CHAPTER – 01

GAMETOGENESIS

The **formation** and **ripening of two highly dissimilar** and **specialized sex cells** or **gametes** from the **germ mother cell** of the **gonads** is called **gametogenesis**.

large-sized, non-motile, nutrient filled cell called the **ovum** or **egg**, and a small-sized, motile, sex cell called **spermatozoa** or **sperm**.

The **formation of spermatozoa** or sperm in the male gonad – **testis**, called **spermatogenesis**; similarly, the **formation of ova** or egg cell in the female gonad – **ovary**, called as **oogenesis**.

SPERMATOGENESIS:

Spermatogenesis takes place in the male gonads, *i.e.,* **testes**. Usually testes are paired structures, present outside the body or in the abdominal cavity. Each of the testes consist numerous tubules called **seminiferous tubules**. The tubules contain different types of cells, of which the most important types of cells are the **primordial germ cells**. The other cells within the tubules help to **nourish** the germ cells called **Sertoli cells** and the **interstitial cells (Leydig cells)** are endocrine in nature and **secrete** male sex hormones, the **androgens (testosterone)**.

The spermatogenesis is a continuous process and it can be divided into **two phases** each characterized by specific morphological changes of nuclear and cytoplasmic components. The two phases are as follows;

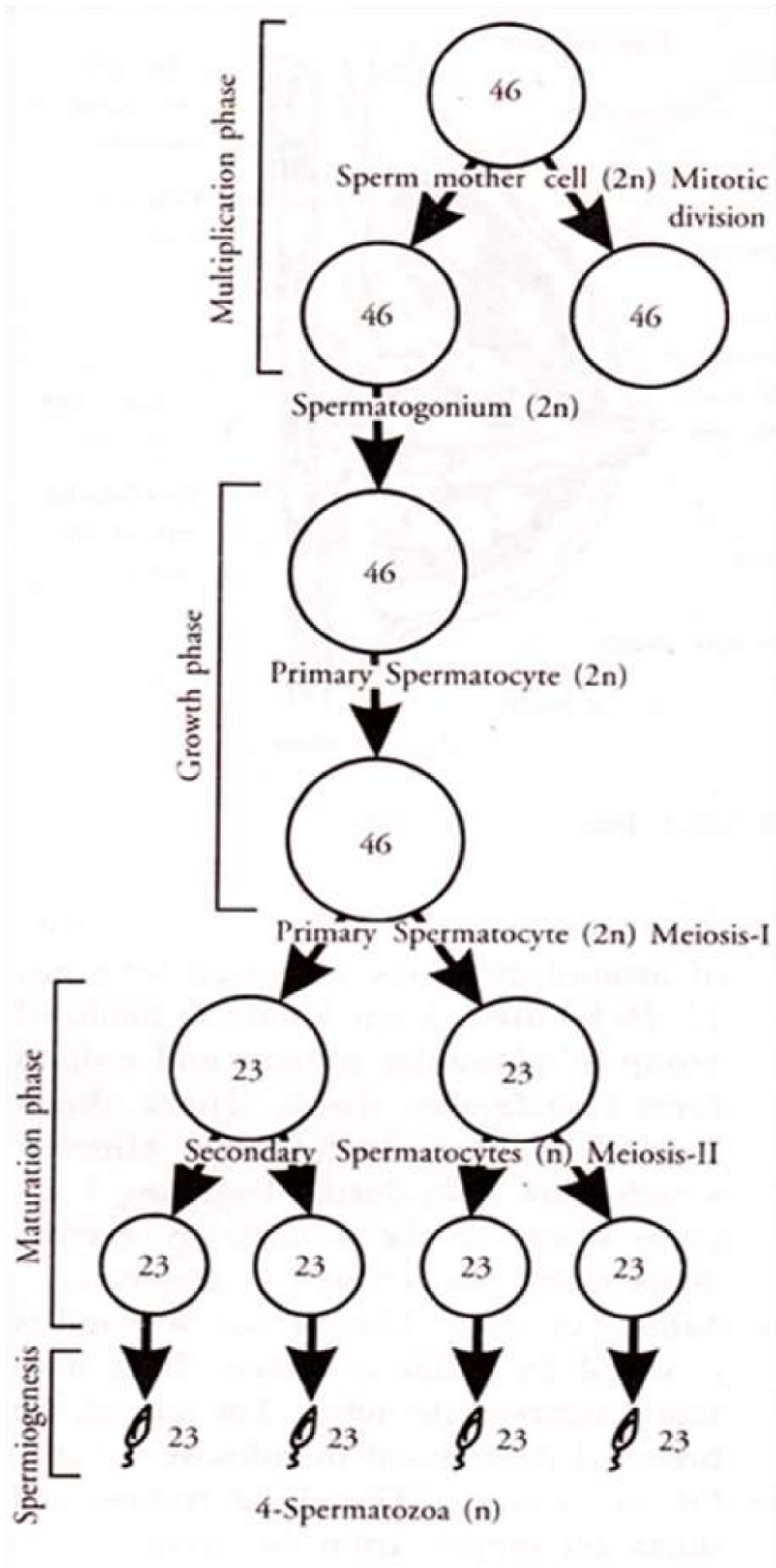
A. Formation of spermatids
B. Spermiogenesis

A. Formation of spermatids:

During the formation of spermatids, each primordial germ cell undergoes three phases as follow; **multiplication phase, growth phase** and **maturation phase**.

1. **Multiplication phase:**

During this phase the diploid primordial germ cells multiply mitotically to form large number of cells. These cells which are formed after repeated mitotic division are called **spermatogonia** (sperm mother cell). This stage of spermatogenesis is called **multiplication phase.** This phase is also known as **proliferation** and **renewal** of spermatogonia.



2. **Growth phase:**

In this phase, the spermatogonia absorb more food and increase in size and they are now called as **primary spermatocytes** and the stage is called **growth phase**. The primary spermatocytes at this stage are still **diploid** in number. The growth phase is shorter in duration.

3. **Maturation phase:**

Then the primary spermatocytes undergo **meiotic division** and this stage is called **maturation phase**.

The **first meiotic division** is the **reduction division** in which the **two daughter cells** get only **haploid** (n) number of chromosomes. Each daughter cell is called **secondary spermatocyte**.

The secondary spermatocytes undergo **second meiotic division** (which is mere mitotic division). Thus, the resulting daughter cells retain same '**n**' number of chromosomes and are called **spermatids**.

In this way, **each primary spermatocyte gives rise to four spermatids**.

Ultimately, each spermatid undergoes various changes and gives rise to a sperm. This process of transformation of spermatids into sperm is called **spermiogenesis**.

B. Spermiogenesis:

The process of transformation of spermatid (non-motile) into sperm (motile) is known as **spermiogenesis**.

Each spermatid consists of **cytoplasm**, a **nucleus** with the gametic chromosomal number, a **pair of centrioles**, **Golgi bodies**, **mitochondria** and other cell inclusions.

The process of spermiogenesis mainly involves a series of changes in nucleus, Golgi bodies, centrioles, and mitochondria.

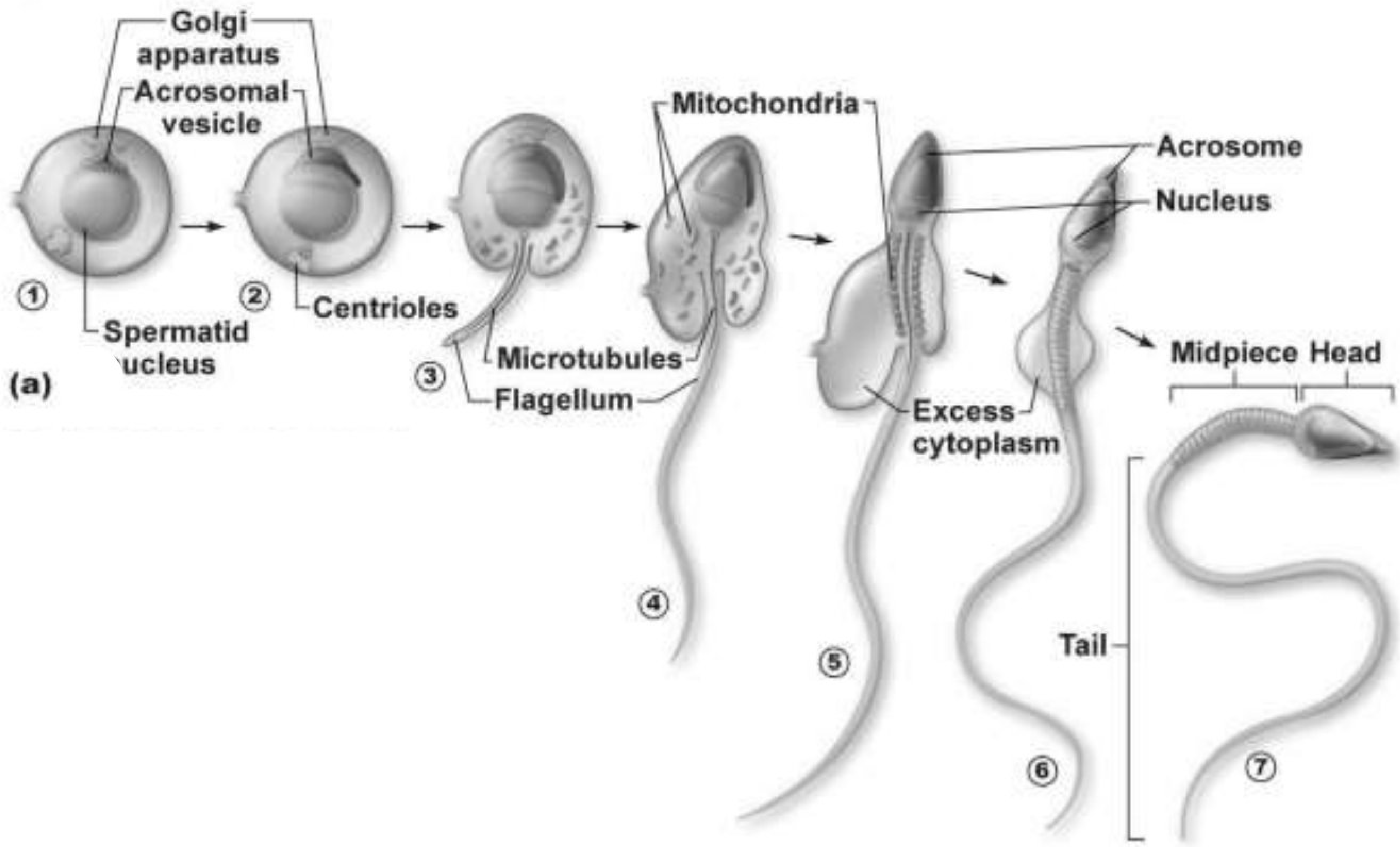
1. **Changes in the nucleus**:

   - ✓ The **nucleus loses water** from the nuclear sap and the **chromosomes** become **short** and **compact**.
   - ✓ **RNA** and other proteins become **scarce** in the nucleus and only the **DNA concentrates in the nucleus**.

- ✓ Thus the **shape of the nucleus** becomes **elongated** and **narrow**.
- ✓ This has a functional significance that **it reduces the weight** and thus facilitates **increased motility** of the sperm.

2. **Changes in the Golgi bodies (formation of acrosome)**:
   - ✓ The **acrosome** of the sperm is **derived from the Golgi bodies** which are arranged around small vacuoles.
   - ✓ One or more vacuoles begin to enlarge and a **dense body** formed inside the vacuole. The dense body is called **pro-acrosomal granule**.
   - ✓ All the pro-acrosomal granules fuse together, further increase in size and now it is termed as **acrosomal granule**, which forms the **core of the acrosome**.
   - ✓ The **vacuole loses water** and its wall spreads out covering the front half of the nucleus and acrosome. This is the **head cap** or **acrosomal cap** of the nucleus.
3. **Changes in the centrioles (formation of the tail)**:
   - ✓ The spermatid consists **two centrioles**, and they move **behind the sperm nucleus**.
   - ✓ A **depression is formed** in the posterior surface of the nucleus and one of the two centrioles is placed in the depression. This is the **proximal centriole** (upper) of the spermatozoa; the other centriole, the **distal centriole** (below).
   - ✓ The **distal centriole** now, **gives rise** to the **axial filament** of the **flagellum** (tail) of the spermatozoa. Thus the region between the two centrioles forms the **middle piece**.
4. **Changes in the mitochondria**:
   - ✓ Most of the **mitochondria of spermatid concentrate around the distal centriole** and **upper part of the axial filament.**
   - ✓ In the mid-piece of sperm, the mitochondria **lose their individuality** by **fusing** to become **spirally arranged mitochondrial bodies**.

Thus, much of the **cytoplasmic fluid** content become **reduced**, **shape of the cell** become **narrow** and finally with all changes a non-motile spermatids **gain the power of motility** become a functional motile, mature sperm.



OOGENESIS:

The process of **formation of egg** or **ovum** in the ovary is called **oogenesis.** An egg acquires its developmental potential during oogenesis. The eggs or ova are formed in the **ovary**. The first cells which give rise to the mass of the ovary are called **primordial germ cells**.

The oogenesis process takes place by three phases; **multiplication phase, growth phase** and **maturation phase.**

1. **Multiplication phase:**

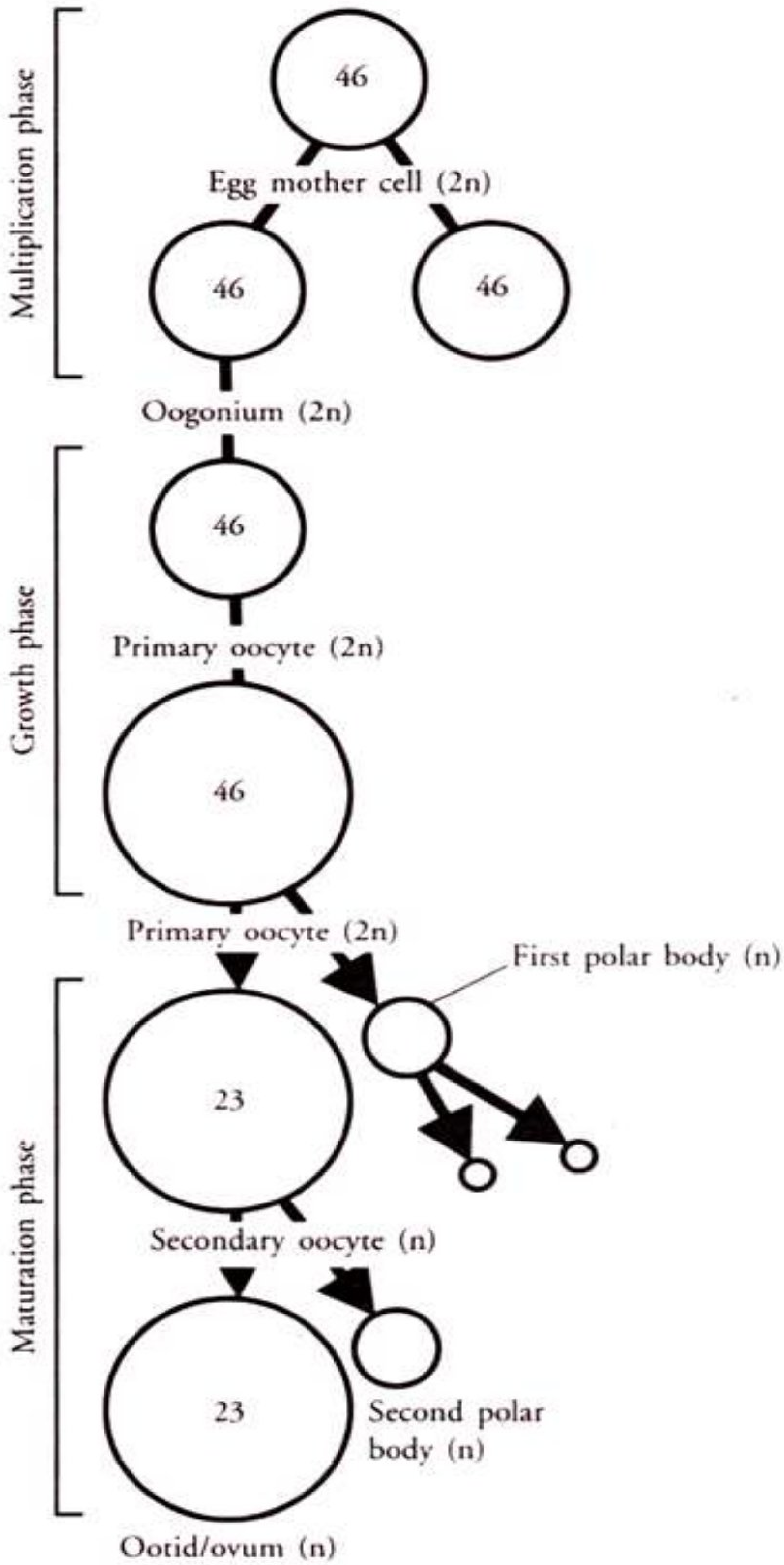
   Each primordial germ cell undergoes repeated mitotic divisions and gives rise to the cells called **oogonia** (egg mother cells). This period is called as the **multiplication phase** of oogenesis.

2. **Growth phase:**

Some of the oogonia enlarges in size periodically and become **primary oocytes.** This stage is called **growth phase.** These cells are '2n' (diploid) in chromosome numbers.

During oogenesis, enormous qualitative and quantitative changes occur in the cytoplasm and nucleus of the oocyte. The primary oocyte acquires large size through progressive growth.

The growth phase of the oogenesis is divided into two sub-phases; **previtellogenesis** and **vitellogenesis**.



Previtellogenesis:

- ✓ During this stage the **cytoplasm** and **nuclear material increase** drastically.
- ✓ <u>The **yolk** and other **food material** are **not synthesized**</u>. But, tremendous increase in the volume of nucleus and cytoplasm of primary oocyte occurs.
- ✓ There is **qualitative** and **quantitative increase** in amount of **cytoplasm**.
- ✓ The **mitochondria increase in number**, the network of **endoplasmic reticulum with ribosome** becomes more **complicated**, the **Golgi bodies** manufacture **cortical granules**.

Vitellogenesis:

- ✓ The **process of formation** and **deposition of yolk** is called **vitellogenesis**.
- ✓ Initially, the developing oocyte **does not** contain any yolk. The nutrients formed only during growth phase.
- ✓ There are **two views** regarding origin of yolk;
  - a. **Endogenous origin:** according to this, **the yolk synthesis takes place in the oocyte cytoplasm** as in vertebrates.
  - b. **Exogenous origin:** a major part of the yolk is **synthesized outside the oocyte** as in **invertebrates** it is synthesized in **liver** and in **insects** in the **fat body**.

3. Maturation phase:

- ✓ Each **primary oocyte** undergoes **first meiotic division** resulting in the formation of **one large cell** and **one small cell.**
- ✓ The larger cell is the **secondary oocyte** and the smaller one is the **I-polar body**.
- ✓ Both of these cells get only **'n'** number of chromosomes.
- ✓ The **secondary oocyte** undergoes the **second meiotic division** which is almost mitotic division so that each daughter cell gets the same 'n' number of chromosomes.
- ✓ Among these cells, **one daughter cell is larger** and becomes the **ootid** and the other **one is smaller** called **II-polar body**.
- ✓ At the same time, the **I-polar body** also **divides** and gives rise to **two daughter II-polar bodies**.
- ✓ **All these (three) polar bodies** will be **lost** and the **ootid** grows into the **functional ovum**.
- ✓ Thus **only one egg** is formed from each primary oocyte and this stage is called as the **maturation phase.**

In vertebrates, the ovum is shed during the breeding season and this **shedding of ovum** is known as **ovulation**.

The process of ovulation in animals is a **seasonal** or **rhythmic** one. The ovum is released into the body cavity and then transported from there into the oviduct and then to the outside as in non-mammals or to the uterus as in mammals.

TYPES OF EGGS:

Generally, eggs have been classified based on the **quantity of yolk, distribution of yolk**, **presence** or **absence of shell** and **type of development**.

The amount of yolk in a fully grown oocyte or egg varies greatly in different animal groups. On the basis of quantity of yolk, eggs have been classified into following four types;

1. **Alecithal egg:**

   In this type of **eggs**, they **do not contain yolk**.

   Example: *eggs of eutherians like human.*

2. **Macrolecithal egg:**

   These are **small sized eggs** which contain a **very small amount** of yolk.

   Example: *eggs of Hydra, sea urchin, Amphioxus, etc.*

3. **Mesolecithal egg:**

   These types of eggs **contain moderate amount** of yolk.

   Example: *eggs of Annelidan worms, Molluscs, Petromyzon, Dipnoi and Amphibians.*

4. **Macrolecithal egg:**

   These types of eggs **contain enormous amount** of yolk.

   Example: *eggs of Insects, Reptiles, Birds, etc.*

On the basis of distribution of yolk, eggs have been classified into three types as follow;

1. **Alecithal egg:**

   In this type, the egg **does not contain any yolk** or **negligible amount of yolk** as the **embryo develops into the egg** and remains **connected to the mother** by **obtaining nutrition** from the mother **through the placenta** and hence requires a negligible amount of yolk in it.

   Example: *eggs of Eutherian Mammals*

2. **Homolecithal or Isolecithal egg:**

   In this type of egg, the **yolk material is distributed uniformly** throughout the egg cytoplasm.

   Example: *eggs of Echinoderms and Amphioxus.*

3. **Telolecithal egg:**

   The yolk is highly **concentrated** towards the **vegetal pole**.

   Example: *eggs of Amphibia, reptilia and Birds.*

4. **Centrolecithal egg:**

   The yolk present at the **central position** of the egg.

   Example: *eggs of Insects.*

EGG MEMBRANES:

All the eggs are covered by the cell membrane called **plasmalemma**. In addition, the eggs of all animals except a few are surrounded by special **egg membranes** or **egg envelopes**.

Depending on their origin, the egg membranes are classified into **Primary, Secondary** and **tertiary egg membranes**.

1. **Primary egg membranes:** this membrane is **secreted** by **egg cytoplasm**. They are closely attached to the surface of the egg. Primary egg membrane is of the following types;
    a. **Vitelline membrane**: it is formed of **mucopolysaccharides** and some **fibrous proteins.** It is a **thin** and **transparent** membrane closely applied to the underlying plasma membrane. The vitelline membrane has been given different name in different animals. For example, **in fishes** this membrane is called **chorion.**
    b. **Zona radiate**: the primary envelops of Shark, some fishes, amphibians and reptiles have striated appearance and are called **zona radiate**.
    c. **Zona pellucida**: it is the modified zona radiate layer, which is unstriated and is formed by the joint efforts of ova and follicle cells. It occurs in mammals.
    d. **Jelly envelope**: in echinoderms and many other eggs of marine invertebrates, the primary envelope is much thicker structure of jelly coat.

    All these primary egg membranes usually adhere closely to the surface of the oocyte, but later stage a space filled with fluid may appear between the egg plasma membrane and primary egg membrane. This space is called **perivitelline space**.

2. **Secondary egg membranes:** the secondary membrane is secreted outside the primary egg membrane by the follicle cells of the ovary. No secondary membrane is found in amphibians, reptiles and in birds. **Nor there is a true membranous envelope around the mammalian eggs**, but the cells comprising the ovarian follicle, with in which the mammalian egg lies.

    It occurs in the form of **chitinous** shell surrounding the egg in insects, ascidians and cyclostomes and is called chorion. These are usually tough and impermeable. It consists of opening called **micropyle**.

3. **Tertiary egg membrane:** the tertiary egg membrane is produced by the cells of the oviduct or other accessory part of the maternal genital organ, as the egg travels down the duct to the exterior.

   a. In **oviparous sharks** and **rays** (elasmobranches) the egg is surrounded by **albumen** and **hard horny capsule** of a complicated shape. The horny egg capsule is secreted by the shell gland of the oviduct. These capsules with twisted horns **serve to entangle the eggs among seaweeds**.

   b. The **amphibian eggs** consist of jelly coat made up of **gelatine**. When amphibian egg is deposited in the water, the jelly absorbs water and swells. The layer of **jelly coat protects** the eggs from **desiccation** (drying) and **serves** to make the eggs **adhere to one another** and to submerged objects such as water plants.

   c. **The albumin (egg white), shell membranes and the outermost calcareous** is found in the egg of hen.

   Albumen is found outside the vitelline membrane.

   Shell membrane is formed around the albumin and made up of **keratin**.

   The shell is the outer covering of land laying eggs. It is made up of **Calcium Carbonate**. It is white or brown in colour consist of air-pores (porous).

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"No one is wise by birth, for wisdom results from one's own efforts."

T. Krishnamacharya

CHAPTER – 02

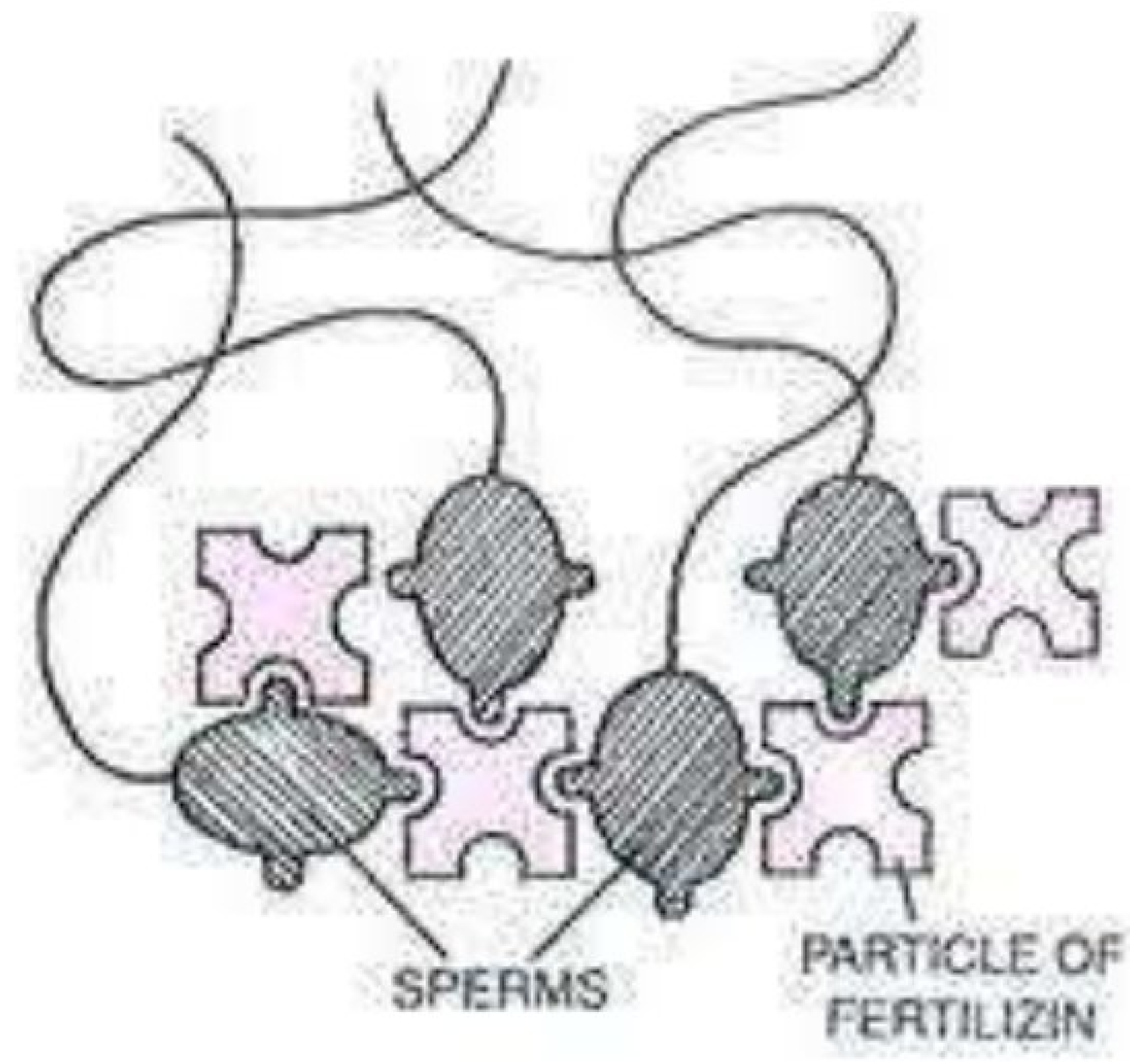
FERTILIZATION

The process of **union of haploid male gamete** (sperm) with the **haploid female gamete** (egg) **to form a diploid zygote** is known as **fertilization**.

THE PROCESS OF THE FERTILIZATION:

The process of fertilization involves many steps as follow; (with reference to Sea Urchin)

1. **Approach of the spermatozoon to the egg:**
   a. The movement of sperm towards the egg attracted by the liberation of some chemical substances. It has been found that the Sea Urchin's **egg** and **sperm** produce **fertilizin** and **antifertilizin** respectively. When the sperm come to the vicinity of the egg, these chemicals interact and attracting sperm towards the egg. This type of **chemical interaction between the gametes** of the same species is known as **chemotaxis**.
   b. **Fertilizin:** it is present in the jelly coat of the egg which slowly gets dissolved in the sea water.
   c. **Antifertilizin:** the surface layer of sperm contains another proteinaceous substance known as antifertilizin.
   d. It has also been reported that the fertilizin in egg-water attracts the sperms of the same species and many sperms adhere together. This type of mutual adhesion of the sperms is known as the **agglutination** and is most common in sea urchins.
   e. The **egg fertilizin** shows **reaction** with the **sperm antifertilizin** of the **same species**.



f. **Gamones**: Hartmann (1930) found that the **substances produced from the sperm** and **ova** are in some way **similar to hormones** and because they are produced by gametes they are called **gamones**.

- The active substances produced by the ova are known as **gynogamones**, and the substances resident in sperm are called **androgamones**.
- There are two gynogamones and two androgamones and are believed to function in the following order.
- **Gynogamone I**: it activates the sperms to **vigorous swimming** movements.
- **Gynogamone II**: it makes the surface of the **sperm heads sticky** and thus enables to attach the egg for sufficient time to initiate penetration.
- **Androgamone I**: it **inhibits the active sperm movement**. Because the spermatozoa contain a minimal amount of energy producing material. Therefore, it inactivates until the action of the Gynogamone I.
- **Androgamone II**: it is responsible for the **dissolving of the outer egg membrane**, thereby facilitating the penetration of sperm calls.

2. Activation of gametes:

The process of activation of gametes is completed in the following stages;

a. **Movement of the sperm towards the egg**: The sperms which occur in the external or internal fluid media around the egg swim towards the egg at random. They collide with the egg by chance. The fertilizin and antifertilizin become active after the chance collision of the sperms with the ova.

b. **Activation of the Sperms:** when a sperm with a specific antifertilizin comes in contact with the egg water of its own species; the peripheral portion of the acrosome of sperm collapses and its enzymes are extruded and dissolve in the water. The central portion of the acrosome elongates and thin tube, known as the **acrosomal filament**. The acrosomal filament is the rigid tube which protrudes out from the sperm head. When the sperm possesses such an acrosomal filament, it is said to be activated for the ready penetration in the unfertilised egg.

c. **Activation of the egg**: when the activated sperms reach to the egg, the acrosomal filaments penetrate into the egg jelly and vitelline membrane by the help of dissolving action of the sperm lysins. As soon as the acrosomal filament touches the egg surface, the ooplasm protrudes out at the point of contact into a cone-like process known as the **fertilisation cone**.

3. **Penetration:**

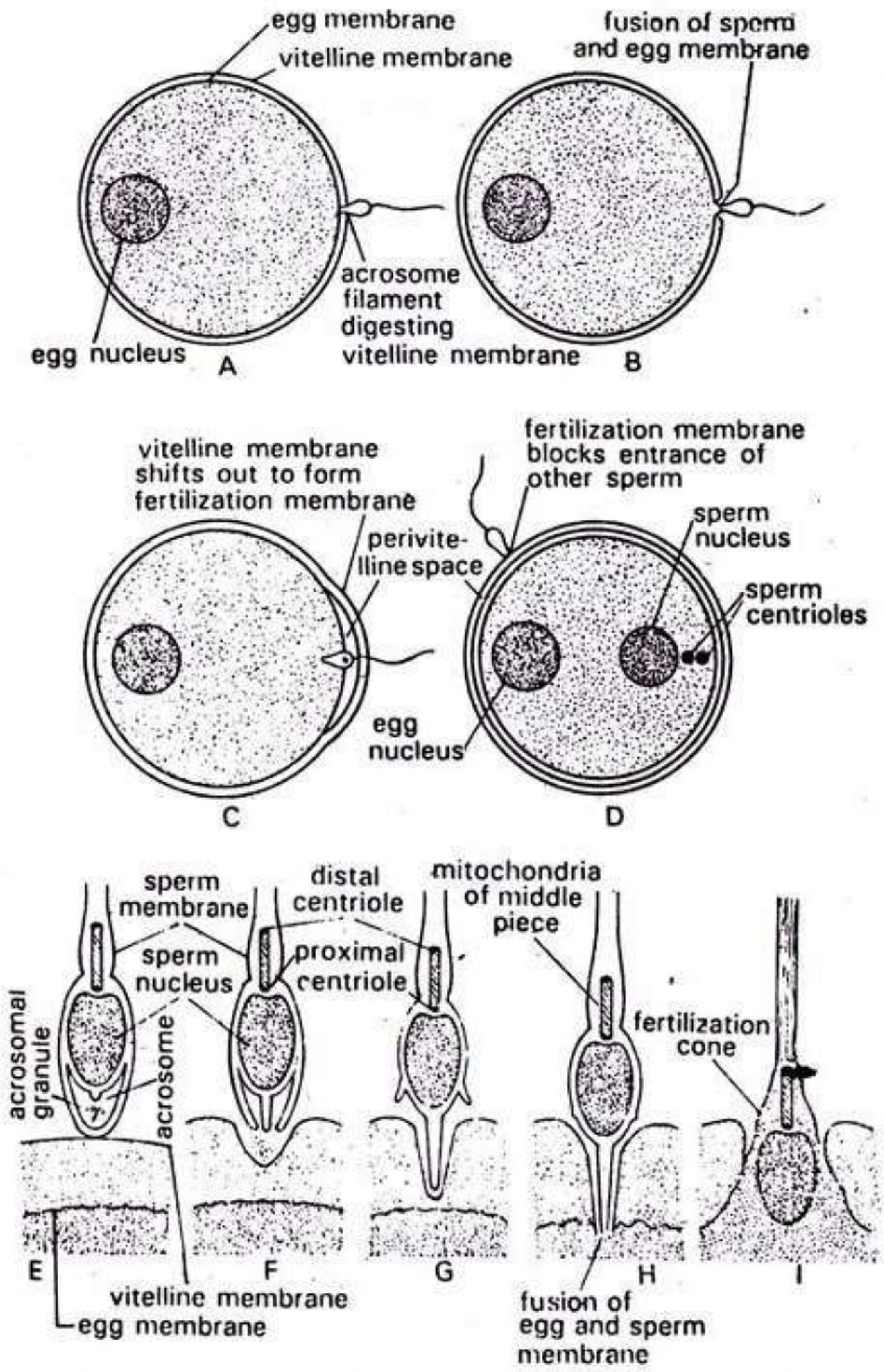
The fertilisation cone engulfs the sperm and the sperm which is surrounded by the hyaline cytoplasm moves inwards. The penetration of the sperm in the egg is known as the **insemination**.

4. **Reaction of the egg:**

Immediately after the insemination, a thin membrane known as the fertilisation membrane is formed around the plasma membrane of the egg. The fertilisation membrane prevents the entrance of further sperms in the egg.

5. **Amphimixis:**

The fusion of male and female pronuclei is called amphimixis. In the case of sea urchins and vertebrates, the two pronuclei (male and female) come close to each other and the close contact takes place between the two. The nuclear envelope is broken at the point of contact and the nuclear contents of both pronuclei are intermingled. The endoplasmic reticulum forms a new common nuclear envelope around the both pronuclei and, thus, forms a zygote nucleus.


egg membrane
vitelline membrane
fusion of sperm and egg membrane
acrosome filament digesting vitelline membrane
egg nucleus
A
B
vitelline membrane shifts out to form fertilization membrane
fertilization membrane blocks entrance of other sperm
perivitelline space
sperm nucleus
sperm centrioles
egg nucleus
C
D
sperm membrane
distal centriole
mitochondria of middle piece
sperm nucleus
proximal centriole
fertilization cone
acrosomal granule
acrosome
E
F
G
H
I
vitelline membrane
egg membrane
fusion of egg and sperm membrane

KINDS OF FERTILIZATION:

1. Monospermic Fertilization:

In most animals, usually **only one sperm enters in the egg**, this type of fertilisation is known as **monospermic fertilisation**. The monospermic fertilisation is common in the **coelenterates**, **annelids**, **echinoderms**, **bony fishes**, **frogs** and **mammals**.

2. Polyspermic Fertilization:

When **many sperms enter in the egg**, the fertilisation is known as the polyspermic fertilisation. Polyspermia may be of two types;

i. Pathological Polyspermy:

Under certain **abnormal conditions**, when in a monospermic type of egg many sperms enter into the egg, the condition is known as **pathological polyspermy**. This type of **egg does not develop** further and **dies** soon.

ii. Physiological Polyspermy:

In the animals with large yolky eggs such as molluscs, sea urchins, Urodels, reptiles and birds, the polyspermic fertilisation usually occurs. Such polyspermic fertilisation is known as **physiological polyspermy**.

In these cases, **many sperms enter in the egg but only one unites with the egg pro-nucleus** and **rest are degenerated** soon. Such eggs are viable and develop further.

SIGNIFICANCE OF FERTILIZATION:

The act of fertilization has many consequences which have been found to be vital significance. However, these consequences may not necessarily depend on fertilization.

1. **Reproduction:**

   The main significance of fertilization is to bring about reproduction by activation and by restoring the diploid number of chromosomes in the zygote.

2. **Activation of egg:**

   Fertilization activates the egg to start cleavage.

3. **Variation in young ones:**

   In reality, variations are brought about in the genes of offspring by mutation and recombination through meiotic division during fertilization.

4. **Sex determination:**

   In higher vertebrates, the event of fertilization enables the determination of the sex by the contribution of X or Y chromosome by the sperm.

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"If you are wealthy, be humble. Plants bend when they bear fruit."

Sai Baba

CHAPTER – 03

PARTHENOGENESIS

Usually, an unfertilized ovum develops into a new individual only after the union with the sperm. In certain cases, the **development of the egg takes place without the fertilization**, known as **parthenogenesis**.

Types of Parthenogenesis: the parthenogenesis may be of two types as follows;

1. Natural parthenogenesis
2. Artificial parthenogenesis

CYTOLOGY OF NATURAL PARTHENOGENESIS:

In certain animals the parthenogenesis occurs regularly, constantly and naturally in their life cycles and is known as the natural parthenogenesis.

M. J. D. White recognizes four types of natural parthenogenesis, from the cytogenic point of view.

a. Haplodiploidy or Arrhenotoky

b. Amictic or Meiotic Thelytoky

c. Apomictic or Ameiotic Thelytoky

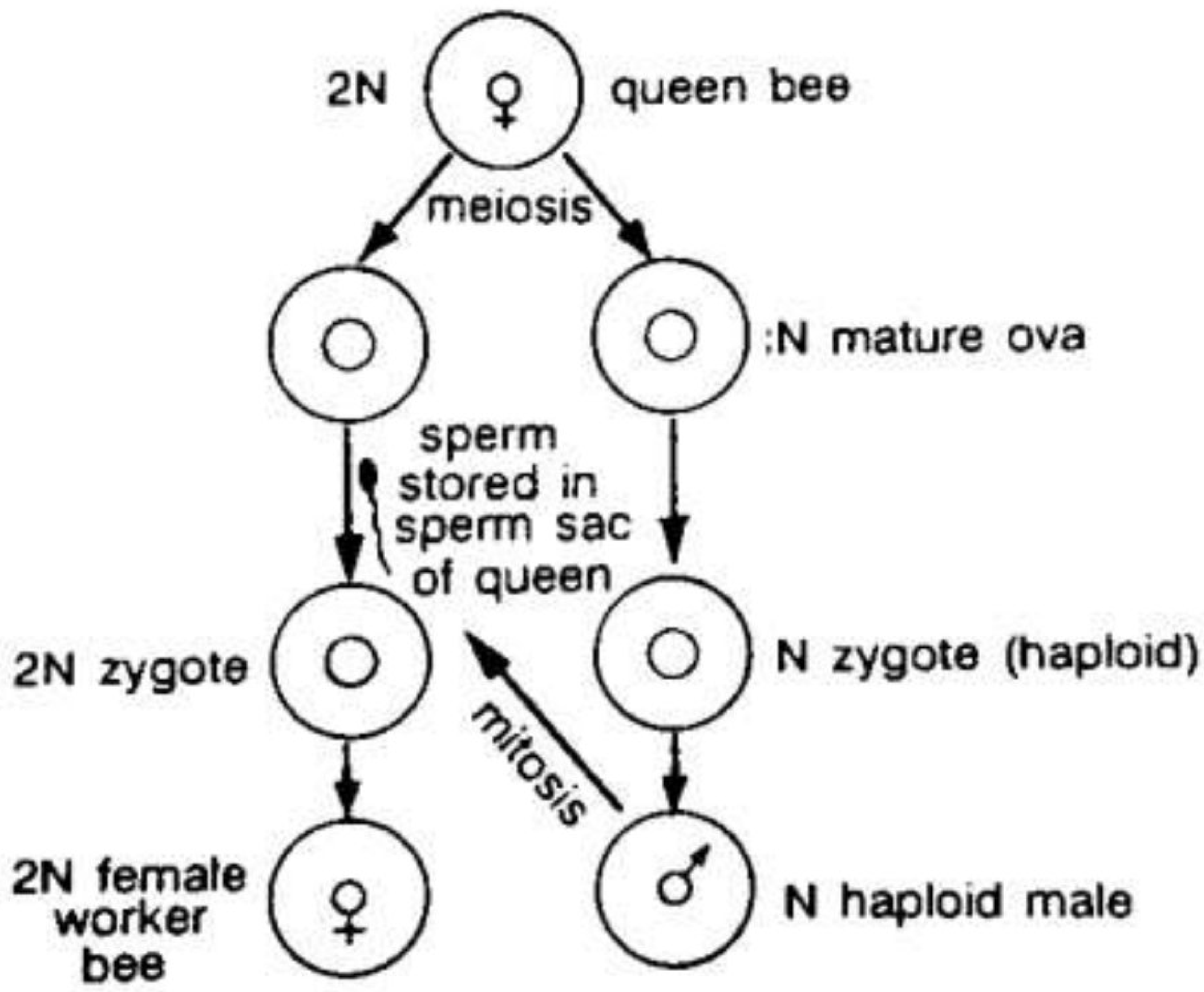
d. Cyclical parthenogenesis or heterogony

a. **Haplodiploidy or Arrhenotoky:** in certain **invertebrate** groups, **males** regularly **arise** from **unfertilized eggs** and **females** from **fertilized ones**. Males are consequently impaternate (have no father) and are haploid. This phenomenon is termed as **arrhenotoky**.

Example: Honey Bees, Wasps, Ants, Ticks, Mites, etc.

In **Honey Bees**, most of the **eggs are fertilized** and thus develop into **diploid females** (worker bees or young queens) and the **unfertilized eggs** develop into **haploid males** (the drones).

In **Bees**, **Wasps** and **Ants**, during gametogenesis the males **lack a true meiosis**, rather a **single mitosis** produce the **haploid male gametes** (sperms). (** Because males are born haploid) Whereas, in female, gametogenesis has normal meiosis and produce haploid ovum.



b. **Amictic or Meiotic Thelytoky**: in this case **males are absent** or **non-functional** in the genetic sense and **females give rise to female progeny without fertilization**. The eggs are developed by the usual process of oogenesis but at certain stages **diplosis** or **doubling of chromosome** number occurs and hence the production of diploid eggs.

Example: Moths

The **diplosis** or **doubling of chromosome** number may occur by the following methods;

i. **Autofertilization**: in this case, the oocyte divides meiotically up to the formation of ootid (ovum) and second polar body. Later, the ootid and the second polar body unite together to form diploid egg, which develops into a new individual.

ii. **Restitution**: sometimes in primary oocyte karyokinesis forms a nucleus of the secondary oocyte and nucleus of the first polar body. But the karyokinesis is not followed by the cytokinesis. The chromosomes of both daughter nuclei are arranged on the equator and undergo second meiotic division to form diploid ootid and a diploid second polar body. The diploid ootid (ovum) develops into a parthenogenetic diploid individual.

c. **Apomictic or Ameiotic Thelytoky**: in this mode of parthenogenesis, the **meiosis is entirely suppressed**. Usually, the eggs go through a single division, which is mitosis. Therefore, the egg develops with a diploid number of chromosomes.

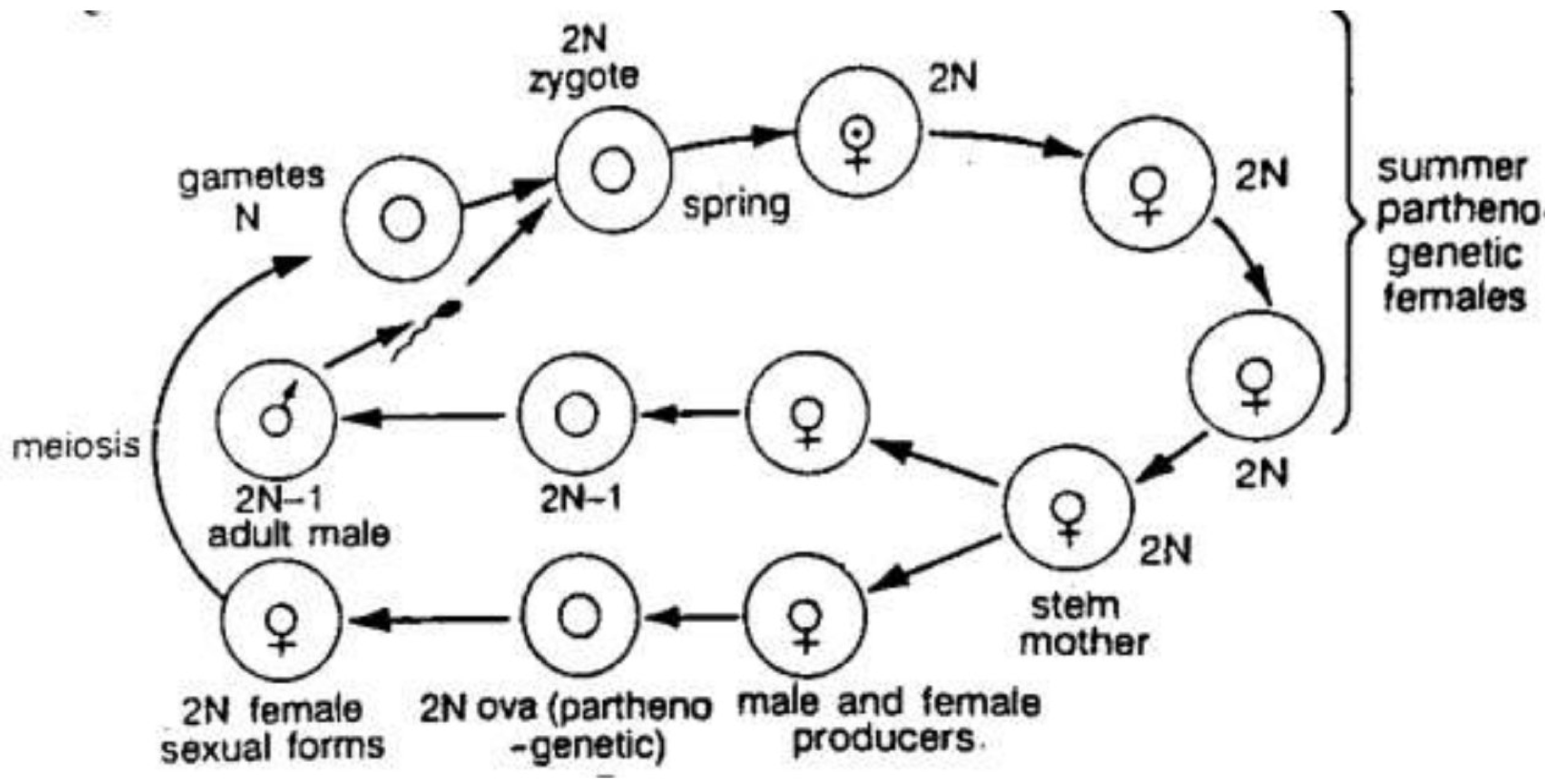
Example: Long horned grasshopper and many species of Weevils.

d. Cyclical parthenogenesis or heterogony: the life cycle of certain **insects** includes **two generations**, the **sexual generation** and **parthenogenetic generation**, both of which **alternate to each other**.

In such cases, the **diploid eggs produce females** and the **un-fertilised eggs produce males**. This type of parthenogenesis is known as the **partial** or **incomplete** or **cyclic parthenogenesis**.

Example: Aphids

In most of the aphids, the **parthenogenetic** (thelytoky) generation occur during the **warmer season** of the year and followed by the **sexual generation** in the **winter**.



ARTIFICIAL PARTHENOGENESIS:

The eggs are developed parthenogenetically under certain laboratory condition is known as artificial parthenogenesis.

Example: eggs of most echinoderms, molluscs, annelids, amphibia (Frog), birds (Turkey) and mammals (rabbit).

Artificial parthenogenesis may have induced by various **chemicals** and **physical** means. **Physical means** like **temperature**, **electrical shock**, **UV light**, eggs are **pricked with fine glass needles**, etc. and **chemical means** are treating eggs with **chloroform**, **hypertonic** or **hypotonic** sea water, **chlorides** of K^+, Ca^{++}, Na^+, Mg^{++}; **acids** like butyric acid, lactic acid; **fat solvents** like toluene, alcohol, benzene, acetone, etc.

LOEB'S EXPERIMENT: Artificial parthenogenesis in Sea urchin

1. **Jacques Loeb** (1913) was studying **embryological development** of **Sea urchin egg**.
2. From his work he discovered that the **sea urchin eggs undergo activation** when they are **treated with hypertonic sea water**.

3. The **fertilization membrane is elevated** in normal fashion, but only a single aster, a "**monaster**" can form.

4. At best, the chromosomes can undergo a few cycles of replication around this monaster; since, there is **only one aster**.

5. Therefore, with this consequence the **egg cannot divide** and **will not develop further**.

6. But Loeb found that if the activated eggs are submitted, after a few minutes, to a **second treatment** with **butyric acid,** this time a **second aster will appear** and the egg will develop parthenogenetically until the **pluteus larval** stage is reached.

BATAILLON'S EXPERIMENT: Artificial parthenogenesis in frog

1. **Bataillon** (1910) worked on **frog eggs** and found that they can be **activated by pricking** them with a **clean fine glass needle**.

2. By the pricking, the eggs form fertilization membrane and undergo a series of **monasterial**, abortive division cycles (to result the polyploidy).

3. However, <u>if the needle is not clean</u> and is **smeared with freshly drawn frog blood**, so that the nucleate cell is introduced into the egg at the time of pricking.

4. Thus, a **second aster will form around** the injected cell. Mitosis will then be normal and development will proceed until the **tadpole stage**.

5. The cell which has been introduced in the unfertilized eggs, thus, contain a "**second factor**" necessary for the **formation of a second aster** and further development take place.

6. The chemical nature of the "second factor" of parthenogenesis is not yet known. But, the recent work has shown that it is not located in nucleus, but in cytoplasm. Most probably it is either centriole, mitochondria or Ca^{++} ions.

SIGNIFICANCE OF PARTHENOGENESIS:

1. The parthenogenesis serves as the means for the **determination of sex** in the honey bees, wasps, etc.
2. The parthenogenesis **supports the chromosome theory of inheritance**.
3. The parthenogenesis is the **simplest**, **stable** and **easy process of reproduction**.
4. The parthenogenesis **eliminates the variation from the populations**.
5. The parthenogenesis is the best way of **high rate of multiplication** in certain insects, e.g., aphids.
6. The parthenogenesis **encourages development of the advantageous mutant characters**.
7. The parthenogenesis **checks the non-adaptive combination of genes** which may be caused due to the mutation.
8. Due to the parthenogenesis, there is **no need for the organisms to waste their energy in the process of mating** but it allows them to utilise that amount of energy in the feeding and reproduction.
9. The parthenogenesis **avoids the sterility in the races**.

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"By plucking her petals, you do not gather the beauty of the flower."

Rabindranath Tagore

CHAPTER – 04

CLEAVAGE

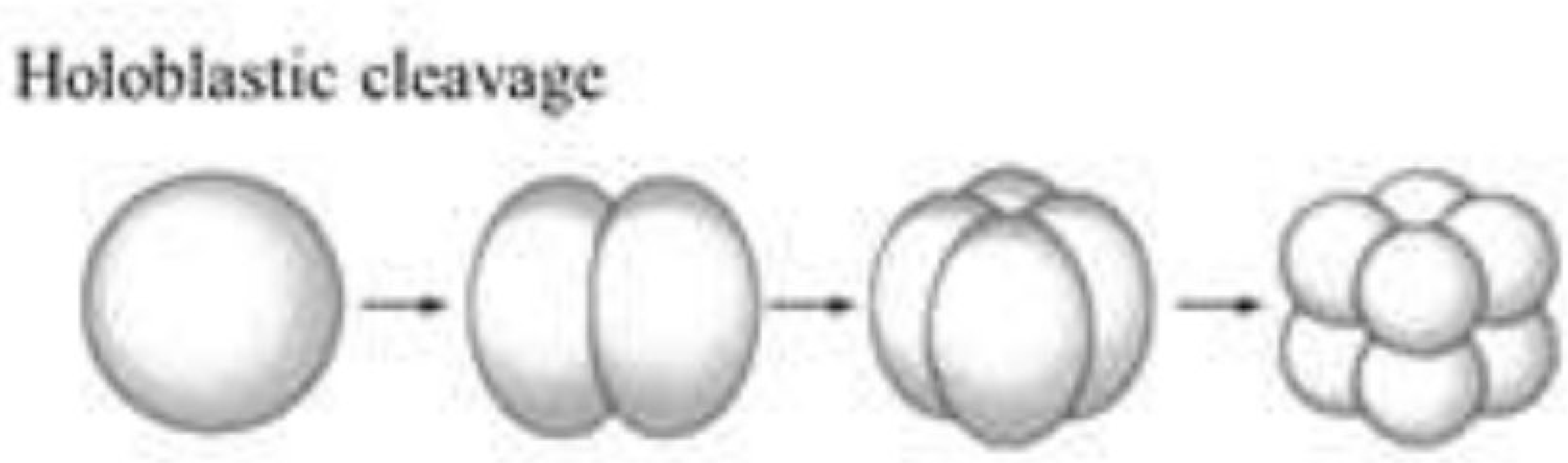
The splitting or division of an activated egg (zygote) by a series of mitotic cell divisions into a multitude of cells which become the building units of future organism is called **cleavage**.

TYPES OF CLEAVAGE:

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

a. **Holoblastic cleavage:**

In this cleavage type, cleavage furrow divides the entire egg, called **holoblastic** cleavage or complete or total cleavage. In holoblastic eggs the first cleavage always occurs along the vegetal-animal axis of the egg, the second cleavage is perpendicular to the first cleavage.



It may be equal or unequal division;

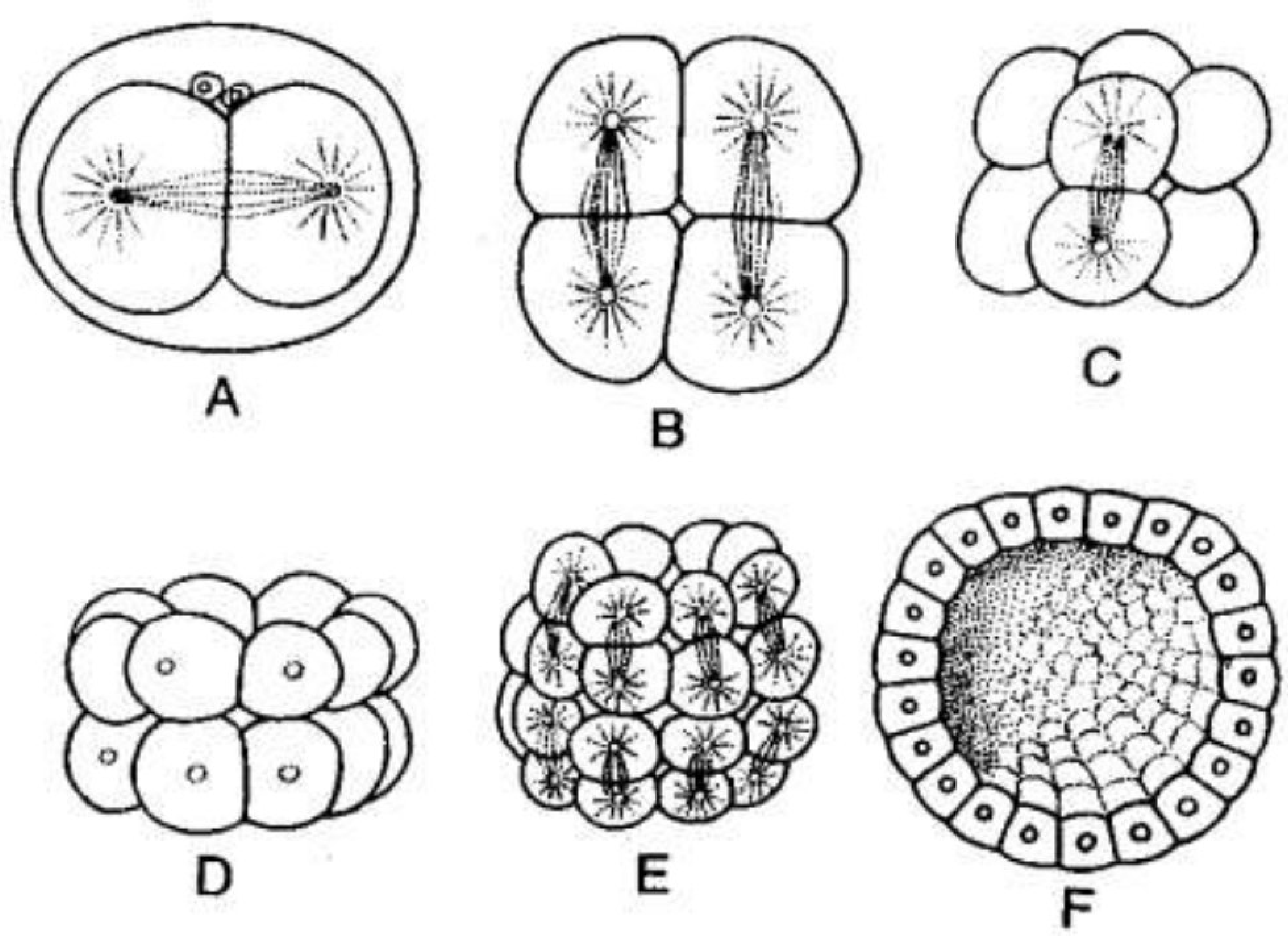
Equal: When the cleavage furrow cuts the egg into two equal cells. It may be radially symmetrical, bilaterally, symmetrical, spirally symmetrical or irregular.

Unequal: When the resultant blastomeres become unequal in size.

i. **Radial cleavage**:

The radial cleavage occurs when the successive cleavage planes cut straight through the egg, at right angles to one another and resultant blastomeres become symmetrically disposed around the polar axis. When which is viewed from either pole, the blastomeres are found to be arranged in a radially symmetrical form.

Example: Echinoderms and Amphioxus

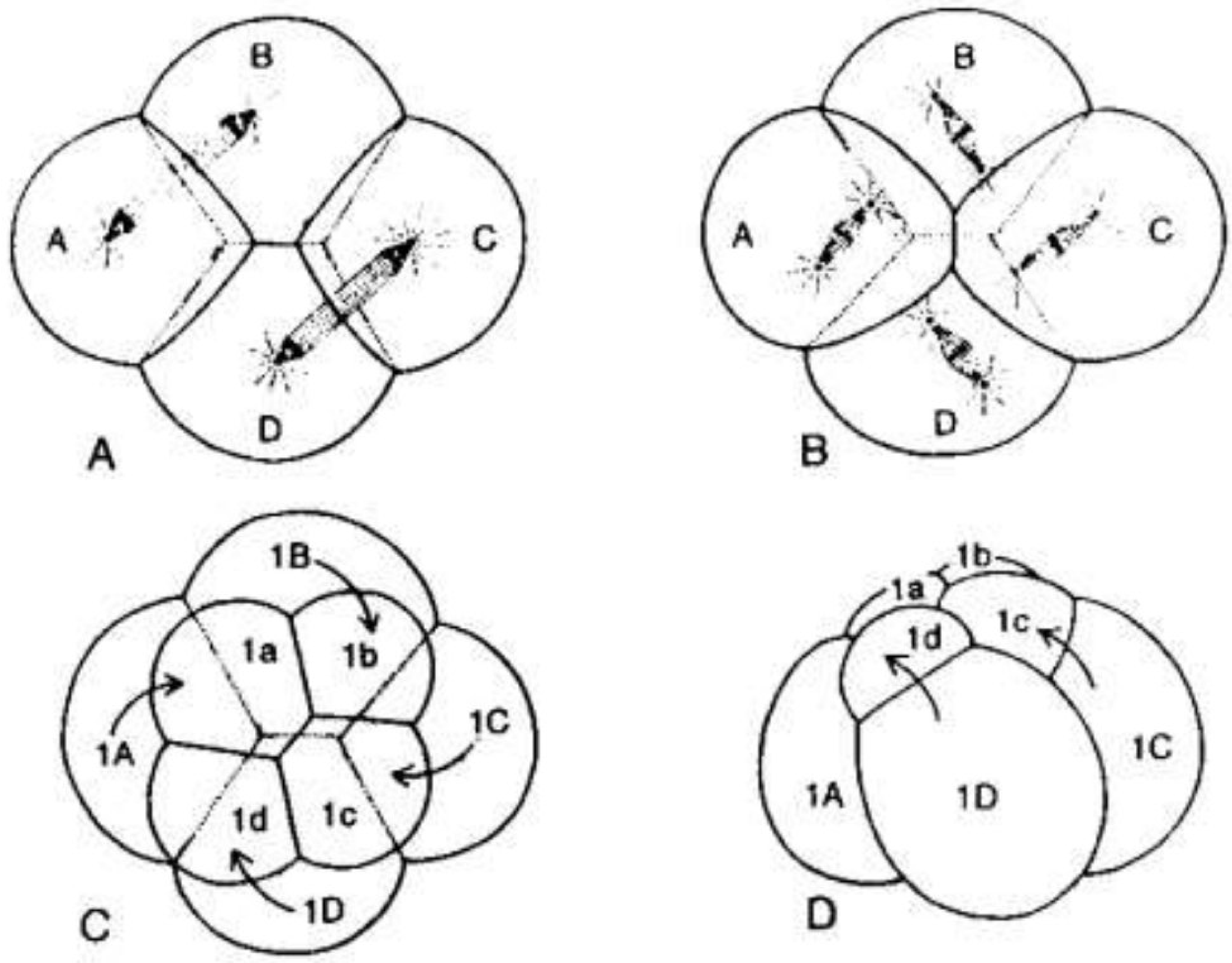


Radial type of Cleavage of Echinoderms

ii. **Spiral cleavage:**

The spiral cleavage is found in those forms in which there is a rotational movement of cell parts around the egg axis, leading to a displacement of the mitotic spindles with respect to the symmetrically disposed radially.

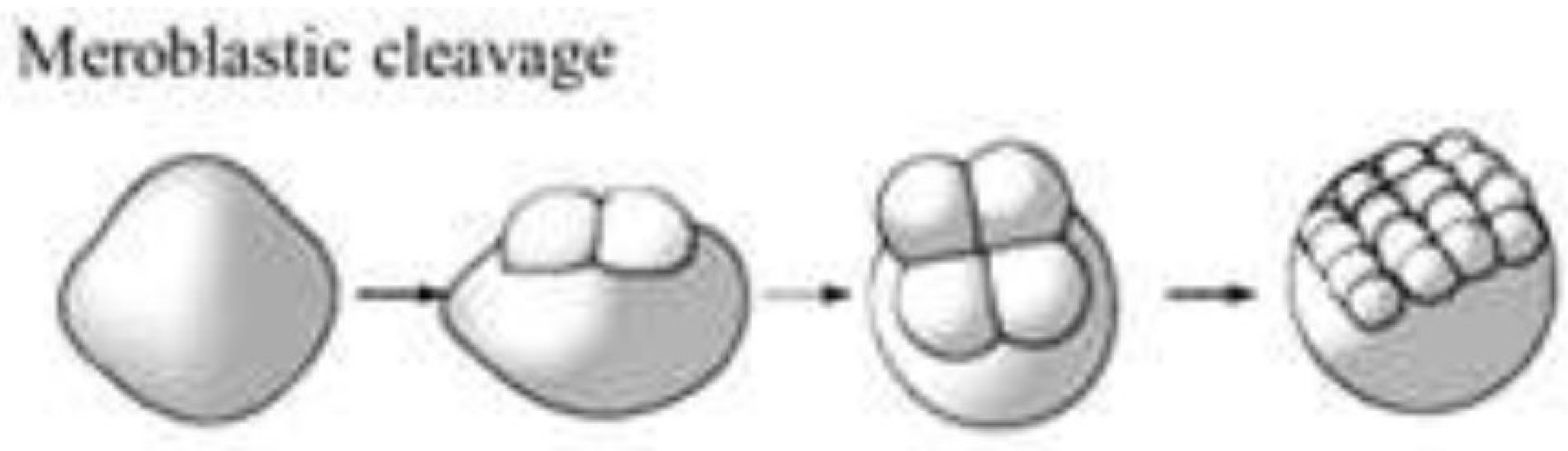
Example: nematode, rotifers, annelid, mollusc, etc.



Spiral Cleavages of Mollusca

b. Meroblastic cleavage:

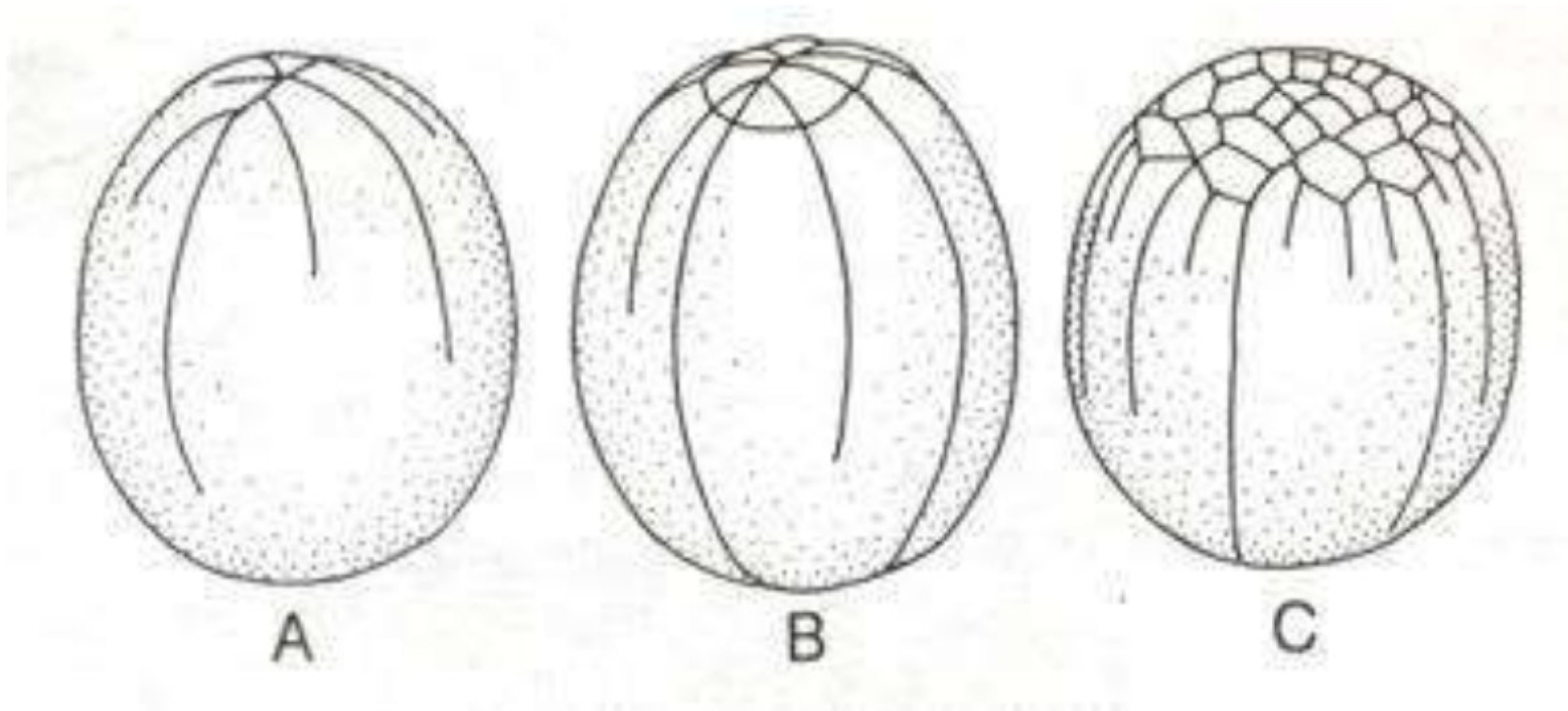
When segmentation takes place **only in a small portion of the egg** resulting in the formation of blastoderm, it is called meroblastic cleavage. Usually the blastoderm is present in the animal pole and the vegetal pole becomes heavily loaded with yolk which remains in an uncleaved state, i.e., the plane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



There are two major types of meroblastic cleavage;

i. **Discoidal cleavage**: in this type of cleavage, the cleavage furrows do not penetrate the yolk. The embryo forms a disc of cells called blastodisc, on top of the yolk.

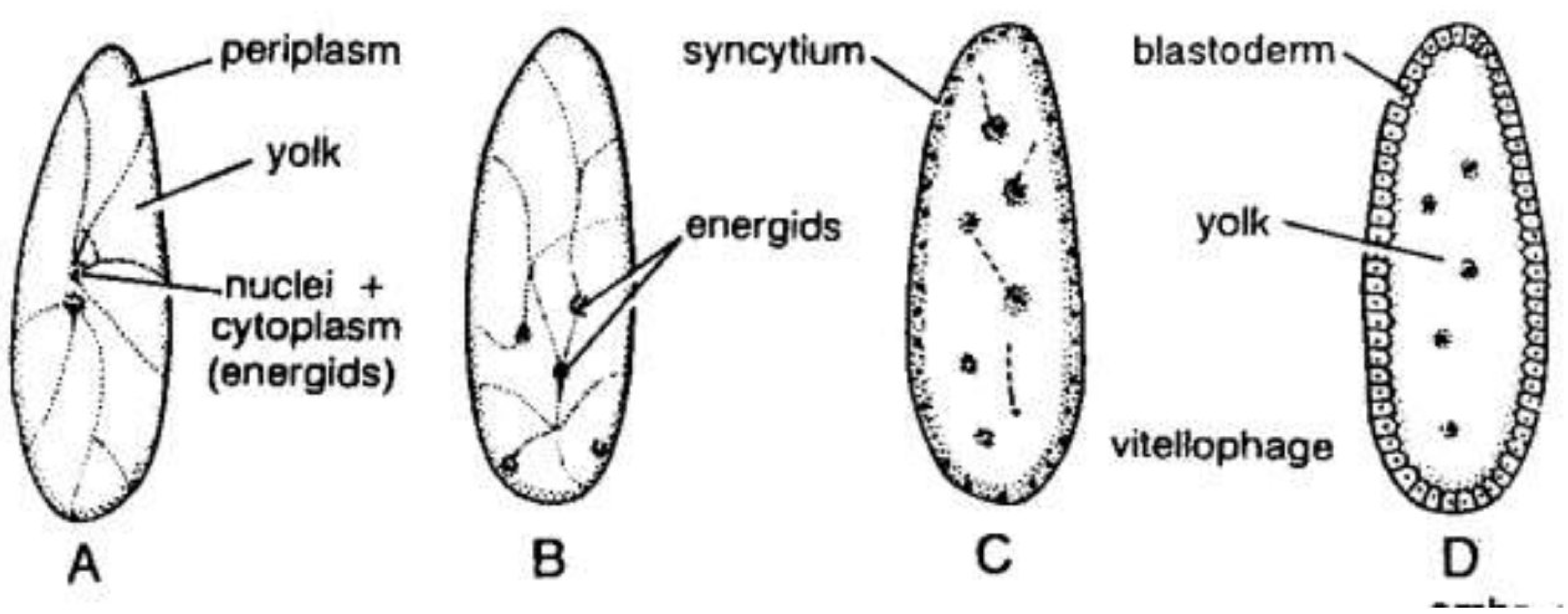
Example: Fishes, birds and reptiles.



Cleavage in the Ganoid Fish

ii. **Superficial cleavage**: in superficial cleavage, (in mitosis) karyokinesis occurs but not the cytokinesis, resulting in a polynuclear cell, with the yolk positioned in the centre of the egg cell, the nuclei migrate to the periphery of the egg and the plasma membrane grows inward, partitioning the nuclei into individual cells.

Example: Insect eggs



PLANES OF CLEAVAGE:

During early cleavage, distinct geometrical relationships exist between the blastomeres, i.e., each plane of cell-division bears a definite relationship with each other.

a. **Meridional plane of cleavage:**

   When a furrow bisects both the poles of the egg passing through the median axis or centre of egg it is called meridional plane of cleavage. The median axis runs between the centre of animal pole and vegetal pole.

   Example: **I** and **II** cleavage of **frog** and **chick** egg development.

b. **Vertical plane of cleavage:**

   When a furrow passes in any direction (does not pass through the median axis) from the animal pole towards the opposite pole.

   Example: **III** cleavage of **chick** and **IV** cleavage of **frog** egg development.

c. **Equatorial plane of cleavage:**

   This type of cleavage plane divides the egg halfway between the animal and vegetal poles and the line of division runs at right angle to the median axis.

   Example: **III** cleavage of **frog** and **IV** cleavage of **mammal** egg development.

d. **Latitudinal plane of cleavage:**

   This is almost similar to the equatorial plane of cleavage, but the furrow runs through the cytoplasm on either side of the equatorial plane.

   Example: **V** cleavage of **frog**.

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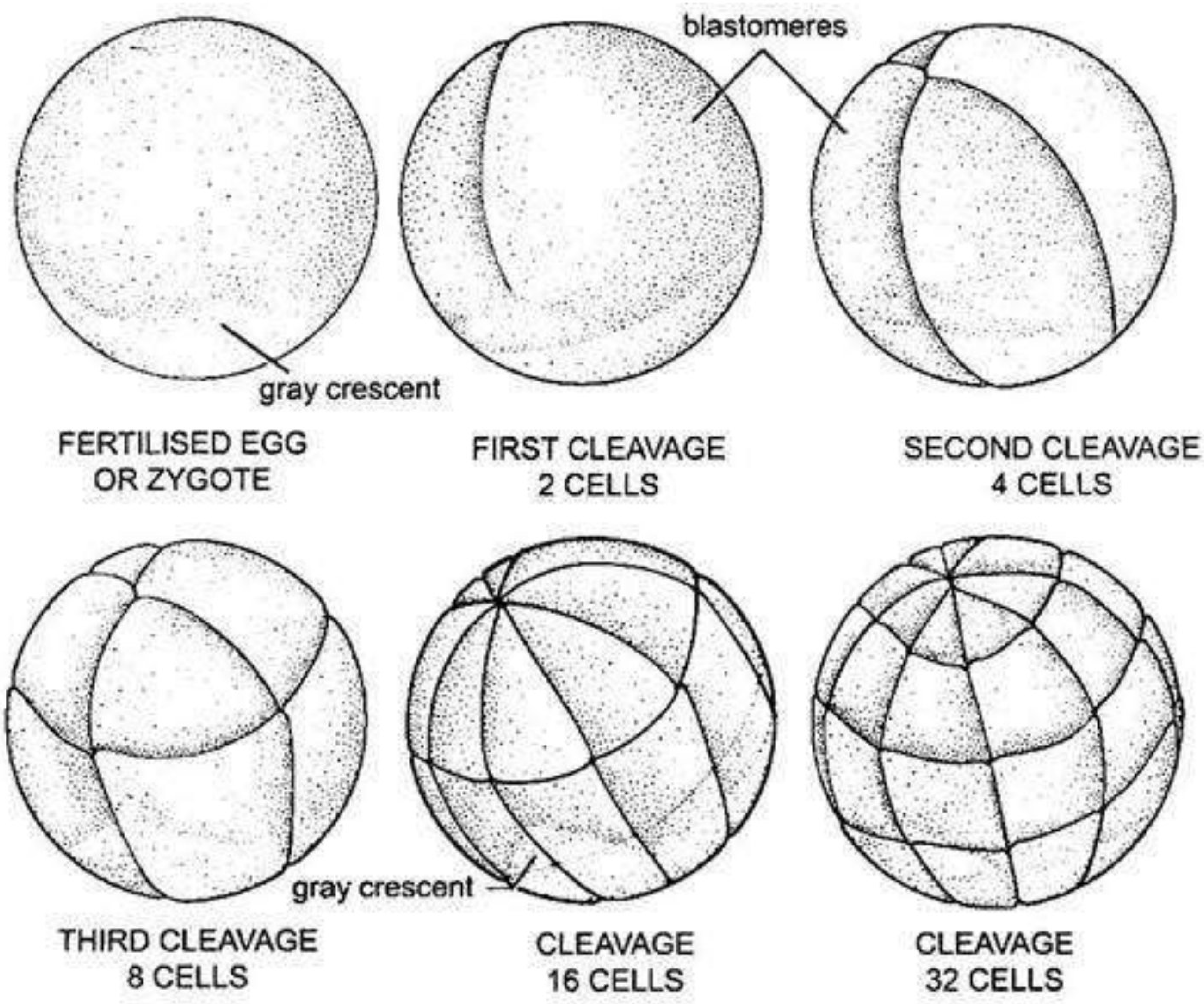
CHAPTER – 05

DEVELOPMENT OF FROG

CLEAVAGE:

1. Cleavage is **holoblastic** and **unequal**.
2. A **first vertical furrow** from the animal to the vegetal pole **divides** the **zygote completely** into **two equal-sized cells**.
3. A **second vertical furrow** at **right angles** to the first **divides** the **zygote** into **four cells**.
4. The **third cleavage** is **horizontal** and **above the equator** which segments the zygote into **upper four smaller blastomeres** and **lower four larger blastomeres.**
5. The cells formed by the cleavage are called **blastomeres**, the **upper smaller** blastomeres are called **micromeres**, and **lower larger** ones are **macromeres**.
6. Further cleavages divide the **micromeres more rapidly than the lower macromeres**; because of the presence of yolk which hinder (slow) the division of macromeres.
7. At this stage the whole embryo acquires a characteristic appearance resemble to the mulberry and so it is called **morula**.
8. About fourth and fifth cleavage stages a small space, the **blastocoel** appears between the blastomeres of morula. In the beginning it is like narrow crevices between blastomeres of morula, which gradually increases as the cleavage goes on.

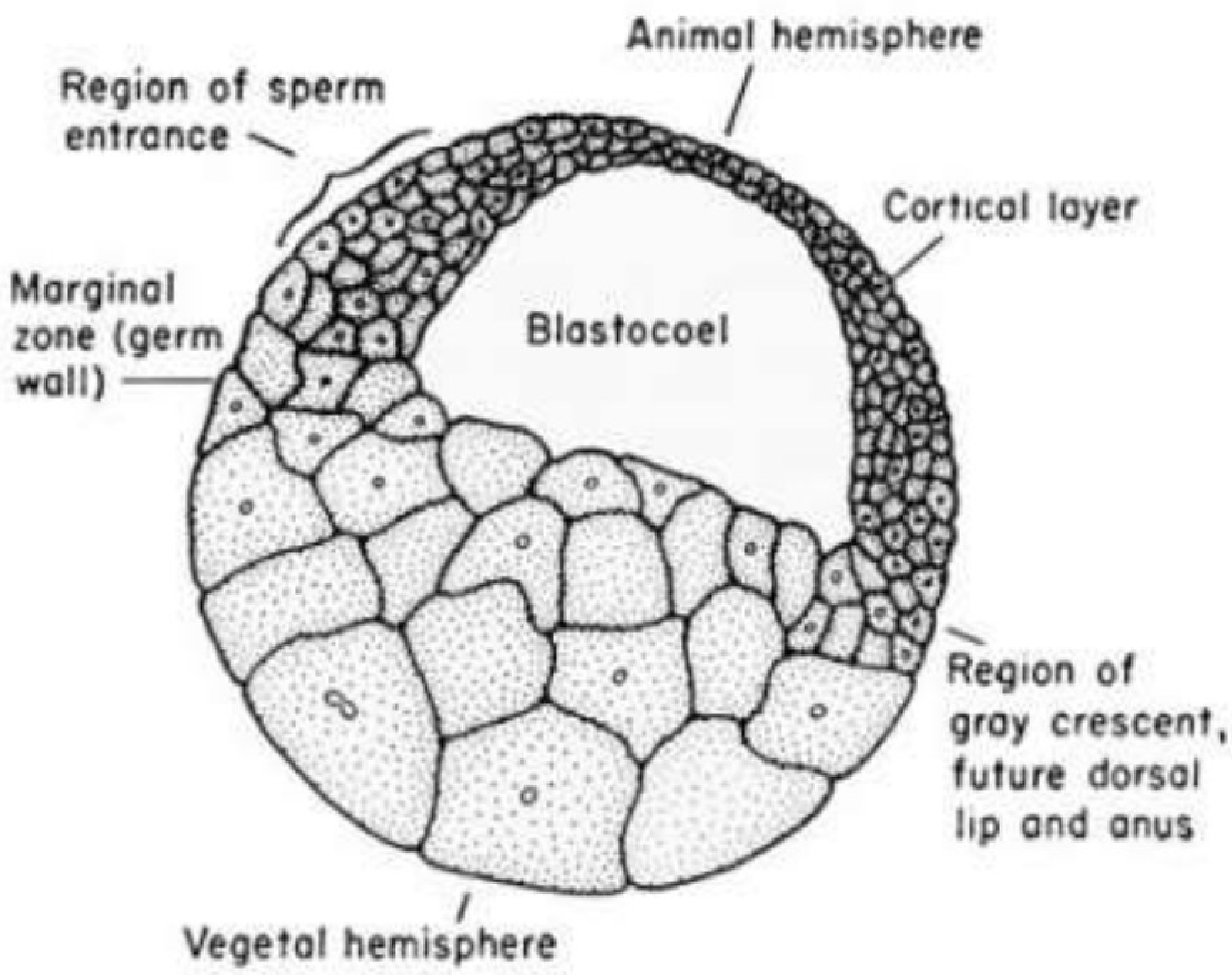


Cleavage in Fertilized Frog Egg (Zygote)

BLASTULA:

1. When the embryo is at **8-celled stage**, a cavity becomes apparent in its centre. It is formed by the surrounding of the inner edges of blastomeres. This cavity is known as **blastocoel**.
2. The blastocoel increases in size as the division proceeds further and at 32-celled stage it becomes very distinct.
3. The blastocoel shifts more and more towards the animal pole due to rapid multiplication of the micromeres, and filled up with **water** and **albuminous fluid secreted** by the surrounding blastomeres.
4. A blastula therefore appears as a hollow sphere enclosing blastocoel.
5. As cleavage proceeds, the blastomeres arrange themselves into a true epithelium called **blastoderm**.

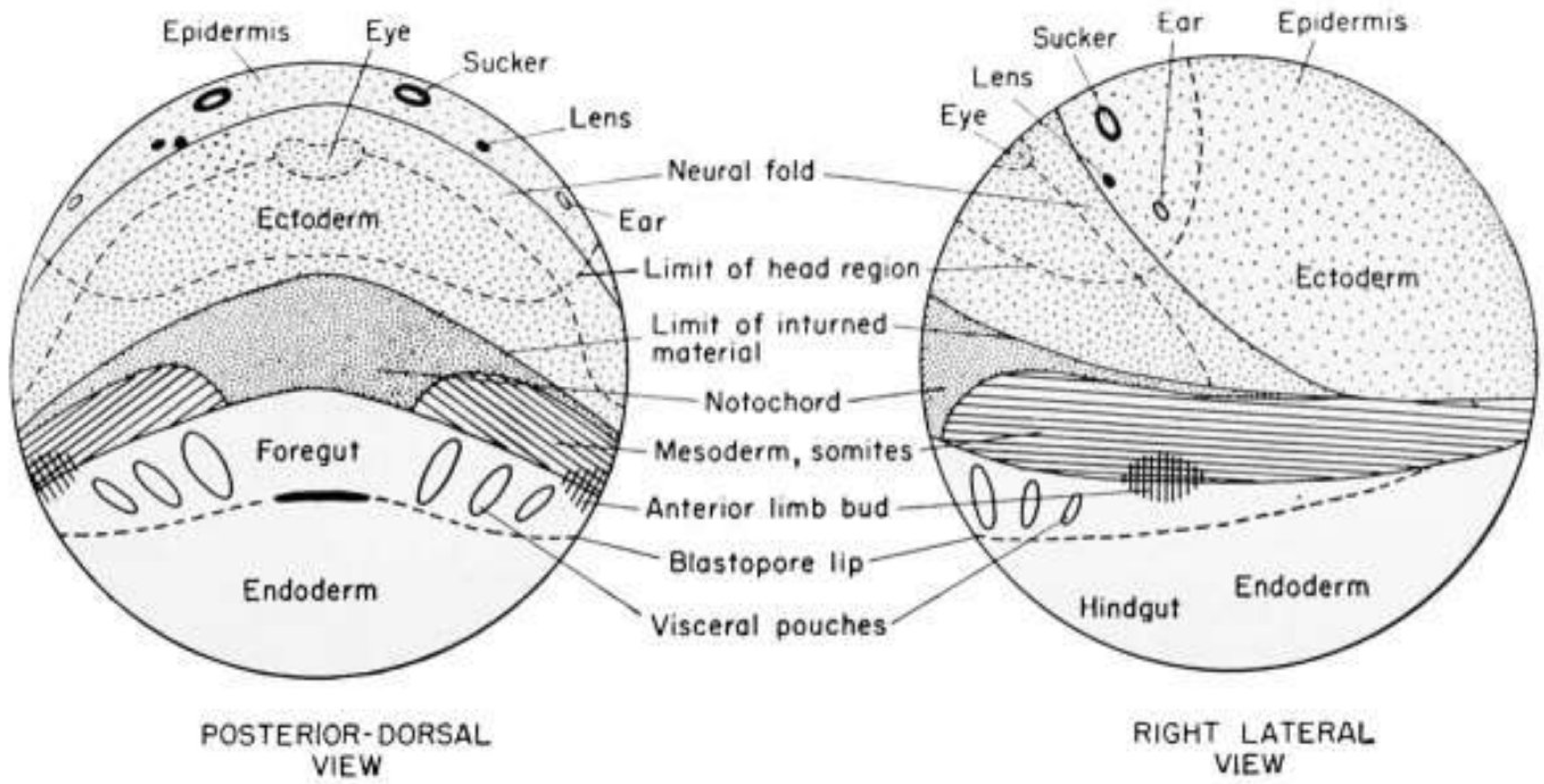
6. **Blastoderm** is **two-cell thick towards animal pole** and **forms the roof of blastocoel**, while the **sides and floor of the blastocoel** is occupied by **multi-layered** blastoderm of large yolky blastomeres. Thus, the resulting embryo having fluid-filled blastocoel is called **blastula**.
7. After **32-celled stage** a gradient of cleavage is established, the most active region being animal pole and least active vegetal pole.
8. Due to the migration of cells the roof of blastocoel becomes thin and double layered. The outer layer of cells contains most of the pigments and represents the epidermal layer and inner layer of blastula roof is less pigmented and is called nervous layer.



FATEMAPS IN BLASTULA:

In the blastula, the **blastomeres** which have to form different **germinal layers** and different organs of the adult frog have their representation at the external surface of the blastula.

The fate of each type of blastomeres has been observed by **artificial vital staining methods** of **Wather Vogt** (1925) and prospective organ region fate maps have been prepared.



According to **fate map studies**, whole surface of the blastula of frog can be **divided into three areas**.

1. **Prospective ectoderm area:**

   It is **present on** and **around the animal pole** and it is **pigmented black**.

   The **neural ectoderm** occurs **largely** on the **future dorsal side of blastula**, while the **epidermal ectoderm** occupies the **antero-ventral side of the blastula**.

   Inside the **neural ectoderm** occurs a **small sub-area** that **develops into the eye** of the **embryo**.

   The **sub-area of nose, sucker, ears** and **mouth** are present **inside the epidermal ectoderm**.

2. **Prospective notochord and mesoderm area:**

   It is **present behind the pigmented animal hemisphere**.

   It is **crescentic gray area,** the **marginal zone** along the **equator of blastula**.

   It has **blastomeres** for the **formation of notochord** and **mesoderm of the embryo**.

   The **large area of dorsal side** of the **gray crescent** is occupied by **notochordal cells**.

   Beneath the **notochordal** area, **toward** the **vegetal pole** lies a **narrow strip of cells** which form the **pre-chordal plate** of the **embryo**.

On either sides of **notochordal area,** the **part of grey crescent forms** the seg**mental muscles** (somites) and **tail mesoderm** is a **narrow strip** of **cells** on the **dorsal s**ide, toward **animal hemisphere**.

Lateral and **ventral parts** of **grey crescent** give rise to **ventro-lateral mesoderm**.

3. **Prospective endodermal area:**

   It is the **entire non-pigmented area** of the **vegetal hemisphere**, which gives rise to **endodermal lining** of the **mouth**, **gill region**, **pharynx**, **midgut** and **hindgut**, and other organs such as **liver**, **pancreas**, **urinary bladder** and **certain endocrine glands**.

GASTRULATION:

Gastrulation is **the development of gastrula from blastula** during this process a **single layered blastula** is converted into **three layered (endoderm, mesoderm and ectoderm) gastrula.**

Gastrulation is a process of migration and re-arrangement of prospective organ forming cells already present in the blastula. It is brought about by several types of morphogenetic movements taking place at the same time.

Invagination of Endoderm and formation of blastopore:

1. A **groove appears below** the **grey crescent**, through this groove the macromere (endoderm) move into the embryo. This **movement of endoderm into the embryo** is called **invagination**.
2. With continued multiplication and attenuation of bottle cells, the invagination deepens, and expands internally to form the **archenteron** or **gastrocoel** and its outer opening (original indentation) is called the **blastopore** lying at the future posterior end.
3. The blastopore has four lips namely, **dorsal lip**, **ventral lip** and **two lateral lips**.
4. The area immediately above the blastopore is the **dorsal lip** of blastopore.

5. Gradually, the blastoporal invagination extends circulo-laterally, so the blastopore becomes crescentic, then horse-shoe-shaped and finally circular. Thus, lateral lips and **ventral lip** of blastopore are also formed and fused with each other along with dorsal lip, forming circular lip of blastopore.
6. The **endoderm** of foregut **involutes over** the **dorsal lip along chorda-mesoderm**. The rest of prospective endoderm of vegetal region passes into the interior of the embryo passively and come to lie in the floor of gastrocoel.

Involution of Pharyngeal Endoderm and Chorda-Mesoderm:

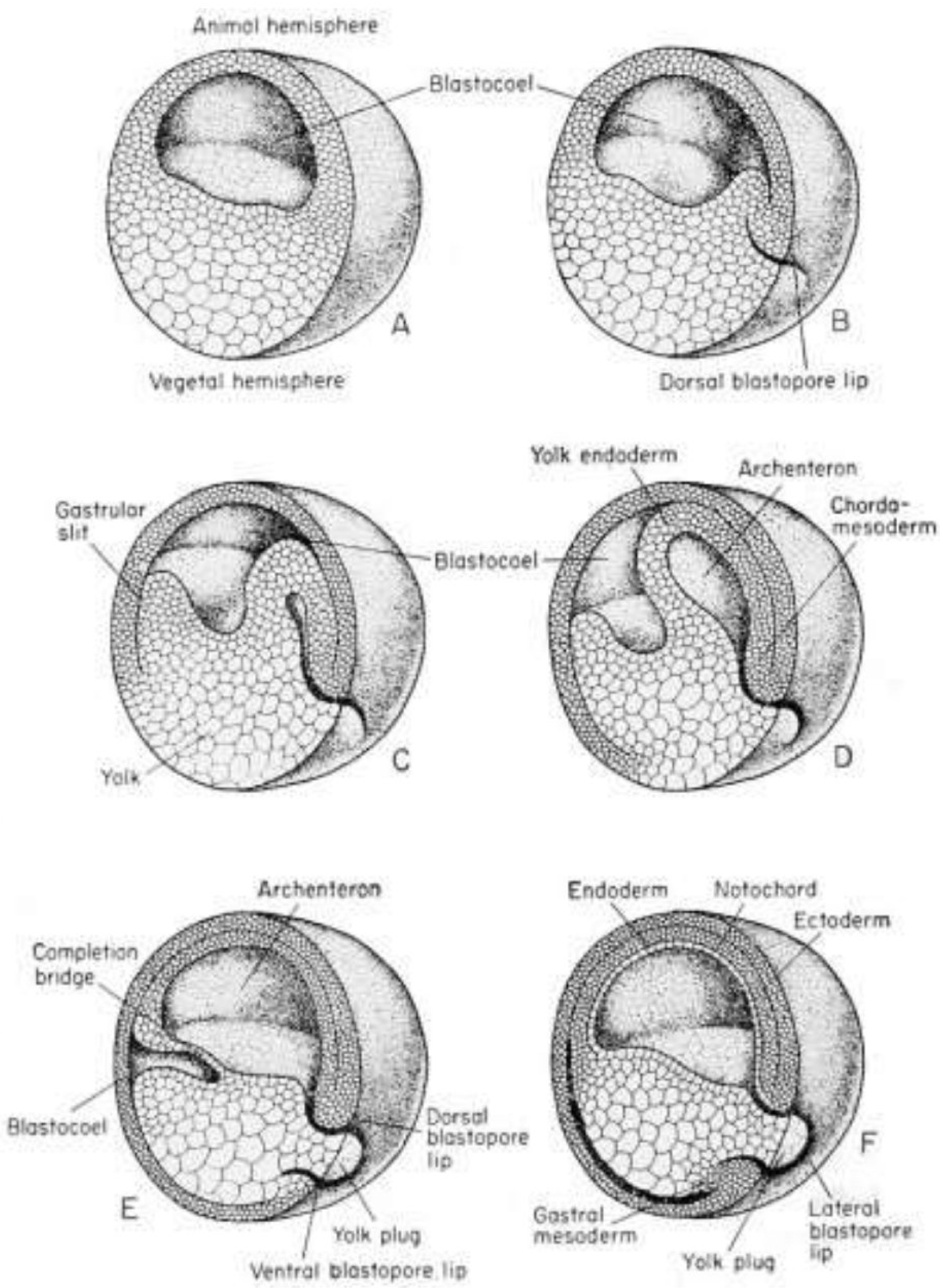
7. After reaching the blastoporal lips these cells roll over the blastoporal lips and move into the embryo. This rolling movement is called **involution**.
8. In the earlier stage, the notochord and mesoderm remain as one continuous sheet called **chordomesoderm**.
9. The mesodermal cells, pre-chordal plate cells and notochord cells migrate towards the blastoporal lips, this movement is called **convergence**.
10. Then, the involuted cells move away from the blastopore into the embryo, this movement is called **divergence**.
11. The prechordal and the notochordal cells are arranged as a plate in the mid-dorsal roof of archenteron, whereas, the mesoderm cells are arranged as two sheets on either sides of the notochord.

Epiboly of Ectoderm:

12. The **movement of the (ectoderm) cells on the surface of embryo** is called **epiboly**.
13. The rapid growth of ectoderm from animal hemisphere over the vegetal hemisphere is an active process.

14. Eventually, the circular blastopore gradually moves downward and diminishes in size. In the end it can be seen as a small closed circle with a few macromeres pushing out of it in the form of **yolk plug**.
15. The protruding yolk plug gradually withdraws to the interior, and the blastopore steadily contracts to form a slit-like opening in the end of gastrulation.

Thus, **gastrulation changes the radially symmetrical single layered blastula into a spherical, bilaterally symmetrical, triploblastic gastrula having a head-to-tail axis**. It is externally covered by ectoderm and endoderm, and mesoderm lies in the interior. Gastrocoel forms the lumen of the forming gut. Its lateral walls and floor is formed by the endoderm and its roof is formed of chorda-mesodermal cells.



NEURULATION:

1. The process of **formation of neural tube** is called **neurulation**.
2. By the time gastrulation is being completed, the ectoderm along the mid-dorsal side of the embryo thickens to form **neural plate**. The neural plate cells change in shape and become elongated and arranged themselves into a columnar epithelium.
3. The **edges of the neural plate** become **thickened** and slightly raised above the general level as ridges called **neural folds**.
4. The neural plate narrows transversely especially in its posterior parts and the neural folds raised higher due to which a **neural groove** is formed along its length.
5. The neural folds grow and fuse with each other in the mid-dorsal line to form a **neural tube**.
6. The lateral epidermal ectoderm of either side also meet and fuse at the mid-dorsal line above the neural tube, thus, enclosing it. The neural tube remains open in front for a time as a **neuropore**.
7. The **anterior broad part** of the neural tube forms the **brain** and the remaining narrow **posterior part** becomes the **spinal cord**. The neural tube also forms neuralgia cells of the

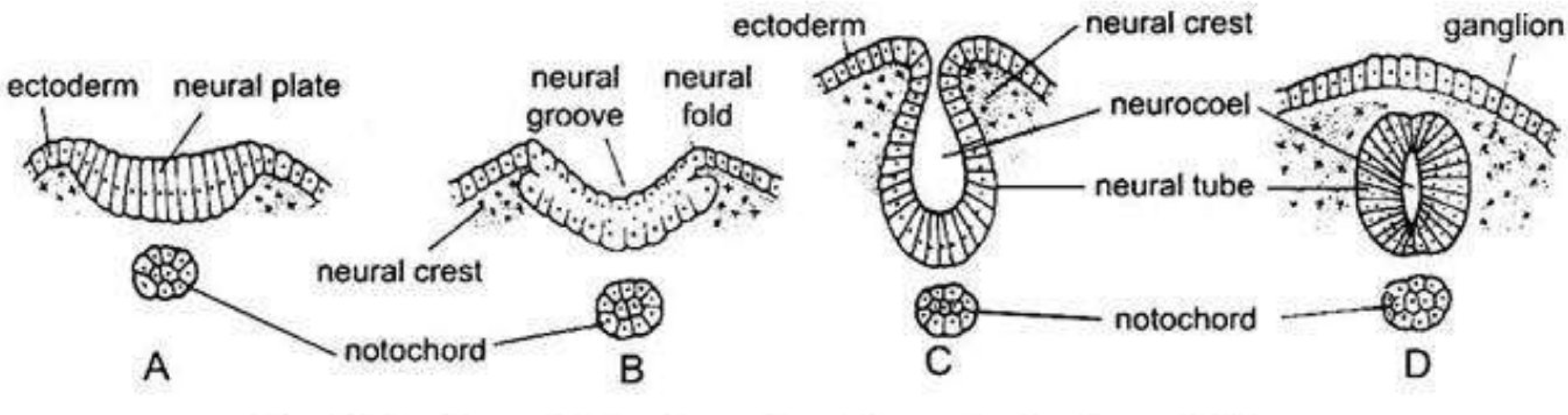


Fig. 37.7. Stages in the formation of neural tube in amphibians.

nervous system.

8. **Neural Crest Cells:** The cells from the neural folds that come to lie between the dorsal epidermis and the dorsal part of the neural tube are the **neural crest cells**. These lie along the dorso-lateral sides of the neural tube. The neural crests give rise to **melanocytes**, **dorsal root ganglia** of spinal nerves, parts of the autonomic nervous system and adrenal glands, and to some mesenchyme cells which form the visceral arches.

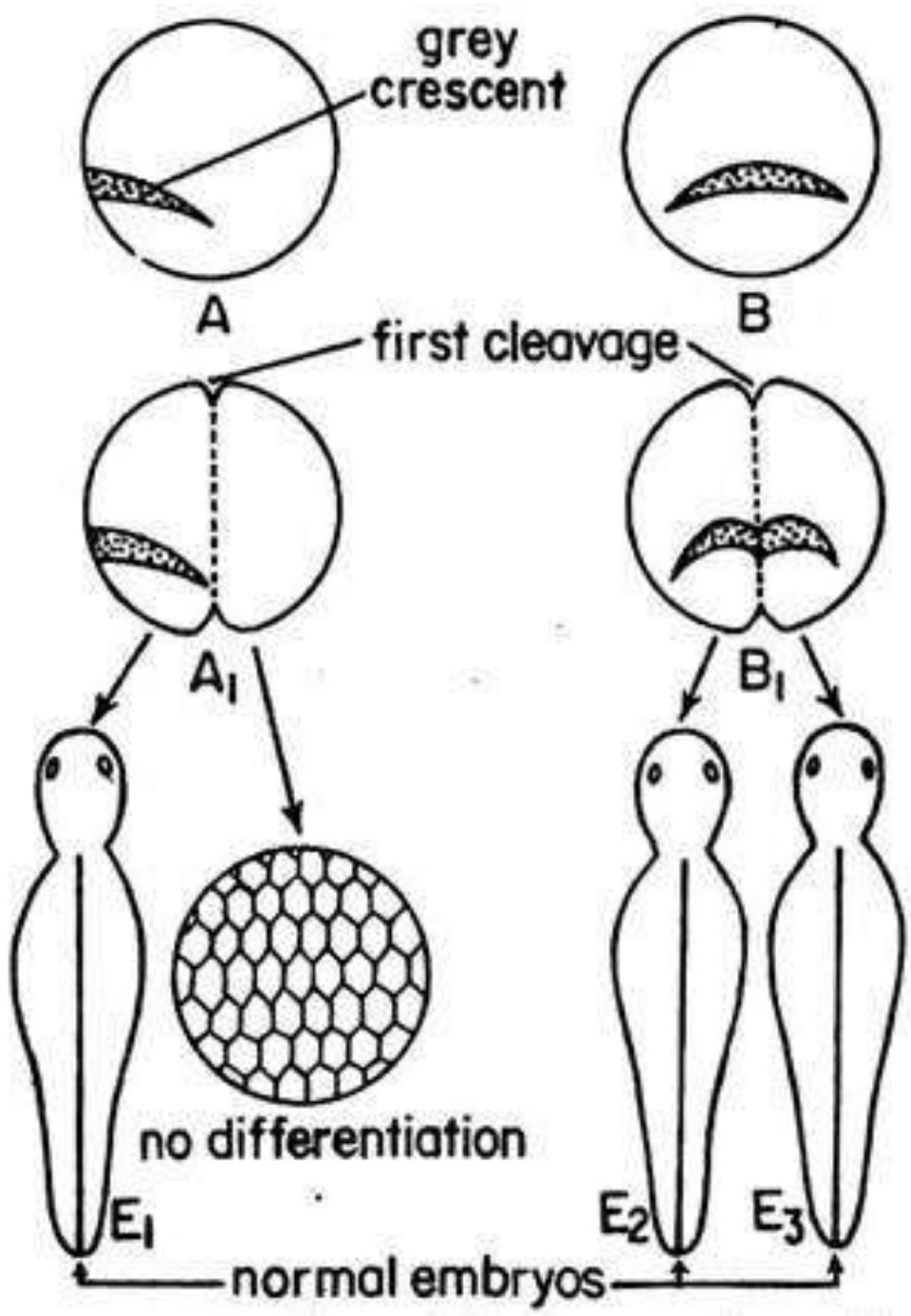
ORGANIZER PHENOMENON:

"A **region of a developing embryo** or a **substance produced by** such a region that is **capable of inducing a specific type of development in undifferentiated tissue**", the phenomenon is called **organizer phenomenon.**

POTENCIES OF THE DORSAL LIP OF THE BLASTOPORE OF AMPHIBIAN GASTRULA:

Wilhelm Roux (1888) first described the **grey crescent** in amphibian egg. The experiments of **Rund** and **Spemann** have emphasised the **vital role of grey crescent** in amphibian development.

If the **egg** is surgically **divided into two halves**, each having **one half of the grey crescent**, **each half of the egg will develop into an entire embryo** if cultured in isolation.



The same operation if performed on an egg in which **one half gets the entire grey crescent**, while the **other blastomeres** __lack__ **the grey crescent material.**

The two blastomeres when cultured in isolation, the **blastomere** which is **devoid of grey crescent** will **develop a simple sac of ectoderm containing endoderm**, while the **blastomere having the grey crescent** will form **an entire embryo**.

Similar operation of **removal of grey crescent** from the egg prior to cleavage has shown that the process of cleavage remains unaltered, but **gastrulation does not occur**.

These experimental studies have revealed that the **grey crescent** material of the egg **gives rise** to the **dorsal lip** of the blastopore in early gastrula.

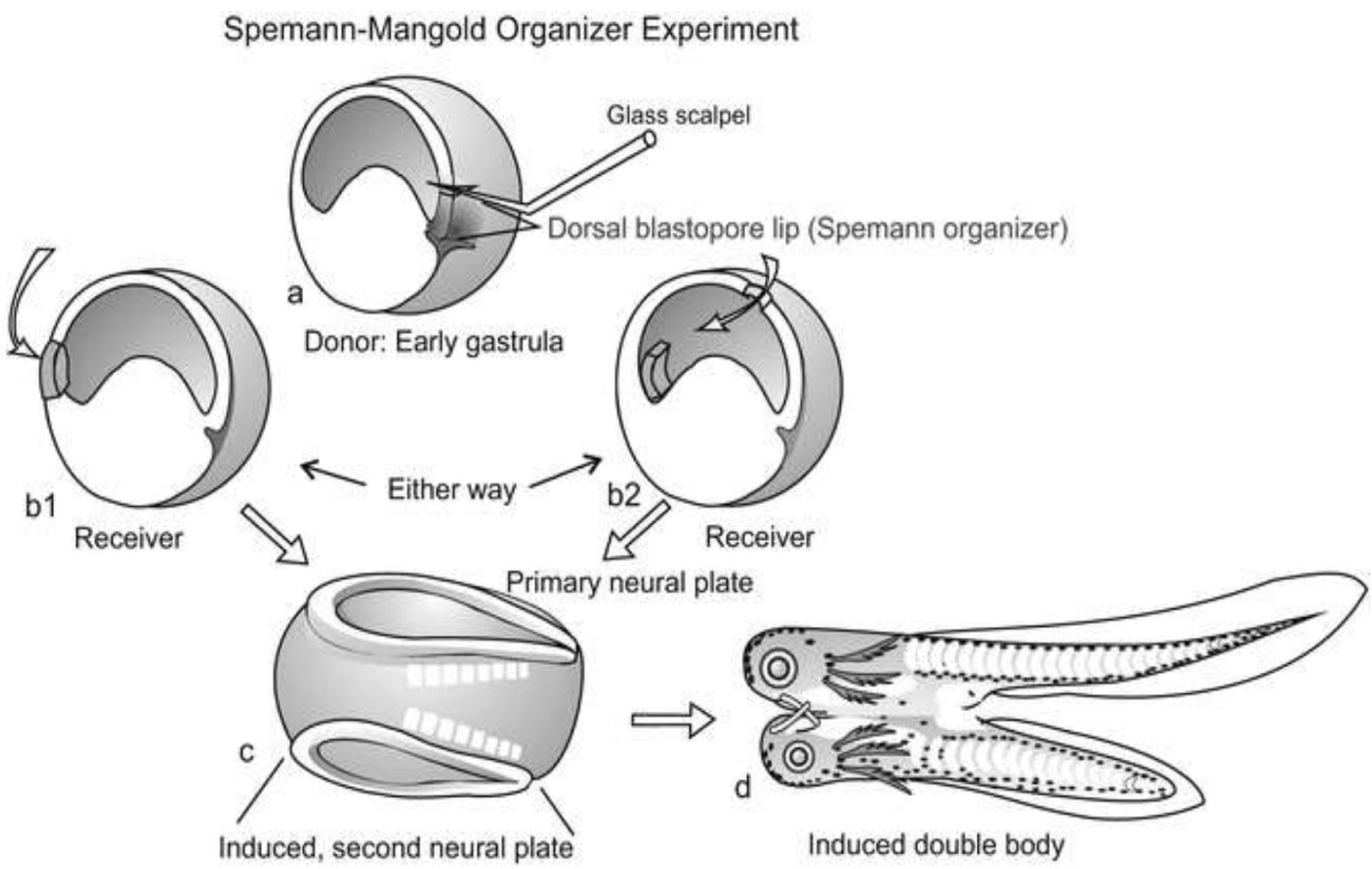
Therefore, it is understood that the dorsal lip of the blastopore has potencies to induce the changes on others cells leading to development.

But in the late stage, i.e., when the gastrula transforms into an embryo, the grey crescent materials become localised in the head endoderm of the primitive gut.

EXPERIMENT OF SPEMANN AND MANGOLD:

1. The **organizer** is an **embryonic tissue**, which organizes the surrounding tissues to develop an embryo. The existence of the organizer was first discovered in amphibians by Embryologist **Hans Spemann** and his student **Mangold (1924)**.
2. They followed the **transplantation technique** to **cut off** and **insert** the "**organizer**" into the **same** or **another embryo**.
3. The embryo from which a part of tissue is taken is referred as the **donor**, and the embryo to which the part is transplanted is called the **host**. The transplanted tissue is known as the **graft**.
4. Spemann exercised (cut off) the cells of the dorsal lip of the blastopore of an early gastrula of a **Salamander** (*Triturus cristatus)* (belonging to Class-Amphibia) before their inward migration. Then he transplanted this small piece of tissue near the lateral lip of gastrula of another Salamander.
5. He studied that the **transplanted piece of dorsal lip invaginated** and **developed into** the **second notochord** and the **somites**.
6. It **induced** the **host ectoderm** above the **location of graft** to **form a neural groove**. This **neural groove** was **totally made up of host cells**.

7. Further, it underwent normal development, forming a neural tube at first and then a central nervous system. At last, a **two-headed** creature was formed.
8. Thus, the dorsal lip of blastopore of the blastula has the ability to induce the formation of neural plate in the ectoderm of the host. This phenomenon is called **neural induction.**
9. Spemann concluded that the transplanted cells changed the normal path of development of the host cells. The structure which induces the formation of another structure is called **inductor** or **organizer**, and the phenomenon is known as **embryonic induction**. The chemical substance that is emitted by an inductor is called an **evocator**.
10. This experiment demonstrates that the neural tissue of the secondary embryo is entirely formed from the tissues of the host—thus suggesting the fact that **the dorsal lip of the blastopore is not only the controller of development but also acts as an instigator to induce the host tissue to differentiate**.



DEFINITION OF COMPETENCE, DETERMINATION AND DIFFERENTIATION:

Competence:

It is a physiological state of a tissue which permits it to react in a morphogenetically specific way to determinative stimuli. (OR) the ability of embryonic tissue to react to inductive stimuli.

Determination:

A cell is said to be **determined** when its specialized fate is fixed, and this event of embryo development is known as determination.

Differentiation:

The full-developed organism consists of a number of different kinds of cells, produced in the process called differentiation.

******

"Be so busy improving yourself that you have no time to criticize others."

Chethan Bhagat

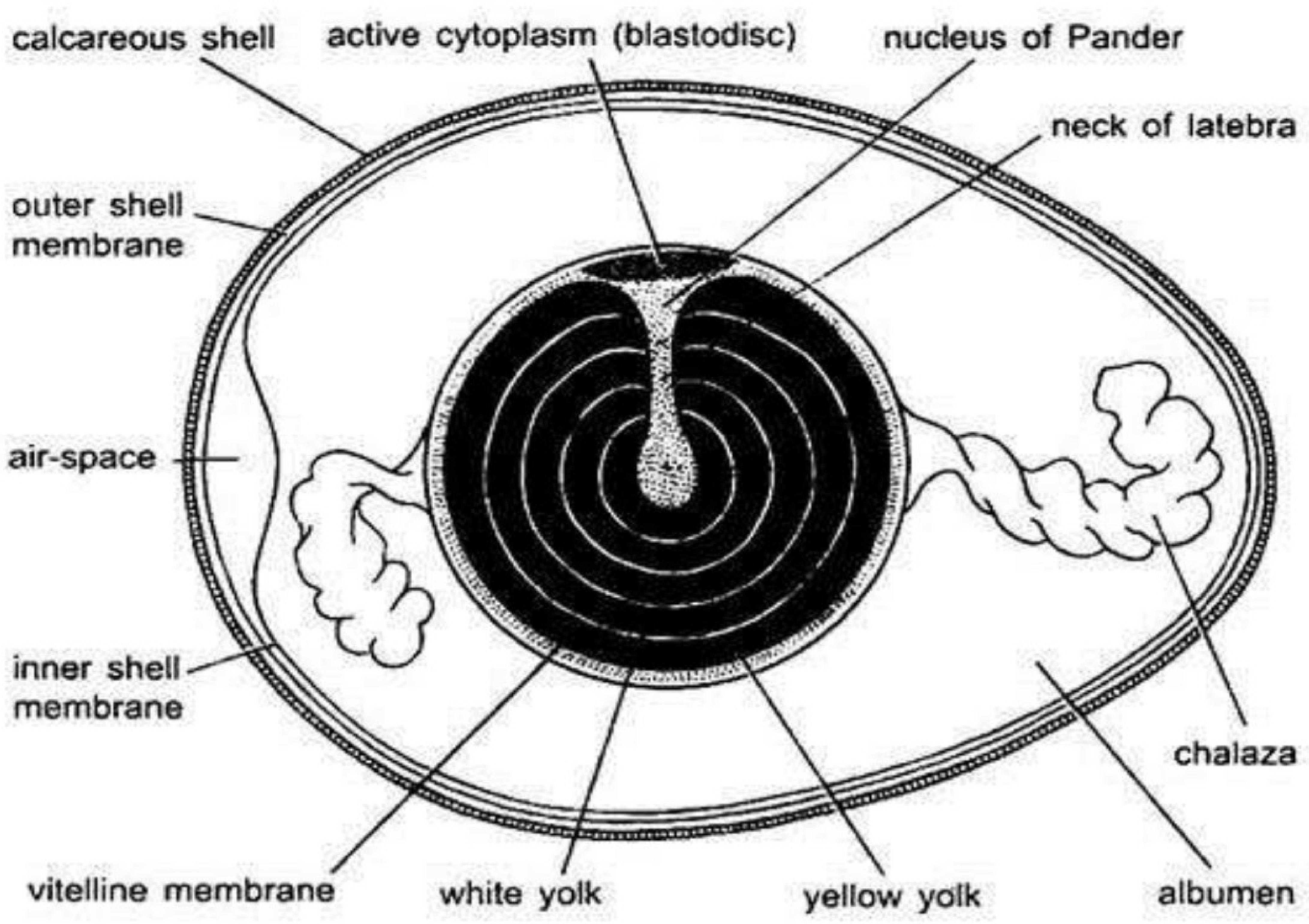
"Man needs his difficulties because they are necessary to enjoy success." –

A.P.J. Abdul Kalam

CHAPTER – 06

DEVELOPMENT OF CHICK

STRUCTURE OF EGG OF HEN:



1. The egg is about **5 cm long** and **3 cm in diameter** and is **megalecithal** type.
2. The animal pole having very small amount of active **cytoplasm with a nucleus**, called **blastodisc** and most of the space is occupied by the **yolk**.
3. The yolk has a **central mass of white yolk** around which are **alternate concentric layers of yellow** and **white yolk**. **Yellow yolk** is produced during the **day time** and contains more **fat**, whereas, **white yolk** is produced at **night** and contains more **proteins**.
4. In the **centre** of yolk there is a **spherical mass of white yolk** called the **latebra**. A **column of white yolk** connects the latebra to the Nucleus of Pander, called **neck of latebra**.
5. The **Nucleus of Pander** provides the place where the embryo develops.

6. The yolk and blastodisc are bounded by a **plasma membrane** and **outer vitelline membrane** (primary egg membrane).
7. Yolk contains **water**, **phospholipids**, **cholesterol**, **proteins, carbohydrates** and **chemical molecules.**
8. The fertilised egg or zygote is covered by a **layer of dense viscous albumen** which forms a thin chalaziferous layer around the vitelline membrane. This dense albumen forms two twisted **cords** or **chalazae**, one at each end of the zygote.
9. Around the chalaziferous layer is a thick layer of **watery albumen**. The function of albumen is to provide nutrition, serves as a **water store** and also acts as **protective envelope** for protecting the embryo from mechanical and chemical injuries.
10. The albumen and yolk also contains a variety of enzymes, vitamins, pigments and phosphorus.
11. The **two shell membranes** are closely applied except at the blunt end of the egg where they are separated by an **air space** formed after the egg is laid. The **shell glands** of the oviduct secrete a porous, **calcareous shell** which soon hardens.
12. The **shell** is pierced by a large number (about 7000) of **fine pores** filled with a protein related to collagen. The diameter of the pores varies from 0.04 to 0.05 mm. These pores allow **exchange of gases** (oxygen and carbon dioxide) during respiration of the developing embryo.
13. The **egg is laid 24 hours after fertilisation**, and its further development takes place, when the egg is incubated by the female. Incubation must continue steadily for 21 days at a temperature of 103°F.

CLEAVAGE:

1. Cleavage of the fertilized hen's ovum takes place when the **ovum in still inside the oviduct**, *i.e.,* before the egg is laid.
2. Because of the **enormous amount of yolk**, **not a single cleavage furrow is able to penetrate through the yolk and divide the egg completely**. Therefore, the **cleavage divisions are confined only to be germinal disc or blastodisc**.
3. Cleavage is partial or **meroblastic** and **discoidal**.
4. **First cleavage** is **vertical** near the centre of germinal disc, in the direction of **animal-vegetal axis**. The **furrow** then **separates** the two nuclei to form **two incomplete blastomeres**. Each blastomere is open from below, *i.e.,* the blastomeres are connected below by a little cytoplasm.
5. **Second cleavage** furrow is also **vertical** and appears **at right angles to the first furrow**. The furrow separates them to form **four incomplete blastomeres**.
6. The **third set of cleavage** furrows is **vertical** but in **double**, cutting across the second set of vertical furrows. These two furrows are **parallel to the first furrow**. The third cleavage furrow divides the four blastomeres resulting **eight blastomeres**.
7. **The fourth cleavage** furrow is also **vertical** but somewhat **parallel to the circumference of the blastodisc**. These furrows divide the eight blastomeres into **sixteen blastomeres**. Of these 16 blastomeres, 8 centrally placed ones are known as **central blastomeres** and the peripherally placed 8 are called **marginal blastomeres**.
8. The **blastodisc** is now called **blastoderm**.
9. **Further cleavages are irregular**. The central cells divide more rapidly. The marginal cells also divide by the appearance of new horizontal and radial furrows.
10. The newly formed inner cells of marginal blastomeres are added to the central cells, resulting in the increase of volume of this area. The radial furrows extend peripherally and these peripheral cells are still continuous with the uncleaved peripheral cytoplasm.

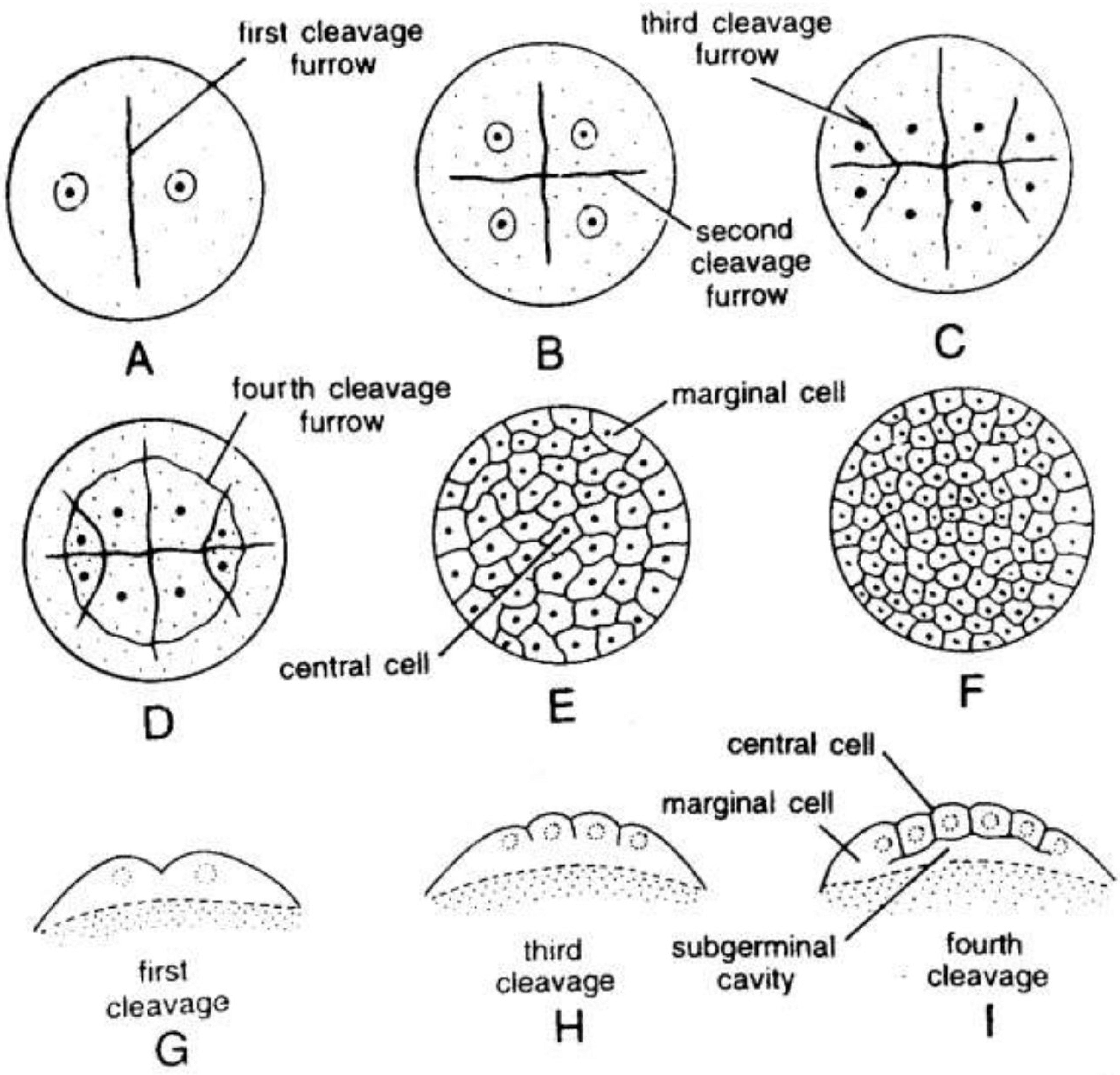


Fig. 13.3. Chick blastoderm in surface view and sections to show the cleavages. A–first cleavage; B–second cleavage; C–third cleavage; D–fourth cleavage; E–inter stage to show the central and marginal cells; F–still later stage; G–section of the blastoderm after the first cleavage; H–section of the blastoderm after the third cleavage; I–section of the blastoderm after the fourth cleavage.

BLASTULATION:

1. After the fourth cleavage, further cleavages become very irregular. After some time three or four layers of somewhat loosely packed cells are formed.
2. Here by cell division **two types of cells** are produced. The cells nearer the **central cells develop complete cell membranes** (central cells). The **other types of cells**, have **incomplete cell membrane** (marginal "open" cells) *i.e.,* their sides and bottoms are open and they remain at the **periphery** of the blastoderm.

3. The cavity beneath the central cells, i.e., in between central cells and yolk is called the **subgerminal cavity**, which is filled with a fluid diffused from the albumen through vitelline membrane.
4. The appearance of subgerminal cavity separates the blastoderm from the underlying yolk, but the marginal cells remain overlapping the yolk. The embryo is now called the blastula stage.
5. The nuclei formed by the division of marginal **'open cells'** start migrating to the cytoplasm below the marginal cells. Thus a ring shaped syncytial layer of cytoplasm is formed all around the marginal open cells. This layer is called **marginal periblast**.
6. In the mean time, some more nuclei migrate to the layer of cytoplasm below the subgerminal cavity. This part of syncytial cytoplasm is called the **central periblast**.
7. Soon, the blastomeres of blastoderm segregate and a narrow space appears between them. The yolk poor and small sized blastomeres are incorporated into upper layer called the **epiblast**. The yolk rich cells subsequently unite and form a thin, flat epithelial layer below the blastocoels called the **hypoblast**.
8. The hypoblast remains separated from the epiblast by narrow blastocoels. This process of separation of epiblast and hypoblast forming areas is called **delamination**.
9. The **delamination** of these yolky cells from the blastoderm starts at the posterior edge and spreads forward until whole blastoderm becomes free from yolky cells.
10. Thus cleavage converts the germinal disc into a disc shaped blastula called **discoblastula**.
11. As a result, the epithelial layer in the central region of blastoderm becomes thinner (few layers of cells) and transparent. Thus, this region is called the **area pellucida** because it seems to be transparent when viewed from the upper side.
12. The peripheral part of blastoderm, the yolky cells is not delaminated (shed), so this part of the blastoderm seems to be **opaque**. Thus this region is called the **area opaca**.

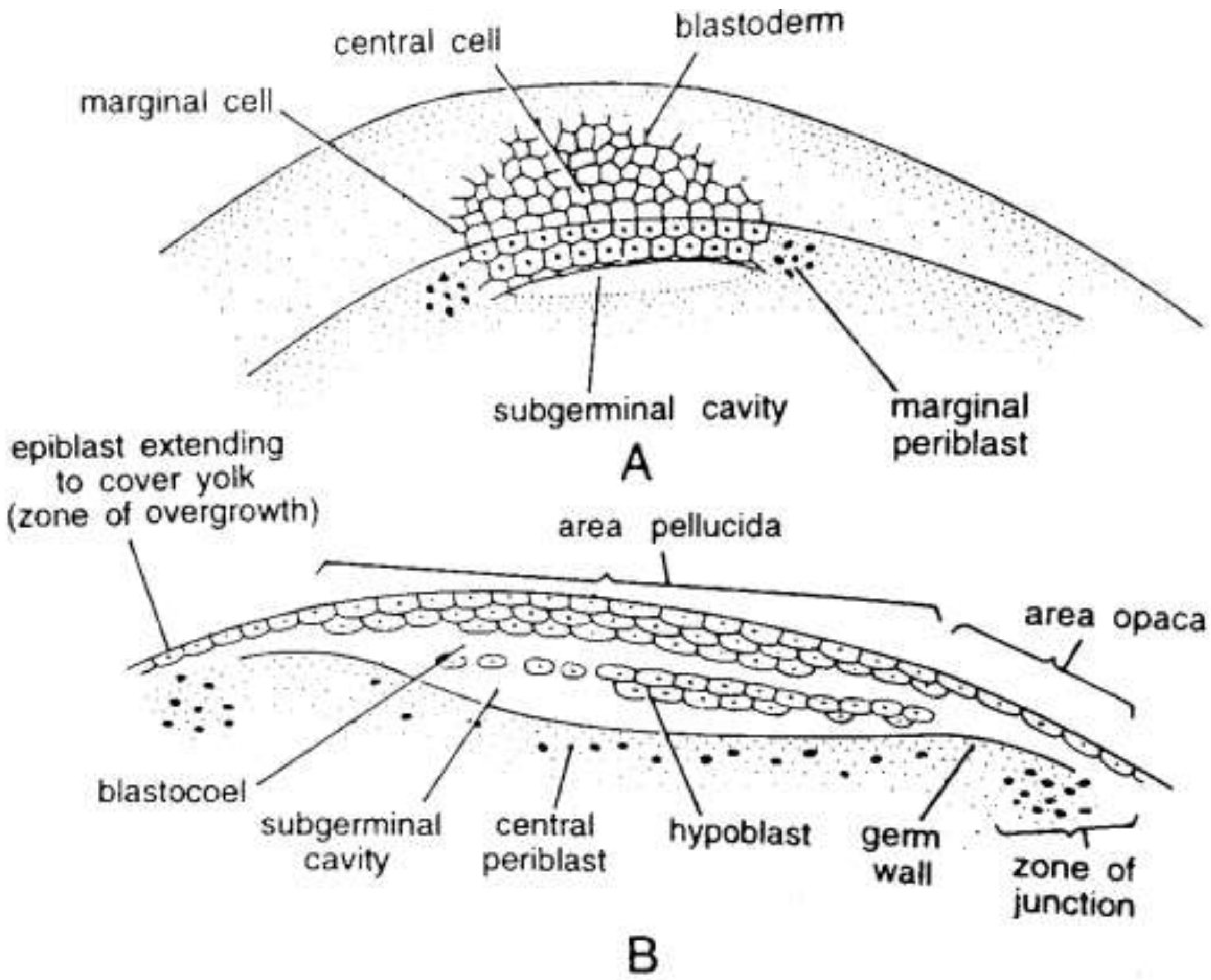


Fig. 13.4. A–Blastula stage of the chick embryo. The blastoderm (blastula now) is shown cut transversely. B–Initial stage of the formation of the yolk sac in chick by radial extension of the epiblast (ectoderm) over the surface of the yolk mass.

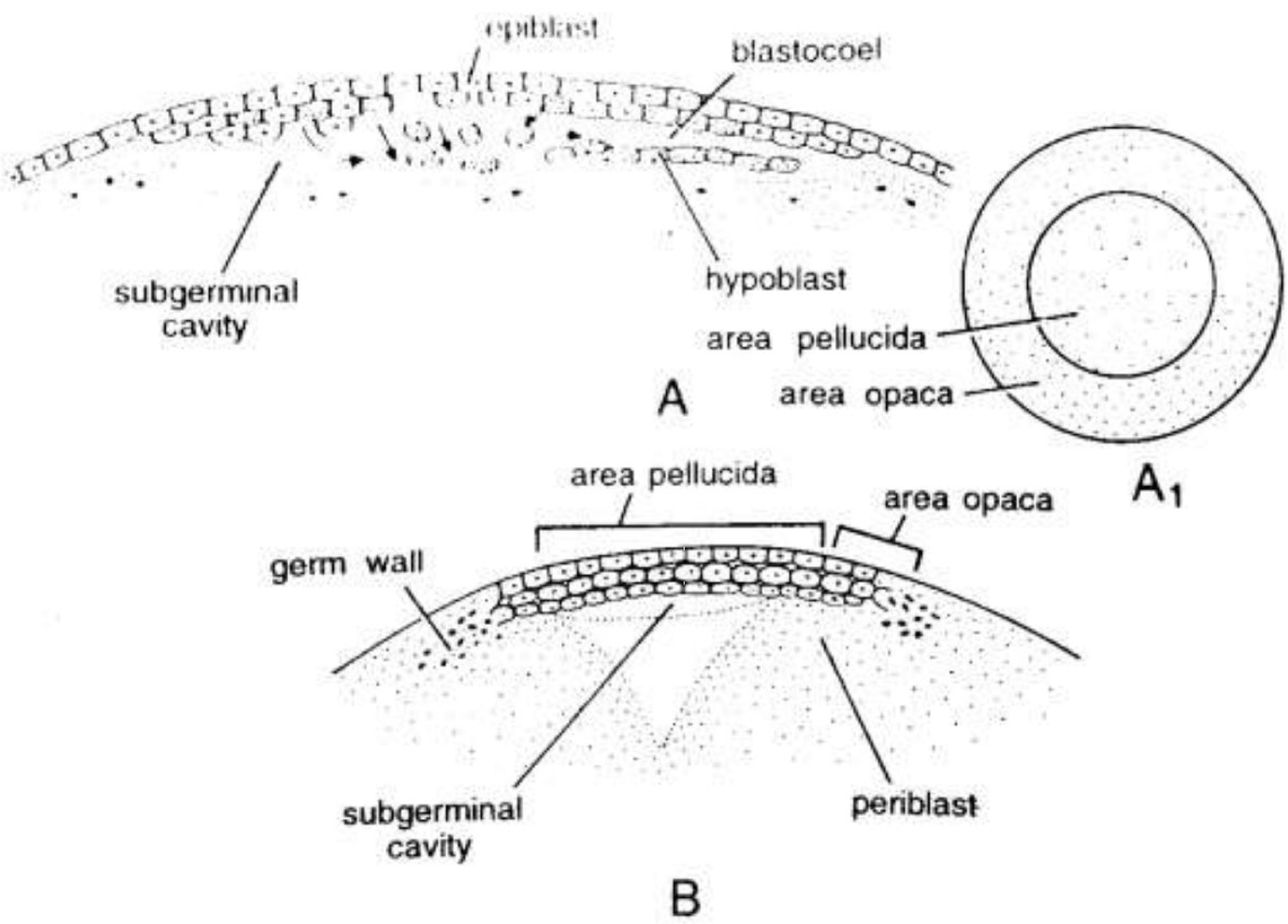


Fig. 13.5. A–Formation of hypoblast in the chick blastoderm. Cell migrating from the epiblast are shown stippled. A_1–Blastoderm of a chick embryo showing the area opaca and area pellucida in surface view, B–Sagittal section.

GASTRULATION: ORIGIN AND DEVELOPMENT OF PRIMITIVE STREAK

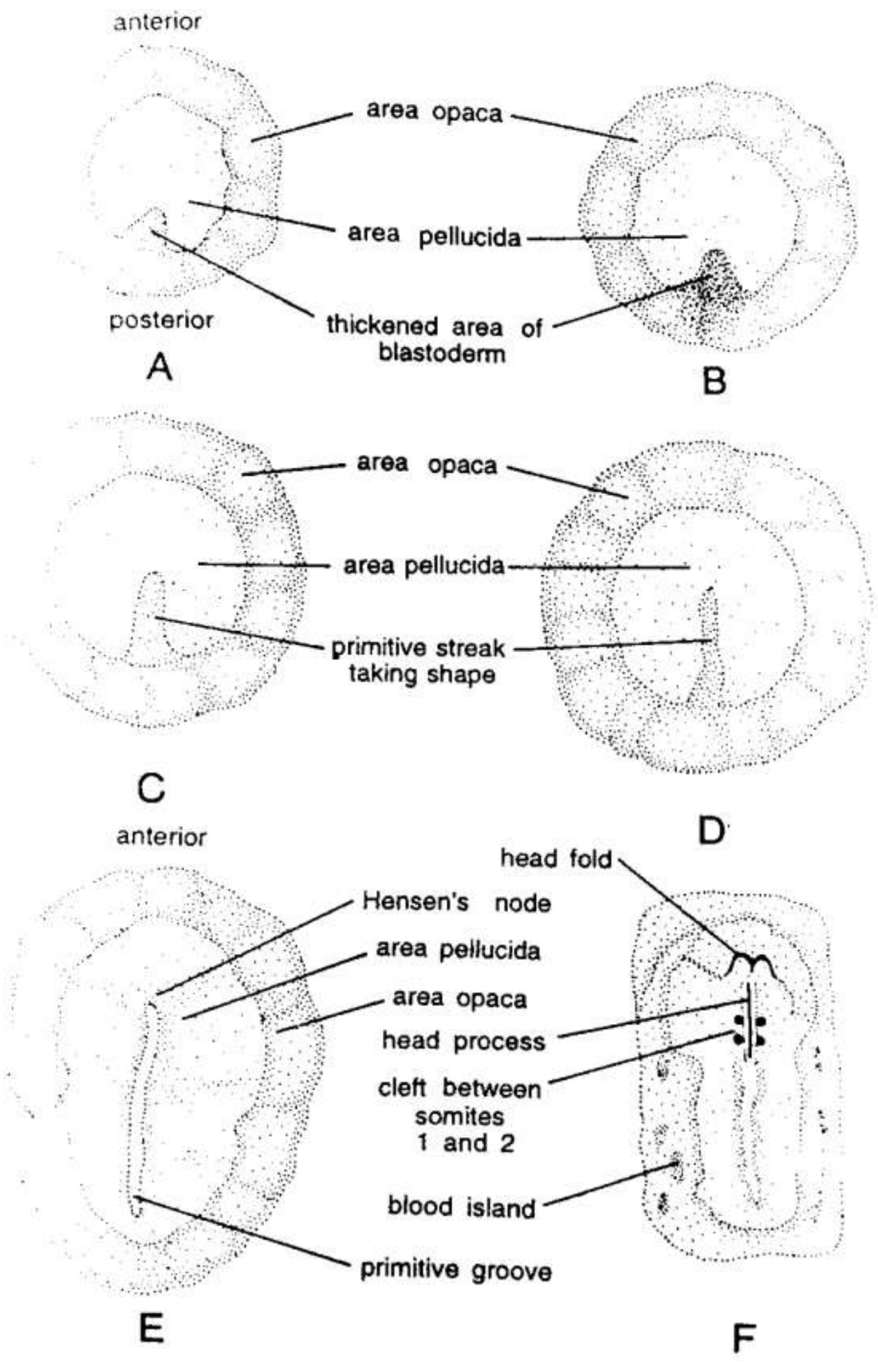
In the chick, the process of gastrulation is prolonged and highly modified than that of frog. The gastrulation is already started when the egg of chick is laid and completes well into the second day of incubation. The main characteristic of avian gastrulation is **primitive streak.**

1. The epiblast converges toward the posterior edge of the area pellucida and form a conical thickening in the midline, called the **initial primitive streak**. It appears after 6 to 7 hours of incubation.
2. The primitive streak grows anteriorly because of proliferation (cell division) of its own cells as well as of the addition of cells that migrate to it from anterior and lateral parts of area pellucida. The elongated axis of the primitive streak marks the antero-posterior axis of the future embryo. It, thus, eventually extends to, about three fifths of the entire length of area pellucida.
3. This is the fully developed definitive primitive streak and it is usually completed after 18 to 19 hours of incubation.
4. The area pellucida also becomes pear-shaped. Along the middle of the primitive streak, when it is fully developed runs a narrow furrow, **the primitive groove**. At the anterior end of the primitive streak there is a thickening, the primitive knot or **Hensen's node**. The centre of Hensen's node is excavated to form a funnel-shaped depression.
5. At the stage of short primitive streak, the cells of the blastoderm already begin to migrate (invaginate and involute) into the blastocoel cavity between epiblast and hypoblast. Immigrating cells are replaced by more epiblast cells converging toward the streak area.
6. The cells entering inside of the avian embryo form a loosely connected **mesenchyme** (mesoderm cells), no true archenteron is formed in avian gastrula.
7. As the cells enter the primitive streak, the streak elongates toward the future head region.
8. The first cells to migrate through the primitive streak are those to become **foregut**.

9. The next cells entering the blastocoel through Hensen's node also move anteriorly, but they do not move as far ventrally as the presumptive endodermal cells. These cells remain between the endoderm and the epiblast to form the head mesoderm and the chorda mesoderm (notochordal) cells. These cells push-up the anterior midline region of the epiblast to form the **head process**.
10. Meanwhile, cells continue migrating inward through the primitive streak. As they enter the blastocoel, these cells separate into two streams.
11. One stream moves deeper and joins the hypoblast along its mid-line, displacing the hypoblast cells to the side. These deep moving cells give rise to all the **endodermal portion** of the embryo.
12. The second migrating stream spreads throughout the blastocoel as a loose sheet, between the hypoblast and epiblast. This sheet gives rise to **mesodermal portion** of the embryo.
13. Now the second phase of gastrulation begins. While the mesodermal ingression continues, the primitive streak starts to regress (disappearance of primitive streak) moving Hensen's node from the centre of the area pellucida to a more posterior position.
14. As the node moves further posteriorly, the remaining (posterior) portion of the notochord is laid down.
15. Finally, the node regresses to its most posterior position, eventually forming the anal region. By this time, the epiblast is formed entirely of presumptive **ectodermal cells**.

"You cannot count on the physical proximity of someone you love, all the time. A seed that sprouts at the foot of its parent tree remains stunted until it is transplanted. Every human being, when the time comes, has to depart to seek his fulfilment in his own way."

Valmiki


anterior
area opaca
area pellucida
posterior
thickened area of blastoderm
A
B
area opaca
area pellucida
primitive streak taking shape
C
D
anterior
head fold
Hensen's node
area pellucida
area opaca
head process
cleft between somites 1 and 2
blood island
primitive groove
E
F

FOETAL MEMBRANES:

The blastoderm besides forming the embryo, gives rise to certain other structures which **do not take part in the formation of embryo**, but are external to the developing embryo. These structures are collectively called **foetal membranes** or **extra-embryonic membranes**.

These membranes are essential for complete development of the embryo. These foetal membranes are concerned with **nutrition**, **excretion**, **respiration** and **protection** from **desiccation** and **shocks**. These foetal membranes are **amnion, chorion** or serosa, **allantois** and **yolk sac**.

These membranes are composite structures involving two germ layers. The **amnion** and **chorion** are composed of extra-embryonic **ectoderm** and **somatic layer of mesoderm**; both are collectively called **somatopleure**. Whereas the **allantois** and **yolk sac** are formed of **extra-embryonic endoderm** and **splanchnic mesoderm** layers, both are collectively called **splanchnopleure**.

Development of Extra-Embryonic Membranes:

During neurulation, the **lateral plate mesoderm splits** into an **outer somatic layer lying beneath the ectoderm** and **an inner layer lying outer to the endoderm layer**. In between these **two layers of mesoderm** lies the **coelomic space**.

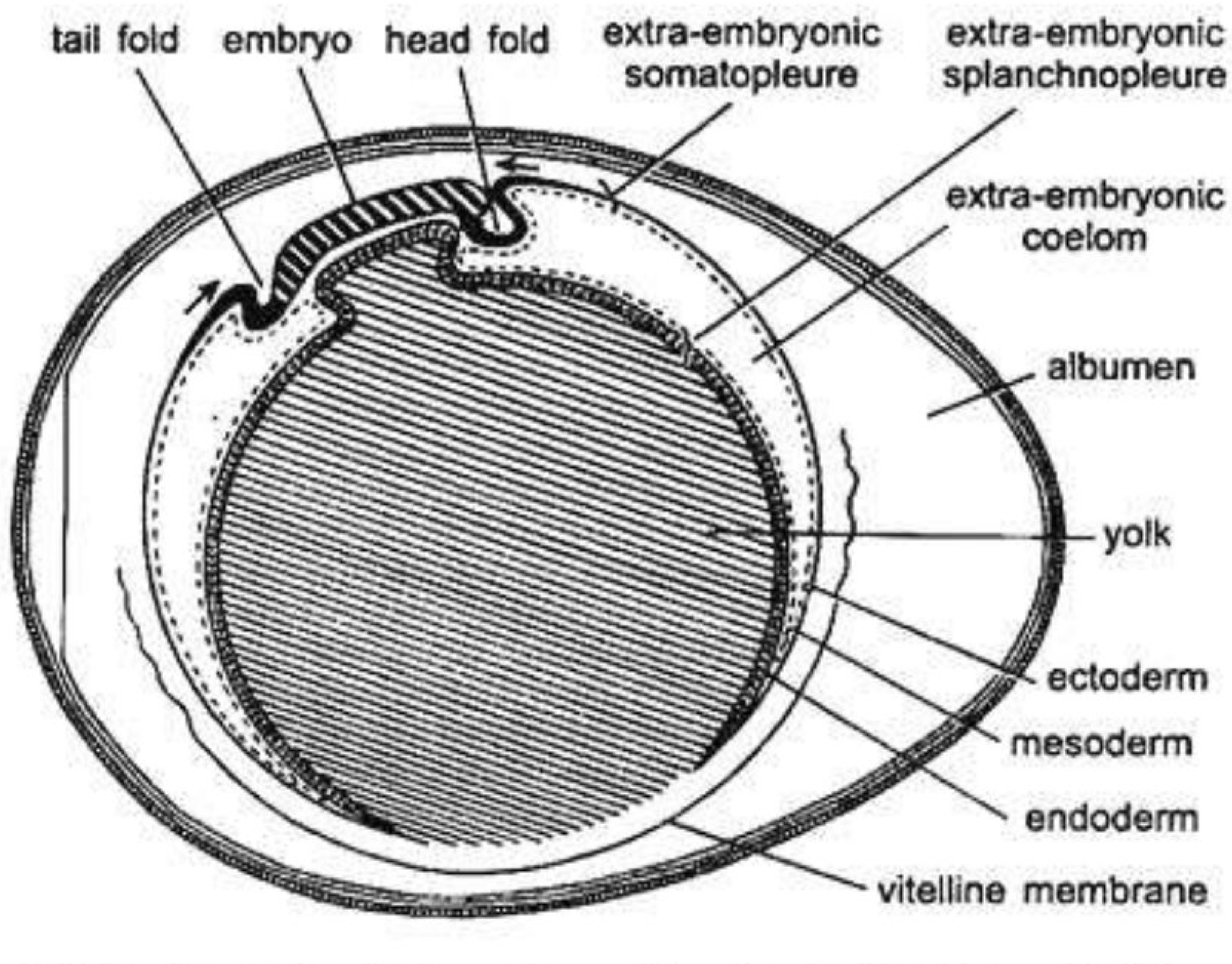


Fig. 38.10. An early chick embryo showing body folds delimiting from extra-embryonic areas.

The **ectoderm** and **somatic layer of mesoderm** are collectively called **somatopleure**, while the **splanchnic layer of mesoderm** and **endoderm** form the **splanchnopleure**. During later developmental stages, the somatopleure and splanchnopleure gradually spread outward beyond the developing embryo.

As the body of embryo grows, it becomes separated from the foetal membranes by the appearance of body **folds-cephalic**, **caudal** and **lateral folds.** These folds limit the body of embryo and separate the embryonic region from the extra-embryonic region.

DEVELOPMENT, STRUCTURE AND FUNCTION OF YOLK-SAC:

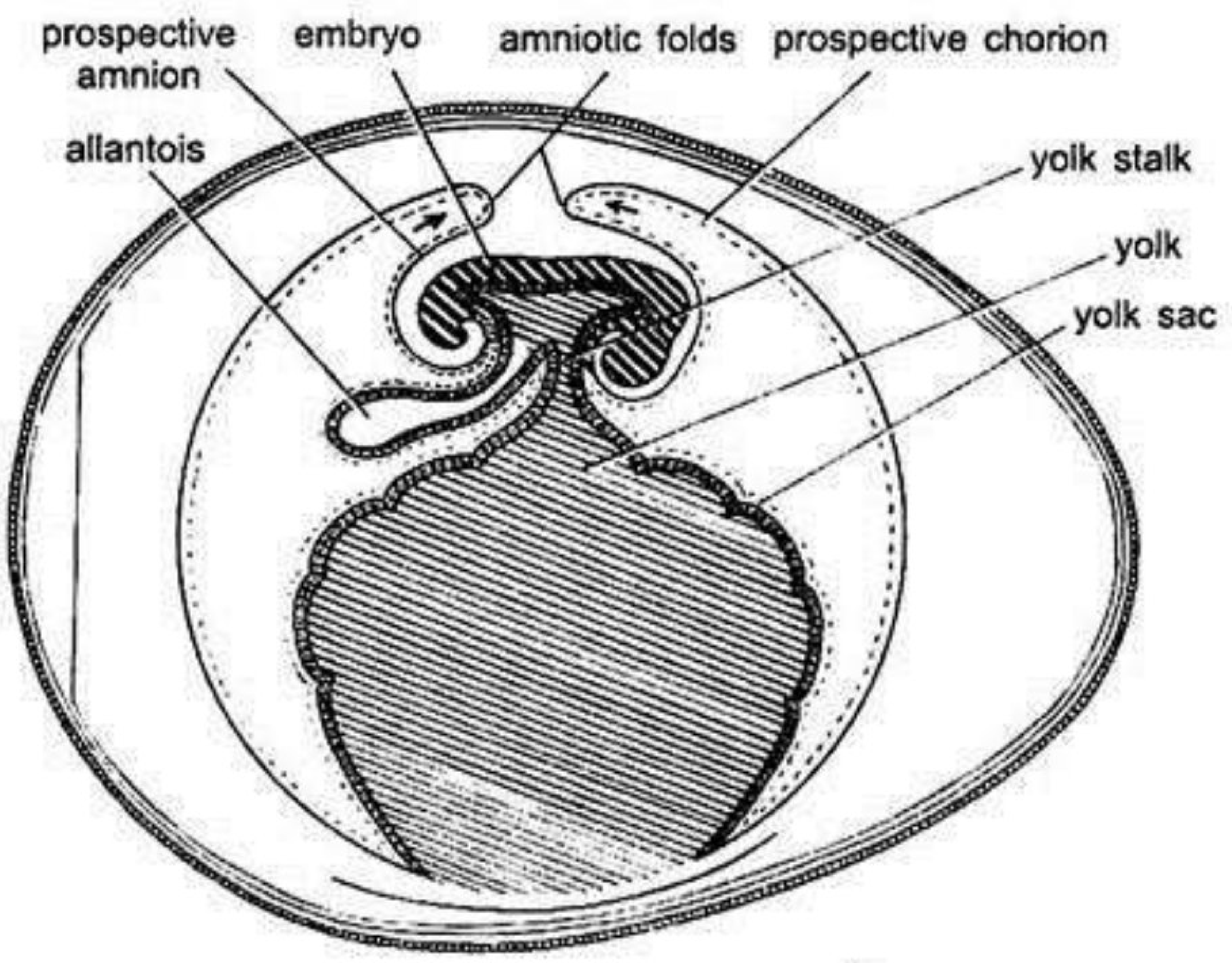


Fig. 38.11. Early stage in the development of the extra-embryonic membranes of chick.

1. The formation of yolk sac first among foetal membranes is essential since yolk is supplied to the developing embryo with the help of yolk sac.
2. The **extra-embryonic splanchnopleure** grows over the yolk and eventually **surrounds the entire yolk** to form the **yolk sac**.
3. It has an **inner layer of endoderm** and an **outer layer of splanchnic mesoderm**.
4. The yolk sac in the beginning is joined by a wide **yolk stalk to the midgut** of the embryo. But later on, as the body folds move toward one another beneath the embryo, a floor of the

gut is formed except a small region of the midgut **through which it communicates with the yolk sac**.

5. Thus, the yolk sac cavity remains in continuity with the gut cavity through **yolk duct** of yolk sac stalk.
6. The endodermal surface of the yolk sac is thrown into folds called the **yolk sac septa** that penetrate the yolk mass.
7. The rich blood circulation develops within the splanchnic mesoderm layer of the yolk sac. These are the **paired vitelline arteries** and **veins**, now called the **omphalomesenteric** blood vessels.
8. The **endodermal cells** of the yolk sac **secrete digestive enzymes** which **digest the yolk**.
9. The **digested yolk** is collected by **left** and **right vitelline veins**, both of which open into an unpaired **ductus venosus** which open into **sinus venosus** of the heart.
10. Thus, the yolk sac serves as a **digestive and absorptive surface** by which yolk is made available to the embryo.
11. Shortly before hatching the shrivelled up remains of the yolk sac is retracted into the abdominal cavity of the embryo, and the walls of the abdominal cavity close behind it.

DEVELOPMENT, STRUCTURE AND FUNCTION OF AMNION AND CHORION:

1. The origin of amnion and chorion is considered together since they develop simultaneously from the extra-embryonic somatopleure.
2. About 30 hours of incubation, the extra-embryonic **somatopleure** of the blastoderm **rises up** in front of the embryo as a fold; the fold grows and forms an arch over the embryo.
3. It forms a **double somatopleuric hood**, called the **cephalic amniotic fold**. As this fold gradually extends backward, its caudally extending side limbs called **lateral amniotic folds** arch over the embryo from either lateral side. A similar fold or elevation over the tail appears, called the **caudal amniotic fold**.

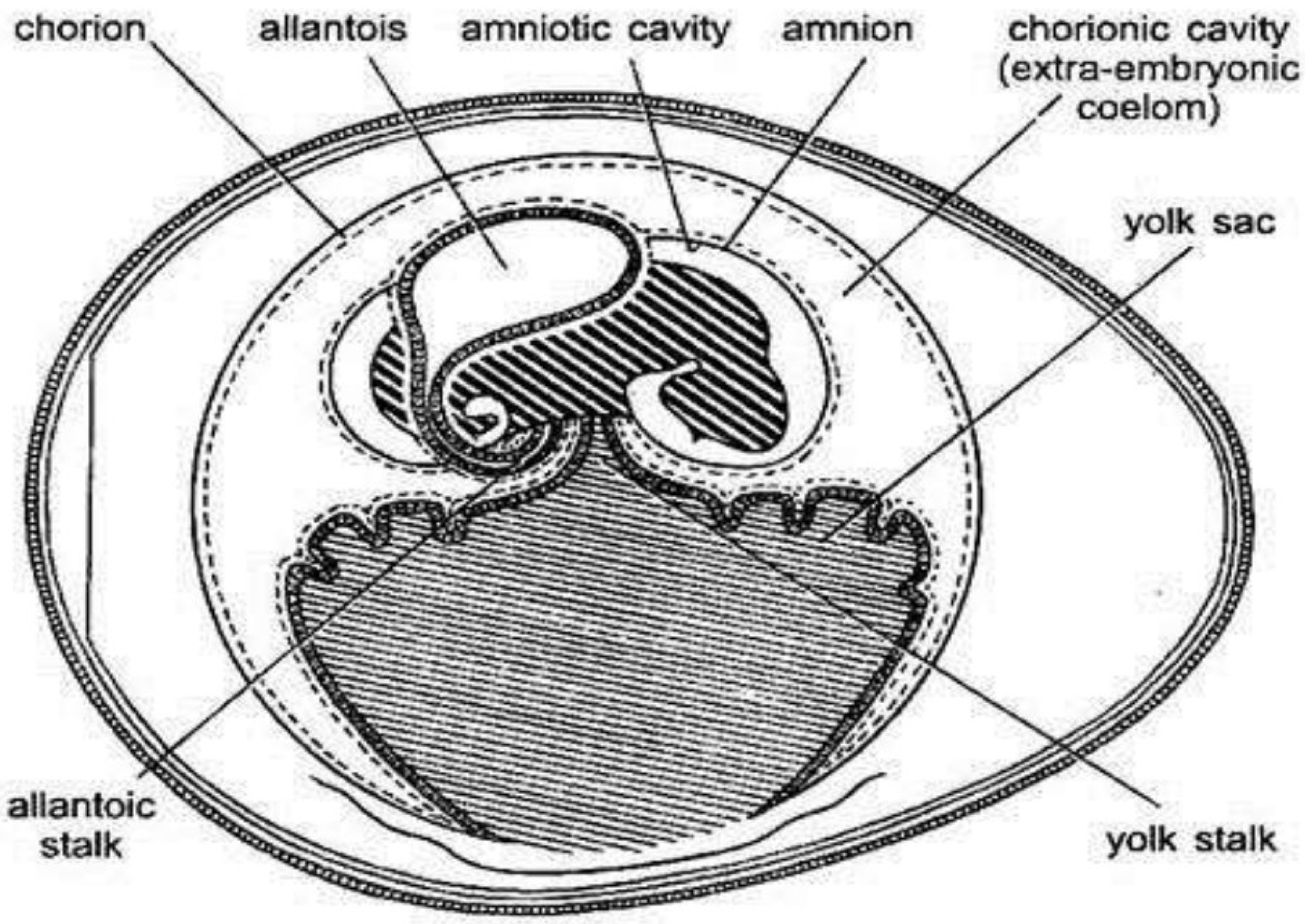


Fig. 38.12. Later stage in the development of the extra-embryonic membranes of the chick.

4. All these amniotic folds converge and fuse over the embryo, enclosing it within two sheets of somatopleure from all sides except the region of yolk stalk.
5. The region of union of the amniotic folds is called the **seroamniotic connection** and the scar-like point of fusion of the folds is called the **seroamniotic raphe**.
6. The **inner somatopleuric sheet becomes the amnion**, enclosing the embryo within amniotic cavity filled with **amniotic fluid**. While the **outer sheet of somatopleure** is the **chorion** and the cavity lying between the amnion and chorion is the **chorionic cavity** or extra-embryonic coelom. It is lined by mesoderm of somatopleure and splanchnopleure.
7. The somatopleure of amnion and chorion grows continuously peripherally and laterally and ultimately encloses the embryo and also the remaining two foetal membranes.

Functions of Amnion and Chorion:

a. The amnion **protects** the embryo from **desiccation** and **sudden temperature changes**.
b. The amniotic fluid is **an efficient shock absorber** and **protects** the embryo from the **mechanical shocks**.
c. The shell and shell membranes are protective and prevent desiccation of the embryo.

d. The mesoderm of amnion during later development forms muscle cells which contract rhythmically, **rocking the embryo** within the amniotic fluid so as to prevent it from adhesion to the embryonic membranes.

DEVELOPMENT, STRUCTURE AND FUNCTION OF ALLANTOIS:

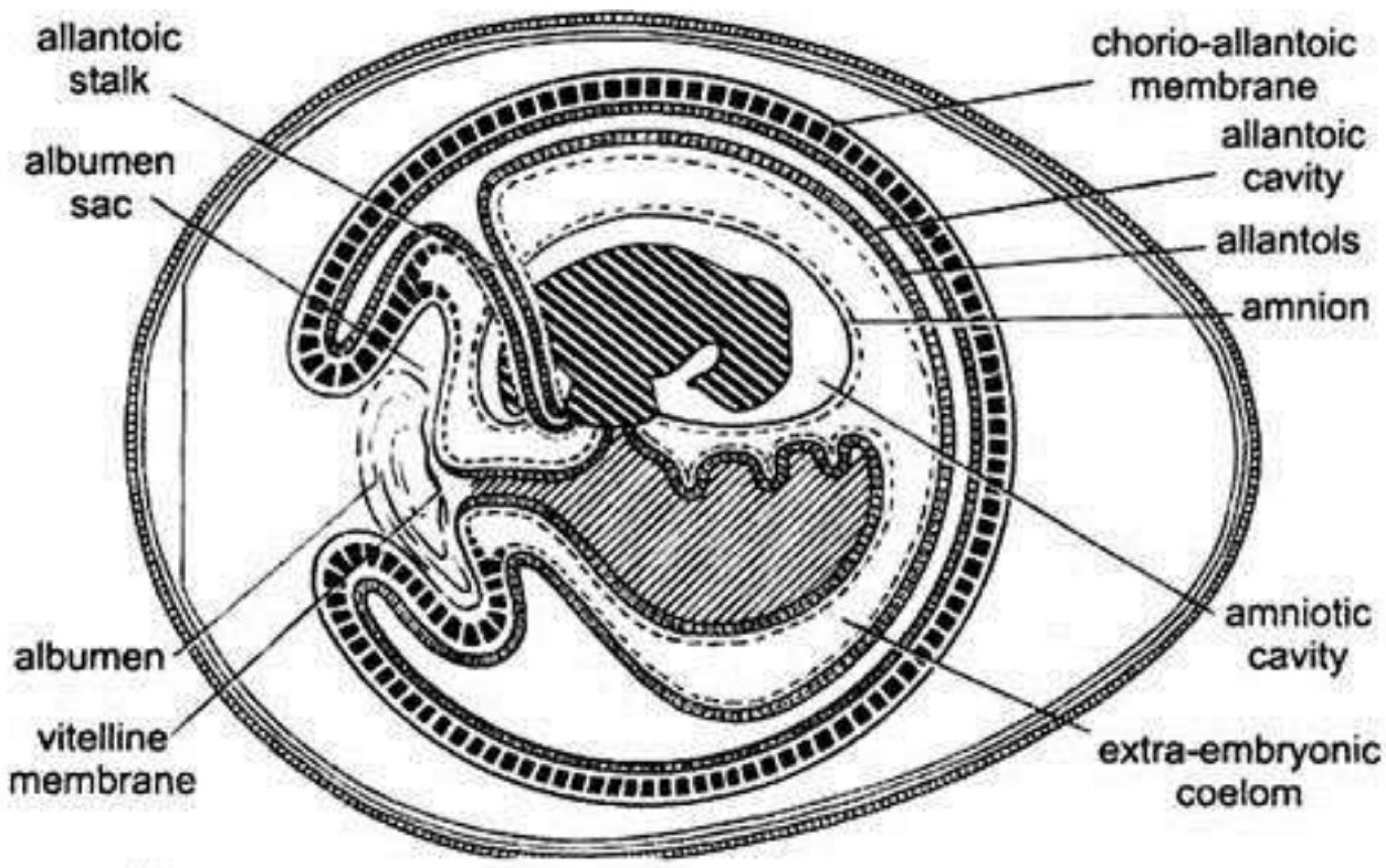


Fig. 38.13. The fully matured extra-embryonic membranes of the chick.

1. About the third day of incubation the floor of the endodermal hindgut begins to bulge as a **bladder**, called the **allantois**.
2. The allantoic evagination is formed from the **splanchnopleure**, that is, inner layer of **endoderm** and an **outer layer of splanchnic mesoderm**. It grows rapidly and spreads into the extra-embryonic coelom, the space between the yolk sac, the amnion and the chorion.
3. The distal part of the allantois expands and remains connected with the hindgut of the embryo by means of a narrow **allantoic stalk**. When the body folds' contract, separating the embryo from the extra-embryonic parts, the allantoic stalk is enclosed together with the stalk of yolk sac, forming an **umbilical cord.**
4. As the allantois vesicle enlarges and spreads outward, its distal part becomes flattened and expands between the amnion and yolk sac on one side and the chorion on the other side. Due

to this the splanchnic mesoderm of the allantois fuses with the inner somatic mesoderm of the chorion to form **chorio-allantoic membrane**.

5. The chorio-allantoic grows around the albumen of the egg to enclose it in an **albumen sac**. It aids in absorption of water and albumen.
6. The allantois becomes highly vascular due to the appearance of blood vessels in the splanchnopleure. It also receives a pair of allantoic or umbilical arteries, and its blood is returned into a pair of allantoic or umbilical veins.
7. The chorio-allantoic circulation continues until the young chick breaks the egg-shell and begins to breathe the surrounding air. Thus, the umbilical vessels close, the circulation ceases and the allantois dries up and separates from the body of the young chick.
8. At the time of hatching, the allantoic vesicle with excretory wastes detached from allantoic stalk and left attached to the broken shell.

Functions of Allantois:

a. The allantois serves as an **embryonic urinary bladder** collecting uric acid from the kidneys. Thus, prevented from escaping into other parts of the embryo where it might be harmful.

b. The vascular allanto-chorion is in contact with shell membranes and it brings about the **respiration** of the embryo by an **exchange of oxygen** and **carbon dioxide** through the porous shell.

"When you work, work as if everything depends on you. When you pray, pray as if everything depends on God."

J.R.D. Tata

PLACENTA:

Placenta is the structure formed by the union of foetal and uterine (endometrium) tissues for the purpose of nutrition, respiration and excretion of the embryo.

MORPHOLOGICAL CLASSIFICATION OF PLACENTA:

On the degree of intimacy of foetal and maternal tissues following types of placentae may be recognised;

a. Non-deciduous placenta or semi placenta
b. Deciduous placenta
c. Contra-deciduate placenta

a. Non-deciduous placenta or semi placenta:

In most of the mammals, the placenta is **superficial**, *i.e.,* the blastocyst lies in the cavity of the uterus in contact with the uterine wall.

The contact may be made more intimate by the surface of the blastocyst by forming **finger-like outgrowths**. These outgrowths are called **chorionic villi**.

At the time of **parturition** (birth) the chorionic villi are simply drawn out from the depressions in the wall of uterus and thus, maternal and foetal tissues are separated **without** further **damage** to the **uterine wall** and **no bleeding** occurs.

This type of placenta is called **non-deciduous** or **semi placenta** and is found in pigs, cattle and some other mammals.

There are two sub types as follow;

i. **Diffuse placenta:**

In some mammals the chorionic villi remain scattered all over the surface of the chorion. Such placenta is called diffuse placenta.

Example: Ungulates, pig, sow, horse, lemur, etc.

ii. **Cotyledonary placenta:**

In cotyledonary placenta, the villi are found in groups or patches, while the rest of the chorion surface remains smooth. The rosettes or patches of villi are called **cotyledons**.

Example: Ruminants (cud-chewing) ungulates - cattle, sheep and deer.

b. Deciduous placenta or placenta vera:

In this type of placenta, the degree of intimacy between the maternal and foetal tissues becomes further increased.

The wall of the uterus becomes eroded to various degrees through the action trophoblast and the embryonic tissues.

Here, because the chorionic villi fuse with the eroded uterine mucosa, such placenta is called **placenta vera** (true placenta).

At the time of birth, a variable amount of maternal tissue is pulled out with the shedding of blood.

Deciduous type of placenta is also differentiated in the following subtypes;

i. **Zonary placenta:**

In a zonary placenta, the villi are developed in the form of belt or girdle-like band around the middle of their blastocyst or chorionic sac, which is more or less elliptical in shape.

Example: Carnivores- cat, dogs, lion, tiger, etc.

ii. Discoidal placenta:

In discoidal placenta, the villi are restricted to a circular disc or plate on the dorsal surface of blastocyst.

Example: insectivores, bats, rodents (rat, mouse), rabbit and bear.

iii. Metadiscoidal placenta:

Primates have special type of discoidal placenta in which villi are first scattered but later become restricted to one or two discs.

Thus, **monodiscoidal** placenta has a single disc-shaped villous area.

Example: Human

Bidiscoidal placenta has two disc-shaped villous area.

Example: Monkeys and apes.

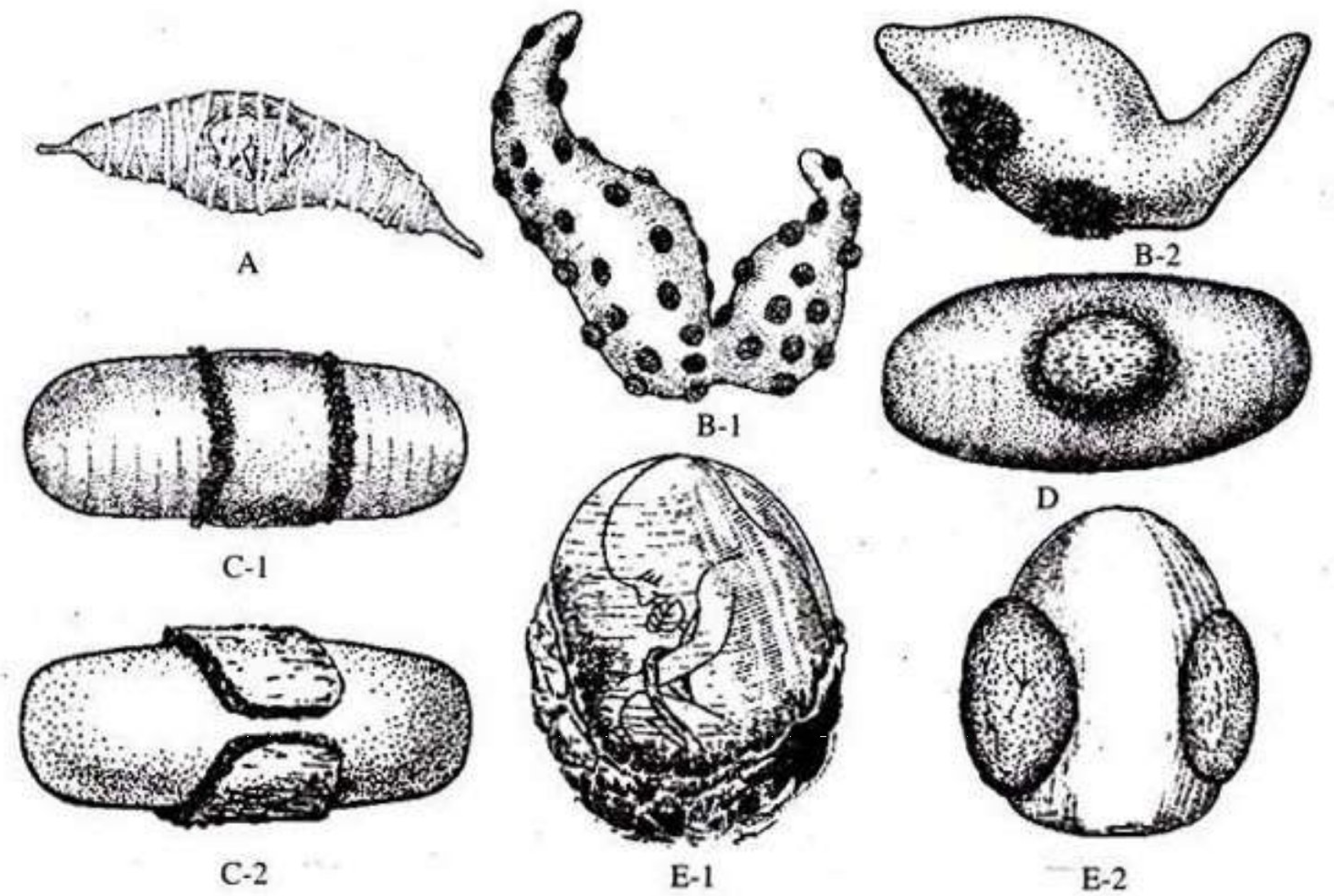


Fig. 5.54 : Types of placenta based on the distribution of villi. (A) Diffuse placenta of pig, (B) Cotyledonary placenta, B-1 calf, B-2 Mexican deer, (C) Zonary placenta, C-1 dog, C-2 incomplete zonary of raccoon, (D) Discoidal placenta in bear, (E) Metadiscoidal placenta, E-1 monodiscoidal type in man, E-2 bidiscoidal type in monkey.

HISTOLOGICAL TYPES OF PLACENTA:

Foetal and maternal bloods in the placenta do not mix up with each other. To start with the two blood streams are separated from each other by at least the following six tissue barriers or membranes.

a. Endothelium of foetal blood vessels
b. Chorionic-allantoic mesoderm
c. Chorionic epithelium
d. Uterine epithelium
e. Uterine connective tissue
f. Endothelium of maternal blood vessel

Exchange of substances in solution between two blood streams (i.e., foetal and mother) occurs by diffusion through these tissues. To increase its effectiveness or efficiency of placenta, it is necessary to reduce the number of tissues between foetal and maternal blood streams.

On histological basis, following types of mammalian placentae have been recognised.

i. **Epithelio-chorial placenta:**

It is most primitive type placenta with **all six tissue membranes** (barriers) occur between the foetal and maternal blood stream.

Because, the immediate contact of two halves of placenta involves chorionic epithelium and uterine epithelium, this type of placenta is called **epithelio-chorial placenta**.

The molecules of nutrients and oxygen, in going from the mother to foetus would pass through in the following order;

The endothelium of maternal blood vessel → Endometrial connective tissue (mesenchyme) → Uterine epithelium → Ectoderm of the chorion → Chorionic connective tissue (foetal mesenchyme) → Endothelium of foetal blood vessel.

Example: Marsupials, ungulates (pig, horse, sow, cattle, etc) and lemurs.

ii. **Syndesmo-chorial placenta:**

In this type of placenta, the foetal and maternal components are fused intimately as to result in a destruction of the uterine epithelium.

Hence, the chorionic epithelium of foetus is in immediate contact with the connective tissue of the uterine mucosa.

Therefore, **only five barriers** lie between the foetal and maternal blood streams called **syndesmo-chorial placenta** and thus the molecules of nutrients and oxygen, in going from the mother to foetus would pass through in the following order;

The endothelium of maternal blood vessel → Endometrial connective tissue (mesenchyme) → Ectoderm of the chorion → Chorionic connective tissue (foetal mesenchyme) → Endothelium of foetal blood vessel.

Example: Ruminant ungulates (cattle and sheep0

iii. **Endothelio-chorial placenta:**

The uterine mucosa is reduced and the chorionic epithelium comes in contact with the endothelial wall of the maternal uterine blood vessels, hence the name **endothelio-chorial placenta**.

There are **only four barriers** found between the foetal and maternal blood streams and the order of diffusion of nutrients and oxygen as follows;

The endothelium of maternal blood vessel → Ectoderm of the chorion → Chorionic connective tissue (foetal mesenchyme) → Endothelium of foetal blood vessel.

Example: Carnivores (dog, cat, bear, etc)

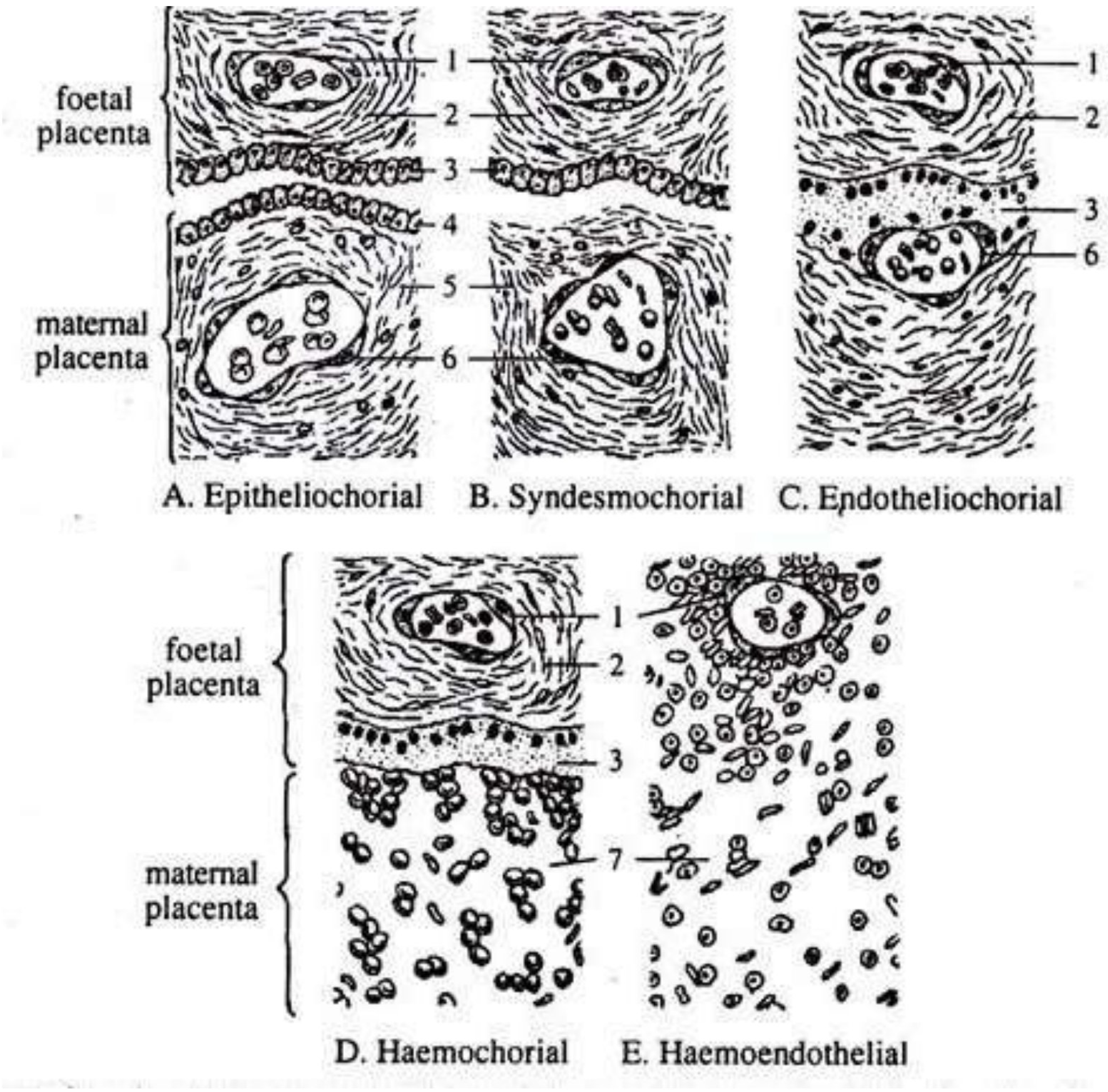


Fig. 5.55 : Mammalian placental types arranged in a series to show the progressive elimination of barriers between the maternal and foetal circulations. 1. Endothelium of foetal blood vessel; 2. Chorionic connective tissue; 3. Chorionic epithelium; 4. Uterine epithelium; 5. Endometrial connective tissue (mucosa); 6. Endothelium of maternal blood vessel; 7. Maternal blood pool.

iv. Haemo-chorial placenta:

In this type of placenta there is further reduction of barriers to three. In such case, the endothelial walls of maternal blood vessel also disappear and thus, chorionic epithelium bathed directly in maternal blood.

The nutrients and oxygen follow the way from maternal blood to Ectoderm of the chorion → Chorionic connective tissue (foetal mesenchyme) → Endothelium of foetal blood vessel.

Example: insectivores (moles, shrews) and chiropterans (bats)

v. Haemo-endothelial placenta:

In this type of placentas, the number of barriers between the maternal and foetal blood stream is reduced to just two.

In them, the chorionic villi lose their epithelial and mesenchymal layers to such a degree that, in most places the essentially bare endothelial lining of their blood vessels alone separate the foetal blood from the maternal sinuses.

The nutrients and oxygen directly diffuse into mesenchyme and endometrial cells of the foetal blood vessels.

Example: Mouse, rat, guinea pig, rabbit, etc.

"Everything in its own pace happens. The gardener may water with a hundred buckets; fruit arrives only in its season."

Kabir

PLACENTAL HORMONES:

Placenta is the tissue connection between the foetus and the uterus of the mother. It is a supporting organ for nourishment of the growing embryo. It also functions as an endocrine gland during pregnancy and secrets protein hormones and steroid hormones.

1. **Human Chorionic Gonadotrophin (HCG) or Chorionic Gonadotrophin (CG):**

   i. It is a protein hormone, secreted by the syncytiotrophoblast cells of the placenta about 10 days after ovulation.

   ii. HCG prolongs the life of corpus luteum. Thereby, it sustains the secretion of progesterone.

   iii. It shows immune-suppressive activity, which may inhibit the maternal processes of immune-rejection of the foetus.

   iv. HCG can be detected in the maternal serum or urine after 7-10 days of fertilization.

   v. HCG content will be high between 60-70 days of pregnancy.

2. **Chorionic Growth Hormone Prolactin (CGP):**

   i. It is a protein hormone, secreted by the placental cells from the first few weeks of pregnancy until the term.

   ii. It stimulates the glandular elements of the mammary glands.

   iii. It plays an important role in carbohydrate and fat metabolism.

   iv. It causes decreased insulin sensitivity and decreased utilization of glucose, thereby making larger quantities of glucose available to foetus.

   v. It also promotes release of free fatty acids from the fat store of mother, thus provides alternate source of energy to foetus.

3. Human Chorionic Thyrotrophin (HCT):

i. It is a protein hormone, secreted by placenta.
ii. It stimulates thyroid gland.
iii. HCT stimulates lactation in the mammary glands and inhibits ovulation.
iv. This hormone stimulates the growth and persistence of corpus luteum.
v. HCT stimulates the growth of uterus and the placenta itself.

4. Relaxin:

i. It is a protein hormone secreted by corpus luteum, uterus, placenta and mammary glands in women and by the prostate gland in men.
ii. It helps in the relaxation of the pubic ligaments and other pelvic joints at the time of parturition.
iii. It softens and dilates the uterine cervix during parturition.
iv. Its plasma concentration reaches the peak during the last week of pregnancy.
v. Its function in non-pregnant women is unknown.
vi. In men, it is found in semen, where it maintains the motility of sperm and helps the sperm to penetrate the ovum.

5. Oestrogen:

i. It is a steroid hormone, produced by ovary and syncytiotrophoblast cells of placenta.
ii. It is responsible for puberty and development of secondary sexual characters in female.
iii. It initiates growth of breast, uterus and vagina.
iv. It is responsible for the feminine body configuration that includes narrow shoulders, broad hips, converged thighs, distribution of fat in breast and

buttocks, high-pitched voice, less body hair, more scalp hair and pubic and axillary hair. Thus oestrogen is referred as feminizing hormone.

v. Oestrogen increases the growth rate of all bones immediately after puberty by inducing the positive calcium balance.

vi. It plays an important role in the cyclic changes in the endometrium, cervix and vagina. They increase uterine blood flow and have significant effects on the smooth muscles of uterus, making uterus about two to three times larger than the child.

vii. The secretion of the sebaceous gland become more fluid under the influence of oestrogen and inhibits the formation of blackheads (comedones) and acne.

viii. It exerts synergistic action with oxytocin for the contraction of uterine muscle to initiate the process of parturition.

ix. The sexual desire (orgasm) of the female is the impact of oestrogens.

6. Progesterone:

i. It is a steroid hormone, secreted by corpus luteum of ovary and syncytiotrophoblast cells of placenta.

ii. It plays major role for the maintenance of pregnancy. Under its influence, endometrium becomes considerably thick and vascular for the reception and embedding of the fertilized egg.

iii. It prevents the premature parturition by neutralizing the effect of oxytocin and prevents the muscular contractility of the pregnant uterus thereby reducing the chances of abortion.

iv. It stops the menstruation and ovulation (release of ovum from ovary) until the pregnancy by preventing Luteinizing Hormone (LH) secretion.

v. In the breast, progesterone promotes the development of lobules and alveoli.

vi. Human placenta starts secreting progesterone from 8th week of pregnancy.

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CHAPTER – 07

HUMAN DEVELOPMENT

STRUCTURE OF MATURE SPERMATOZOAN:

1. The male spermatozoon is divided into four regions: Head, Neck, Middle piece and Tail.

2. **Head:**

Human sperm has got a **flattened head**.

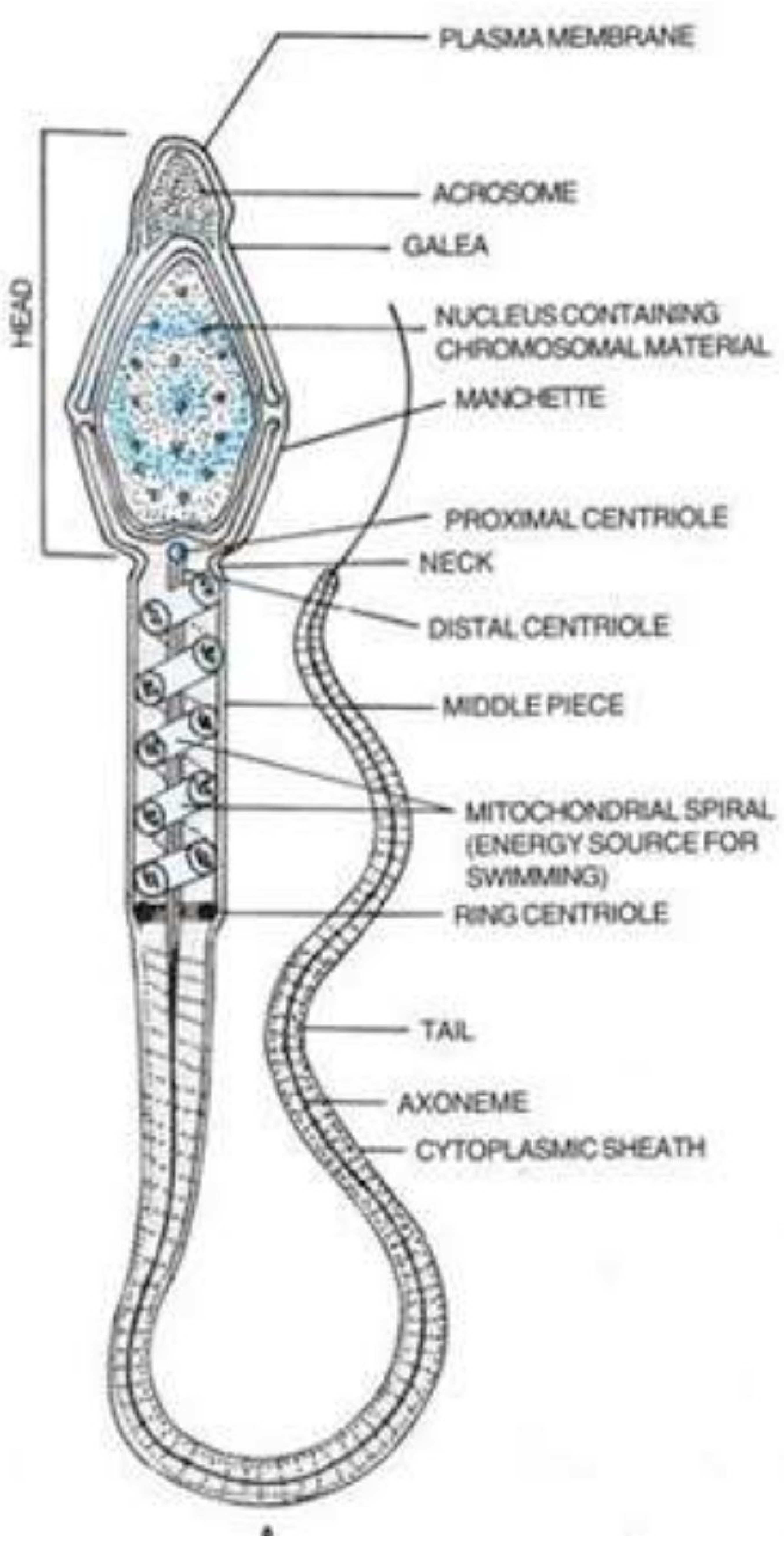
Head is made of two parts **Acrosome** and **Nucleus**.

Acrosome is present at the tip of the nucleus and it is small and pointed.

It mainly consists of Golgi bodies and at the time of penetration into egg it secretes enzyme **hyaluronidase** which helps the nucleus to penetrate.

Nucleus mainly consists of condensed **chromatin material**. This carries the **genetic information**.

Both acrosome and anterior half of nucleus is covered with fibrillar sheath called **galea**.



3. **Neck:**

It is the **smallest part** of spermatozoon.

It consists of **two centrioles** – **proximal** and **distal** centrioles placed perpendicular to each other. Both the centrioles are microtubular triple structure having 9 + 0 arrangement.

Centrioles are responsible for the **formation of spindle fibers** during first zygotic cleavage.

Distal centriole acts as **basal body** and gives rise to **axoneme** of tail.

4. **Middle Piece:**

It lies between the neck and tail.

It is made of nebenkern, mitochondrial spiral.

Since mitochondria carries enzymes- responsible for oxidative phosphorylation the middle piece is also known as power house of sperm.

Posterior part of nucleus, neck and middle piece is covered by a sheath – manchette.

5. **Tail:**

This is the **longest part** of sperm which is flagellate.

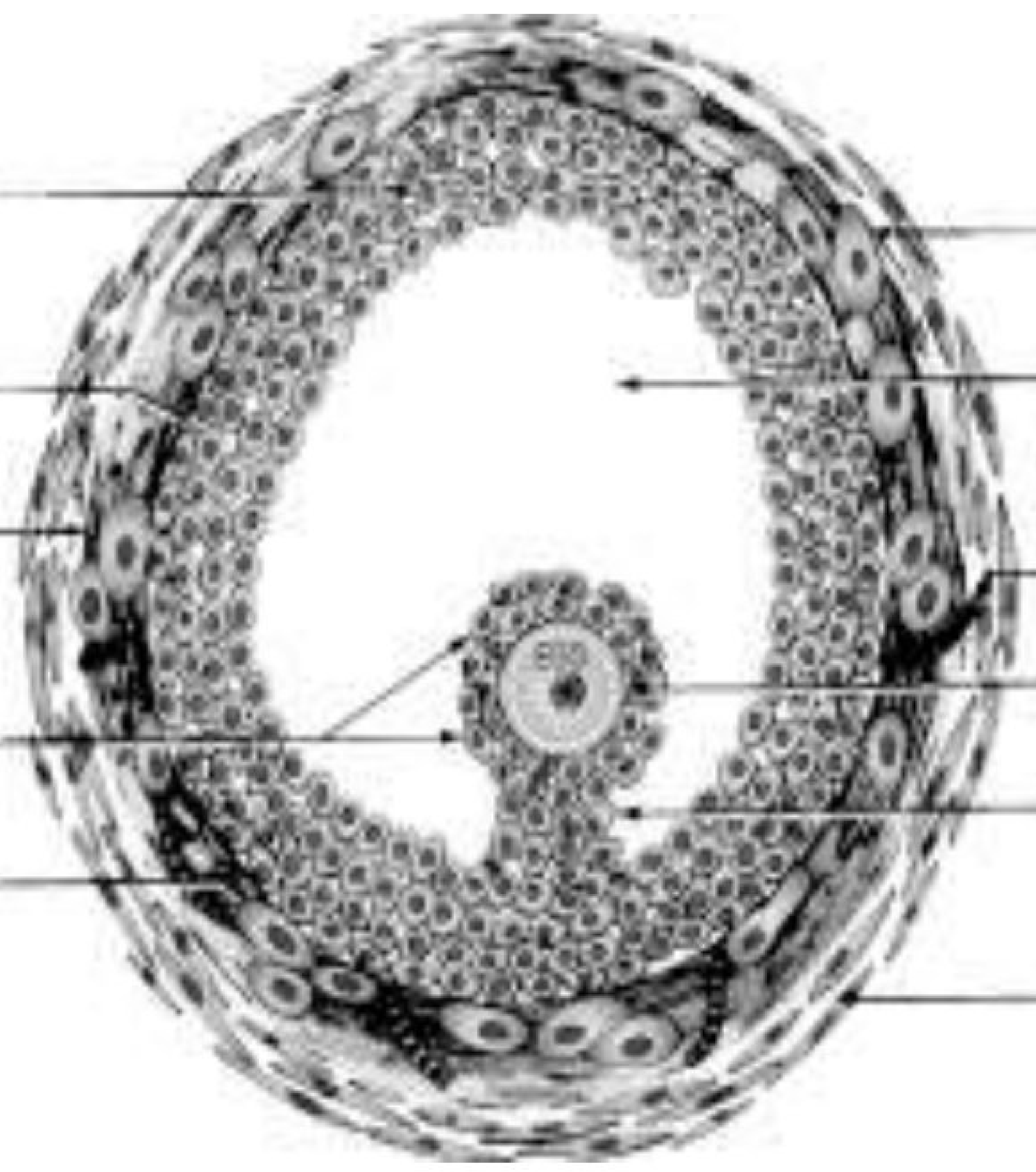
Tail is divided into outer and central part. **Outer part** is **protoplasmic sheath** whereas **central part** is called **axoneme** or **axial filament**.

Axoneme is microtubular and has 9 + 2 arrangement of proteinaceous tubules.

Junction of middle piece and tail may have ring centriole.

Tail helps in forward movement of sperm. Viability of human sperm is 24 hours.

GRAAFIAN FOLLICLE:



A healthy Graafian follicle is a complex functional unit that comprises multiple layers of precisely positioned cells.

The **theca externa** is **innervated** by **autonomic nerves** that seem to play an active role in their contraction.

In the **theca interna**, the number of differentiated theca **interstitial cells** increases progressively and there is **five to eight layers** of theca interstitial cells in a Graafian follicle.

Internal to the theca is a **basal lamina** that functions as a **barrier to vascular tissue**, as well as **multiple layers of granulosa cells**. The position of the granulosa cells creates at least four different domains:

1. An outer or **membrane domain** that comprises a pseudostratified epithelium, which makes contact with the basal lamina, composed of mural granulosa cells.
2. An inner or **periantral domain**, which makes contact with the membrane cells.
3. The **cumulus domain**, which makes contact with the periantral cells.

4. A **corona radiata domain**, which makes contact with the cumulus cells, as well as with the Zona pellucida.

The healthy human Graafian follicle passes through small (1 to 6 mm), medium (7 to 11 mm), large (12 to 17 mm), and preovulatory (18 to 23 mm) stages. The size of a Graafian follicle is determined largely by the size of the antrum, which, in turn, is determined by the volume of follicular fluid

OVULATION:

It is the **process of release of egg from the matured Graafian follicle**. On the 15th day of menstrual cycle and involves the ovulation from Graafian follicle. It is caused by contraction of smooth muscle fiber and turgidity around the Graafian follicle. Fimbriae of fallopian tube receive the ovum. Life span of ovum is 48 hours. Increased level of **LH** controls ovulation. LH also helps in changing the empty Graafian follicle into corpus luteum and in secretion of progesterone from corpus luteum.

FERTILIZATION:

The process of union of a haploid male gamete or sperm with a haploid female gamete or ovum to form a diploid cell, the zygote, is called fertilization.

Site of Fertilization: In human female, fertilization is **internal**. It takes place usually in the **ampulla-ischemic** region of the **fallopian tube**.

Process of Fertilization:

Male discharges the semen into the vagina of the female during copulation (coitus). From the vagina, the sperms reach the ampulla partly by the movement of their tails and partly by the action of uterus. The sperms present in the semen travel a long way from vagina through the uterus into the fallopian tube.

Sperms may reach fallopian tube within five minutes. The **sperm** can **survive** in the female's reproductive tract for 1-3 days and it can fertilize the ovum in 12 to 24 hours following ovulation.

During sexual intercourse, nearly 300 million sperms are introduced into the vagina, but only few hundreds of them reach near the ovum.

Events of Fertilization:

1. **Activation of sperm and ovum:**

   The sperms can fertilize an ovum only they are able to secrete the chemical hyaluronidase and possess a surface protein called **antifertilizin** (composed of acidic amino acid). The ovum secretes a chemical named **fertilizin**). It mixes with the water to form egg water which attracts the sperms of its own species.

2. **Penetration of sperm:**

   The fertilizin of an egg interacts with the anti fertilizin of sperm of the same species. This **attraction** between **fertilizin** and **antifertilizin** makes the **sperms stick to the egg surface**. The process of acquiring the capacity to fertilize the egg by the sperm is called **capacitation**. In this process, the membrane surrounding the acrosome of the sperm breaks and releases its contents, the sperm lysine. It is the chemical substance present in the sperm's acrosome.

   At first the sperm passes through corona radiata to reach zona pellucida. There it releases the enzyme hyaluronidase or sperm lysine from its acrosome. This enzyme dissolves zona pellucida as a result of which the sperm reaches the plasma membrane of the egg. The above changes on the sperm head are called **acrosome reaction**.

   At the point of contact with the sperm, the egg forms a projection, termed the **cone of reception** or **fertilization cone** which receives the sperm. Once one sperm has entered the egg (ovum) the **vitelline membrane thickens** and is **converted into fertilization membrane**. This membrane is **rigid** and **never allows other sperms** to pass through this membrane. Penetration of the sperm initiates a second maturation division of the ovum and a second polar body is given off.

3. **Amphimixis:**

Mixing up of the chromosomes of a sperm and an ovum resulting in a diploid zygote nucleus is known as amphimixis or karyogamy. The mother is now said to be pregnant. The centrosome form asters and spindle fibres. The paternal and maternal chromosomes move to lie in the equator of the spindle and the zygote is ready for division by cleavage.

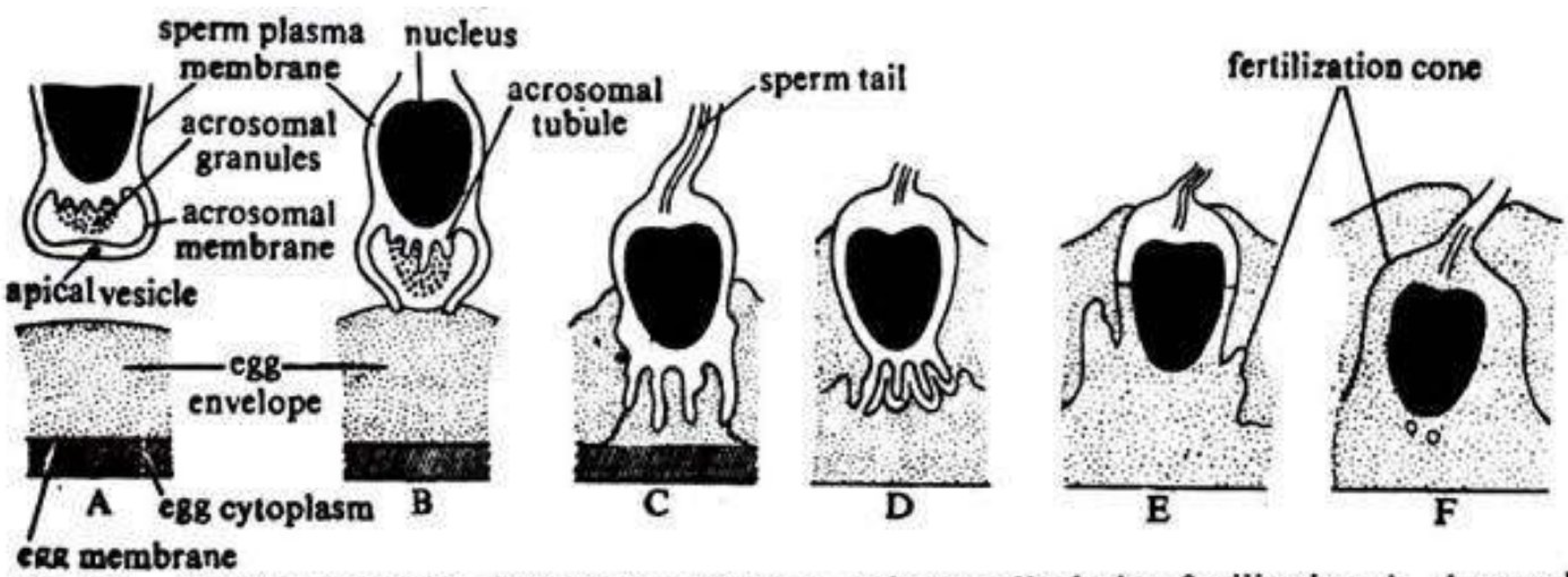


Fig. 5.8. Showing the events of the fusion of sperm and egg cells during fertilization. A. Approach of a sperm towards egg. B. Opening of the sperm tip after its contact with egg envelope. The acrosomal and sperm plasma membranes become continuous. C. The acrosomal wall is everted. D. Sperm and egg plasma membranes interdigitate and become fused (E) and fertilization cone arises. F. Sperm parts mingle with egg cytoplasm.

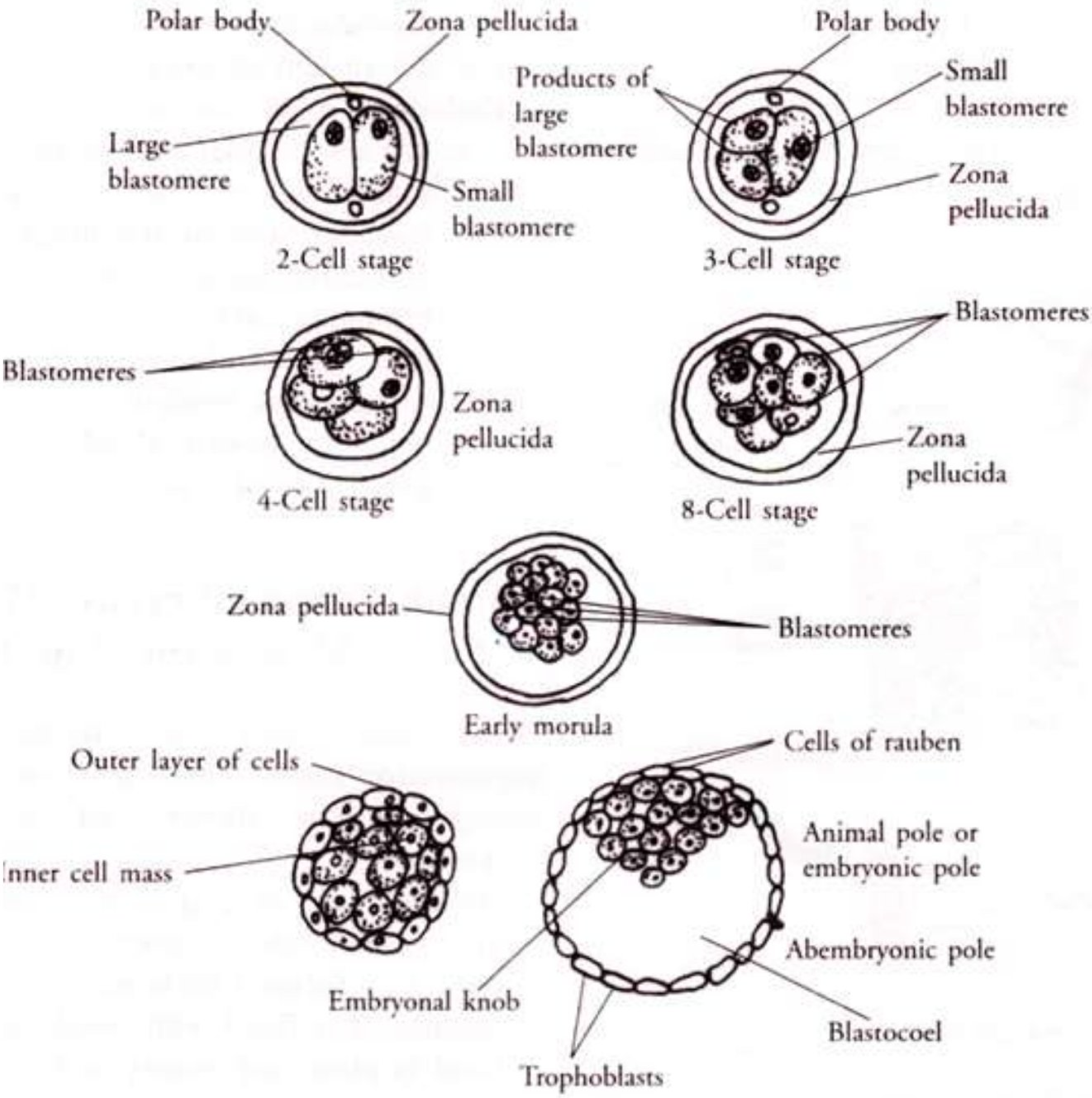
"The hunger for love is much more difficult to remove than the hunger for bread."

Mother Teresa

CLEAVAGE:

Successive and rapid mitotic divisions in the zygote, changing it into ball or disc like structure. Cells forming this structure are called **blastomere**. This results in the formation of **blastula**. The blastomeres enclose a space called as **blastocoel**. This process is known as **blastulation**.

During cleavage there is no growth of cells, so the cell size becomes smaller and smaller. This type of cleavage is called fractionating process. Due to increase in DNA and no addition of cytoplasm the nuclear-cytoplasmic ratio keeps on increasing. Initially the blastomeres show synchronous division but, it is lost after some time.



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MORULA:

Cleavage starts in the **fallopian tube**, as the **zygote moves** towards the **uterus**. After a few cleavages the zygote **resembles a little mulberry** so it is called **morula**. Morula is the 32 cell stage and it takes four days to reach the uterus.

BLASTOCYST:

Next step is formation of **blastula**. This involves rearrangement of blastomeres. Outer cells are flat and are called **trophoblast**. The fluid which is absorbed by these cells is collected in a central cavity called **blastocoel**. With increase of fluid in **blastocoel**, the size of morula increases and now it is known as **blastocyst**.

IMPLANTATION:

After the fertilization the cleaving egg enters the uterus and gradually increases in size. Later on, a vascular organ called placenta develops by embryonic and maternal tissues in between the blastocyst and uterine wall. This process is called implantation.

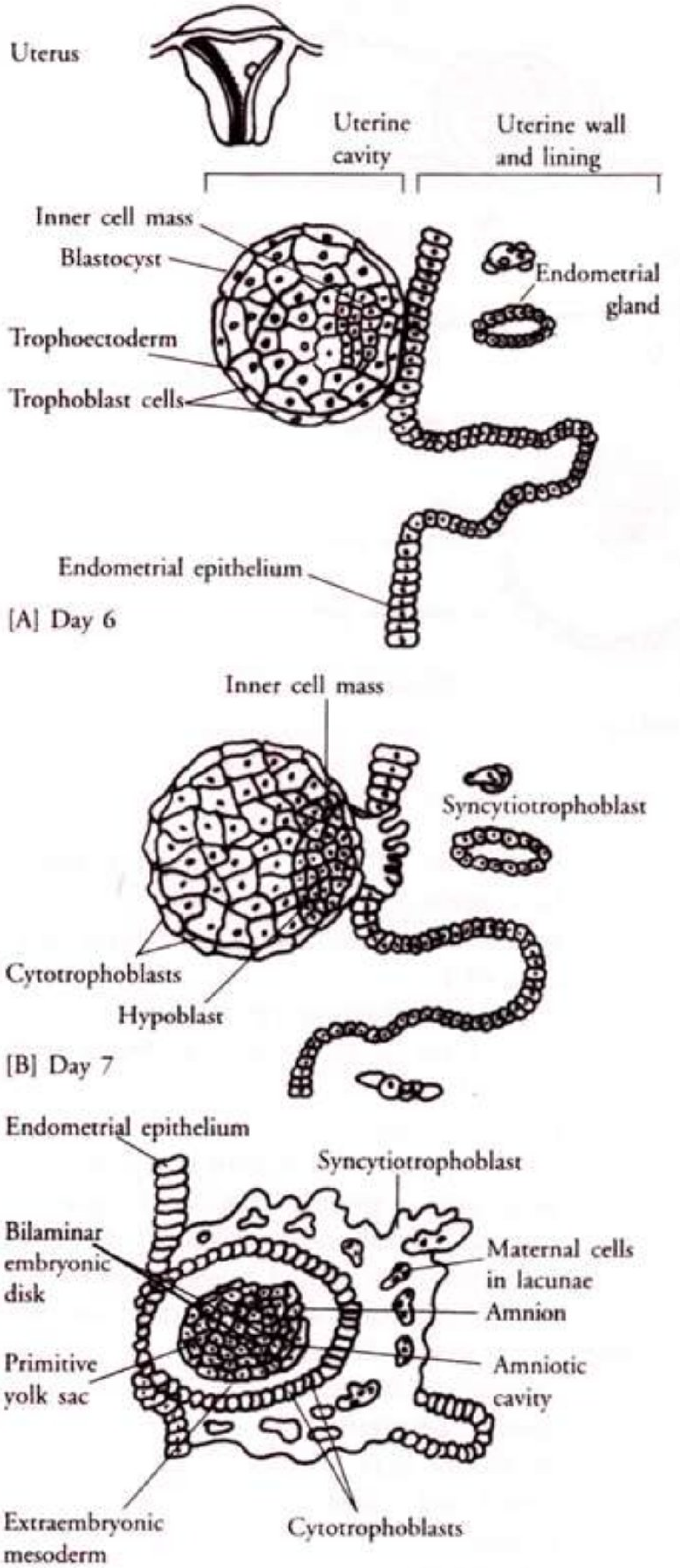

Fig. 16 Implantation of embryo in the uterus and formation of extraembryonic membranes.

ORGANOGENESIS:

Organogenesis is the process by which the **three germ tissue layers** of the embryo, which are the **ectoderm, endoderm,** and **mesoderm**, **develop into the internal organs of the organism**.

DERIVATIVES OF DIFFERENT GERM LAYERS:

ECTODERM	ENDODERM	MESODERM
i) Epidermis of the skin.	i) Epithelial parts of the thyroid, thymus, parathyroid, middle ear, eustachean tube.	i) Dermis of the skin.
ii) Brain and spinal cord.	ii) Epithelial portions of the liver and pancreas.	ii) Skeletal system.
iii) Cranial and spinal nerves, oral epithelium and epithelium of oral glands.	iii) Epithelial lining of the respiratory system beginning with the larynx.	iii) Most muscles as well as adipose tissue and all other varieties of connective tissue.
iv) Nasal and olfactory epithelium.	iv) Epithelial lining of the vagina, urinary bladder.	iv) Certain types of scales, horns in animals.
v) Epithelium of anal canal.	v) Epithelial lining of the gut, except the mouth and the anal canal.	v) Dentine portion of teeth.
vi) Lens and retina of the eye.	vi) Auditory tube and middle ear cavity in mammals, etc.	vi) Blood vascular system including blood.
vii) Epithelium of sweat, sebaceous and mammary glands.		vii) Greater part of the urino-genital system.
viii) Hair, nails, (feathers, hooks, scales in animals).		viii) Adrenal cortex.
ix) Adrenal medulla, anterior and posterior pituitary and pigment cells.		ix) Coelomic epithelium, mesenteries, and outer layers of the gut.
x) Inner ear vesicle (labyrinth).		x) Lining of gonads.
xi) Enamel of teeth.		
xii) Cutaneous sense organs.		

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