HAND BOOK

OF

VETERINARY EMBRYOLOGY

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GENERAL EMBRYOLOGY

1. HISTORY OF EMBRYOLOGY

Embryology may be defined as that division of biological science which deals with the development of the individual organism. It is concerned primarily with the orderly series of changes in form and function by which the initial germ of the new individual is transformed into a sexually mature adult.

Sometime the word ontogeny is also employed to designate the period of embryonic development, but more often the term is used to define the entire life history of an individual from its origin to its death.

History of Embryology:

Early Embryologists:

Aristotle (384 - 322 B.C.) - who wrote a book "De Generatione Animalium", which describes the reproduction and development of many kinds of animals ,and "De Historia Animalium" which gives the first account of the development of the hen's egg. His conclusion was based on his observations on the hen's egg that development always proceeds from simple formless beginnings to the complex organization of the adult. He pointed out that in the early embryo, he could see certain structures such as the heart blood vessels etc. but no trace of other organs such as the lungs, which appeared latter. He concluded that all structures are not present from the beginning but that they develop in succession until the adult condition is attained. This explanation of the process of development is the basic concept of the theory of "epigenesis."

William Harvey (1578-1657) He wrote a book"Exercitationes de Generatione Animalium" is based on the development of chick and he was limited by the fact that microscope had not yet come into general use. He also studied the development of deer & compared it with chick. He concluded that mammals also formed eggs & all animals arise from eggs "Ex ovo omnia".

Marcello Malpighi (1628-1694) - 1672 - Performation theory

Restudied the development of hens egg with microscope & stated his conclusion that the various parts of the embryo were already contained in the egg fully formed just as a miniature plant is present in the seed and becomes visible as it increases in size.This concept of the process of development is known as the"performation theory" as opposed to Aristotle's theory of epigenesis.

Anthony van Leeuwenhock (1632-1723) made many microscopes of his own & did much to improve the instrument. He made numerous studies of natural objects and among other things discovered spermatozoa in human seminal fluid.

Hartsoeker (1694) - theory of emboitment

Hartsoeker illustrated a miniature human being (Homonculus or Little man) in the sperm.

Bonnet stated that each germ cell of the female parent contained a miniature individual. Moreover, each of these (egg & sperm) in turn must also contain a miniature off spring.

Wolff (1733-1794) made a very careful study of the development of the intestine of the chick and demonstrated that the tubular gut arises from the folding & remolding of a flat layer of tissue in the embryo at an early stage of incubation. This was a direct refutation of the performationist idea which held that the intestine was present as a tubular structure from the start.Thus the theory of epigenesis was reestablished.

Von Baer (1792-1876) - "Father of modern embryology."

Von Baer studied comparative embryology. He discovered the egg of the dog and other mammals & further elaborated the theory of "Specificity of the germ layers" (The various structures of the body arise from the same germ layers in different species of animals). He wrote a book on animal development in which he compared in detail the development of different animals. From these he drew 4 important conclusions known as Von **Baer's law:**

1. The more general characteristics of any large group of animals appear in the embryo earlier than the more special characteristics.
2. After the more general characteristics those that are less general arise and so on until the most special character appears.
3. The embryo of any particular kind of animal grows more unlike the forms of other species instead of passing through them.
4. The embryo of a higher species may resemble the embryo of a lower species but never resembles the adult form of that species.

Cellular embryology:

Schleiden & Schwann (1838-1839) announced the cell theory stating that all living things are composed of and arise from living units called as cells. Cellular embryology unites embryology with cytology & it has come to be realized that the structure and activities of the cells of the embryo are of fundamental importance in the process of development.

Genetics and Embryology:

Gregor Mendel (1866) discovered the laws by which individual characteristics are inherited from one generation to another. Johannsen (1911) developed the theory of gene which is the unit of heredity. Embryology is fundamentally the study of heredity in action, i.e. to study how the gene produces its effect in the developing organism.

Gene: - Each chromosome bears on itself a very large number of structures called genes. Chromosomes are made up predominantly of a nucleic acid (DNA) and all information is stored in molecules of this substance. The genetic expression of a particular cell depends on its previous genetic history and its current cellular environment. Gene expression is the ultimate explanation for the process of cell differentiation and embryogenesis. E.g. about 10 lakhs of genes are present on one chromosome of human.

Phylogeny & Embryology:-

In 1859, Darwin announced theory of natural selection. In 1866, Ernst Haeckel published a theory which is supported to Darwin's theory of evolution. It is also called as fundamental biogenetic law or recapitulation theory. This theory states that ontogeny is a brief & incomplete recapitulation of phylogeny; that is to say an animal passes through stages in its development comparable to those through which its ancestors passed in their evolution.

So far as the vertebrates are concerned this would mean that a mammalian embryo must pass through stages which are definitely fish like and later through stages which are essentially reptilian (but the fact is different). This theory is not accepted & applied so unreservedly as formerly.

Experimental Embryology:

Wilhem His (1874) - denied the theory of recapitulation.

Wilhelm Roux (1883) - studied mechanics of development.

Weismann (1891) - theory of germ plasm (chromosomal inheritance).

Loeb (1899) – Artificial Parthenogenesis. He discovered a method of inducing development in unfertilized eggs.

Vogt -Theory of presumptive organs (regions).

Needham & Brachet (1932) - chemical embryology. During this period much progress has also been made in regard to the metabolic aspects of development; including such phases as the role of food substances, enzyme activity, hormonal control & various other conditions affecting development.

In general embryology has passed through 3 specialized stages:

1. Description and fact gathering
2. Comparative embryology
3. Experimental & Analytical Embryology

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2. Importance of Embryology

Embryology deals with the origin & development of the adult body. There is a fascination (charm) in tracing out the history of the different anatomical structures as they take form, grow and gradually assume the appearance familiar to us in the mature animal. In the history of different organs are found clues to their relationship and functions.

It is also possible to find clues to ancestral relationships. Embryologists recognize that there are structures in the body which correspond to similar parts used for the some purposes in the bodies of some distant ancestor. (The retention theory has been proposed by de Baer as an explanation). Thus the vestigial tail of the human embryo arises in the same place & manner as the tails of other vertebrates and it may be that some remote prehuman ancestor sported and made use of a tail.The embryo retains this tail because it inherits the genes which initiate the development of a tail.Thus it becomes possible to find homologies in the mode of origin and manner of development of any (interested) adult organs.

Embryology is not an easy subject. It requires a high type of visual imagination.The student must bear in mind that he is dealing with living objects, three-dimensional and continually changing in volume, shape and constitution, Much of his attention must be given to the cells of the embryo as they multiply, migrate, take on different appearances, and carry on different functions.

The knowledge of embryology is very useful for medicine. Knowledge of embryological relationship is the best possible preparation for the study of anatomy. It is also prerequisite to the study of obstetrics.The practitioner of medicine must be prepared to answer all sorts of questions about human development.

Number of chromosomes in cells of different animals:

1. Ascaris (round worm) - 2 (smallest number)
2. Cat – 38
3. Pig - 38 or 40
4. Rabbit – 44
5. Human – 46
6. Sheep – 54
7. Goat – 60
8. Cow/ox – 60
9. Donkey – 62
10. Guniea pig - 64
11. Fowl - 77 to 78.
12. Dog - 78
13. Duck – 79 - 80.
14. Turkey – 81 to 82.
15. Moth - 224 (largest no.)
16. Horse - 64
17. Mule - 63

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3. Reproductive Habits

When the vertebrate organism becomes a sexually mature adult, it has reached the time when reproduction normally takes place. In many species characteristic changes in behavior pattern accompanying reproductive activity develop and in some animals the whole plan of existence may be profoundly modified (e.g. migration of some fishes, birds etc.)

These responses are often direct reactions to changes in environmental conditions. They may have a seasonal aspect and may be associated with various physiological & morphological responses in the organism (mating season/breeding season varies). It is sometimes possible to change certain environmental conditions experimentally.

E.g. light intensity is a very important factor in birds. It is possible to accelerate the seasonal development of the gonads of birds by the use of artificial light (prolonging the length of daylight).

Temperature: - is another factor of importance especially in some fishes for spawning.

Various physiological factors also influence the reproductive activity of animals. At the time of sexual maturity the animal is usually at the height of physical vigor but any disturbing factor viz; sickness or physical abnormality may completely destroy its ability to reproduce. Dietary deficiencies often injure the germ cells of the animal and result in reproductive failure.

E.g. Deficiency of vit.E, lack of essential amino acids such as tryptophan etc.

It is also possible to modify reproductive activity by experimental production of hormones since there is a relationship between various endocrine glands and the gonads.

With the onset of reproductive activity there may be striking changes in certain morphological sexual characteristics. In the male these changes are generally pronounced.

Reproduction

General Plan of Vertebrate Development:

The general plan of development is essentially the same in all vertebrate animals. However, there are some exceptions.

Vertebrates are characterized in the first place by the bisexual method of reproduction involving the production of germ cells by the male and female parents. Among the protochordates (tunicates) we find

groups in which the same individual produces both eggs and sperm. Such individuals are called hermaphrodites. Occasionally also a condition of false hermaphroditism occurs in which an individual of one sex may have external genitalia resembling to some extent those of the other.

The production and liberation of germ cells is therefore the first real step in reproduction. Then after fertilization or their union further development takes place.

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4. Cell Division

(Mechanism of heredity)

Somatic (body) cells multiply by mitosis in which chromosomes of cell divides into two sets exactly similar and in equal number, type etc. Process of division of nucleus is known as karyokinesis. While process of division of cytoplasm is called as cytokinesis. (First karyokinesis occur and then cytokinesis occurs).

Cell differentiation is the result of cells expressing some genes an suppressing others within a common genome. Cells differ because they produced different proteins/peptides.

Embryonic Period — defined as the time from fertilization to the earliest (primordial) stages of organ development (about 30 days in dog, cat, sheep, Pig; almost 60 days in horse, cattle and human).

Fetal Period — the time between the embryonic period and parturition (the end of gestation), during which organs grow and begin to function.

Mitosis

30-60 minutes are required for mitosis in warm blooded animals. Resting stage (between two divisions) is termed as interphase. Mitosis is a continuous process. It is divided in to 4 stages, Prophase, Metaphase, Anaphase & Telophase for convenience of description.

1. **Prophase**: - Begins at the moment when the chromosomes first become visible. Chromosomes condense and become thick. Each is double consisting of 2 strands called as chromatids. Chromatids undergo coiling. Nucleolus reduces in size and lastly disappears. Centrioles undergo reduplication resulting two pairs of centrioles and which migrate to opposite poles of the nucleus. Nuclear envelope breaks down and disappears. This marks end of prophase.

2. **Metaphase**:- Begins with development of mitotic spindle and gathering of chromosomes in the same plane in the middle of the dividing cell called as equatorial plate/plane.

The spindle forms numerous microtubules. These become organized around the centrioles which are located at opposite poles of the spindle. Some microtubules extend from pole to pole called as continuous fibers and others extend only from poles to centromeres (kinetochore) called chromosomal fibers.

3. Anaphase: - Initiated by doubling (splitting) of centromeres (kinetochore) and is marked by separation of two chromatids, so that each chromatid becomes independent chromosome and begin their migration towards opposite poles of the spindle apparatus. Then the spindle fibers separate and thus form two groups of chromatids called as daughter chromosome.

4. Telophase: - Segments of nuclear envelope begin to reform around each group of chromatid & Nucleoli also regenerate. Thus karyokinesis take place and two daughter nuclei which are genetically identical are formed. They attained the interphase condition. Cytokinesis also takes place and two cells are formed.

Meiosis

Development of male and female reproductive cells involves a special form of cell division known as meiosis. It occurs during the formation of gametes.This consists of two successive divisions called the first and second meiotic divisions. The cells resulting from these divisions (gametes) differ from other cells of the body in that,

i) No. of chromosomes are reduced to half the normal number.
ii) The genetic information in the various gametes produced is not identical.

First Meiotic Division:-

1. Prophase:-The prophase is prolonged and usually divided into 4 stages (Leptotene, Zygotene, Pachytene & Diplotene).

a) Leptotene:-The chromosomes become visible.

b) Zygotene: - Homologous chromosomes begin to come together and form pairing. They come to lie side by side forming a 'bivalent'.

In mitosis homologous chromosomes never pairs,

Homologous - Paternally & maternally derived counter parts & having similar genes (alleles) called homologous chromosomes.

In human, Female - 23 H chromosomes.

Male - 22 H Chromosomes (and one pair of sex chromosome X & Y, which are different).

For every maternally derived autosome in a somatic cell there is a paternally derived counterpart or homologue. Alternate forms of the same genes termed alleles are present on the two homologues.

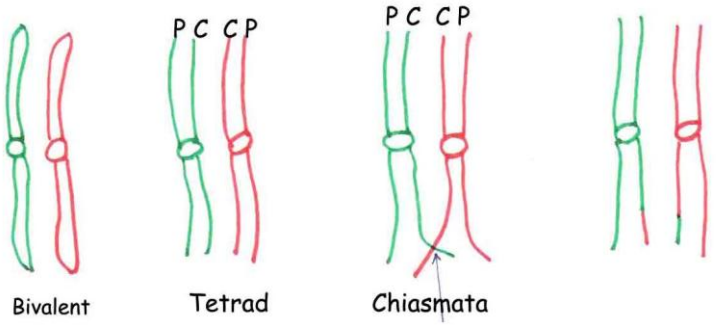
23 - Chromosomes in germ cell (½ of 46)

22 – Autosomes

1 - Sex chromosome

X and Y chromosome (in male) are not considered homologues because almost all the genes they bear are different.

c) Pachytene:-The two chromatids of each chromosome become distinct. Each bivalent thus has 4 chromatids in it called as tetrad. There are 2 central (c) and 2 peripheral (P) chromatids, one from each chromosome.The 2 central chromatids become coiled over each other, so that they cross at number of points. This is called '<u>crossing over</u>'. At this site they become attached, this point is called as <u>chiasmata</u>. The crossing over takes place at several points.



d) Diplotene: - The chromosomes now separate. The central chromatids break at the point of crossing & unite to opposite chromatid.This results in exchange of genetic material between these chromatids.

2. **Metaphase: -** The nuclear membrane disappears.Spindle is formed as in mitosis. Chromosomes are attached by centromeres.
   Bivalents gather on metaphase plate.
3. **Anaphase: -** Differs from that in mitosis. There is no splitting of the centromeres. One entire chromosome of each pair moves to each pole of the spindle.The resulting daughter cells therefore have half chromosomes, each made up of 2 chromatids.
4. **Telophase: -** Karyokinesis takes place or without it cell enters in 2nd division of meiosis, which is similar to mitosis.

Second meiotic division

Ist division is known as Reductional division.

IInd division is known as Equational division.

The second meiotic division is similar to mitosis, however because of the crossing over that has occurred during pachytene of the I^{st} division the daughter cells are not identical in genetic content.

Gametes

Human body is made up of 2 types of cells.

1. Somatic cells - make different units of body.
2. Germ cells - (gamete) - These are specialized cells carry out the function of reproduction.These cells are located in the gonads or sex organs.The male gonad is known as testis whereas the female gonad is known as ovary. The mature germ cells or gametes are formed from these gonads only.The male gamete is called as spermatozoon (sperm) and the female gamete is called as ovum.

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5. Structure of Spermatozoon (Sperm)

The male gamete or sperm of vertebrates is a very minute flagellate cell ranging in size from 0.020 mm (crocodile) to more than 2 mm (Discoglossus - amphibian). The general shape is that of a tadpole with an excessively long tail but there are sufficient differences among different species.

The sperm consists of a head and tail. Some sperms e.g. human have a short neck between head and tail. The head is about 2-3 μ in length and contains a compact nucleus with haploid chromosomes.The head is covered by a cap called the acrosomal cap (acrosome) or anterior nuclear cap or galea capitis, originating from the Golgi bodies of spermatid. This acrosome is possibly concerned with production of enzyme hyaluronidase. Head is surrounded by a delicate plasma membrane. Neck is a narrow, constricted part about 1 μ in length.

The tail consists of 3 divisions,

i) Middle piece - about 9-10 μ in length
ii) Main piece - about 50 μ in length
iii) End piece orTail piece - about 4-5 μ in length.

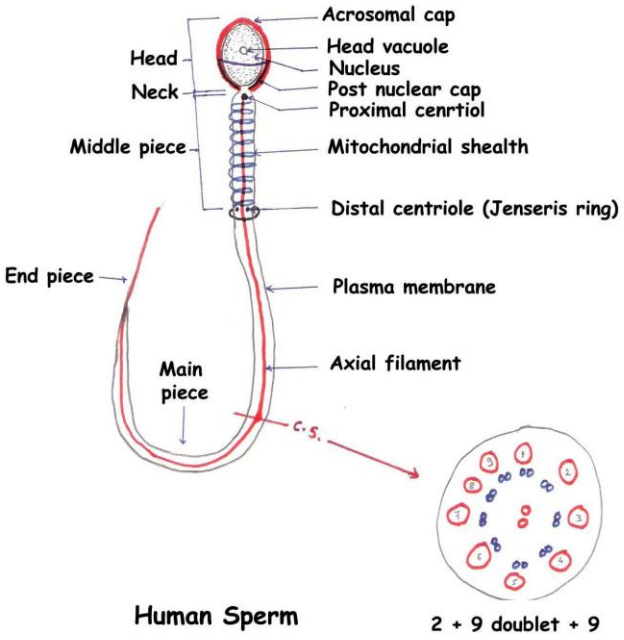
The total length of a sperm is about 68 ± 3 μ.

The middle piece contained 2 centrioles (centrosome) the one nearer the head is called as proximal centriole and the other away from head is called as distal centriole. Distal centriole is in the form of a ring called as Jensen's ring.The portion between proximal & distal centriole is known as middle piece. The axial filament (flagellum) arises apparently from the proximal centriole and passes through the Jensen's ring upto end piece.This

structure is the contractile filament which gives the sperm its power of locomotion. Mitochondria become condensed and form mitochondrial sheath in the middile piece or around the axial filament (to give energy). Surrounding all these structures is a delicate plasma membrane.

The main piece is the longest part and consists of axial filament & plasma membrane. The end piece is the terminal region in which the naked axial filament projects. In main piece (principal piece) and also in other parts of tail, the axial filament have 11 fibrils, 2 are in centre and surrounded by 2 rows of 9 fibers (2 + 9 + 9 core complex).

Fig. human sperm



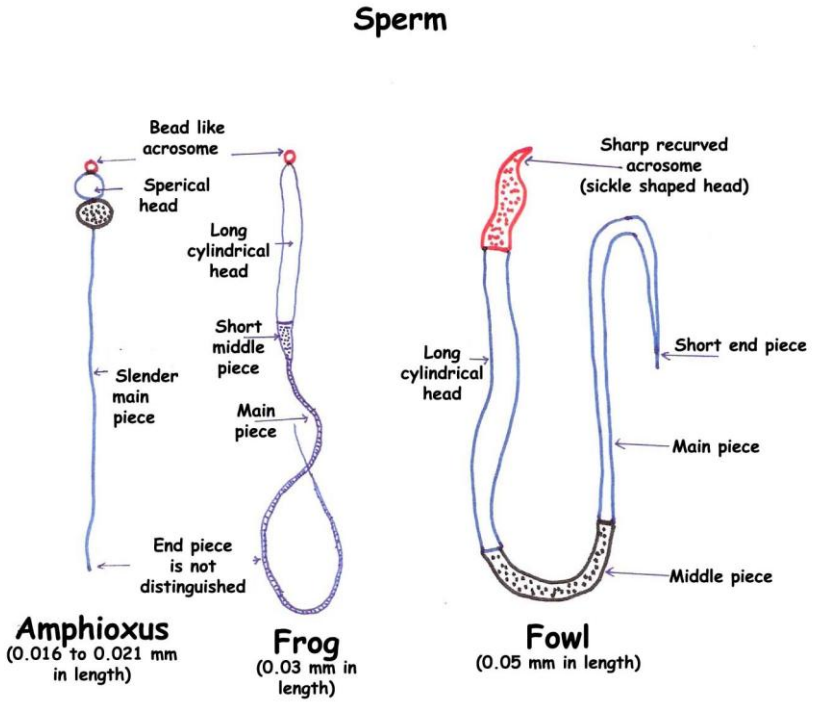


Fig. sperm of amphioxus, frog & fowl

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6. Structure of female germ cell (egg/ovum/female gamete)

The female germ cell or ovum is quite similar to a generalized cell in many ways. Prior to its maturation the egg contains a large, vesicular nucleus and the cytoplasm is relatively abundant. Centrosomes, mitochondria and Golgi bodies are also present in immature eggs. The colour of the egg is because of the pigment in the cytoplasm.

The female germ cell is extremely large & is protected by envelopes of various kinds, contains reserve food material and is without power of locomotion. In vertebrates size (diameter) ranges between 0.06 mm (mouse)

to 85 mm (ostrich). The latter figure is the diameter of the egg cell without shell or albumen i.e. of only yolk.

The albumen and shell are egg envelopes which are added to the yolk make the egg very large. The shape of the egg varies from spherical to oval.

Yolk: - The yolk form bulk of the egg & contains the principal food materials stored for the developing embryo. It contains water, proteins, fats carbohydrates, inorganic salts, vitamins, enzymes and Pigments. The yolk is present in the form of spheres, ovoids or discs & it tends to accumulate in one hemisphere of the egg forcing the nucleus and much of the cytoplasm into the other.

In large yolked eggs such as those of the frog & chick the accumulation of the yolk in one region is so marked that they are known as telolecithal eggs. In small yolked eggs like those of the amphioxus and man the yolk is distributed more uniformly hence they are classed as isolecithal or homolecithal.

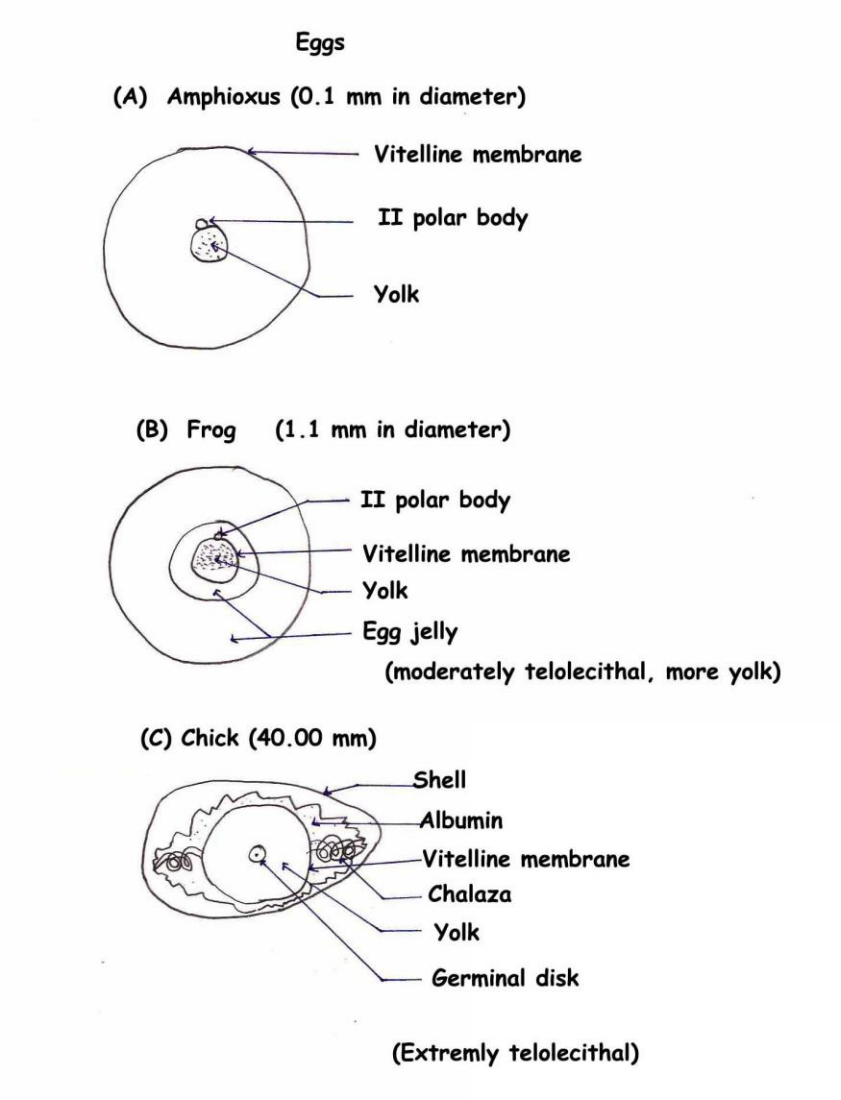
Egg Envelopes:- The egg usually possesses in addition to plasma membrane a variety of protective envelopes which are divided into 3 classes, according to the mode of their formation.

Primary envelopes are those formed by the egg itself such as the delicate vitelline membrane.

The secondary envelopes are those formed by the follicle cells which immediately surround the egg in the ovary.

The tertiary envelopes include all those formed by the walls of the oviduct during the passage of the egg e.g. egg albumen, shell membranes & shells.

Eggs:-Fig of egg of amphioxus, frog, chick, human & sectioned hen's egg.



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7. Gametogenesis

When the individual becomes sexually mature production of mature germ cells begins.The gonia first under go a period of rapid growth after which they are known as auxocytes or meiocytes. In the male they are called as spermatocytes and in the female oocytes.

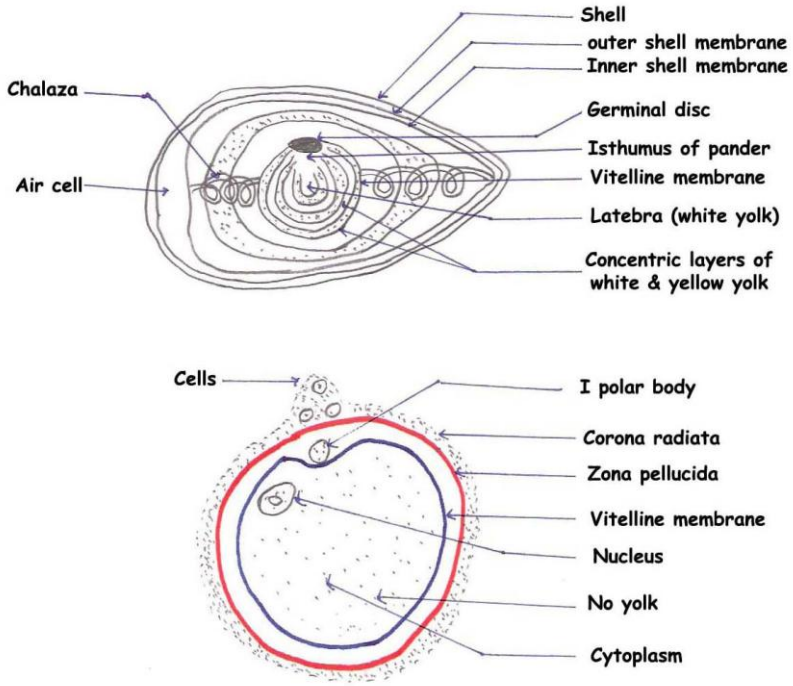
The process by which the auxocytes become mature germ cells is known as gametogenesis; spermatogenesis in male and oogenesis in female.

Spermatogenesis

Spermatozoa are formed in the wall of the seminiferous tubules of testis. Here the Sertoli cells (sperm mother cells) provide nutrients to the developing spermatozoa.

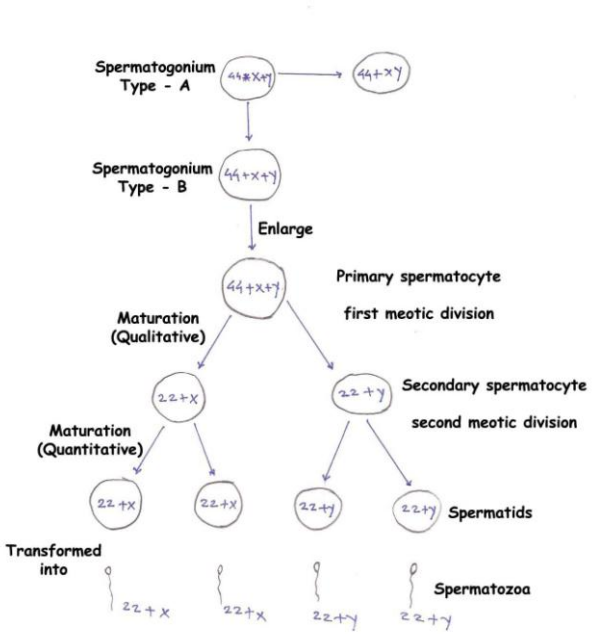
The various cell-stages in spermatogenesis are as follows:

Sectioned Hens Egg



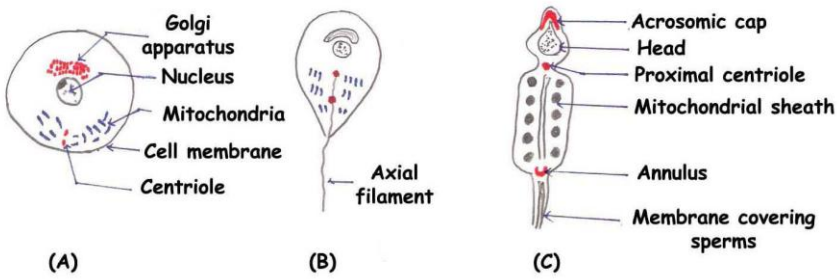
1. The spermatogonia (type A) (44 + X + Y) divide mitotically to give rise to more spermatogonia of type A and also to spermatogonia type B.
2. The spermatogonia type B (44 + X + Y) enlarge or undergo mitosis to form primary spermatocytes.
3. The primary spermatocytes (44 + X + Y) divide and forms two secondary spermatocytes. This is the first meiotic division; it reduces the number of chromosomes to half (Maturation, Qualitative).
4. Each secondary spermatocyte has 22 + X or 22 + Y chromosomes. It divides to form two spermatids. This is the second meiotic division and hence there is no reduction in chromosome number.
5. 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.

Fig. Stages of Spermatogenesis



Spermiogenesis or spermateleosis or metamorphosis:-

The process by which a spermatid becomes a spermatozoon is called spermiogenesis. The spermatid is more or less circular cell containing a nucleus, Golgi apparatus, centriole & mitochondria. All these components take part in forming the spermatozoon.



The nucleus forms the head. The Golgi apparatus is transformed into acrosomic cap. The centriole divides into two parts. One centriole becomes spherical and lies in neck & other forms annulus. The part of the axial filament between head & annulus becomes surrounded by mitochondria. Most of the cytoplasm of spermatid is shed but the cell membrane persists as a covering for the spermatozoon.

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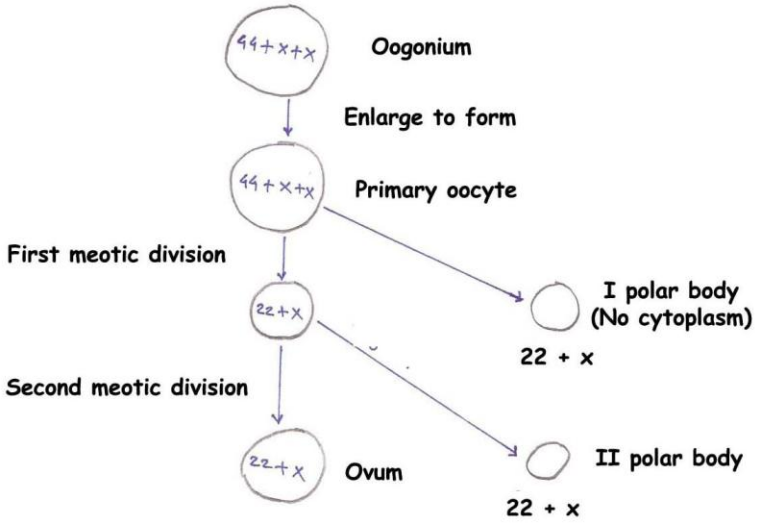
Oogenesis



Stages in oogenesis

The female gonad is the ovary. The cortex of ovary contains many large round cells called oogonia. All the oogonia to be used through out the life of a woman are produced at a very early stage possibly before birth and do not multiply there after. The process of oogenesis is somewhat similar to the process of spermatogenesis. However there are some differences as follows:

i) One primary spermatocyte gives rise to 4 spermatozoa whereas one primary oocyte forms only one ovum.

ii) When primary spermatocyte divides its cytoplasm is equally distributed between two secondary spermatocytes formed, however, when the primary oocyte divides almost all its cytoplasm goes to secondary oocyte the other daughter cell (first polar body) receives half the chromosomes of primary oocyte but no cytoplasm. Later on the polar bodies degenerate.

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8. Abnormalities in formation of gametes

i) Abnormalities of Form:- Spermatozoa may be too large or too small. Head, tail, body may be duplicated.

ii) Chromosomal abnormalities:-

Trisomy- (zygote containing 47 chromosomes); there being 3 identical chromosomes in one pair instead of one of the normal pair (of 2 chromosomes).

Trisomy of chromosome 21 results in a condition called mongolism (baby with furrowed lower lip, flat head/face & mentally retarded)

The presence of extra X or Y chromosome can give rise to various syndromes:

E.g. XXX - Abnormal female.

XXY - Abnormal male (Klinefelter syndrome) e.g. tricolor shell tortoise (male) or tricolor cat (male) / Klinefelter cats.

Monosomy: - zygote containing 45 chromosomes since one pair is represented by single chromosome (only one sex chromosome is present).

e.g. female with only one X chromosome (Turner's syndrome) - sterile female.

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9. Fertilization

Fertilization begins with gamete fusion (zygote formation). The fusion of a spermatozoon with a secondary oocyte takes place in the uterine tube, near the ovary.

It is a process of fusion of a male gamete (sperm) and a female gamete (egg) or it is a process in which fusion of haploid sperm nucleus and haploid egg nucleus takes place and a diploid zygote nucleus is formed. (A single cell capable of developing into a new individual).

Fertilization occurs in ampulla part of the uterine tube.This is widest part of tube & is located nearer to the ovary. While spermatozoa can stay alive in the female reproductive tract for about 24 to 48 hrs (exception horse 2-6 days) the secondary oocyte thought to die 12 – 24 hrs after ovulation, if not fertilized.

Spermatozoa pass rapidly from the vagina into the uterus & subsequently into the uterine tubes due to contraction of uterine tube & its musculature.

Male & female haploid pronuclei make contact, lose their nuclear membranes, and begin mitosis (mitosis begins 12 hours after sperm fusion, DNA synthesis takes place before mitosis).

The spermatozoa on arrival in the female genital tract are not capable of fertilizing the oocyte immediately. They must undergo

i) Capacitation and ii) Acrosome Reaction

i) Capacitation: - It is the period of conditioning in female reproductive tract (in human approx. 7hrs.). During this time a glycoprotein coat & plasma proteins are removed from the plasma membrane which is present over acrosomal region of the spermatozoa. Completion of capacitation permits the acrosome reaction to occur.

ii) Acrosome Reaction: - This reaction occurs at the place just near the oocyte under influence of substance released from the corona radiata cells & the oocyte. Morphologically multiple point fusions between the plasma membrane & outer acrosomal membrane take place and permit the release of acrosomal contents.During this reaction, there is release of

a) Hyaluronidase - needed to penetrate corona radiata barrier.

b) Trypsin like substance - needed for digestion of zona pellucida.

c) Zona lysin (sperm lysin) - needed to help the spermatozoon to cross the zona pellucida.

Fertilization occurs in 3 phases

Phase -1- Penetration of corona radiata

Out of the 200 – 300 million spermatozoa deposited in the female genital tract, only 300 – 500 reach at the site of fertilization. Only one of these needed for fertilization. It is thought that the remaining sperms aid the penetrating sperms to cross corona radiata. Previously it was thought that the hyaluronidase enzyme helps in dispersal of coronal cells, but now it is thought that the dispersion of coronal cells occurs due to the combined action of themselves and the tubal mucosa enzymes.

Phase-2:- Penetration of zona pellucida

This second barrier protecting the female gamete is penetrated by the sperm with the help of enzymes released from the inner acrosomal membrane. Once the sperm touches the zona pellucida it becomes firmly attached (via Ca^{++} influx) and penetrates rapidly. The permeability of zona pellucida changes at this time & its properties are changed. There is a spilling of contents (protease) of cortical granules into this space. Here occurs 'zona reaction' i.e. the penetration of zona pellucida by other sperms is prevented. It is not an absolute safeguard; other spermatozoa can sometimes be seen in the perivitelline space. Only one sperm seems to be able to penetrate the oocyte proper. On rare occasion two sperms penetrate the female gamete simultaneously and embryo with 69 (23 x 3) chromosomes have been found.

Phase-3:- Fusion of oocyte - sperm cell membranes (syngamy)

The spermatozoon then penetrates the vitelline membrane by phagocytosis and enters the cytoplasm. After this entry the 'vitelline block occurs which is a second reaction to guard against fertilization by other spermatozoa. Cortical granules may also participate in the vitelline block.

Cortical Reaction:- cortical granules swells becomes vesicle cortical vesicle contain enzyme protease which is released after bursting, Protease make changes in electrical potential & chemical properties of plasma membrane of egg/oocyte; This prevents polyspermy.

Vitelline block:- is a second reaction to guard against fertilization by other spermatozoa. Thus only one sperm can enter in the ovum. Upon entering the cytoplasm the tail of spermatozoon separates from the head. Mitochondria associated with the tail degenerate and other parts appear to dissolve in the cytoplasm. The cytoplasm shrinks and the second polar body is extruded. Both the male & female pronuclei are formed. This involves an unfolding of chromosomes in preparation of pairing.

Syngamy:- A merging (union) of pronuclei then occurs known as syngamy. Zygote has been formed thus completing fertilization. Fertilization ends with the initiation of zygote cell division (the start of cleavage).

Table:- Estimated fertile life of sperm & ova in farm animals

Species	Fertile life in hrs.	
	Spermatozoa	Ova
Cattle	24-48	8-12
Swine	24-48	8-10
Sheep	30-48	16-24
Horse	72-120	6-8
Hen	3 weeks	
Terrapin (sp. of Turtle)	4 years	

Effect of fertilization on the egg cell or zygote:

1) Increase in metabolic activity.
2) Increase in viscosity.
3) Increase in permeability.

Sperm of one species can not fertilize ovum of other species because the enzyme reaction is species specific, fertilizin by ovum and antifertilizin by sperm are the enzymes containg proteins with amino acids have characteristic of particular species.

Implantation

Following zona pellucida rupture the blastocyst is initially free in uterine lumen (nourished by uterine glands).

Implantation of the mobile blastocyst is a gradual process beginning with apposition leading to adhesion or invasion in case of human & guniea pig.

Approximate implantation times are:

One week - (human)

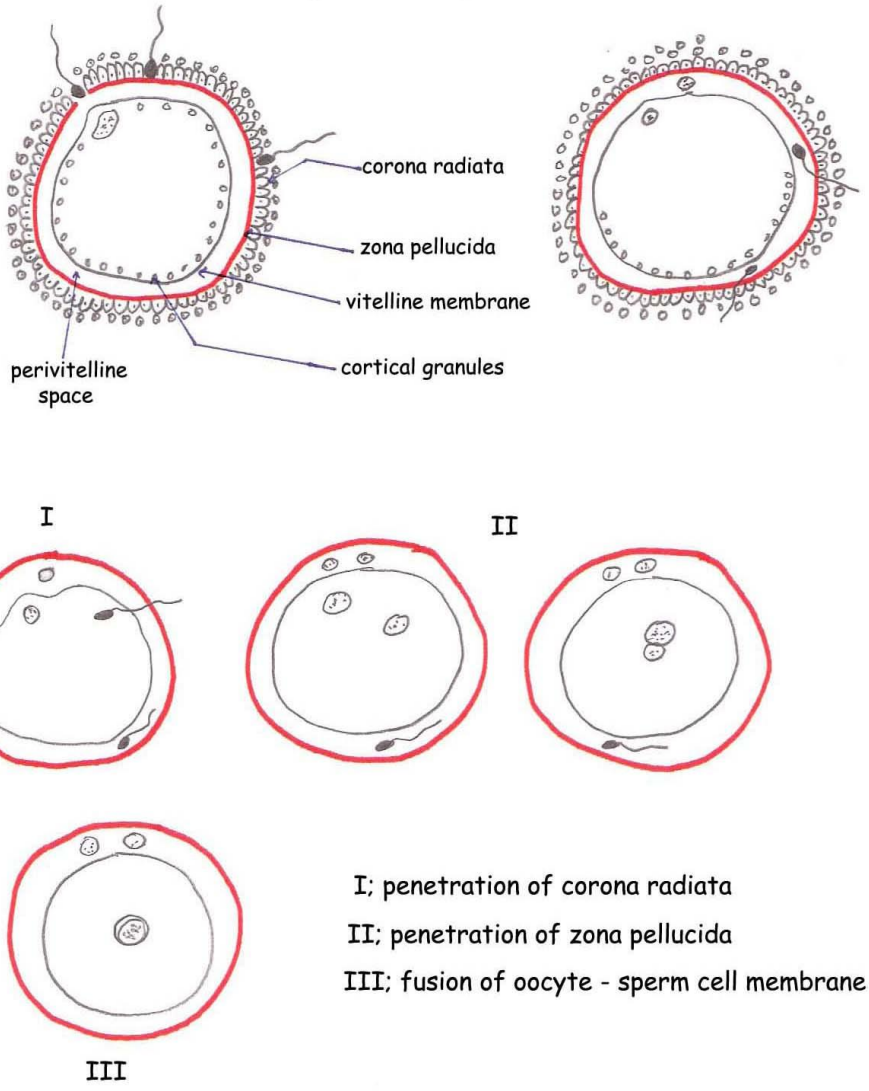
Two weeks - (dog, cat, sheep)

3-5 weeks (cattle)

3-8 weeks (horse) and

upto 4 months (deer, bears).

Sequential steps in fertilization



Parthenogenesis

Parthenogenesis is a method of sexual reproduction in which the egg develops without fertilization by a sperm.

Under normal circumstances the egg of the vertebrates does not begin to develop until fertilization has occurred and the diploid number of chromosomes has been restored.

However among some organisms, development of unfertilized egg may occur naturally .e.g. honey bee and plant aphid.

Clone:- created from single cell without sexual reproduction.

Clone is not parthenogenesis, since it is not naturally.

E.g. Dolly sheep

Dolly sheep is produced from an udder cell of her mother without male derived genes. Nucleus (genes/DNA) of udder cell is injected in egg whose own nucleus is removed, resulting embryo developed in other mother. Different species are produced by this method e.g. Holstein calves & also human.

In honey bee and plant aphids development of unfertilized egg may occur naturally. In the bee the unfertilized egg develops into a male (drone) and the fertilized egg becomes a female (either a queen or worker) according to the type of food supplied.

Moreover, artificial parthenogenesis has been induced in the eggs of many other vertebrate animals by various means. In the frog's egg artificial parthenogenesis has been produced by slightly puncturing the egg with a finely pointed glass needle.

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10. Cleavage & Formation of Blastula

After fertilization, the zygote undergoes a series of mitotic cell divisions by which the large zygote is fractionated into numerous "normal size" cells. Each daughter cell of the cleavage process is termed a blastomere.

In this way a large number of cells is formed and the process of cleavage terminates in the formation of a blastocyst or blastula where the embryo is in the form of a hollow sphere or disc.The first eight blastomeres are undifferentiated and have identical potential in domestic mammals; thereafter, blastomeres differentiate into inner & outer cells with different missions. Following the formation of blastula further changes occur in the embryo resulting in the segregation of the 3 primary germ layers. The process is called gastrulation and as a result of it an outer layer of ectoderm and an intermediate layer of mesoderm are formed.

A morula is a solid ball of blastomeres, within a zona pellucida. A morula typically consists of 16 to 64 blastomeres, four to six cell divisions. Blastomeres become compacted; cells packed on the inside differentiate from those along the surface of the morula.

Outer blastomeres become flattened and form tight junctions (resulting in reduced permeability to fluids); they develop the capacity to secrete fluid (internally); they are destined to become trophoblasts which form the chorion & amnion (fetal membranes).

Inner blastomeres form gap junctions to maximize intercellular communication; they are destined to become inner cell mass which forms the embryo (plus two fetal membranes).

A blastocyst (or blastula) develops during week two following rupture of the zona pellucida.It consists of a large number of blastomeres arranged to form a hollow (fluid filled) sphere/cylinder containing an inner cell mass (embryoblast), a collection of cells localized inside one pole (end) of the blastula. The surface cells of the blastocyst are designated trophoblasts, and the fluid cavity is called a blastocoele. Eventually the blastocyst attaches to the uterine wall (implantation).

Cleavages are mitotic divisions taking place in embryo because of which a unicellular embryo is converted into a multicellular structure.

Type or Nature of Cleavages:-

In frog cleavages are holoblastic (means complete) and unequal.

Rules of Cleavages:-

Cleavages take place as per the following rules

i) Every next cleavage is at right angle to previous one.

ii) Yolk resists the rate or speed of cleavages.

Process of Cleavages:-

The first 5 cleavages take place as follows:

Ist Cleavage:-

It is vertical, single and equal. Because of this two blastomeres are formed and it completes at about 3.5 hrs after fertilization.

IInd Cleavage:-

It is also vertical, single and equal, but it is at right angle to Ist cleavage. Because of this 4 blastomeres are formed and this completes at about 4.5 hrs after fertilization.

IIIrd Cleavage:-

It is horizontal, single but unequal.This takes place more in animal hemisphere because yolk resists it. (Hence it is unequal) Because of this

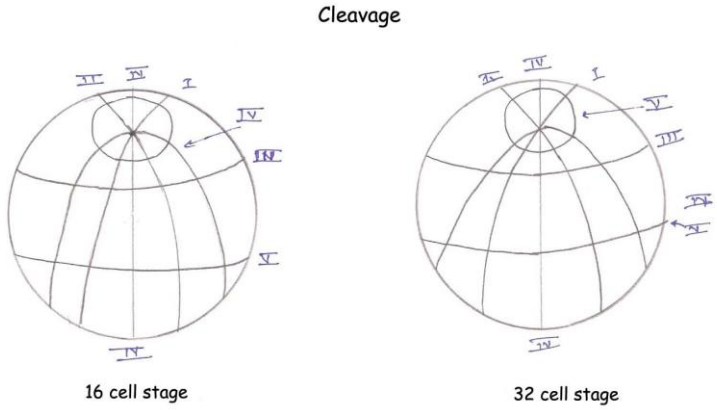
cleavage 8 cells are formed out of which 4 cells of animal hemisphere are smaller called as micromeres, while the other 4 cells of vegetal hemisphere are larger and called as megameres. This cleavage completes at about 5.7 hrs after fertilization.

IVth Cleavage:-

It is vertical, unequal and double in nature (means two at a time). Because of this cleavage 16 cells are formed having 8 micromeres and 8 megameres. This completes at about 6.5 hrs after fertilization.

Vth Cleavage:-

It is horizontal, unequal and double in nature. Because of this 32 cells are formed having 16 micromeres and 16 megameres. It completes at about 7.5 hrs after fertilization.



After the 5th cleavage, the cleavages become irregular and as megameres contain yolk, they divide slowly but micromeres divide fast. Because of cleavages a unicellular embryo is converted into a multicellular structure. At this stage embryo appears externally like a mulberry fruit and this stage of embryo is called as morula.

Summary of Cleavages

No. of cleavage	V/H	S/D	E/UNE	Time	Total no. of cells
1	V	S	E	3.5 hrs	2
2	V	S	E	4.5 hrs	4
3	H	S	UNE	5.7 hrs	8
4	V	D	UNE	6.5 hrs	16
5	H	D	UNE	7.5 hrs	32

V-vertical; H-horizontal; S-single; E-equal; UNE-unequal; D-double

Blastulation

Definition: It is a process in which blastula is formed. Blastula is a multicellular but single layered and hollow ball like embryo containing a cavity called as blastocoel.

Process of Blastulation:-

Blastulation is a result of cleavages. After fertilization cleavages start and unicellular embryo gets converted into multicellular embryo called blastula. First early blastula is formed and then late blastula is formed.

Early Blastula:-

V.S. of Early blastula at 8 cell stage

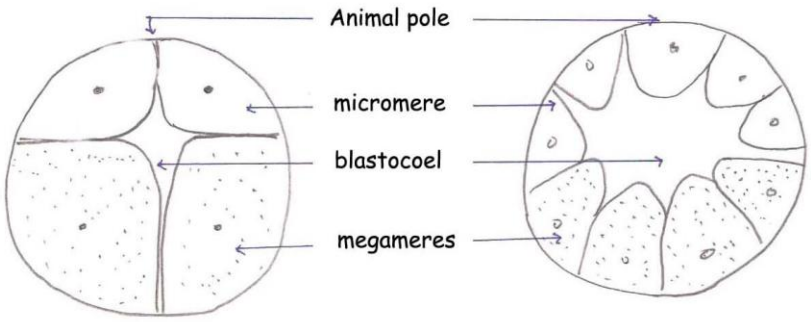
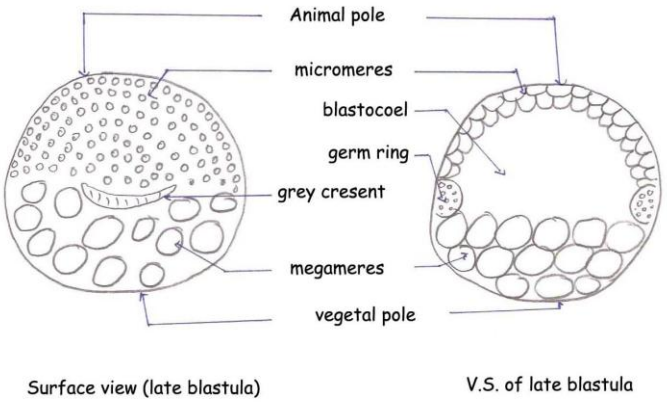


Fig. V.S. of early blastula at 8-cell stage.

It is made up of a single layer of cells, i.e. micromeres & megameres. Internally it has a cavity called as blastocoel. It first appears at third cleavage or 8-cell stage in the form of a slit like cavity in between micromeres and megameres. Along with successive cleavages number of micromeres & megameres increases and along with them blastocoel also increases.

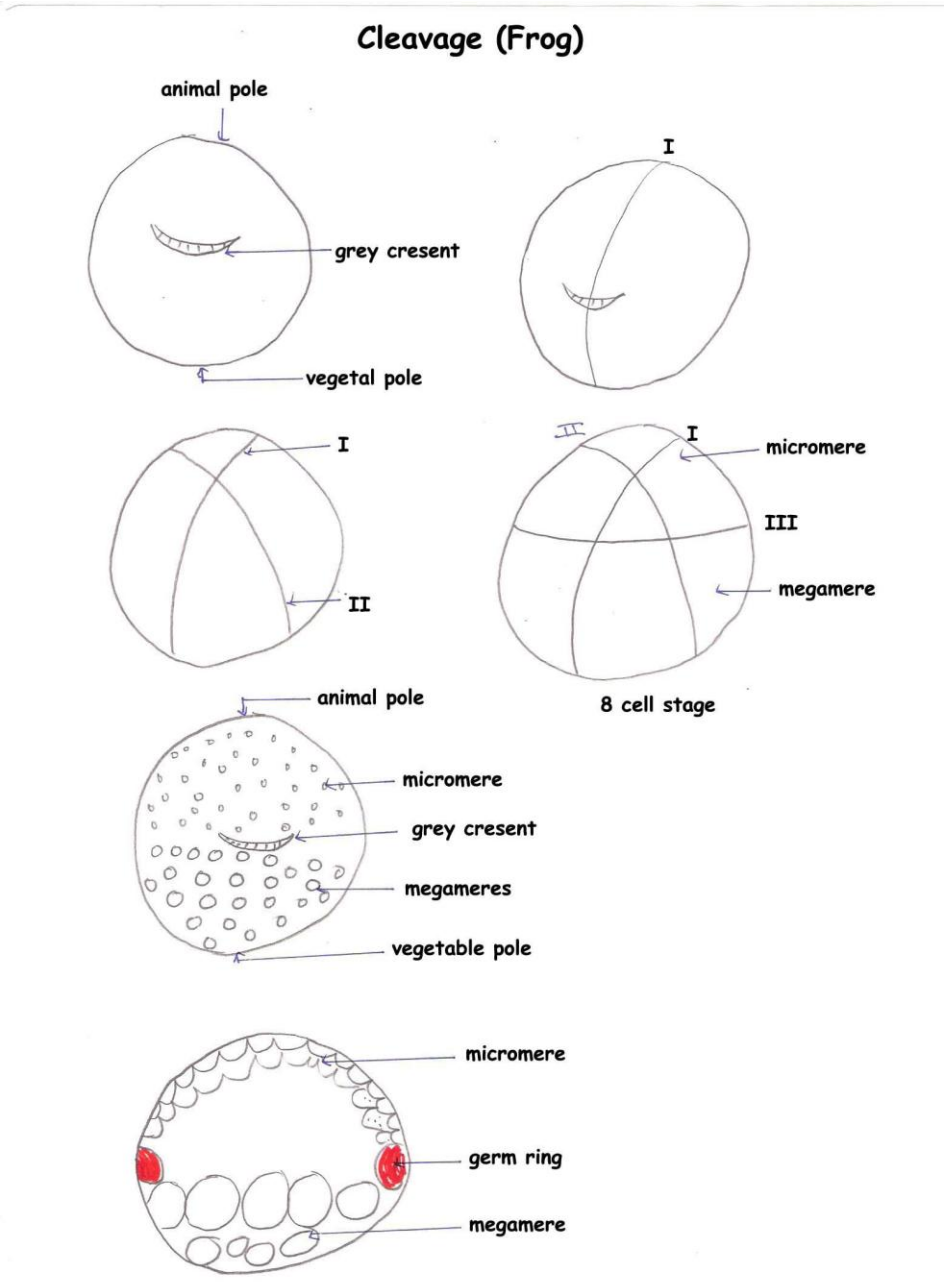
Late Blastula: -

It consists of many micromeres and megameres. Micromeres lie in animal hemisphere and megamere lie in vegetal hemisphere. Grey crescent is also present on one side in between micromeres & megameres. Internally blastocoel is present and it lies in animal hemisphere only. The roof of the blastocoel is formed of micromeres and floor is formed of megameres. At the junction of micromeres and megameres or at the level of grey crescent there is a ring of cells of intermediate size called as germ ring or germ belt.



Fig; v.s. of late blastula

The outermost cells of blastula are ciliated and because of this blastula can move inside the fluid of perivitelline space.

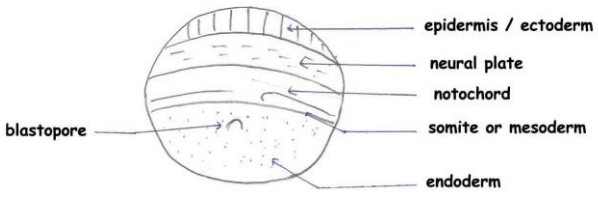


V.S. of late Blastula

Fate map of blastula:

The blastula of the frog shows certain regional differentiation.Thus the cells of the animal hemisphere are smaller than those of the vegetal hemisphere and contain pigment granules. Between the micromeres of the animal pole and the megameres lies a band of cells of intermediate size known as marginal belt or germ ring. This region corresponds to the region of gray crescent.

Presumptive ares of fate map



Formation of germ layers

Vogt has demonstrated the fate of different regions of the amphibian blastula in normal development by marking them with harmless dyes as Nile blue and neutral red. The stain persists long enough so that the migration of the colored cell groups can be traced through gastrulation and even later. In the fire toad (Bombinator) Vogt has succeeded in mapping out the surface of the blastula into presumptive organ regions. Although the frog (Rana pipiens) has not yet been similarly studied, it seems fairly certain that its organization is similar.

Types of cleavages:-

1. Holoblastic:- Cleavage planes divide the egg completely into separate blastomeres. Blastomeres are equal in size. (It occurs in isolecithal eggs & moderately telolecithal eggs E.g. amphioxus.

2. Meroblastic:- Cleavage planes do not pass through the yolk & blastomeres lie upon a mass of undivided yolk. It occurs in extremely telolecithal eggs e.g. chick.

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11. - Formation of Germ Layers

(Man and other mammals)

After fertilization the zygote will divide and redivide many times without any increase in the cytoplasm. The overall size may increase due to absorption of water but the cellular material will decrease. This process of cell division with growth is called as cleavage. The first cleavage is vertical and will result in 2 cell embryo which is followed by additional cleavages resulting in 4 cell, 8 cell, 16 cell, 32 cells etc. When the embryo passes from

the oviduct into the uterus a ball of 16-32 cells will be there within the zona pellucida. This structure with cells which are numerous to count accurately is called morula. During the next few days fluid collecting in the intercellular spaces will push the center forming the Blastocyst a structure with a fluid filled cavity (the blastocoel) surrounded by a layer of cells.

Derivatives of the Germ Layers

The first evidence in differentiation is the appearance of germ layers. The endoderm; the innermost germ layer first appears when a single layer of cells pushes out from the inner cell mass & grows around the blastocoel. The endoderm is the origin of digestive system, liver, lungs & most other internal organs. The mesoderm, the middle germ layer, arises from inner cell mass pushing between the endoderm & ectoderm. The mesoderm is origin of skeletal system, muscles, circulatory system & reproductive system.The ectoderm, the outer germ layer is the origin of nervous system, sense organs, hair, skin, mammary gland & hooves.The pattern by which such organ systems emerge commences with the process of neurulation; so named because it involves the establishment of a primitive C.N.S. (brain & spinal cord).

After gastrulation:

Table: Time of Early Developmental stages in various domestic animals.

Stage	Cow	Horse	Dog	sheep
2- cell	1-2	1	5	
4-cell	2	2	-	
Morula	4-6	4-5	7	4-6
Blastula with inner cell mass	7-8	6-7	11	5-9
Endoderm appears	10-11	9	12	10
Endoderm lines blastocele	12-13	12	15	-
Primitive streak present	15	12-14	15	14
Mesoderm present in embryo	15	12-14	15-16	12
Somites beginning	20	16	16	15
Zona pellucida lost	9-10	7-8	11-18	9

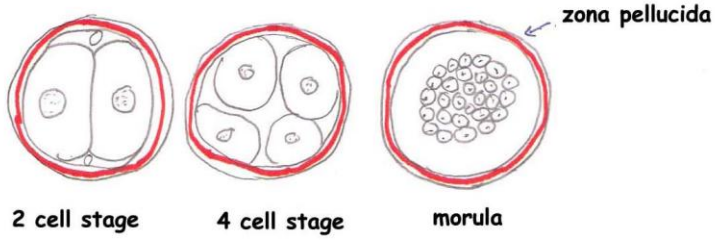
(Times are in days after ovulation).

Blastocyst

Blastocyst- consists of a blastocoel & an inner cell mass completely surrounded by an outer layer of cells, trophoblast which help to provide nutrition to the embryo. The cells of the blastocyst are not yet differentiated. Therefore it is not possible to identify cells that will form a particular organ of the body. By the end of the cleavage the zona pellucida

will crack and weaken & then blastocyst hatching from this gel like layer. Zona pellucida disappears soon the blastocyst reaches the uterus. Thus it prevents implantation of blastocyst at abnormal sites. Loss of zona pellucida permits the blastocyst to elongate.

After the period of cleavage cell division will continue but with growth.The pattern of cleavage is similar for all farm species.The period of cleavage extends from fertilization to about 12 days for cow, 10 days for ewe & 6 days for sow.



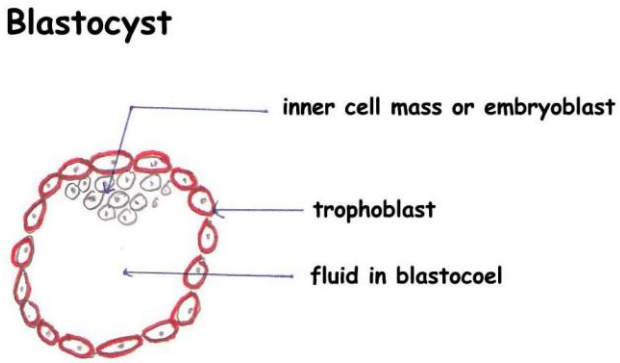


Fig. Blastocyst, 2 cell stage, 4 cell stage & Morula.

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12. Gastrulation and Neurulation

The vertebrate blastula is converted into a strastified embryo or gastrula by the process of gastrulation as a result of which the three primary germ layers-ectoderm, mesoderm and endoderm are ultimately segregated. This is accomplished by migration of cells from the exterior to the interior of the embryo. When this occurs, the blastocoel is obliterated and replaced by a new cavity, the gastrocoel or archenteron. In form, with a

discoblastula, like the chick or with a blastocyst like the mammal the blastopore is replaced by a longitudinal groove, the primitive streak.

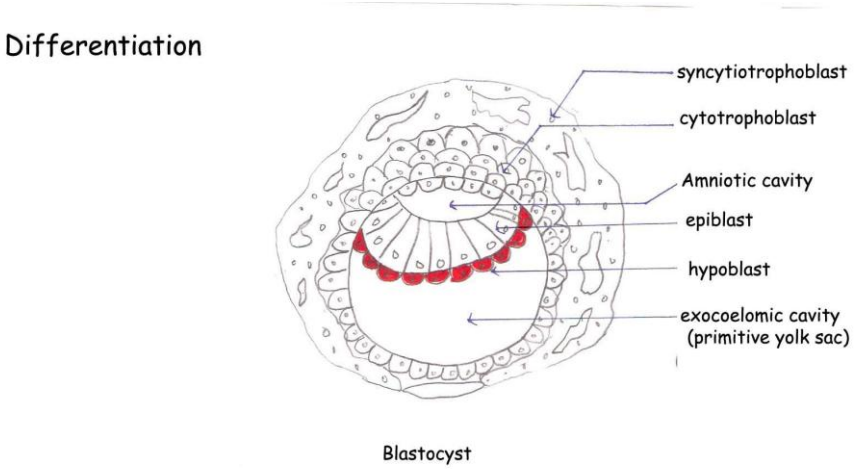
While the germ layers are being segregated, further differentiation is taking place, the process being continuous. This is particularly prominent in ectoderm, when formation of neural tube gets under way.This is neurula stage or neurulation. It is the period during which the neural plate is transformed into the neural tube.

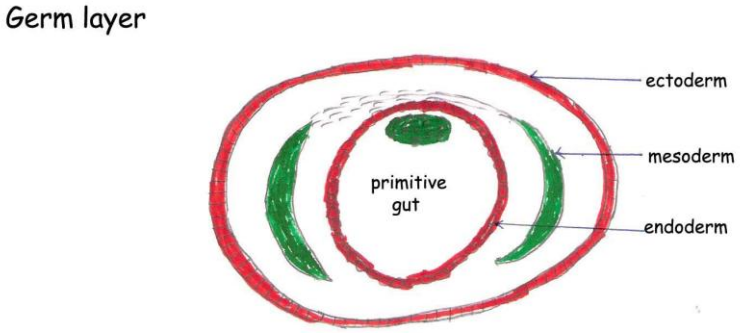
Differentiation: - This is the true period of embryo. In this period, the cells undergo a process of forming specific organs in the body of embryo. The events during differentiation include the formation of germ layers, extraembryonic membranes and organs. In addition, rapid changes occur in relative size.

The blastocyst is partially embedded in endometrial stroma. The trophoblasts differentiate into i) inner cytotrophoblast and ii) the outer syncytiotrophoblast. The inner cell mass or embryoblast differentiate into i) Epiblast and ii) hypoblast; together forming the bilaminar germ disc. Then there is a formation of trilaminar germ disc i.e. formation of mesoderm germ layer. Primitive streak, primitive node are formed. Establishment of mesoderm is known as gastrulation. Cells invaginating the primitive pit move straight forward until they reach the prochordal plate; (towards anterior part of embryo); they form a tube like structure, the notochordal or head process. The lumen of process disappears forming a solid cord, the notochord. After formation of the 3 basic germ layers, further tissue and organ differentiation begins.

With the rapid progress of trophoblast development the villus system is ready to supply oxygen & nutrients to the embryo for further development. Neural plate, neural groove & somite formation is there. Neural fold is formed. After this, all the systems of the body are developed from germ layers.

After differentiation is completed, the product of conception is called a fetus.





Fig; differentiation & Germ Layers
(Germ layers as they appear in a section of an embryo 2-3 days after start of differentiation.)

GASTRULATION

Gastrulation is the process whereby the blastula is transformed from a single layered structure in to the gastrula which is trilaminar (has 3 layers).

The three layers are the basic germ layers namely ectoderm, mesoderm & endoderm. The centre of activity for gastrulation lies in the inner cell mass. Hypoblast forms endoderm while epiblast forms mesoderm & ectoderm. The first step in gastrulation is delamination of the inner surface cells of the inner cell mass into the blastocyst cavity. These delaminated cells form a layer on the inner side of the inner cell mass called the hypoblast. The hypoblast is the presumptive endoderm of the embryo. While the hypoblast is forming the layer of trophoblast cells overlying the inner

cell mass degenerates and the exposed cells of the mass begin to proliferate forming a disc like structure on the surface of the blastula. This structure is the embryonic disc or shield. Once the hypoblast is formed the disc is essentially made up of two layers, the hypoblast that comprises the inner layer and the epiblast that makes up the remainder of the cells of the disc. The hypoblast forms the endoderm and the epiblast forms mesoderm & ectoderm. The hypoblast begins to form just before the zona pellucida is lost and it rapidly extends beyond the edge of the inner cell mass soon coming to underlie the entire trophoblast.

Primitive streak: On the epiblast surface a primitive streak is formed as differential cell growth generates a pair of ridges separated by depression. The primitive streak defines the longitudinal axis of the embryo.

By the time that the primitive endoderm has almost lined the blastocele, epiblast cells on the embryonic disc migrate toward a position along the diameter of the disc. This migration plus the ensuing proliferation of epiblast cells results in the formation of two parallel ridges along the diameter of the disc. Collectively when viewed from above the ridges and the depression between them have the appearance of a streak. Thus the collective structure is called the primitive streak.

The main function of the primitive streak is the formation of the third germ layer the mesoderm. In addition the appearance of the primitive streak establishes the longitudinal axis of the embryo and therefore the cranial end of the embryo and caudal end may be designated. The role of the primitive streak in the formation of mesoderm is to serve as a center of cellular proliferation and movement. The cells produced from the epiblast of the primitive streak move inward toward the hypoblast and come to occupy a position between the epiblast & hypoblast. These cells comprise the mesodermal layer. Mesoderm initially formed at the caudal end of the primitive streak. However mesoderm soon becomes actively formed throughout the length of the primitive streak. Soon most of the germinal disc is comprised of 3 layers namely the ectoderm an outer single cell layer which was formerly the epiblast the endoderm an inner single cell layer which was formerly the hypoblast, and the mesoderm which is between endoderm & ectoderm and which is several cells in thickness.

Formation of Notochord: Notochord is a rod-shaped aggregate of cells located cranial to primitive streak of the embryo. It extends along the entire length of embryo. It marks the future location of the vertebral column.

The notochord develops from the primitive node located at the cranial end of primitive streak. From the node mesoderm forming cells proliferate & migrate forward into the future head region where they become the rod shaped notochord.

Although notochord does not form a major structure in adult mammalian embryo, it is of great developmental significance. It defines the cranial-caudal axis of the embryo proper and serves as the inductor for the formation of C.N.S. and the head of the embryo. The notochord is important because it induces formation of head, nervous system and somite formation. Its ultimate fate is to become nucleus pulposus of intervertebral discs. After the process of gastrulation the embryo is said to be triploblastic. Three fundamental layers are referred to as germ layers.

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13. Extra-embryonic membrane

Early in blastulation a portion of the cleaving cell population (the inner cell mass) becomes differentiated and forms the embryo proper. The remainder of the cells of the blastula forms the extra embryonic membranes. These in concern with the endometrium make up structures involved with carrying out the protective, nutritive, & excretory functions for the embryo & fetus. These structures form the placenta. There are 4 extraembryonic membranes. These are the yolk sac, amnion, chorion & allantois.

1. Yolk sac
2. Amnion
3. Chorion &
4. Allantois

Allantois: The allantois forms as an evagination from the hind gut of the embryo. Thus this membrane like the yolk sac is comprised of splanchnopleure. The allantois pushes out into the extraembryonic coelom. In domestic mammals, it becomes very large and fuses with the chorion & amnion. In this process it fills & obliterates the extraembryinic coelom.

The umbilical vessels are formed from the splanchnic mesoderm of the allantois; which serves as the origin of the fetal vessels of the placenta. In addition, it is the origin of the vessels in the allanto amnion. Therefore the chorion and amnion do not become vascularized until they have fused with the allantois. E.g. Placenta of the Horse, Hippomanes etc.

A characteristic of the equine placenta is the presence of hippomanes. Similar structures have also been described in the pig & ruminant, but they are not as common as in the horse. Hippomanes are soft, dark brown masses that usually float freely in the allantoic fluid. They may also be lodged in fetal membranes. The hippomanes are concentric rings of amorphous material & are composed of allantoic calculi from cellular debris. They are formed from nuclei of destroyed epithelial cells. Material from allantoic fluid is then deposited on these nuclei. Their chemical composition is mostly mucoprotein & calcium phosphate. Hippomanes can become quite large, sometimes attaining a length of 10 cms. They have no known function and their constant presence in the horse placenta, probably represents something unique about the chemical enviromentof the allantoic cavity in this species.

Soon after appearance of germ layers, formation of extraembryonic membrane will begin. They develop outside the body of the embryo so called as extraembryonic membranes.These are Amnion, chorion, allantois, umbilical cord & yolk sac. They are discarded at the time of birth as they are not necessary.

Two extraembryonic membranes the amnion & allanto-chorion will form during this period & function throughout the remainder of gestation period. A third extra embryonic membrane the yolk sac is seen early during differentiation but will disappear by the end of this stage of development. The yolk sac contains an early source of nutrients for the developing embryo. Along with the depletion of yolk, the yolk sac regresses. A portion of yolk sac is folded into embryo forming its primitive gut.These membranes are produced in a process called implantation and are essential for close relationship between fetus & mother for physiologic exchange & as a result a combined organ is formed i.e. the placenta.

1. Yolk Sac

The formation of the yolk sac starts when the hypoblast delaminates and lines the cavity of the blastula. The mesoderm formed at the primitive streak then migrates between the epiblast & hypoblast. These transform the blastula into a 3 layered structure. The epiblast layer will become the trophoblast of the chorion. The endodermally lined cavity is the yolk sac. The yolk sac becomes separated from the chorion as the mesoderm splits into splanchnic & somatic layers forming the coelom. The separation becomes more nearly complete as the extraembryonic portion of the coelom enlarges. Thus the yolk sac is a splanchnopleure pouch that initially has an extensive attachment to the chorionic somatopleure.

The yolk sac is continuous with the embryonic gut. The latter is formed by the incorporation of a portion of the yolk sac into the embryo. The mesoderm of the yolk sac becomes vascular. The vitelline vessels thus formed are connected to those of the circulation of the embryo proper.

The yolk sac of domestic mammals is initially large but it regresses as the permanent placenta develops. Although it is a transitory structure and has several important functions. It serves to nourish the embryo before the permanent placenta is formed. This is especially important in the horse & carnivore. The first embryonic erythrocytes are formed in the splanchnic mesoderm of the yolk sac. Some of the vitelline blood vessels inside the embryo are retained as major visceral blood vessels in the adult. Thus the gut is derived from a portion of the yolk sac. The yolk sac endoderm is the source of primordial germ cells (primary sex cells). Later they migrate to the fetal gonad. In addition endodermal cells of the yolk sac have the property to produce steroid hormones. Therefore some yolk sac cells may have an endocrine function. Yolk sac is most important in egg laying vertebrates. It forms an early temporary placenta in horse & dog.

2 & 3. Amnion & Chorion

The formation of the amnion & chorion is inter related. Amnion is formed by folds of chorion in domestic animals. The amnion encloses the embryo within a fluid filled amniotic cavity.The somatopleure on either side of the embryo folds dorsally and unites. This folding & fusion process begins cranially and progresses caudally. Once the initial cranial folding is formed similar folding occurs at the caudal end of the embryo. When the cranial & caudal amniotic membranes meet, they fuse with one another. Then the inner layer of the somatopleure separates from the outer layer. This result in one layer of somatopleure covering the embryo and another layer potentially surrounding all of its extraembryonic tissue/entire conceptus.

At this time the yolk sac becomes completely separated from the chorion. The layer covering the embryo becomes amnion and the layer surrounding the entire conceptus become chorion. As the amnion grows it pushes ventrally until it completely surrounds the embryo except for the area where it wraps around the umbilical cord. Both the amnion & chorion are relatively avascular since their mesodermal component is somatic rather than splanchnic.

Modification of epithelium:

The ectodermal epithelium of the amnion and chorion is initially squamous. The epithelium of the chorion becomes cuboidal and forms the trophoblast. In some species some trophoblast cells lose their cytoplasmic boundaries and form a syncytium as the placenta develops. Such a trophoblast is referred to as syntrophoblast while that retaining its cellular nature is called as cytotrophoblast.

4. Allantois

From the inner cell mass, develops as an outgrowth of hindgut splanchno-pleure.The allantois grows to fill the entire extra-embryonic coelom with fluid filled allantoic cavity. The outer surface of allantois binds to the inner surface chorion and the outer surface of amnion. The allantois is highly vascular and provides the functional vessels of the placenta via umbilical vessels.

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14. Placentation

The placenta is the area of apposition between uterine lining & fetal membranes where metabolites are exchanged for sustaining pregnancy.

Placentation:- The manner of formation & attachment of placenta is known as placentation.

Placenta is an apposition or fusion of the fetal membranes to the uterine mucosa for physiological interchange between the vascular systems of mother & embryo. (Nutrients pass from mother side to fetus and waste products from fetal side to mother.)

Placenta is different in various species of animals.

Classification:-

A) As per fetomaternal relationship) depends on depth of the contacted tissue.

i) Indeciduate- There is a superficial contact and there is no loss of maternal tissue during parturition e.g. pig.

ii) Deciduate- There is a close contact between the two and there is a loss of maternal tissue or mucosa e.g. man, bitches.

B) According to shape-

i) Diffuse- may be complete (pig) or incomplete (mare).

ii) Cotyledonary- villi like convex areas known as placentome are present in ruminants. Surface of cotyledon is convex in cow. Flat in goat & concave in sheep.

iii) Zonary- Band like contact area with maternal tissue e.g. bitch, cat (carnivore).

iv) Discoid- Disc like area contact with maternal tissue. e.g.woman, monkey.

C) Morphological Classification **-** Depends on the contact of the two tissues between the maternal & fetal blood i.e. layers of fetal tissue in contact with layers of maternal tissue.

Maternal tissue	**Fetal tissue**
A - Endothelium of capillary	a- epithelium of chorion
b - C.T. (Lamina propria)	b- C.T. (L.P.)
c - Epithelium of uterus	c- endothelium of capillary

Epitheliochorial: - epithelium of maternal side is in contact with chorionic epithelium.

1. Epitheliochorial:

(Maternal tissue)	(Foetal tissue)
a - yes/present	a - yes/present
b - Yes	b - yes
c - yes	c- yes

2. Syndesmochorial: - chorionic epithelium is in contact with connective tissue of maternal mucosa E.g. cow (cotyledonary)

a- Yes	a- Yes
b- Yes	b- Yes
c- no	c- Yes

3. Endotheliochorial:- chorionic epithelium is in contact with endothelium of capillary of maternal side E.g. cat, dog, (zonary).

a- yes	a- yes
b- no/absent	b- yes
c- no	c- yes

4. Haemochorial:- Direct contact between maternal blood & chorionic epithelium. e.g. man.

a- no	a- Yes

b- no	b- Yes
c- no	c- Yes

5. Hemoendothelial:-Endothelium of fetus (chorionic) is in direct contact with maternal blood E.g. rat, guniea pig, rabbit, (discoid).

a- no	a- no
b- no	b- no
c- no	c- yes

Functions of placenta

1. Nutrients & oxygen passes from mother blood vessels to the blood of embryo.

2. CO2 & excretory products from embryo carried into the maternal blood by diffusion through capillaries i.e. it acts as a external lung & excretory organ.

3. It protects delicate fetal tissue & check the direct flow of blood from mother, which is at high pressure.

4. It allows only nourishing material to pass in embryo and avoid the harmful substances as poison, bacteria etc.

5. It serves as a store of glycogen to fetus before liver formation.

6. Trophoblast breaks proteins & digests before the entry into the fetal circulation.

7. It stimulates secretion of hormone in ovary which maintains pregnancy.

8. It secretes progesterone which maintains the corpus luteum.Thus the embryo & placenta become almost completely independent of the maternal hormone & form a self differentiating unit.

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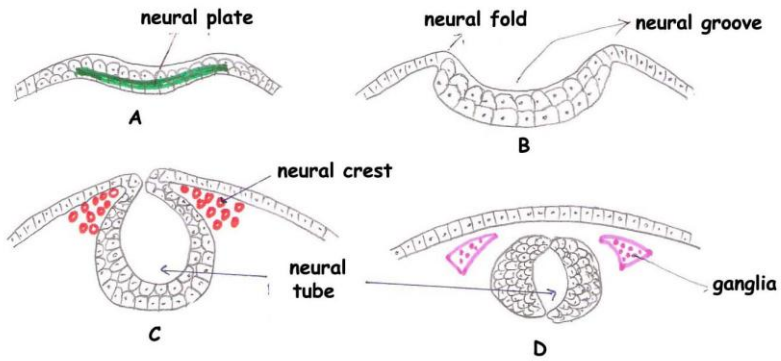
SPECIAL EMBRYOLOGY

15. Development of Nervous System

Both the nervous system and the sense organs arise from specialized regions of dorsal ectoderm known as neural plate and sense plate or placodes respectively.

In the dorsal ectoderm of embryonic cells a plate like structure is formed known as neural plate. Subsequently there is a formation of neural groove and then neural tube in advanced stage. Extending on each side of neural tube there are some cells called as Neural crest. Neural tube gives rise to brain and spinal cord where as neural crest gives rise to autonomic nervous system, dorsal ganglia and ganglia of parasympathetic nervous system.



Origin of neural tube & crest

Neurula is that embryo in which the nervous system made his appearance. In all vertebrate embryos the brain arises as dilation at the anterior end of the neural tube. As the brain extends somewhat forward than the notochord it consists at first of a prechordal and an epichordal portion.

Neural Tube:-

Neural tube is a tubular structure. It has got wide lumen and very thin wall. It is lined by a single layer of epithelial lining. The cavity of the tube remains open as cerebro spinal canal while its wall gives rise to brain and spinal cord. In neural tube differentiation and multiplication occurs. The new cells are pushed to outside and thus 3 zones are formed.

i) Ependymal zone or centrum-innermost cells which are larger.

ii) Middle zone- consists of spheroid & immature cells.

iii) Peripheralzone- consists of oldest cells.

Cellular Population: - There are two types of cells in the wall of the neural tube which are differentiated in the beginning. This population of cells is known as cerebral mantle which gives rise to various cells of nervous tissue. The lumen of the neural tube is narrowed posteriorly due to large number of cells and broader at anterior/cephalic end.

i) Neuroblast- It is a stem cell for the nerve cell/neuron.
ii) Spongioblast- It is a stem cell for the neuroglial tissue or supporting tissue of nervous system except the microglia which are derived from the mesoderm.

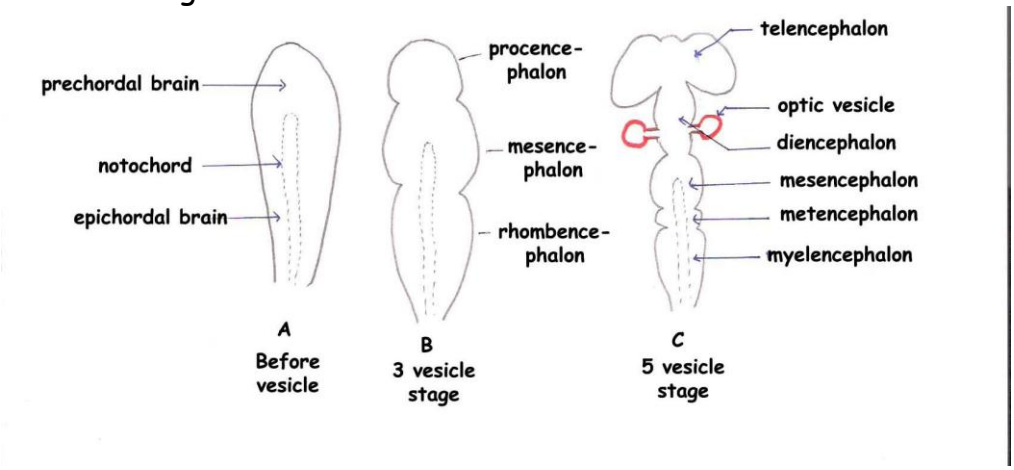
Development of Brain

In all vertebrate embryos the brain arises as dilation at the anterior end of the neural tube. As the brain extends somewhat forward than the notochord it consists at first of a prechordal and an epichordal portion. Neural tube differentiate into 3 dilated regions known as primary vesicles.These 3 regions are

i) Prosencephalon- Anterior Portion
ii) Mesencephalon- Middle portion
iii) Rhombencephalon- Posterior Portion

Prosencephalon forms fore-brain mesencephalon forms mid-brain and the rhombencephalon forms the hind brain.

The primary vesicles are soon converted into five definitive vesicles through the division of prosencephalon into the anterior telencephalon and posterior diencephalon and through a similar division of the rhombencephalon into the anterior metencephalon and posterior myelencephalon- which merges into the spinal cord. The mesencephalon remains unchanged.



These vesicles later on gives rise to various parts of brain as follows:

1. Prosencephalon	1. Telencephalon - olfactory lobes & its surrounding Cerebral hemispheres.
	2. Diencephalon-Part of 3rd ventricle and its surrounding structure.
2. Mesencephalon	1. Corpora quadrigemina (dorsal)
	2. Cerebral peduncles (ventral) and

3. Cerebral aqueduct (middle)

3. Rhombencephalon – 1. Metencephalon- pons, part of 4th ventricle

2. Myelencephalon- medulla oblongata.

On either side of diencephalon eyes also develop from optic vesicle. The lens of the eye develops from the ectoderm from lens placode.

Fig- Development of brain- before vesicle stage, 3 vesicle stage & 5 vesicle stage.

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16. Development of Ventricular system

Early in development, the cavity within the neural tube is filled with amniotic fluid. As the brain & spinal cord grows, this fluid filled space makes up the majority of the nervous system. Upon closure of the neuropore & development of the embryonic vasculatuere, this fluid is then synthesized by the choroid plexus. The choroid plexus form one region of the blood-brain barrier that regulates the brain's internal environment.

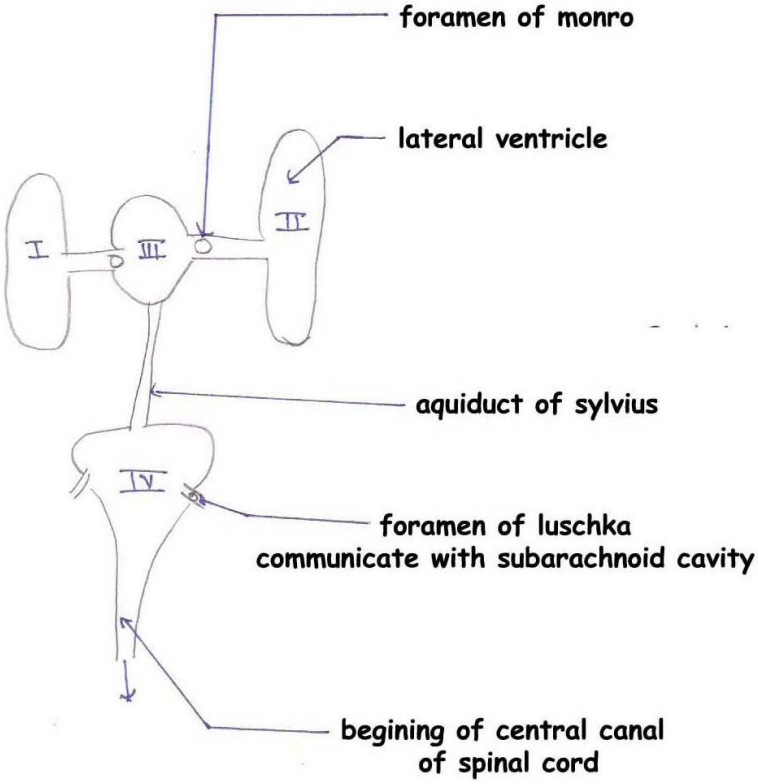
The ventricular system develops from the single cavity formed from the hollow neural tube. This fluid filled space is separated from the amnion following fusion of the neural tube & closure of neuropores.

Flow of cerebro-spinal fluid

CSF is produced by modified ependymal cells of the choroid plexus found in all components of the ventricular system except for the cerebral aqueduct and the occipital & frontal horns of the lateral ventricles.

CSF flows from lateral ventricles via the foramen of Monro into the third ventricle; and between the fourth ventricle via the cerebral aqueduct in the brainstem. From there it can pass into the central canal of the spinal cord or into the cisterns of the subarachnoid space via three small foramina: the central foramen of Magendie and the two lateral foramen of Luschka.

Ventricular system of brain



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17. Digestive System

The digestive tract of the vertebrate is a tubular structure derived from the primitive gut or gastrocoel formed at the time of gastrulation. Its inner lining is derived largely from endoderm, but its openings (mouth, anus, gill, clefts etc.) arise from ectodermal pouchesand the whole tube is ensheathed in splanchnic mesoderm. Thus all three germ layers contribute to the formation of digestive system.

At a very early stage, three regions of the gut can be recognized these are,

1) fore-gut-situated anterior to the yolk mass and extending as a blind pocket into the head.

2) Mid-gut- lying immediately above & dorsal to the yolk mass and

3) Hind-gut- a blind pocket extending posterior to the yolk mass Later on, the anterior and posterior opening to exterior develops. The tube (gut) produces various organs of digestive tract as well as other structures such as respiratory organs and certain endocrine glands.

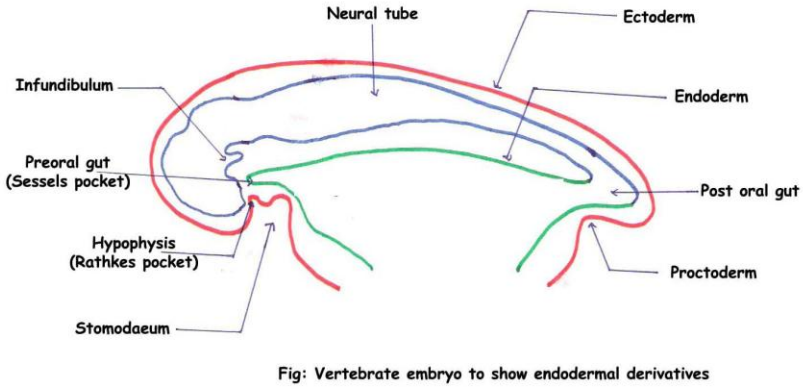

Fig: Vertebrate embryo to show endodermal derivatives

Foregut, midgut and hind gut gives rise to various parts of digestive system as follows:

I- Foregut- Pharynx, oesophagus, stomach, part of ileum.

II- Midgut- part of ileum and colon.

III- Hindgut- part of colon, caecum, rectum.

1. Foregut and its derivatives:-

Mouth Cavity is derived from stomodaeum and foregut. The stomodaeum is an invagination of the ectoderm on the ventral side of the head. The stomodaeum grows inward to meet the ventral side of the fore gut. Thus a small blind pocket of the foregut called the preoral gut or Seessel's pocket extends forward beyond the developing mouth cavity. The apposing surfaces between stomodaeum and fore-gut composed of ectoderm and endoderm eventually ruptures, forming the oral cavity or mouth.

Pituitary body- This structure takes its origin from two sources viz. Rathke's pocket and the infundibulum (both are ectodermal in origin) Rathke's pocket or the hypophysis develops as an evagination of the anterior surface of the stomodaeum.

Rathke's pocket gives rise to- Anterior Lobe (pars anterior)

Infundibulum - Posterior lobe (pars nervosa)

Both fuses with each other & loose connection with mouth cavity. But retains connection with floor of brain and hence known as hypophysis.

Teeth: - arise from dental ridge or lamina of maxillary and mandibular processes of first visceral arch (pharyngeal arch). They are formed of a core of mesoderm covered with epithelium derived from ectoderm of stomodaeum.

Tongue: - The tongue arises from two sets of paired bud like prominences (lateral lingual swellings) on the floor of mouth cavity. These are anterior and posterior lingual primordia.

Salivary glands: - are derived largely from ectoderm, although they arise near the junction of ectoderm & endoderm.

Pharynx and its derivatives: - This region of the foregut is generally marked in the early embryo by the development of the pharyngeal pouches or visceral pouches or clefts. There are 4 pharyngeal pouches or clefts, which give rise to various structures as follows:

I- Forms middle ear & Eustachian tube.

II- Tonsillar sinus.

III- Primitive thymus, parathyroid & thyroid.

IV- Post-broncheal bodies.

Liver:- is the largest gland in the body. It develops as a ventral evagination of the floor of the foregut at its distal end. Several independent primordia may form.The original evagination persists as a hollow saccular structure forming the gall bladder and its tubular connection with the gut becomes the bile duct.

Pancreas:- also arises from the posterior end of the foregut. There are usually several primordial. One dorsal and one or two ventral.These develops as solid out growths or cords of cells into the condensed mesenchyme of the dorsal mesentery supporting the gut.

2. Midgut-

The intestine is derived in part from the foregut and in part from the hind gut. It is impossible to indicate exactly which regions arise from these divisions of the gut. Two main divisions of the intestine may be noted, the small intestine (ileum) and the large intestine (colon).

3. Hindgut-

This portion is the prolongation of gut posterior to the mig-gut. It empties into the cloaca but continues beyond it as postanal gut. The cloaca is derived in part from an ectodermal invagination the proctodaeum and from the associated region of the hind gut.

The cloaca becomes divided in mammals by a partition into a dorsal rectum and a ventral urogenital sinus. These later on give rise to final openings the anus and the urogenital orifice respectively.

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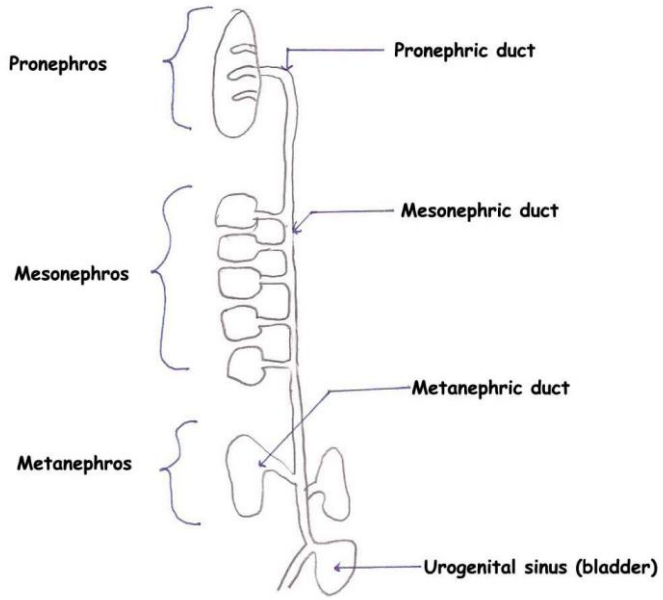
18. Urogenital System

The urogenital system is a combination of two separate systems namely the excretory system whose functionis to eliminate nitrogenous wastes and the reproductive system whose function is to produce and

liberate germ cells. Both sets of organs arise in the intermediate mesoderm or mesomere of the somites.

Excretory system (urinary system)

In the intermediate mesoderm there is a formation of cord like structure known as nephrogenous cord which divides into nephrotomes. There is a formation of serially repeated segments in the cord. These segments as per their position and origin are known as pronephros, mesonephros & metanephros. Ducts develop from each segment and ultimately unite into a urogenital sinus.The ducts are pronephric ducts, mesonephric ducts and metanephric ducts.



Devlopment of Excretory system

Pronephros:- arises in the anterior nephrotomes. It is present and functional only in simpler form of life e.g. cyclostomes larvae. In chick it remains functional for a short time about 3-4 days. In lower fishes it is present for a greater period. In mammals also for a short period about a month in cattle. The pronephros is not functional except in sheep.

Mesonephros:- arises from the nephrotomes posterior to the pronephros. Pronephros degenerates & the pronephric duct connects with the mesonephric duct. Mesonephros remains for a greater period in embryo. Glomerulus appears in the form of glomus/prominence of blood capillary which is surrounded by capsule of Bowman's.

Mesonephric kidney is present in adult fishes & amphibians (In fishes and reptiles there is no metanephric kidney). In mammals & birds mesonephric kidneyis present in embryo and is functional for certain period, till its work is taken up by metanephric kidney. In adult

mesonephros degenerate and metanephros develops. The mesonephros is the functional kidney for fish & amphibians.

Metanephros:- Mesonephric duct gives and open in cloaca. From this there is an evagination or diverticulum of mesonephric duct occurs which forms the metanephros. It extends forward and formation of pelvis calices & nephrons in cortex & medulla occur. It is the functional kidney of adult mammals & birds. The metanephros is the functional kidney of reptiles, birds and mammals.

In case of mammals & birds the metanephros tubules form the kidney tubules while metanephric duct system is responsible for the formation of its rest of the structures i.e. ureter, urethra etc. except urinary bladder (urinary bladder is endodermal in origin).

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19. Reproductive System

The connecting system i.e. duct system of the mesonephric kidney is utilized for the formation of genital system.

In development of reproductive system in male and female there is indifferent stage. In this stage genetic sex has been established but phenotypic sex is not visible. The formation of gonads (may be male or female) takes place in early embryonic period. It is formed due to migration & establishment of primitive germ cells which first appear in endoderm of primitive gut. Then pass through mesentery via blood & goes to ventromedial to the mesonephros. Here a thickening is formed known as genital ridge. Appearence of gonads takes place at mesonephros i.e. at genital ridge.

As mesonephros degenerate mesonephric tubules are utilized for formation of genital duct system. In male they form small thread like ducts known as Aberrent ductules which later on forms epididymis and paradidymis. In female epoophoron and parepoophoron are formed.

Mesonephric duct becomes modified or split up into two i.e. Wolffian ducts in male and Mullerian duct in female.

Male Reproductive system:- Wolffian duct gives rise to part of epididymis, ductus deferens, seminal vesicle and ejaculatory ducts in male. It also gives rise to rudimentary structures or vestigial structures in male E.g. uterus musculinus.

Female Reproductive system:- Mullerian duct gives rise to fallopian tubes, ovary, uterus & part of vagina in female. Other part of vagina is

formed by side of bladder. In female rudimentary structure of male or of Wolffian duct persists known as Gartner's canal.

External Genitalia: - In indifferent stage, appearance of genital eminence or tubercle occurs. In male, it gives rise to penis & genital folds i.e. scrotum.

In female, it forms clitoris and labiae.

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20. Cardiovascular System

The vascular system is mesodermal in origin. It consists of several distinct elements namely,

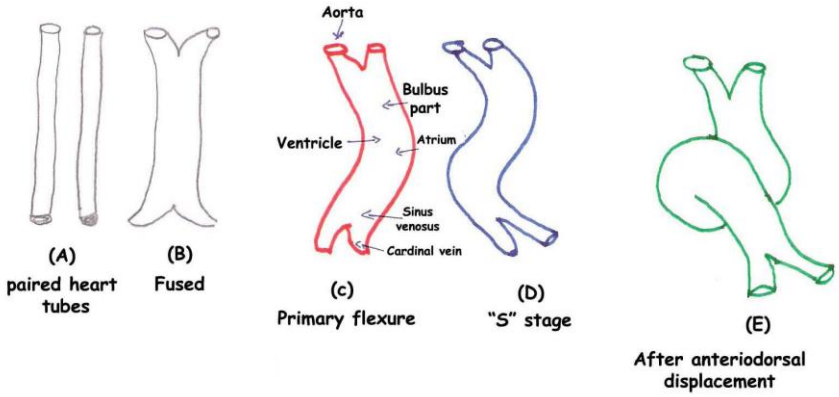
i) Blood (development from blood islands).
ii) Heart- a muscular pulsating organ by means of which the blood is kept in circulation.
iii) A system of tubes or blood vessels.

Development of the Heart:-

The heart takes its origin from the splanchnic layer of mesoderm, ventral to the gut and associated with the region where the fore-gut opens into the mid-gut by way of intestine.

Heart develops in cephalic part of embryo from cardiac primordia of splanchnic mesoderm. It is a tubular structure in early embryonic life. These tubes are simple, paired and situated in ventral part of pharyngeal region. They come nearer & fuse with each other to form a single tube. Posteriorly they connect with vitelline veins & later with cardinal vein. Cardinal veins open in sinus venosus part of heart. Then it is translated into atria or atrium of heart. Then there is a bulbus part of the heart and then aorta at anterior part.

The tube become more longer, since the space for expansion is small. As space enlarges this structure modifies. The tube bent/curve on right side forming primary flexure. Thus the primary flexure changes the shape of organ from a straight tube to a "C" shaped structure. Further growth results in the twisting of the heart into "S" shaped curve. Then there is torsion or bending. The original posterior loop of the "S" is pushed forward & dorsal, so that it comes to lie dorsal to the morphologically anterior end.



Early stages of development of Heart

In the later stages there is a subdivision of heart into special chambers. Partitioning starts in ventricle & there is appearance of interventricular septum containing interventricular foramen and it communicates with right & left ventricles.

Similarly in atrium interatrial septum originates. First primary interatrial septum develops which is thin and consists primary interatrial foramen.Then secondary interatrial septum appears which consists secondary interatrial foramen. First the two atria communicate each other by primary interatrial foramen with the establishment of secondary interatrial foramen and the primary foramen closes. Secondary interatrial foramens then communicate the two atria which becomes foramen ovale. Later on it closes to form fossa ovalis.

Between the atrium & ventricle atrio-ventricular canals arise which are smaller & short. At this junction, there is a formation of bicuspid and tricuspid valves occur on left & right sides respectively. In bulbus region it is divided into two parts to form 2 vessels i.e. pulmonary artery and aorta. Thus right side is completely separated from left side.

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21. Skeletal System

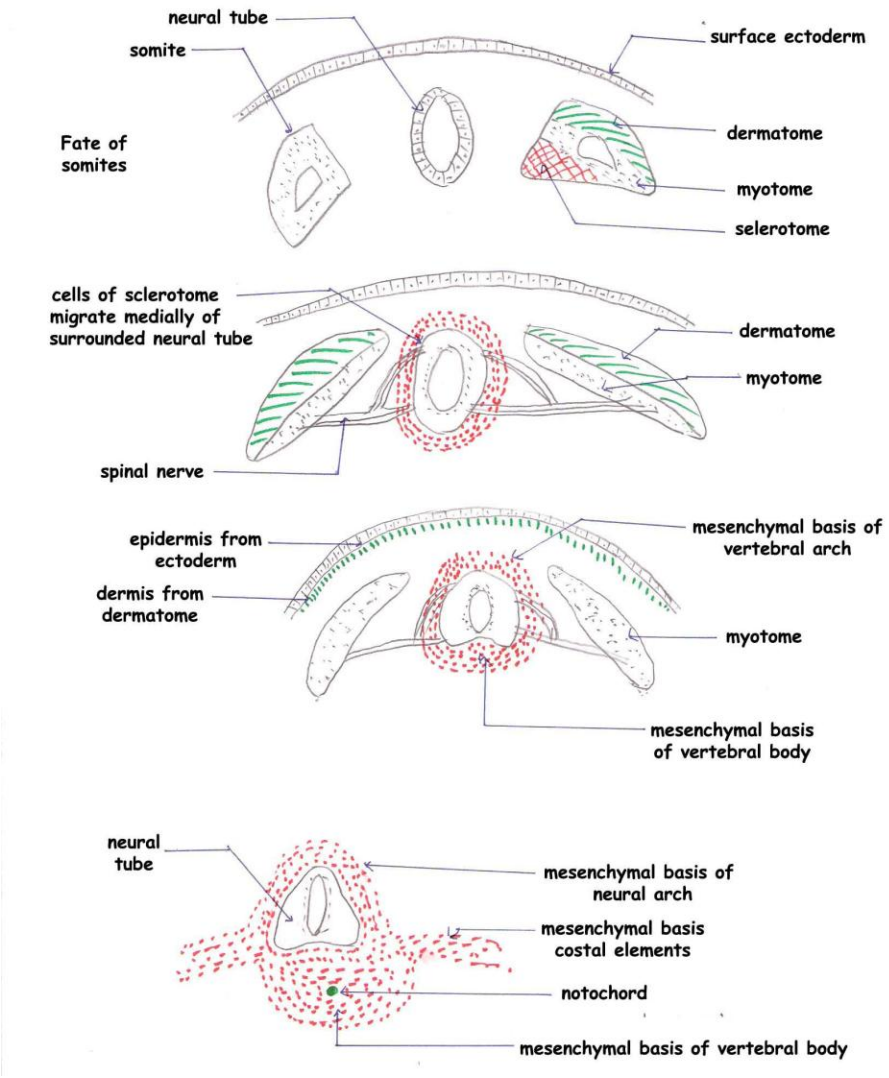
The skeletal system develops from mesodermal germ layer. It forms a series of mesodermal tissue block and the somites on each side of neural tube. Somite gives rise to sclerotome (skeleton), dermatome (dermis) and myotome (muscles).

All bone is mesodermal in origin and the process of formation of bone is known as ossification. Initially cartilage is formed that closely resembles bone to be formed. This cartilage is subsequently replaced by

bone. This kind of bone formation is known as endochondral or perichondral ossification and the bones are called as cartilage bones.

Vertebral column:- It is formed from the sclerotomes of the somites.The cells of the sclerotome become converted into loose mesenchyme which migrate medially & surrounds the notochord. It extends backward on either sides of neural tube & surrounds it. Lateral extension also takes place to be subsequently occupied by transverse process. Ventral extension in the body wall to be occupied by ribs. Intervertebral discs are formed from perichordal discs, which is the centre of somite. Vertebra, transverse process & ribs are inter-segmental structure made up from portions of two somites. Spinal nerves are segmental structures. The mesenchymal basis of vertebra converte into cartilage.

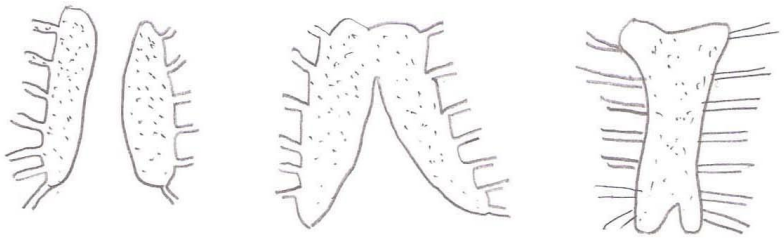
Formation of mesenchymal basis of neural arch and the costal element



The sternum: - The sternum is derived by fusion of two sternal bars or plates that are formed on either side of the midline. According to some workers the sternal bars are formed independently, but soon fuse with the ventral ends of the developing ribs. Other workers believe that the bars are formed by fusion of ventral ends of the ribs with one another.

The fusion of the sternal bars first occurs at the cranial end (manubrium) and proceeds caudally. The manubrium and body are chondrified & ossified separately. The xiphoid ossifies late in life.

Development of sternum



The Skull: - The skull is developed from mesenchyme surrounding the developing brain.The skull can be divided into two parts, the neuro cranium, which forms a protective case around the brain and viscero-cranium, which forms the skeleton of face.

Neurocranium consists of 2 parts, flat bones & cartilaginous part or chondro cranium. Flat bones are membranous part.

Viscerocranium consists of the bones of the face & is formed mainly by the cartilages of the first two pharyngeal arches from which different parts of the skull are formed.

Formation of Limbs

Bones of the limbs shoulder & pelvic girdle are formed from mesenchyme of the limb buds except clavicle. These all are formed by endochondral ossification. The limb buds are paddle shaped outgrowth that arises from side wall of the embryo. The forelimb buds appear little earlier than the hindlimb buds. From each limb bud different parts of limb appear.

Joints: - The tissues are derived from mesenchyme-intervening between developing bone ends. It may differentiate into fibrous tissue forming a fibrous joint or into cartilage forming cartilage joint.

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22. Muscular System

The intermediate part of the somite is the myotome, which gives rise to striated muscles. All the musculature of the body walls & limbs is derived from the myotomes. In man, the myotomes give origin to the musculature of trunk only in whole or part. Occipital myotomes form musculature of tongue while extrinsic muscles of eyeball are the derivatives of preoccipital myotomes. Soon after its formation each

myotome in neck & trunk separates into a dorsal part, which gives rise to the muscles supplied by the dorsal primary ramus of the spinal nerve and a ventral part gives origin to muscles that are supplied by the ventral ramus.

Other changes occuring in myotome are:-

It may migrate to a new site. Striated muscles may form from mesenchyme of that region. It may undergo splitting to form several muscles. E.g. various layers of intercostal muscles. The myotome or its subdivisions may fuse with other myotomes for the formation of muscles supplied by several spinal nerves. It may degenerate & may form fascial structures.

Smooth muscles :- Almost all smooth muscle is formed from mesenchyme. Smooth muscles in the wall of viscera are formed from splanchnopleuric mesoderm in relation to them. However the muscles of the iris are derived from the ectoderm of the optic cup. The myoepithelial cells of the sweat glands are also ectodermal in origin. Cardiac muscles: - This is derived from the splanchnopleuric mesoderm in relation to the developing heart tubes and pericardium. Purkinje fibers are formed by special bundles of muscle cells.

23. Respiratory system

The respiratory system consists of the nasal cavity, pharynx, larynx, trachea and lungs. The lining of the nasal cavity is derived from ectoderm; the lining of the rest of the respiratory system comes from endoderm.

In man, the lungs arise toward the end of the fourth eek from a laryngotracheal groove. This separates itselffrom the overlying esophagus by lateral grooves. After which the posterior end grows rapidly and divides to form a primary bronchi. The bronchial buds continue their branching until seventeen generations of renewed and in all 24 generations are present. The bronchi push out into the plural cavities and will become the visceral plural lining. The anterior portion of laryngotracheal groove gives rise to larynx and trachea.

These respiratory structures originate as an evagination of endoderm along the floor of the pharynx. The evagination is designated the laryngotracheal groove. From lateral walls of the laryngotracheal groove, ridges grow medially and fuse along the midline, establishing a tracheo-esophageal septum. The septum separates a laryngotracheal tube (future trachea & lung buds) from the esophagus. The larynx develops rostrally, where the lumen of the groove retains communication with the pharynx.

Trachea and bronchi

The laryngotracheal tube grows caudally into splanchnic mesoderm located ventral to the pharynx.The mesoderm contributes cartilage and connective tissue and endoderm contributes respiratory epithelium to the developing trachea. Tracheal elongation shifts bronchi caudally into the thorax.The blind, caudal end of the tube develops bi-lobed bronchial buds which grows to form the future principal bronchi. Outgrowths of each principal bronchus form future lobar bronchi, each of which gives rise to outgrowths those become future segmental bronchi, each of which gives rise to more than a dozen additional bronchial branches. The smallest branches are bronchioles. They give rise to lung terminal sacs and alveoli.The bronchial branchings continue to occur throughout the fetal period and into the postnatal period.

Lungs

Continued branching of the bronchial tree results in lung tissue occupying more and more of the pleural cavity coated by visceral pleura. The endoderm-lined bronchial tree grows into splanchnic mesoderm which forms the cartilage, fascia, smooth muscle, and vessels of the lung. Initially, bronchiole-lung branches are solid cores of cells that grow into splanchnic mesoderm (growth is like exocrine gland growth into mesoderm). Eventually, terminal branches become hollow, dilated and sac-like with endoderm becomes a thin epithelium (terminal sacs). Alveoli are created by the formation of septae that partition the terminal sacs. Some endodermal alveolar cells become cuboidal rather than flat and produce a phospholipids surfactant that reduces surface tension and thus facilitates alveolar expansion (as opposed to alveolar collapse). Fetal lungs contain fluid that facilitates the breathing movements that take place in utero to prepare for postnatal respiration. At birth, lung fluid drains or is absorbed as air is breathed.

Species differ in degree of lung maturity at birth. Also, within a single lung, distal regions are less mature than proximal ones. Formation of new alveoli occurs post-natally to a considerable extent in all mammals. Subsequently, lung growth is due to hypertrophy (increased size) of alveoli and air passageways.

24. Foetal circulation

The anatomy of the fetal blood vascular system is identical to thet of the independent animal but has four additional structures.

1. The paired unbilical arteries
2. The unbilical vein
3. The foramen ovale
4. The ductus arterious

No part of the fetus receives fully oxygenated blood. However its requirements are considerably less than those of independent individual. Its body temrature is provided, inpart by its environment and therefore requires little oxygen or food. The food is predigested. Respiration is a function of the placenta and requires no energy on the part of the fetus.

An essential structure in the nutrition of the foetus is placenta. The placenta is the structure through which the exchange of the gases and metabolic substances between the fetal and maternal circulation takes place.There is no contuinity of maternal and fetal blood vessels.

The Large, paired unbilical arteries carry venous blood to the placenta. They arise from the internal iliac artery.The course of the arteries is dounword and foreword from the sublumber region to the umbilicus. Outside the fetal body they are incorporated in the umbilical cord and remifies between allantois and chorion. The capillaries of the unbilical arteries are in the fetal placenta.

The umbilical veins receive blood from the fetal placenta.This Blood is oxygenated and contains the food necessary for fetal growth. The branch of unbilical veins unites to form a single unbilical vein at the umbilicus. The abdominal part of unbilical vein passes to the liver & joins the portal vein at hilus forming a venous sinus. At this point venous blood from the stomach, intestine, pancrease and spleen is added to oxygenated blood via portal vein. The ductus venosus connects the venous sinus to the posterior vena cave. In posterior vena cave second dilution with the venous blood from the posteror part of the body occurs.

The fetal lung does not function. Two structures, the foramen ovale and the ductus arteriosus serve to direct the bloo from the pulmonary artery.

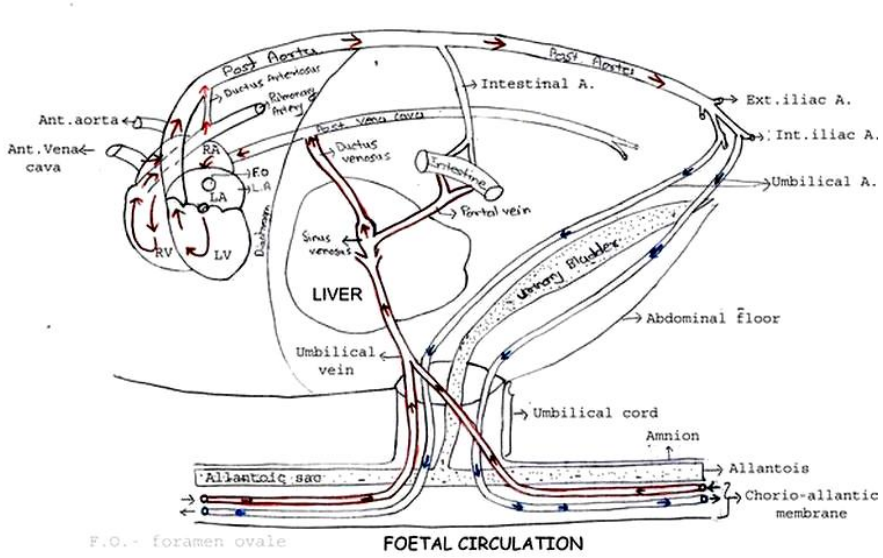
The foramen ovale is the tubuilar structure passing obliquely from right atrium to left atrium. The inter venous crest helps to direct blood from posterior vena cava into foramen ovale and then into left atrium.

Blood carried to the heart by anterior vena cava is directed downward into right ventricle by intervenous crest. This blood passes into pulmonary artery. Pulmonary artery is connected with aorta by a vessel called as ductus

arteriosus. From pulmonary artery blood passes into aorta through ductus arterosus. Here the final dilution with venous blood occurs.

After birth, the following changes occur –

1. Umbilical arteies become the round ligament of the urinary bladder.
2. Umbilical vein become the round ligment of the liver.
3. The foramen ovale is closed by membrane and called as Fossa ovalis.
4. Lumen of ductus arteriosus become very small or completetly closed and it forms ligamentum arteriosum.



FOETAL CIRCULATION

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"It is neither the strongest of the species that survives nor the most intelligent that survives. It is the one that is the most adaptable to change".

-----Charles Darwin

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