EMBRYOLOGY

DEVELOPMENTAL- BIOLOGY (EMBRYOLOGY)

Embryology is the branch of biology which involves the study of all those processes, which take place during the development of an adult from the egg.

In lower animals, as a result of asexual reproduction the structure formed is termed as blastema and it gives rise to the complete animal. This is termed as " blastogenesis" and the animals of formed are termed as blastozoids.

In majority of animals, as a result of sexual reproduction the structure formed as the zygote and it gives rise to complete animal. This is termed as " embryogenesis " and the animals, so formed are fermed as oozoids. They have the most advanced characters.

History :-

(1) **Aristotle** is known as" Father of Embryology" he first studied the development in chick and other embryos. He gave its description in his book" Historia Animalia"

(2) **Leeuvenhock** (1671) –He observed and described human sperm for the first time According to Hartsoeker and Leeuvenhock there is a small model of developing animal present in the head of the sperm of that animal. This small model is called homunculus. Both these scientists are called spermists, and this theory is called " theory of spermist"

(3) **Swammer Dame, Haller. Bonette& Malpighi :-** According to these scientists, small model of animal is always present in the egg. These scientists are called Ovisis, and their theory is known as 'Ovists thory'

(4) **Schleiden & Schwann:-** Both the scsientists established the cellular structure of egg and sperm.

(5) **Pander :-** He described the presence of three germinal layers in chick embryo.

(6) **FredrichWolff :-** He first presented the" theory of epigenesis"

(8) **Muller:-** He gave the recapitulation theory.

(9) **Haeckel :-** He gave the details of Recapitulation theory and named it as the bio-genetic law.
-Bio-genetic Law :- According to this each organism during its embryonal developent, passes through all stages, through which is its species has evolved or embryo repeats its ancestry. i. e. Ontogeny recapitulates its Phylogeny.

(10) **"Carl Eenest Von baer" :-** He is known as the " fater of modern embryology. " He gave the Baer's Law which in turn proves the recapitulation theory.
According to this law. During embronal devlopent, the development of feneral structures takes place earlier and specific structures devlop at last or later on.

(11) **A. Weismann:-** He gave the theory of germplasm or the theory of continuity of germplasm. According to him. there are 2 types of protoplasm in the body of animals:-
(i) Somatoplasm
(ii) Germplasm.
Somatoplasm dies but the germplasm is never destroyed. rather it is transferred to the progenies.

(12) **Wilhelm :-** He studied embryonal development in frog and gave the mosaic theory. -He said the there are some presumptive areas in the eggs of frog. Theses areas form specific structures during embryonal development. this is fermed as "Promorphology" and these type of eggs are termed as the mosaic eggs.

(13) **Hans Driesch :-** He studied embryonal development in sea-urhin and gave the regulative theory.
-In the eggs of Sea-Urchin presumptive areas are not found. i. e. promorphology is not found. So, each part of the egga is capable of forming the complete embryo. These type of eggs are termed a regulative eggs.

(14) Boveri & Child :-

They gave the gradient theory to explain the mosaic development in eggs.
According to them, a metabolic gradient is present inside the eggs.
Different parts of the egg have different metabolic rates.
The rate of metabolism is faster at the animal – pole of the egg and is slower at the vegital pole of the egg.
Due to different metabolic rates, different structures are formed from different parts of the egg.

(15) Spemann :- He gave the " Theory of organizers"

-according to it embryo has some special type of tissues, which induce development of some specific structures.
These are termed as the " Theory of organizer"
-These organizers secres secrete some special chemicals called evocators which induce the formation of specific structures.
-Spemann got the Nobel prize for his theory of organizers.

(15) R. V. Graff :-

-He studied a follicle in human ovary and termed it as " Graafian follicle"

FORMATION OF GAMETES:-

Follicle stimulating hormone stimulates gametogenesis. Besides this hormone vitamin E is also essential for gametogenesis. Deficiency of vitamin E leads to sterility. Vitamin A is also required for the formation of healthy gametes.
Gametogenesis is divided in three stages :
(i) Multiplication phase (ii) Growth phase (iii) Maturation phase
As there are two types of gametes, the spermatozoa and ova, gametogenesis can studied under two broad headings : spermatogenesis and oogenesis. Spermatogenesis is the formation of spermatizoa. Wheras oogenesis is the formation of ova. Both the spermatiozoa and ova originate from primrdial germ cells or PGCs, which are extra –gonadal in origin. In humans the PGCs originate during early embryonic development form the extra- embryonic mesoderm. Eventually they migrate to yolk sac endoderm, and ultimately. to the gonds of the developing embryo. where they undergo further development. you can recall that spermatogenesis occurs in the seminiferous tubules of the testes and oogenesis occurs in the follicles of ovary. Formation of gametes starts at puberty.

Gametogenesis

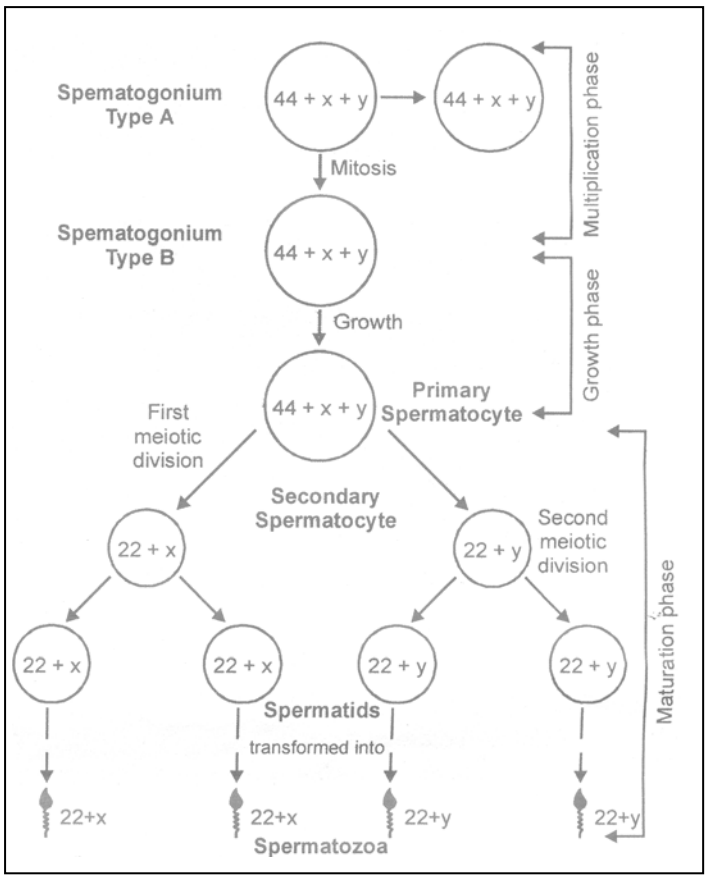
Spermatogenesis : i. e. formation of sperms. In most of the animals spermatogenesis takes place in testes, (exception - earthworm). Mammalian testes contain seminiferous tubules and wall of seminiferous tubule is composed of germinal epitelium. it contains some special types of cells called primordial germ cells and these cells start spermatogenesis. On the basis of origin. primordial germ cells are extra embryonic mesodermal Besides these cell, germinal epithelium contains some large sized cell called sertoli cells. Occurrence of sertoli cells is the unque feaure of mammalian testis. Sertoli cells provide nutrition to developing sperm. i. e. developing sperms are embedded in cytoplasm of sertoli cells and absorb nutrition. After maturation sperms comes out from sertoli cells and librate in seminimferous tubules.
Liberation of sperms from Sertoli cells is called spermiation.
Liberation of sperms from testes is called spermiation.
Liberation of sperms from body of male is called ejaculation.
Mammalian sperms are transferred to vegina of female by the process called insemination.
Sertoli cells form 'blood testes barrier' and protect the sperm from immune system of the body. (because antibody may attack on haploid cells and destroy them. (Sperms are haploid and other cells of body are diploid).
Sertoli cells function as an endocrine gland. i. e. secrete three types of hormones :

(i) Antimullerian hormone : function of this hormone is degradation of female gonads in male embryo. (In mal seminal vesicle is the ruminant part of oviduct of female),
(ii) Inhibin hormone : Function of this hormone is to control excess secretion of pituitary gland and prevent the over-production of sperms.
(iii) And drogen binding protein : Function of this hormone is to concentrate testesterone in seminiferous tubules because testosterone is must for spermatogenesis in seminiferous tubules.

SPERMATOGENESIS

Spermatozoa are formed in the wall of the seminiferous tubules of the testes. The various cell – stages in spermatogenesis are as follows (the number of chromosomes at each stage is given in brackets).

An adult male produces over 1012 to 1013 sperm cells each day. These gradually move into the epididymis and the first portion of the vas deferens, where they undergo further maturation and are stored.



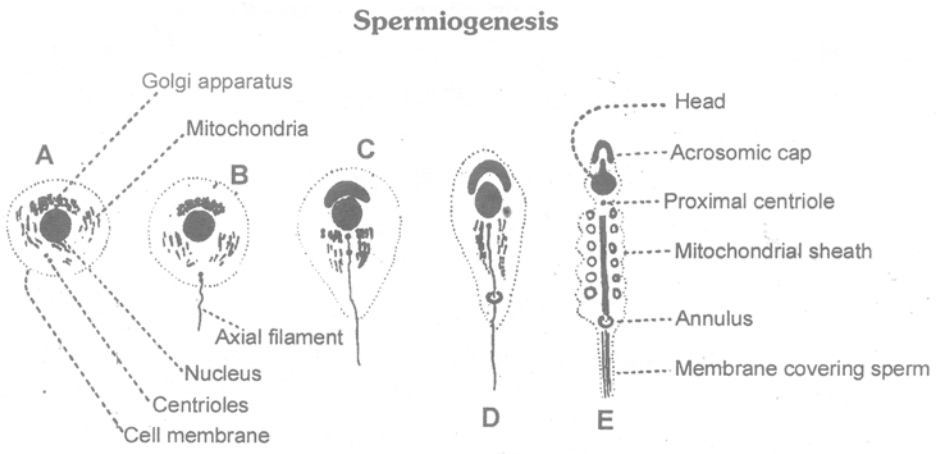
A. The spermatogonis (type A) or germ cells (44 X+Y) divide mitotically. To give rise to more spermatogonia of type A (spermatogenic lineage) and also spermatogonia of type B.

B. The spermatogonia (type B) (44+X+Y) enlarge. t o form primary spermatocytes (spermato cytogeneis)

C. The primary spermatocytes (44+X+Y) now divide so that each of them forms two secondary spermatocytes. This is the first meiotic division : it redurces the number of chromosomes to half.

D. Each secondary spermatocyte has 22+Xor 22+ Y chromosomes. It divides to form two spermatids. This is the second meiotic division and this time there is no reduction in chromosome number.

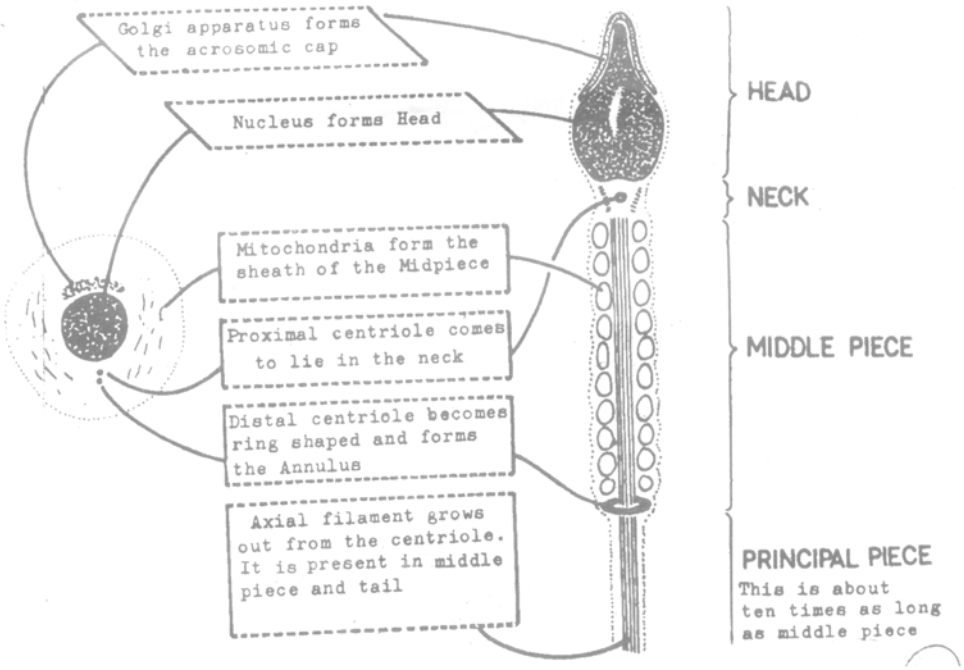
E. Each spermatid (22+X or 22+Y) gradually changes its shape to become a spermatozoon. This process of transformation of a circular spermatid to a spermatozoon is called spermiogenesis /



In spermiogenenesis fierst, of all nucleus of spermatid shift at one side. Except chromatin material, all the structures come out from nucleus as a result nucleus as a result nucleus become small and ligth is weight. Then several golgi vesicles are gathered just above the nucleus. Some of the Golgi vesicles develop granules called proacrosomal granules. Such granule containing vesicle is called proacroblast. Rest of the golgi vesicles are called golgirest, the golgirest dissolve in cytoplasm. All the proacroblast fuse nad form large vesicle called acroblast and it's granule is a called acrosomal granule. Acroblast arrranged just above the nucleus. Then cytoplasm of spermatid starts moving towards posterior side. As a result, plasma membrane shrinks and gets attanged at right angle to each nucleus. Due to this head of sperm is forme. Now centriole of spermatid are arranged at right angle to each other just beneath the nucleus and centriole starts forming axonema, then all the mitochondria of spermatid are arranged in spiral order around axonema. In this way middle piece of sperm is formed. Now axonema elongates towards posterior side and forms tail. Cytoplasm of spermatid continuously flows towards posterior side.

Structure of sperm :

The spermatozoon has a head, a middle piece and a tail. The head is covered by a cap called the acrosomic cap, anterior nuclear cap, or galea capitis. Acrosome is a bag like structure filled with lytic enzynes called sperm lysins. In the anterior part of middle piece neck is present. the neck is narrow: it contains a proximal & distal centrilie (or Basal body) An axial filament begins just behind this centriole, it passes through the middle piece and extends into the tail. At the point where the middle piece joins the tail. this axial filament passes through a righ – like structure called the annuls (or ring centriole of zensons ring). That part of the axial filament which lies in the middle piece, is surrounded by a spiral sheath made up of mitochondria (Nebenkern sheath)

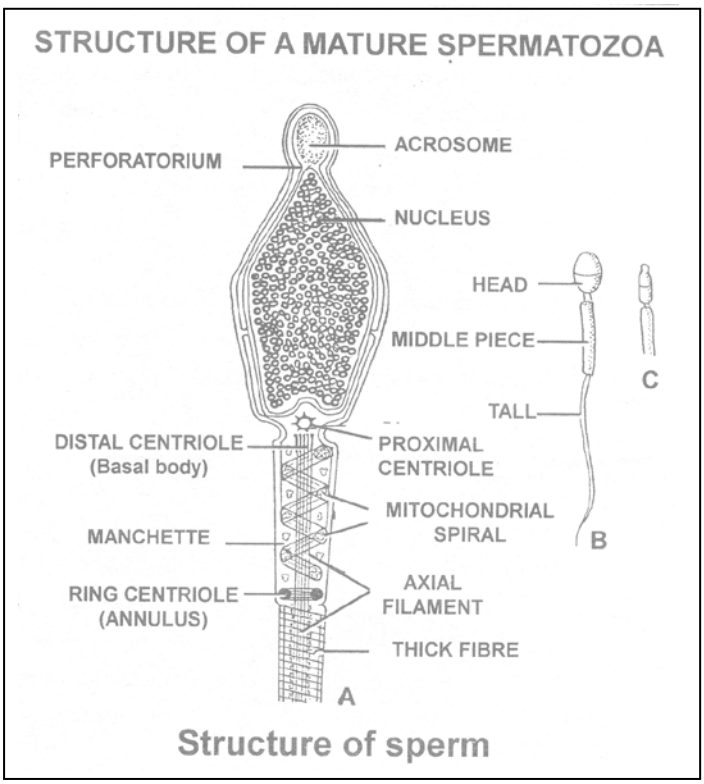


Nuclear part of head of spermatozoa consist of chromatin (mostly DNA) that is extremely condensed. It contains a basic nature protein called protamin.
The basal body id made up of nine segmented rod like structures each of which is continuous distaly with one coarse fibril of the axial filament.

The axial filament. that passes through the middle piece and most of the tail, is actually composed of several fibrils arranged. There is a pair of central fibrils, surrounded by nine pairs(doublets) arranged in a circle around the central pair(9+2). (This arrangement of one central pair of fibrils surrounded by nine doublets is covered by nine solid protein fibres in the middle place (making the arrangement as 9+9+2).

In the proximal tail part it is covered by only two solid protein fibres (therefore arrangement is 2+9+2). While end part of tail has no protein covering (therefore arrangement is 9+2). Immediately outside the fibrils there is a febrous sheath.

Middle pice (also called as the energy chamber)is surrounded by spirally arranged mitochondria (Nebenkern sheath). Finally the entire sperm is enclosed in a plasma membrane.



OOGENESIS:-

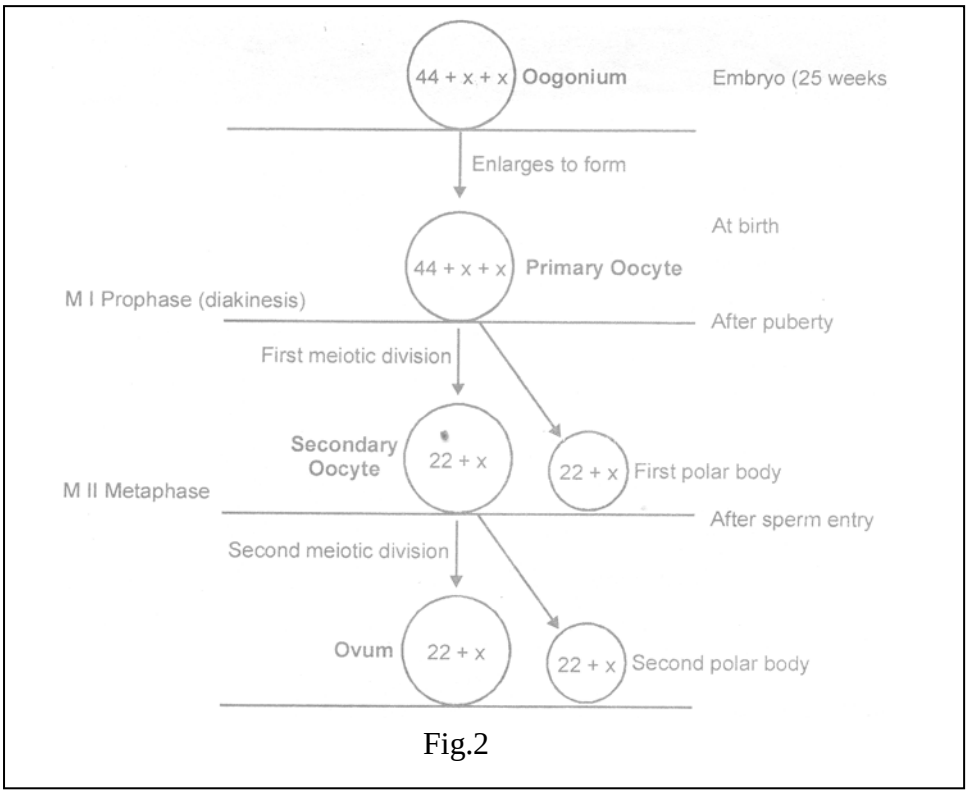


Fig.2

Like spermatogenesis oogenesis process also can be divided int three stages :

(A) Multiplication phase (B) Growth phase (C) Maturation phase

(A) **Multiplication phase :** In this stage primordial germ cells or ovum mother cells repeatedly divide by mitosis toform large number of diploid oogonia.
This process completes in embryo stage of female in most higher animals.

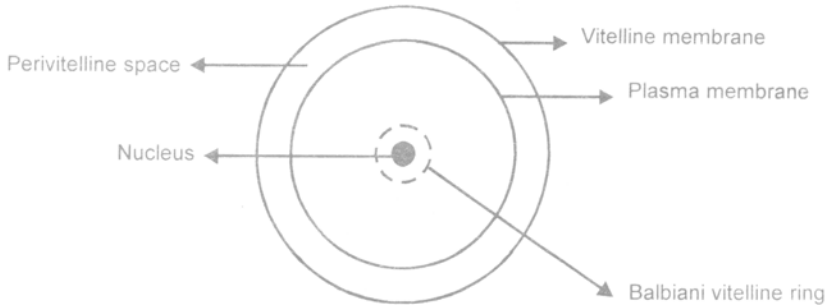
(B) **Growth phase :** Like spermatogenesis, in this process oogonia grow in size and form primary oocytes. The growth phase is the longest phase in oogenesis (except humans). During growth phase size of egg increases many times.
During growth phase several changes occur in egg and all these changes are classified in 2 sub-stages :

- **Pervitellogenesis**
- **Vitellogenesis**

Privitellogenesis Duting previtellogenesis, changes occur in nucleus and cytoplasm of egg.
Changes in nuclesus :
- Amount of nucleoplasm increases in nucleus.
- Number of nucleolus increases in nucleus.
- Formation of lamp brush chromosome starts.
- Activity of FNA increases in nucleus, as a result FNA become highly active and rapidly synthesises different types of RNA. Increased activity of DNA is called a Gene redundancy/ gene amplification. Due to all these changes, size of nucleus increses and nucleus becomes vesicular. This vasicular nucleus is called germinal vesicle.

Changes in cytoplasm :

- In cytoplasm. rate of protein synthesis increases. Cytoplasm rapidly synthesises different type of protein and enzyme. Due to more availability of protein and enzymes, synthesis of new protoplasm takes place and size of egg increases.
- Number of cell organelles increase in cytoplasm, specially endoplasmic reticulum, golgi body and mitochondria. Mitochondria become very large in number so mitochondrial clouds are found in cytoplasm of egg.



Later on all these 3 cell organelle (Golgi body, endoplasmic reticulum, mitochondria) are arranged in the form of ring around the nucleus, it is called as Balbiani vitelline ring. In this stage golgi body of egg secsrsestes a membrane around the egg which is it called as vitellilne membrane? Aspace appears in between plasma membrane of egg and vitellline membrane called as perivitellline space. It is filled with a fluid called perivitelline fluid.
At the end of previtellogenesis endoplasmic reticululm disappear. Golgi bodies gets converted into corticle granule. Corticle granules are filled with mucopolysacharide Large number of changes occur in mitochondria also.
Vitellogenesis : During vitellogenesis egg stores food in the form of yolk.
Some part of yolk is synthesised in egg only, but major part of yolk is received from liver. yolk received from liver is liss viscous and is therefore soluble but this type of food cannot be stored for long periods (because it easily gets converted into simple form)
So mitochondria of egg with the help of kinase enzyme make the yolk more viscous and insoluble.

2 types of yolk is found :
Granular yolk occurs in the form of fine granules.
Eg. Protostomia animals.
Yolk platelets occur in the form of plate disc like granule.
Eg. Deuterostornia animals (higher animals)

Chemical composition of yolk :

1. Most abundant compound in yolk is phospholipid
   Most common phospholipid id lecithin
2. Yolk contains different type f protein :
   - Simple protein :Albumin, Globin, Globullin
   - Phosphoprotein : Phosvitene, Ovovitelline
   - Lipoprotein : Lipovitelline

3 In yolk. leat amount of substance found is carbohydrate.

(C) Maturation phase : Oogenesis (Fig. 2) takes place in the ovaries. In contrast to males the initial steps in egg production occur prior to birth. By the time the foetus is 25 weeks old. all the oogonia that she will ever produce, are alredy formed by mitosis. Hundreds of these diploid cells develop into primary oocytes, begin the first steps of the first meiotic division, proceed up to diakinesis, and then stop any further development. the oocytes growss much larger and completes the meiosis I, forming a large secondary oocyte and a small polar body that receives little amount of cytoplasm but one fullset of chromosomes.

In humans (and most vertebrates), the first polar body does not undergo meiosis II, whereas the secondary oocyte proceeds as far as the metaphase stage of meiosis II, . However. it then stops advancing any further. it awaits the arrival of the spermatozoa for completion of second meiotisc division. Entry of the sperm restarts the cell cycle breaking down MPF (M –phase promoting factor and turning on the APC (Anaphase promoting complex). Completion of meiosis II cenverts the secondary oocyte into a fertilised egg or zygote (and also a second polar body)

Ove are derived from oogonia present in the cortex of ovary. Some important differences between oogenesis and spermatogenesis are

(i) Whereas one primary spermatocyte gives rise to four spematozoa. one primary oocyte foems only one ovum.

(ii) When the primary spermatocyte divides, its cytoplasm is equally distributed between the two secondary cell which forms the secondary oocyte. The other daughter cell (first polar body). Receives half the chromosomes of the primary oocute, but almost no cytopasm.
The first polar body is therefore, formed merely to get rid of unwanted chromosomes.

TYPES OF EGGS

(A) On the basis of amount of yolk

(i) Alecithal or Microlecithal of Oligolecithal eggs-
The amount of yolk is very small or absent in these types of eggs. (oligolecithal, or microlecithal or alecithal).
The term ‘alecithal’ (absence of yolk eg. Man) was by Kent. and term microlecithal’(eg. Urchin) was given by Tori.
Examples:- Egg of Amphioxus, Eutheria, Metateria and dea-urchin.

(ii) Mesolecithal Eggs :- In this type of egg, the amount of yolk is moderate i. e. medium, neither more nor less.
Example –Eggs of Amphibia, Petromyzon and lung –fishes.

(iii) Polyalcohol or Macrolecithal or Megalecithal eggs :-
Eggs are with large amount of yolk. e. g. Insect’s egg.

(B) On the basis of destribution of yolk :

(i) Isolecithal homolecithal eggs: The yok is evenly or hmogenlusly distributed n these egss. eg. : micro. oligo or alecthal eggs.

(ii) Telolecithal egg : The yolk i concentrated n one part of the gg.
eg. : mesolecithal eggs of amphibia. (Moderately telocithal)
Discoidla eggs A type ot teloithal and megalecithal eggs, where the yok is in enormous quantity and concentrated in one part of the egg. Thus only a dic of cytoplsm clled germnal disc remains in the egg which is located t the other pole of egg. (Heavily telolecithal)

(iii) Centrolecithal eggs : Megalecithal eggs where the enormous amount of yolk is located in the centre ans cytoplam is in th efrm of superficial layer around the yolk.

(C) Classification of Eggs of the bsis of Shell :

On the basis of shell, egs are of 2 types :

(i) Cleidocid eggs:

eggs surounded by a hard shell are known as cleidoic eggs. These eggs are found in those animls which have a terrestiral moede of life or which lay eggs on land.

These eggs have more amount of yolk. These re adapttions to terrestrial mode of life. Shell prevents the eggs from dessication.

e. g. :- eggs of “Reptiles”, “Birds”, “Insects” and “Prototherians”

(ii) None - Cleidoic eggs :

Eggs which are not surrounded by a hard shell are called non-cleicoic eggs.

e. g : -all viviparous animals (Mammals) and all oviparous animals which lay eggs in water (Amphibians)

Reptilia eggs are called leathery eggs.

STRUCTURE OF AN OOCYTE

The nucleus of egg is also called germinal vesicle.

Oocyte is surrounded by membranes termed as the egg-membnes.

Oocyte/Ovum along with the egg-membrane are termed as the egg.

Egg = Ovum / Oocyte + egg membrane.

Majority eggs are oval but the eggs of insects are long and cylindrical. Smallest eggs re of 50μ in polychaeta and the largest eggs are of an Ostrich.

Classification of egg - membranes :

On the bais of origin, egg - membranes are of 3 types :

(1) Primary egg membrane :

This membrne is secreted by the Oocyte itself.

eg. Vitelline membrne, Zona Pellucida (mammals)

(2) Secondary eggs membrane :

This is found outside the primary egg membrane and is secreted by the obrar.

(3) Tertiary egg membrane :

This is present outside the primary egg membrane. It is either secreted by the uterus or the oviduct.

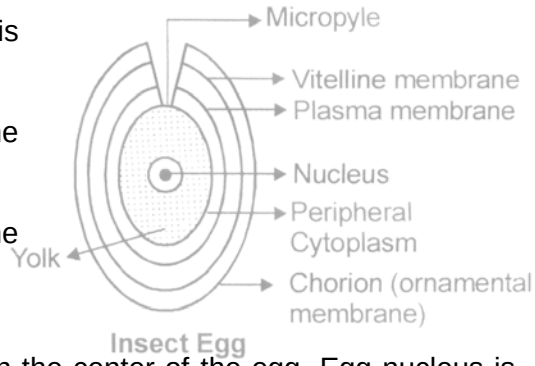
Function of Egg-membranes

(i) To provide protection (ii) to hek polyspermy (iii) to provide buoyancy to the amphibian eggs

Different types of eggs

(I) INSECT EGG

Eggs of insects are megalecithal or polylecithal In them yolk is present in the centre, so the eggs are also centrolectihal.



Insect Egg

Two egg membranes are present here, inner vitelline membrane(primary) and outer chorion (secondary)

The sperm enters the egg through micropyle because on the head of insect sperm acrosome is absent.

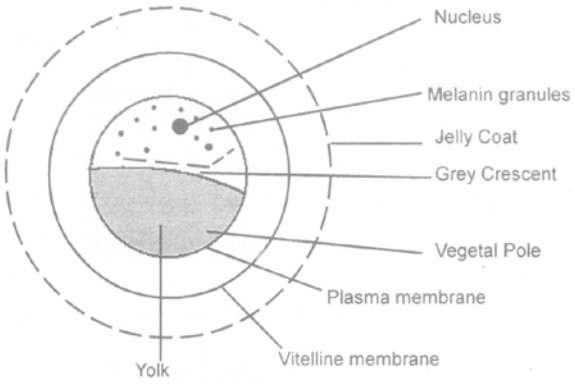
The Cytoplasm here is found in two parts :

(a) Central cytoplasm : It is present in a very smll amount in the center of the egg. Egg nucleus is located in it.

(b) Peripheral Cytoplasm : It is present in a very small amount along the periphery of the egg.

(II) FROG'S EGG

Eggs of frog are moderately Telolecithal & Mesolecithal



Frog's Egg

Two types of egg membranes are found in frong egg :

(i) **Vitelline membrane :** This is primary egg membrane which is secreted by the ovum around itself.

(ii) **Jelly coat :** This is tertiary egg membrane, secreted by oviduct. Jelly coat has air hubbles trapeed in it due to which it floats an water. This group of frogs eggs is called spawn, Jelly coat is bitter in taste so enemies do not eat it.
Secondary egg emmbrane is absent is frog's egg.

Internal part of the egg is divided to two parts :

(i) **Animal pole :** This part has cytoplasm, egg nucleus in also located in this part. In the cytoplasm melann granules are found which prevent the egg from harmful radiations. They also hel in protection of egg by camoflage.

A sperm always enters into the ovum at some point in animal hemisphere. This point is nor mally other than the animal pole itself.

At the sperm enters into the ovum, taking some pigment granules with it, a grew \ ceresent shaped region appears in the equatorial zone geometrically opposite the sperm entrance point. This region is called grey ceresent. It is formed due to movement of some pigment granules away from it towards sperm entrance point.

(It marks the dorsal side of future embryo). The area of sperm entrance point marks the interior side of future embryo. The side diagonally opposite to it in the vegetal hermsphere marks the future posterior side. Thus the sperm entrance establishes the anteroposterior and dorsoventral axis as well as bilateral symmetry of future embryo.

(ii) Vegetal pole : yok is concentrated in this prt of egg.

(III) CHICK EGG

Thee eggs are megalecithal or polylecithal and discoidal eggs.

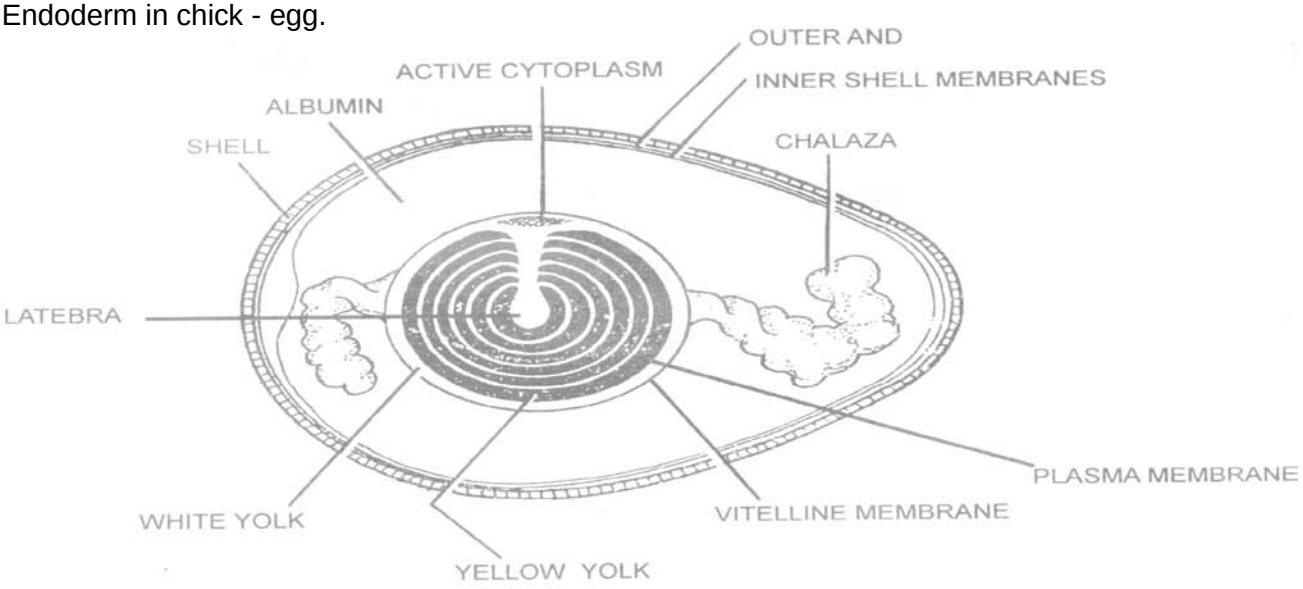
In these eggs, yolk is present in the centre of the eg in the form of a dense mass. The cytoplasm of the egg is in the form of disc above the yolk, which is termed as the germinal - disc.

Yolk is of 2 types i. e. yellow yolk and white yolk.

Yellow - yolk has more amount of phospholipids and is secreted during the night. White yolk has less amount of phospholipids and is secreted during the day time. Central white part of yolk is called latebra.

Both the types of yok are arranged in alternate and concentric layers.

Pander was the scientist, who discovered the 3 germinal layers i. e. Ectoderm Mesoderm and Endoderm in chick - egg.



Chick Egg

Around the egg, a porous shell of $CaCO_3$ is present which is secreted by the cell of posterior ligamentl part of the oviduct.

In between the vitelline membrane and the shell membrane albumin is filled which is also called the white of egg. It conains 13% proteins.

(IV) EGG OF MAMMALS :-

Mammalian eggs have very less amount of yolk, so the eggs are oligolecithal and isolecithal or microlecithal and homolecithal.

The egg has 2 egg-membranes : -

(1) Zona pellucida : This is a tarnsparent membrane like covering and in a primary membrane secreted by the ovum/ooctye itself.

(2) Corona radiata : This is a layer of follicular cells “and these cell are attached to the surface of egg through” hyluronic acid” This is a secondary membrane, which is secreted by the ovary. These eggs dont’ have tertiary membrane.

Mammalian eggs are approx 0. 1 mm in size.