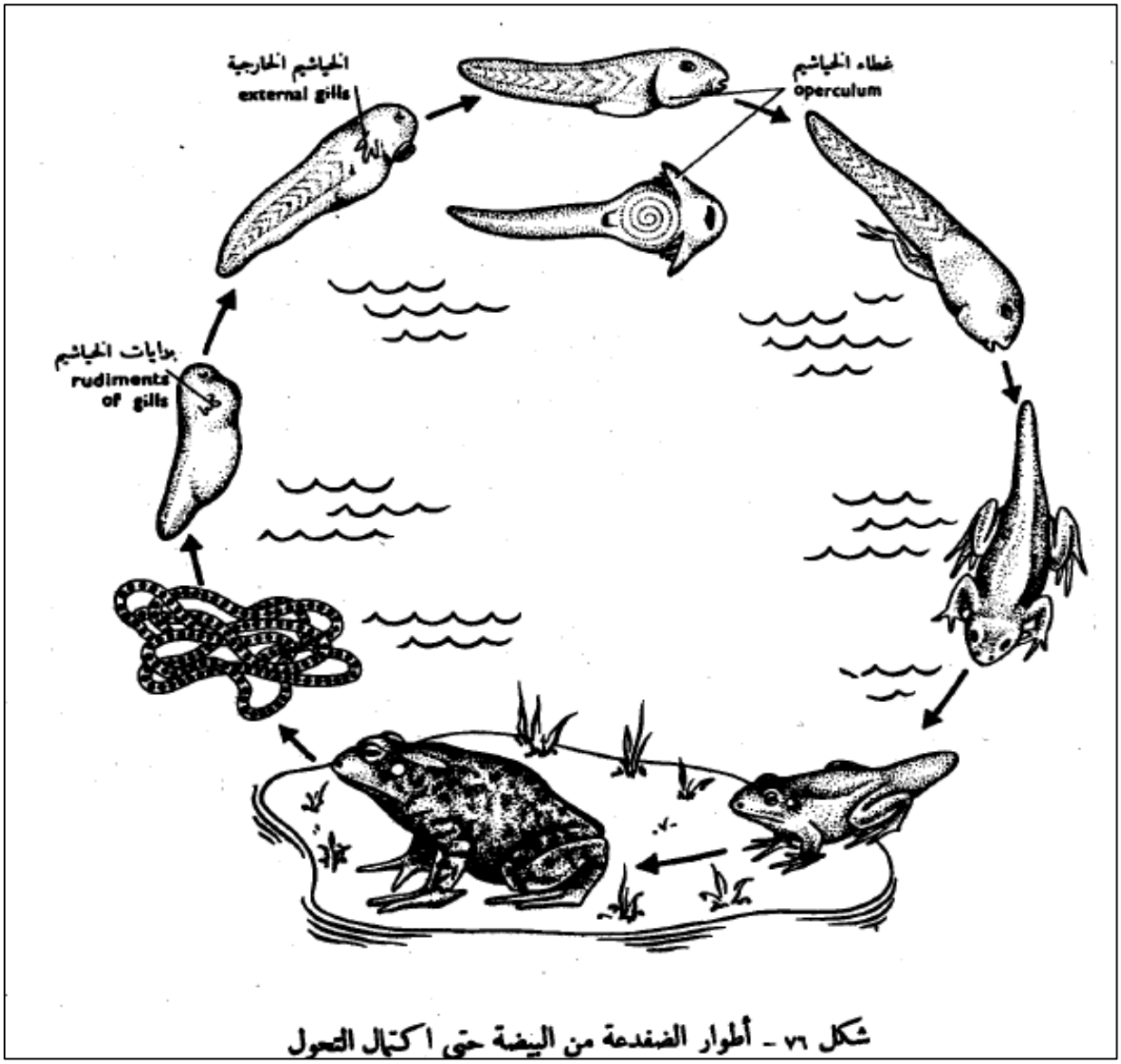
The mesolecithal eggs of frog enclosed in a protective gelatinous albumen are laid in water. The cluster or masses of eggs which remain stick together is called spawn. A spawn of *Rana tigrina* may have 3000 to 4000 ova. The spawn is laid during pseudocopulation or amplexus.

- ✓ Type of cleavage: Unequal holoblastic cleavage.
- ✓ Adult toads live on land most of the time and rely on water for hydration, breeding, and temperature regulation, Mating.
- ✓ Cleavage and blastulation the period of cleavage and blastula formation completed within 24 hours.
- ✓ The cleavage furrow elongates at a rate of about 1mm/minute in the animal hemisphere but slows to 0.03mm/minute in the vegtal pole.

Draw




الإكتودرم
ectoderm
تجويف البلستولة
blastocoel
D.
الإندودرم
endoderm
Ant
Post
ثقب البلستولة
blastopore
V.
7
الإكتودرم
ectoderm
المعى القديم
archenteron
الإندودرم
endoderm
السدادة المحية
yolk - plug
8
منظر خلفى لجسترولة مبكرة
Posterior view of early gastrula
قطاع سهمى من «٧»
Sagittal section of «7»
منظر خلفى لجسترولة تامة التكوين
Posterior view of fully formed gastrula
قطاع سهمى من «٨»
Sagittal section of «8»
الصفيحة العصبية
neural plate
النتوءان العصبيان
neural folds
الأنبوبة العصبية
neural tube
الحبل الظهرى
notochord
الميزودرم
mesoderm
المعى القديم
archenteron
الإكتودرم
ectoderm
الإندودرم
endoderm
9
المعى
enteron
10
القطعة الأدمية
dermatome
القطعة العلوية
epimere
الميوتوم
myotome
القطعة الهيكلية
sclerotome
السيلوم
coelom
الصفيحة الجانبية
lateral plate
البريتون الجدارى
somatopleure
البريتون الحشوى
splanchnopleure
البشرة
epidermis
المعى
enteron
11
قطاعات عرضية من أطوار بعد الجسترولة
T. S. of post-gastrula stages
شكل ٧٥ .. أطوار التكوين الجنينى المبكر للضفدعة



شكل ٧٦ - أطوار الضفدعة من البيضة حتى اكتمال التحول

Early embryonic development of Birds

Egg and fertilization

Testes

The male bird or rooster, possess a pair of testes, each testis is an oval body, cream white in colour and. From its inner border, a vas deferens emerges to run backwards, lateral to the ureter to open into the cloaca. Just before its opening, it dilates forming a small vesicular seminalis.

Ovaries

In the adult of most flying birds only one ovary of the left side, the right one degenerates.

The structure of ovum:

The oocyte grows due to the accumulation of yolk in it, the cytoplasm localized at the animal pole in which the nucleus embedded.

The mature oocyte migrates towards the periphery and finally buldged out from the ovary, connected with the ovary only by means of stalk. The fully formed egg contains a large amount of yolk. The cytoplasm is very little and is in the form of a small disc (the blastodisc or germinal disc).

After fertilization the ovum is surround by various envelopes added to the delicate vitelline membrane.

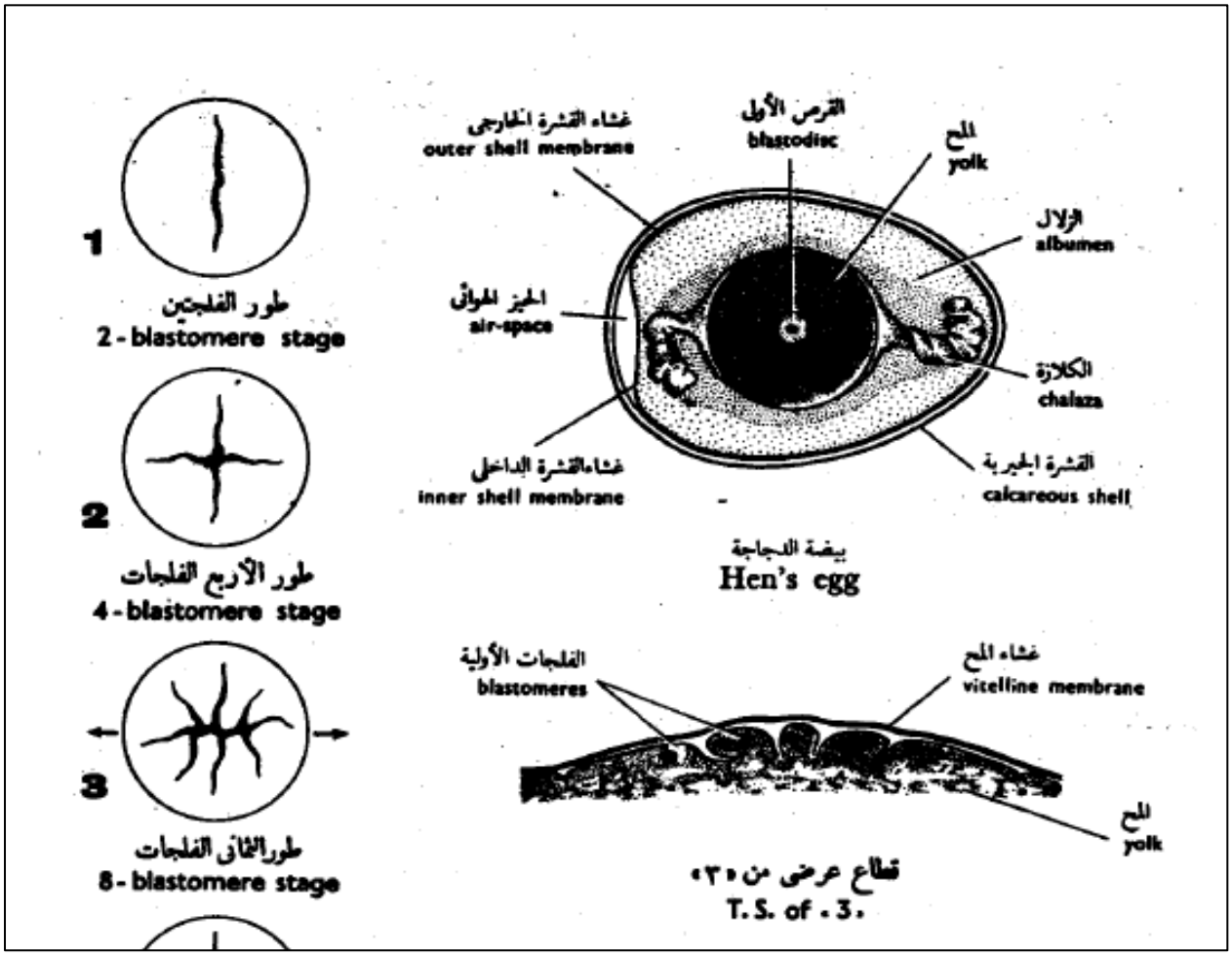
The cleavage starts immediately in the germinal disc. The fully formed and laid egg is surrounded on the outer side by a calcareous shell. The shell consisting chiefly of calcium carbonate.

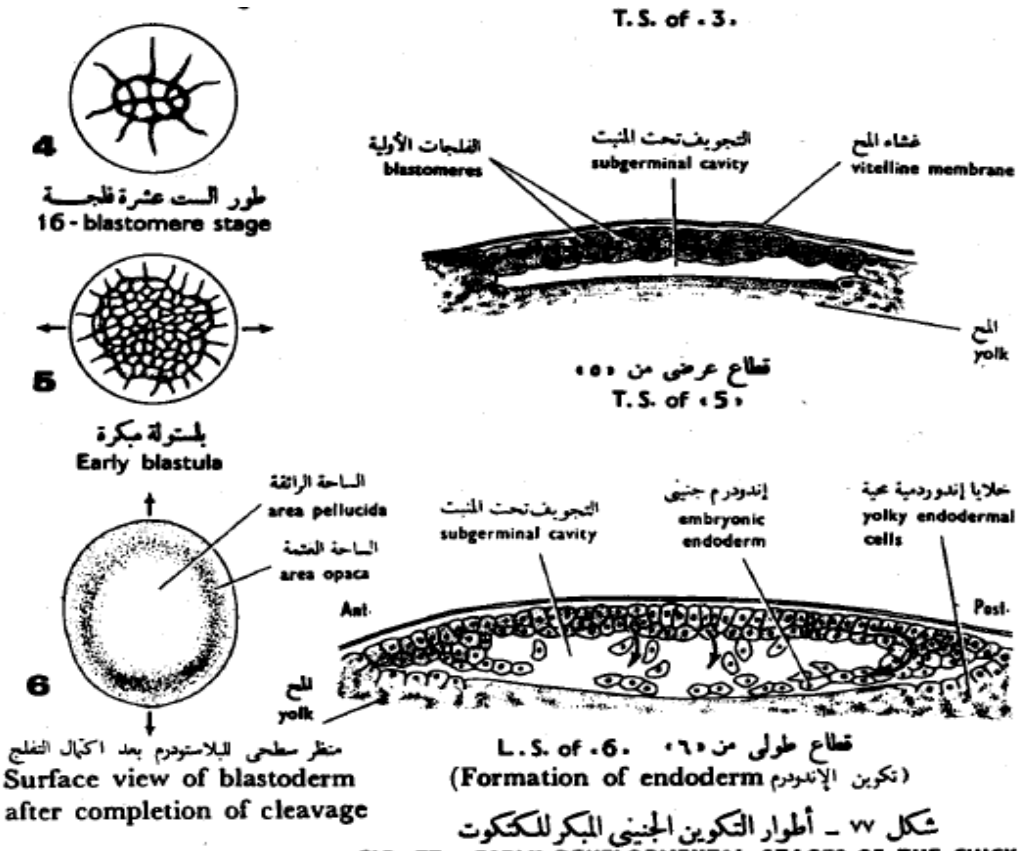
Fertilisation of the egg occurs in the oviduct, before the albumen and shell are added to it. The egg is laid about 24 hours after fertilisation, by which time the development has reached the blastula stage.

Cleavage and blastula

Consistent with having a large yolk, cleavage is meroblastic and is restricted to the germinal disc, and cell divisions do not extend into the yolk at all. The first division passes near the centre of the germinal disc and the next few divisions are at right angles to the preceding one, but then divisions becomes more irregular and asymmetric.

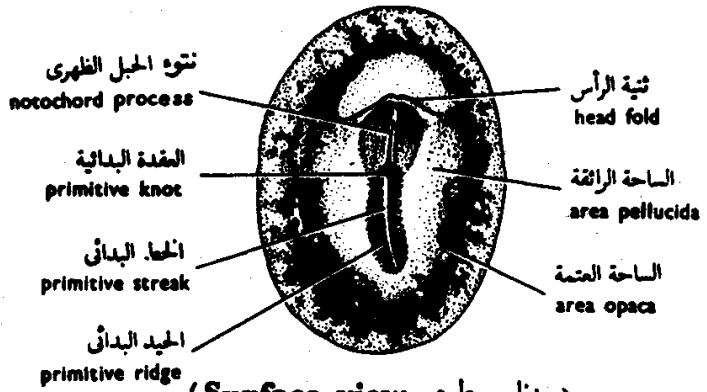
Draw



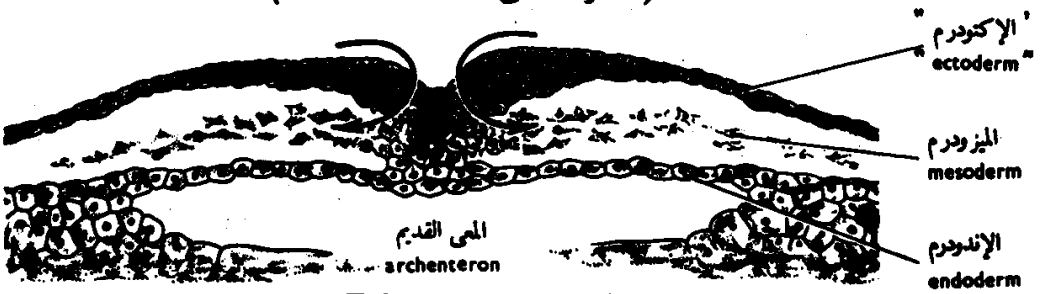


شكل ٧٧ ـ أطوار التكوين الجنيني المبكر للكتكوت

FIG. 77 - EARLY DEVELOPMENTAL STAGES OF THE CHICK



(Surface view منظر سطحي)

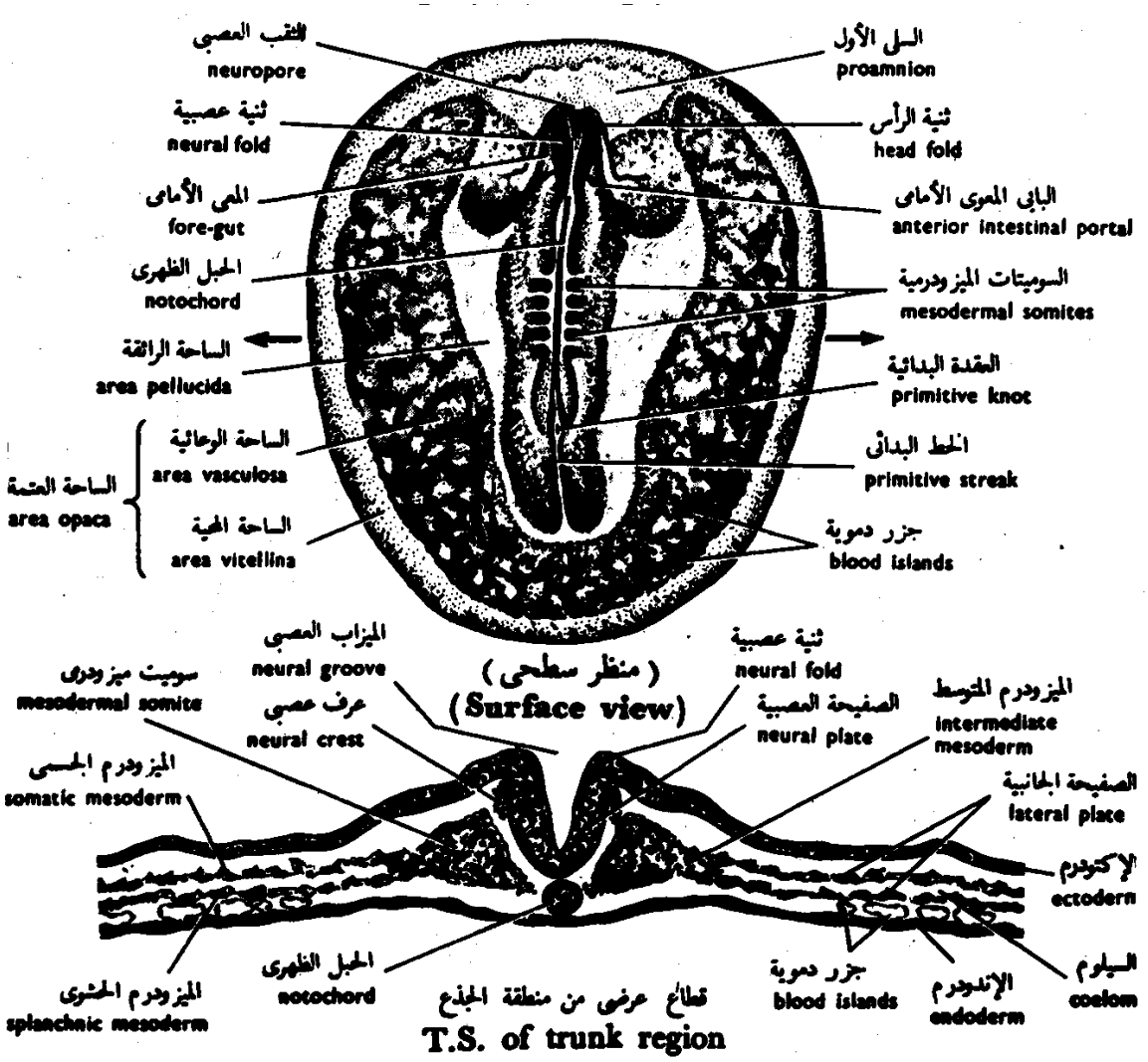


T.S. قطاع عرضي

(Formation of mesoderm تكوين الميزودرم)

شكل ٧٨ ـ جنين الكتكوت في طور العشرين ساعة

FIG. 78 - 20-HOUR STAGE OF CHICK EMBRYO

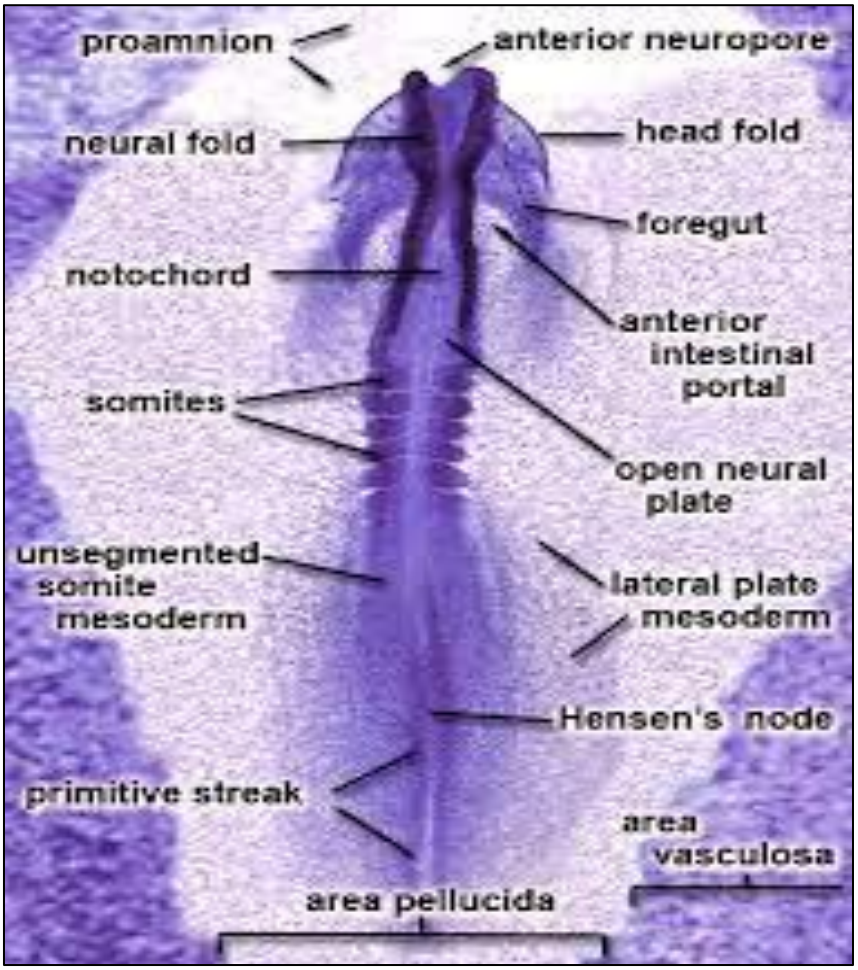


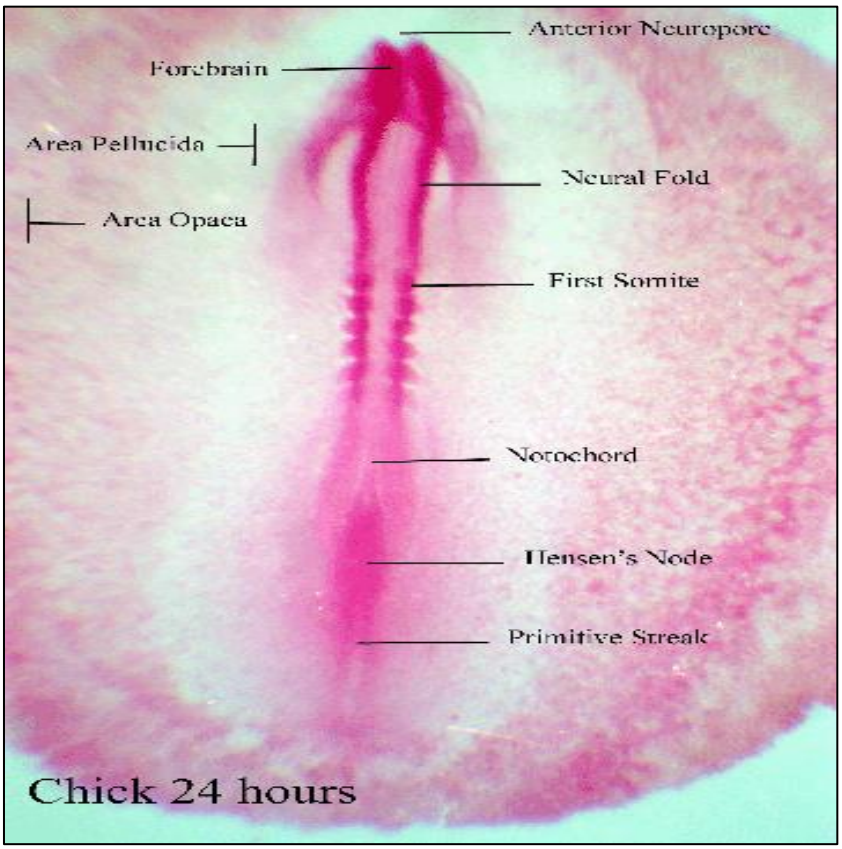
شكل ٧٩ ـ جنين الكتكوت فى طور الأربع والعشرين ساعة

FIG. 79 - 24-HOUR STAGE OF CHICK EMBRYO

Chick 24 hour

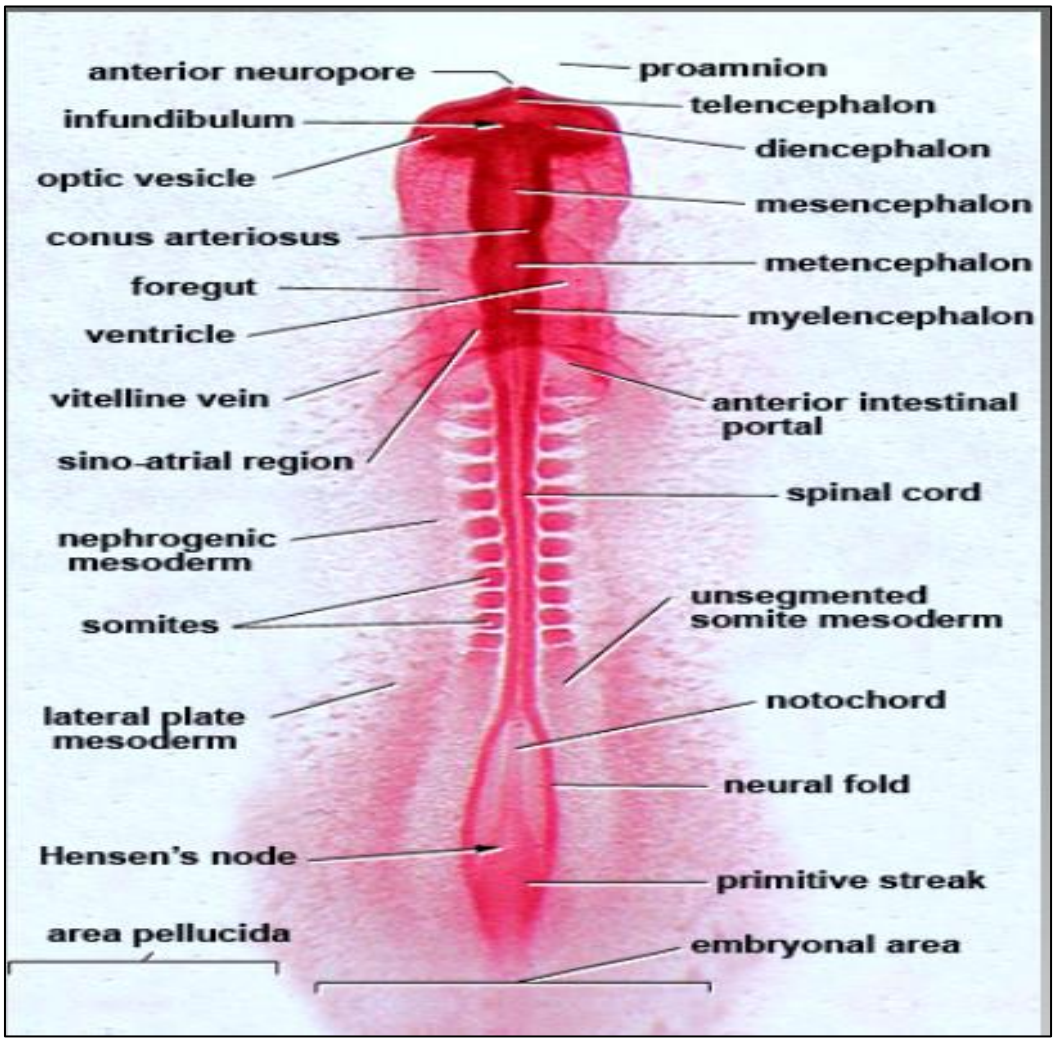
The somites are formed in the mesoderm at the left and right side of the neural walls. In this stage, they are visible as 4 to 5 segmented paired blocks. Afterwards these structures will differentiate in to the vertebrae, the ribs, a part of the skin and the dorsal muscles. Only this head region elevates above the underlying area pellucida. In this preparation, one can see the chorda (notochord) in the region of the differentiating foregut.

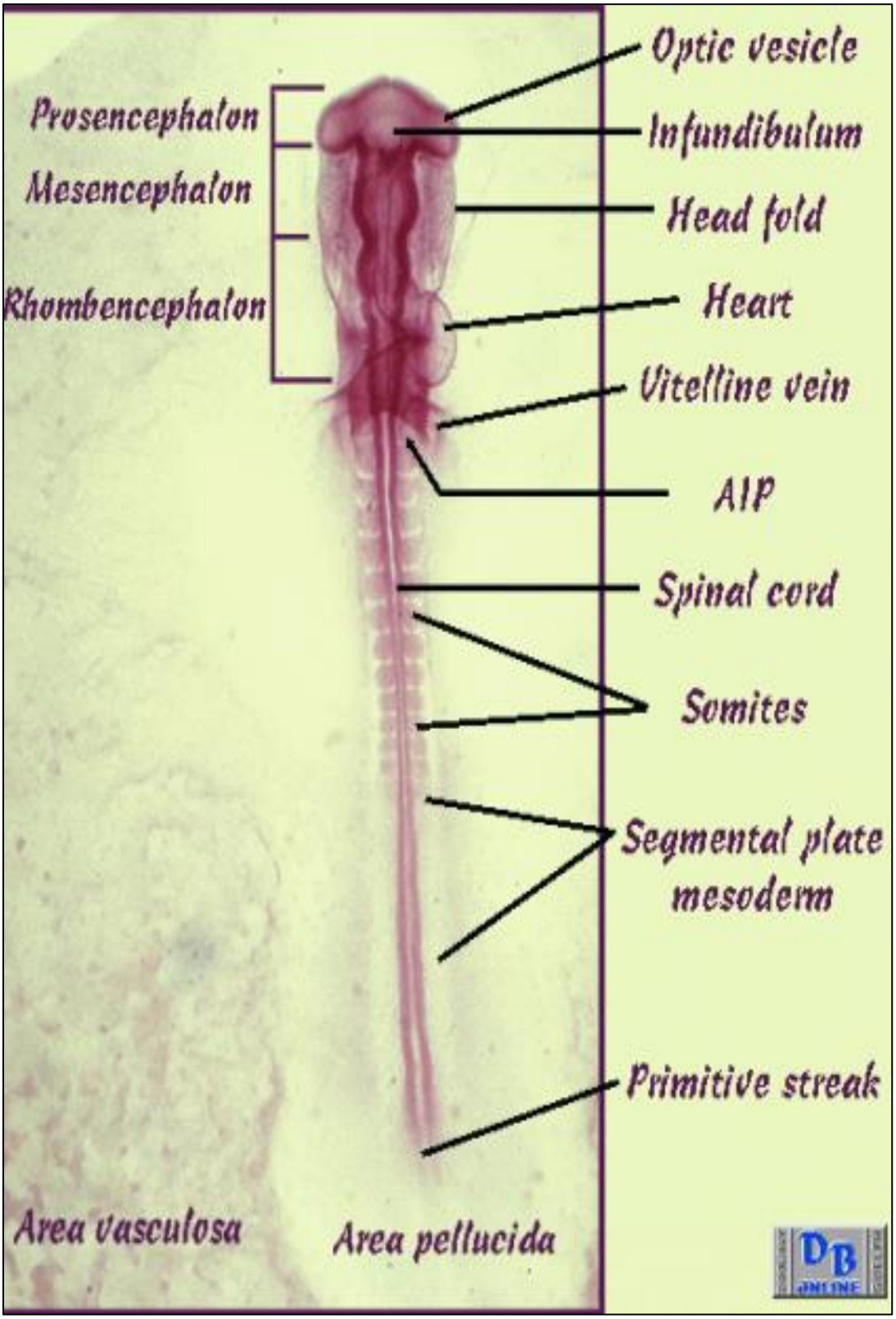

proamnion
anterior neuropore
neural fold
head fold
foregut
notochord
anterior intestinal portal
somites
open neural plate
unsegmented somite mesoderm
lateral plate mesoderm
Hensen's node
primitive streak
area vasculosa
area pellucida


Anterior Neuropore
Forebrain
Area Pellucida
Neural Fold
Area Opaca
First Somite
Notochord
Hensen's Node
Primitive Streak
Chick 24 hours

Chick 33 hour

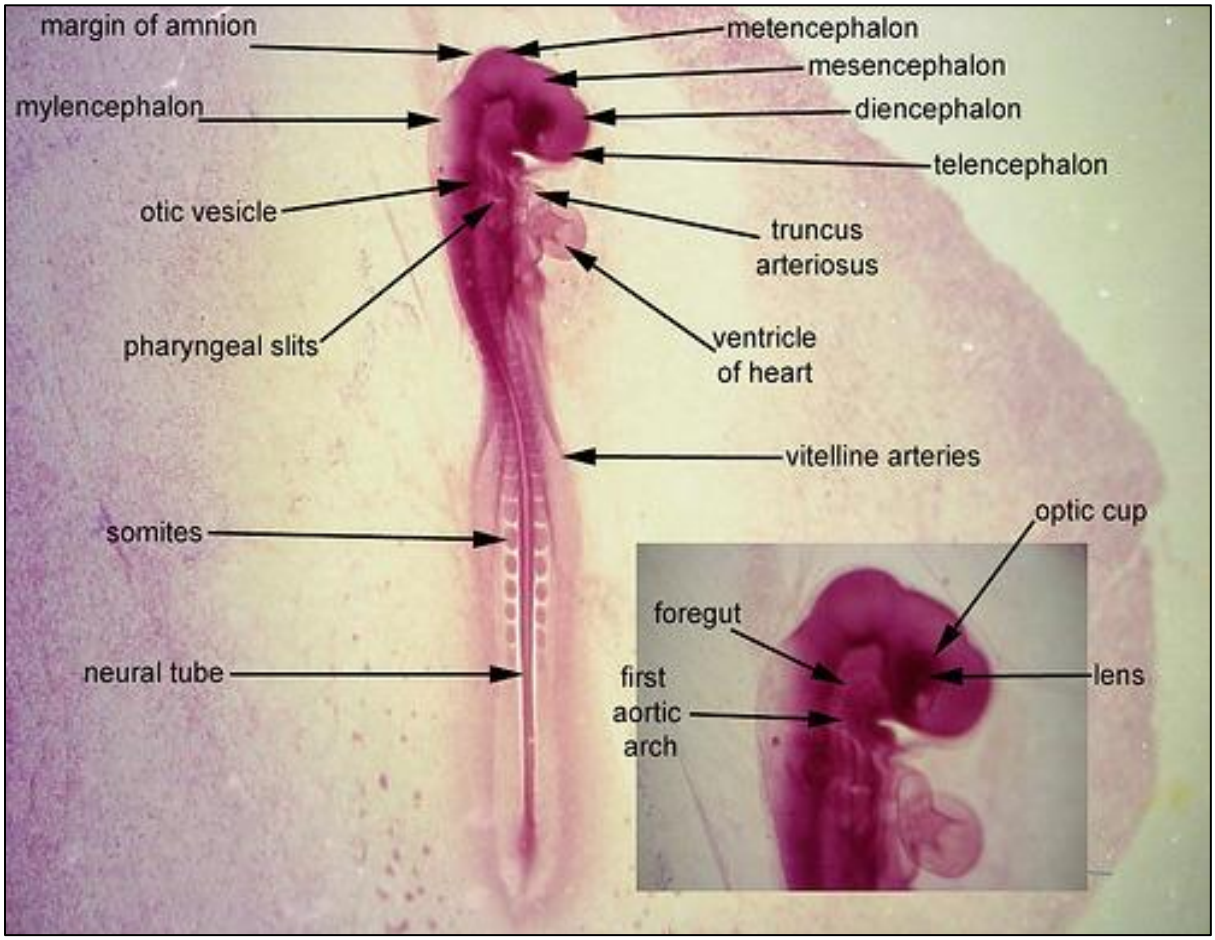
At about 33 hours after fertilization, the embryo is about 4 mm long and the first flexion of the originally straight embryo starts in the head region and the cranial flexure will be visible a few hours later. At this stage 12 to 13 somites are formed. The eye vesicles are rather large. The forebrain vesicle or prosencephalon will divide, the midbrain vesicle or mesencephalon remains undivided while the hindbrain vesicle or rhombencephalon will form a series of smaller neuromeres. The sinus rhomboidalis (diamond-shaped???) is still present as the only opening of the neural tube and the primitive streak is only rudimentary. The infundibulum (= derived from the diencephalon) appears as a half circular structure at the ventral side of caudal part of the forebrain. The notochord or chorda dorsalis ends just behind this venral vesicle.

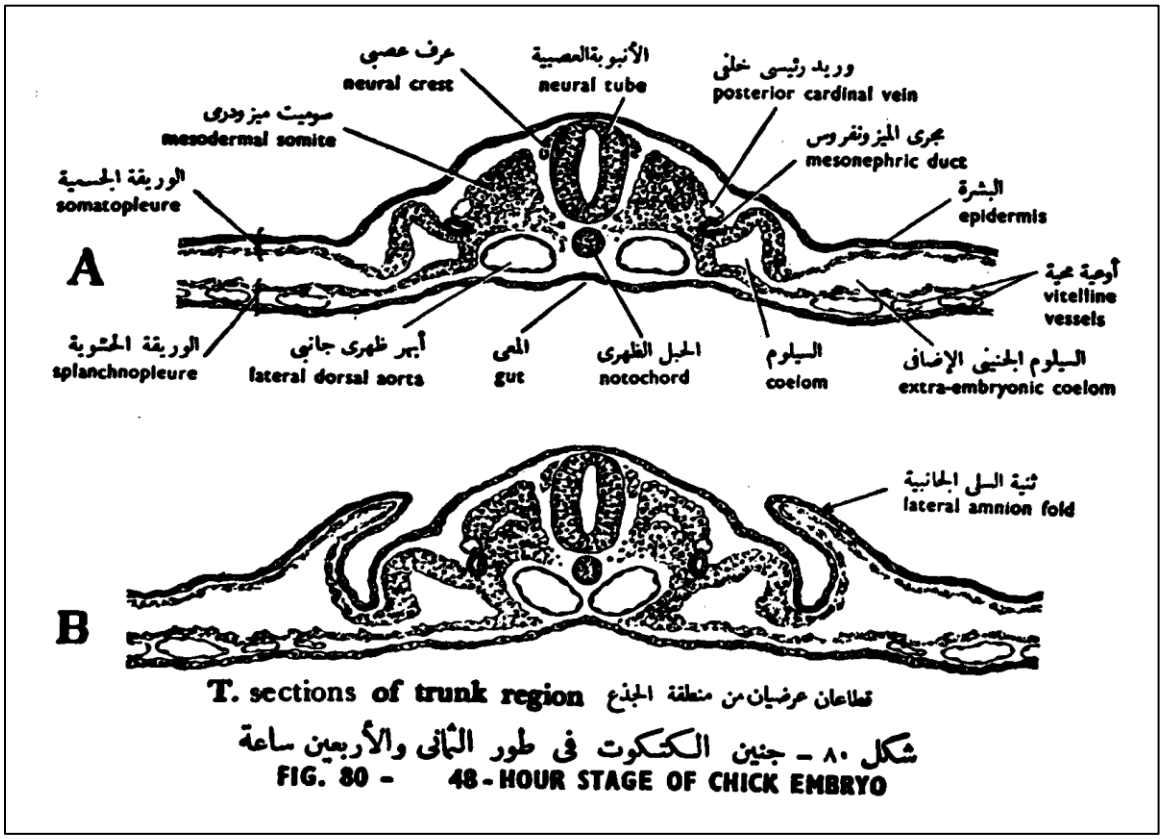



Optic vesicle
Prosencephalon
Infundibulum
Mesencephalon
Head fold
Heart
Rhombencephalon
Vitelline vein
AIP
Spinal cord
Somites
Segmental plate mesoderm
Primitive streak
Area vasculosa
Area pellucida

Chick 48 hour

The position of the embryo with respect to the yolk changes strongly about 48 hours after fertilization. In addition to the head fold of the amnion, also the lateral and caudal amniotic folds begin to form. The outgrowth of the cranial flexure is so strong that the forebrain and hindbrain vesicles become almost located to each other. The cephalic region of the embryo is twisted in such a manner that the left side comes to lie next to the yolk. A second flexure appears at the transition of the head and the body just behind the heart region. The embryo takes now the shape of a C. The head becomes covered by a double fold. These folds definitely establish the first extra embryonic membrane (=outside of the embryo): the amnion membrane. The vitelline (yolk rich) arteries and veins become connected with the extra embryonic circulatory vessels. A few branchial grooves are already visible. The brain divides in to 5 vesicles: telencephalon and diencephalon (both formed by the division of the forebrain vesicle), mesencephalon, metencephalon and myencephalon (both formed by the division of the hindbrain vesicle). The lens placode (placode=plate) will form the lens vesicle, the optic vesicle will become the optic cup and the auditory placode the auditory pit. The heart differentiates in to 4 compartiments: the sinus venosus, connected with the veins, the atrium, the U-shaped ventricle and the bulbus cordis. The atrium and ventricle are well distinguishable in the figure.





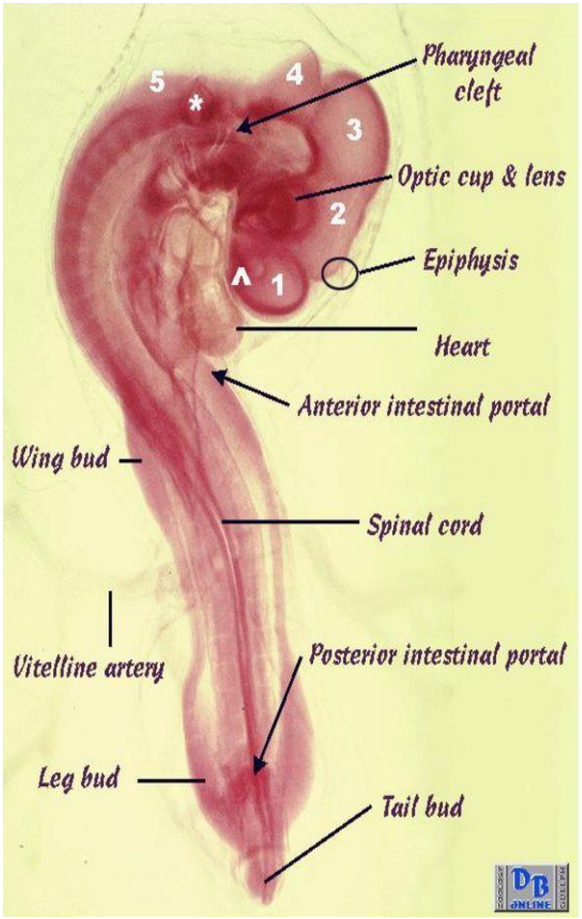
T. sections of trunk region قطاعان عرضيان من منطقة الجذع

شكل ٨٠ ـ جنين الكتكوت فى طور الثمانى والأربعين ساعة

FIG. 80 - 48-HOUR STAGE OF CHICK EMBRYO

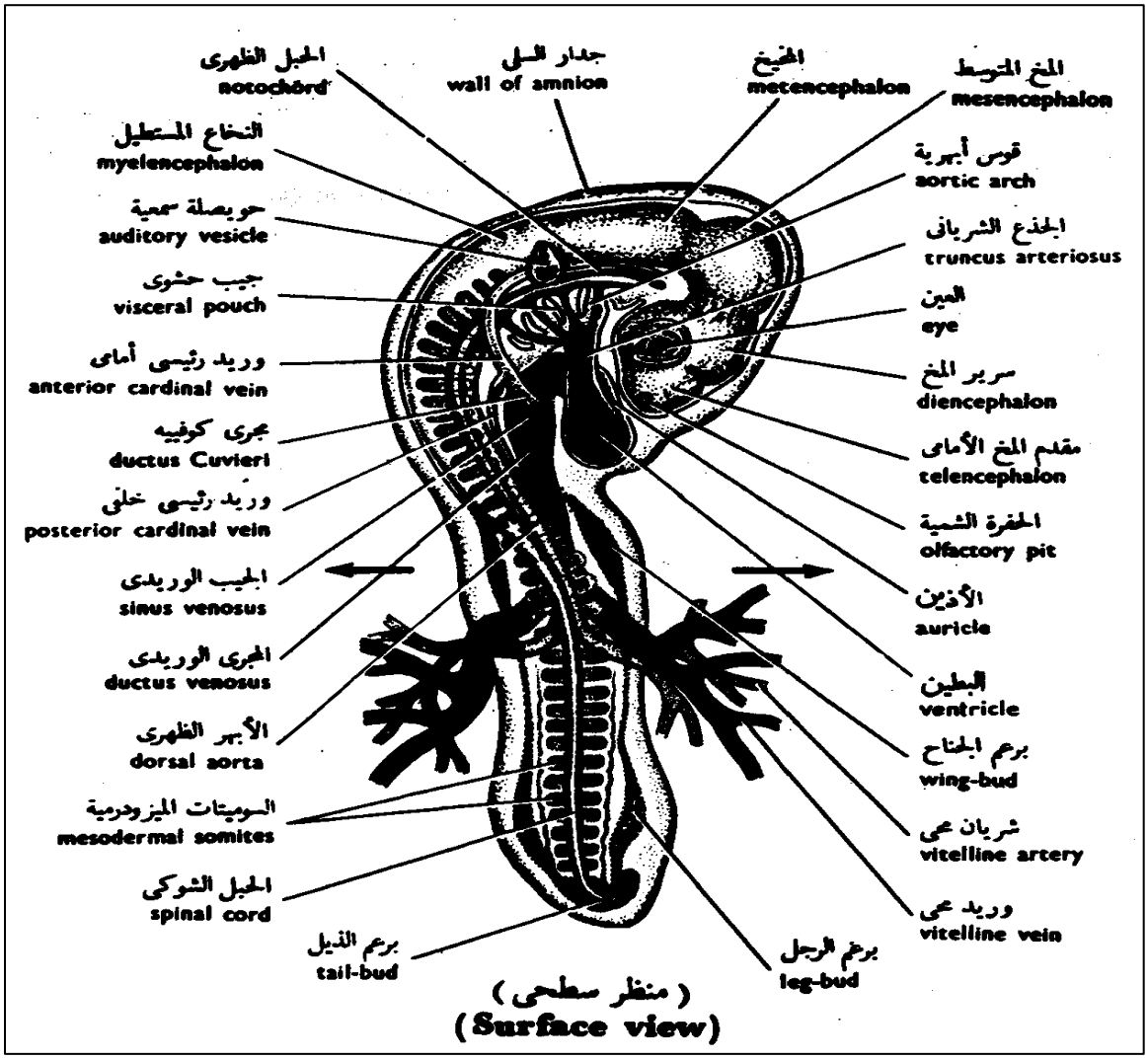
Chick 72 hour

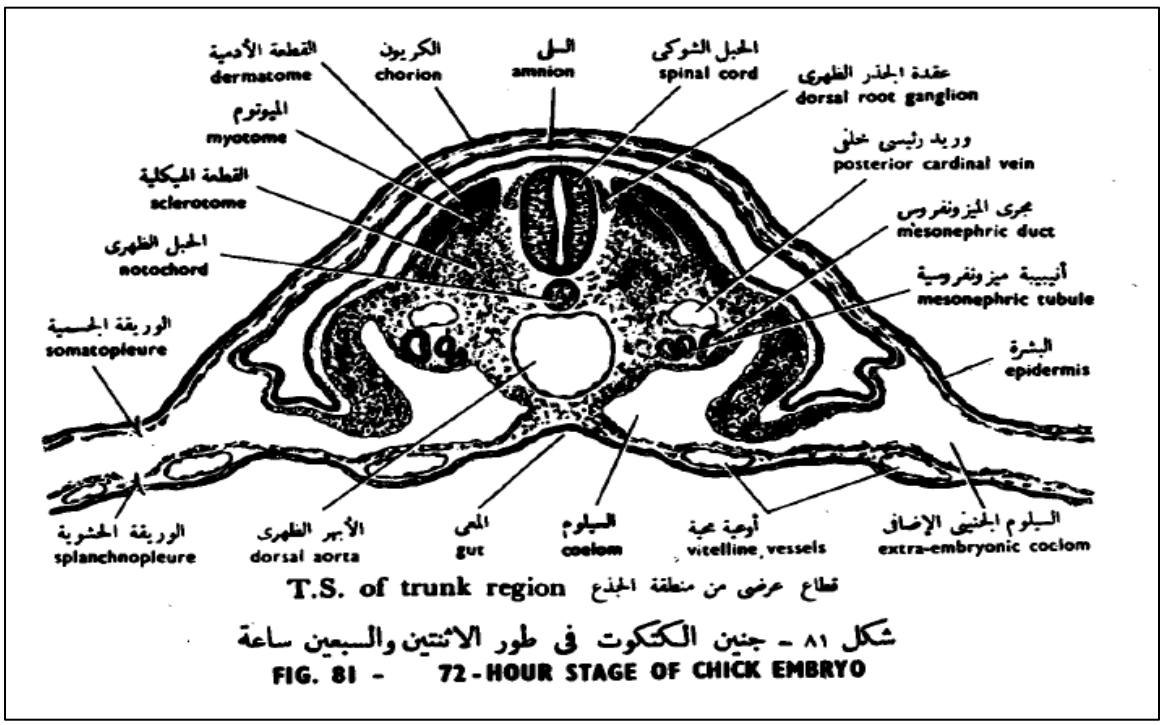
72 Hours after fertilization, the rotation of the embryo to the left is arrived such behind the region of the heart and only the caudal part of the embryo must twist 90 degrees. The two flexures in the head region are almost completed. The fourth pharyngeal groove develops and the pharyngeal arches are thicker. Due to the cranial flexure, the pharyngeal region (= region of the trachea) is now located at the ventral side of the head. The fore and hind limbs at the level of the 16th to the 20th respectively the 27th to the 32th somite pairs are visible as small buds at an incubation time of about 3 days.



72 Hour Chick Embryo Whole Mount

1 = Telencephalon
2 = Diencephalon
3 = Mesencephalon
4 = Metencephalon
5 = Myelencephalon
*** = Otic capsule**
^ = Olfactory pit



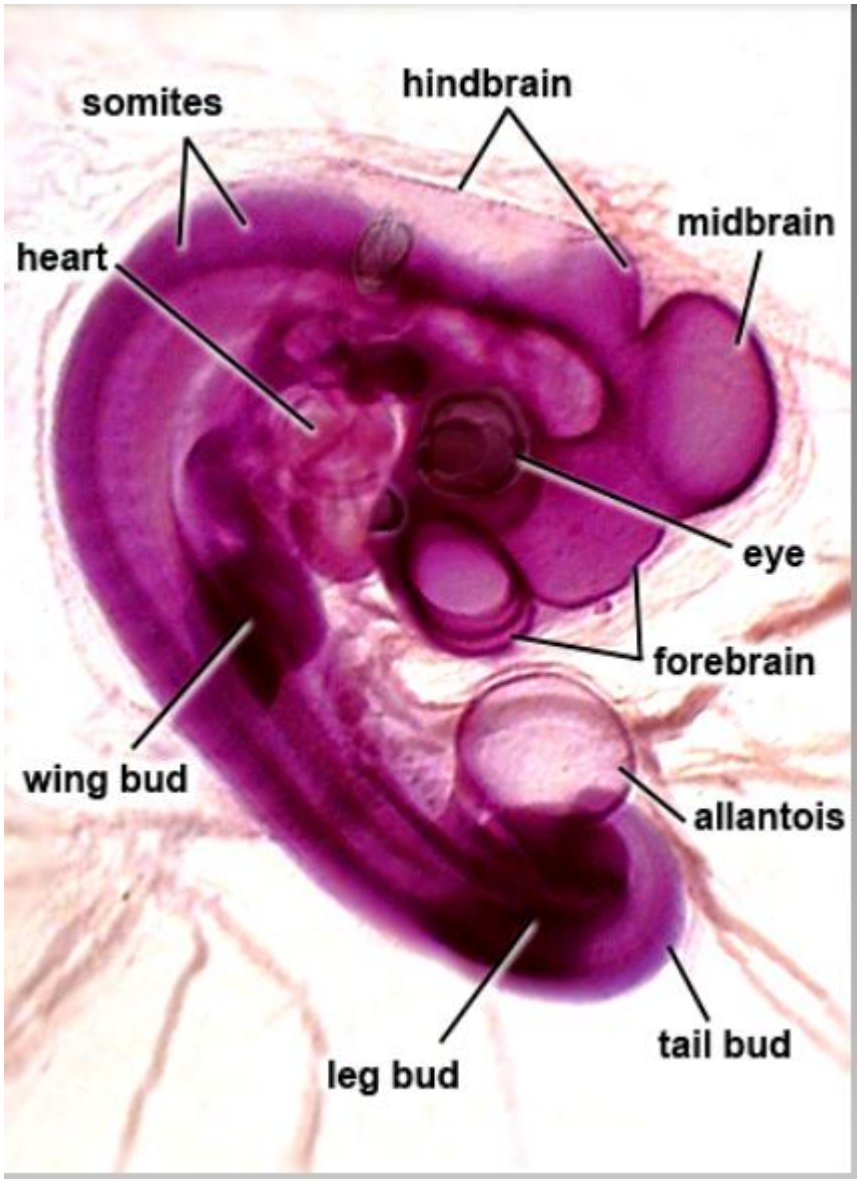


T.S. of trunk region قطاع عرضى من منطقة الجذع

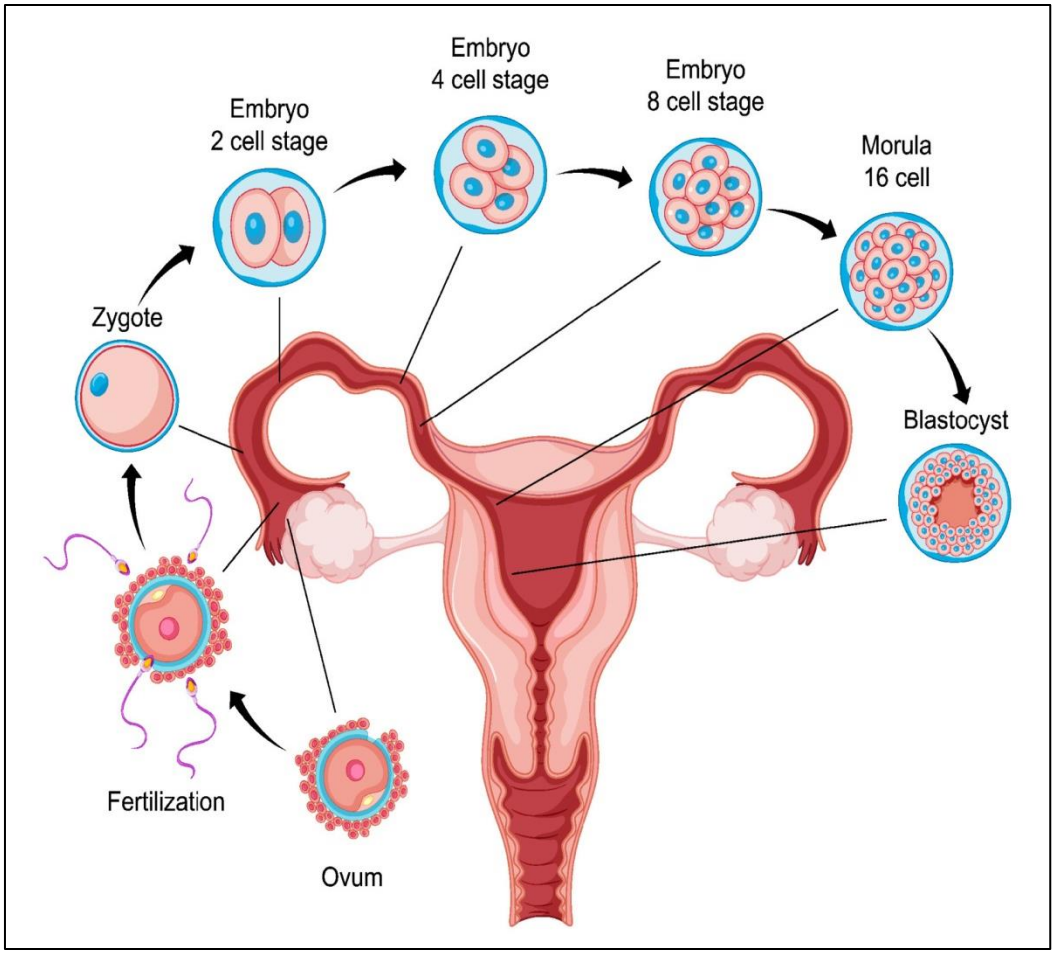
شكل ٨١ - جنين الكتكوت فى طور الاثنتين والسبعين ساعة

FIG. 81 - 72-HOUR STAGE OF CHICK EMBRYO

Chick 96 hour



Embryonic development of mammals (humans)



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