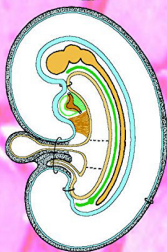
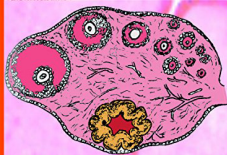


R. K. GHOSH

ESSENTIALS OF
VETERINARY
HISTOLOGY
&
EMBRYOLOGY



2nd edn.



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Essentials of

VETERINARY

HISTOLOGY
&
EMBRYOLOGY

COMPLIMENTARY COPY

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***Dedicated
to the Students
who find romance in
Anatomy***

PREFACE

(Essentials of Veterinary Histology & Embryology)

“**Essentials of Veterinary Histology and Embryology**” is being published considering the demand of the day particularly for the Under Graduate students in the field of Veterinary Science. The earlier book – “**Essentials of Veterinary Embryology**” written by the author in the year 2002 has been improved and merged with the freshly written text of Histology in this edition. The Histology portion has covered most of the basic tissues of various organ systems of the body along with sufficient elastration, diagrams and photomicrographs. Almost all the tissues which have been presented in the text were prepared by the author himself. Most of the photomicrographs have been printed with their original colors as appeared in stained slides.

The text has been written in easy and simple form and the diagrams of both Embryology and Histology portions have been colored to provide a user friendly appearance for studying this subject.

The information provided in this book although precise for Under Graduate education but will surely be useful for Post Graduate students as well.

Due care has been taken to minimize the mistakes and errors as far as practicable but it is not possible to make it cent percent accurate in this first edition of Histology and the author is aspirant that the short comings will be overcome in future editions with constructive criticisms of his colleagues, friends and the user of the book.

The author acknowledges the help and co-operations those have been extended by his colleagues, P.G. and Ph.D. students and non-teaching staff of the Department of Veterinary Anatomy & Histology, W.B.U.A.F.S., while making the manuscript.

The co-operation that has been extended towards publication of this book by Mrs. Sarbani Bhattacharya, Mr. Aninda Bhattacharya and Mr. Chiranjit Burman of Current Books International is thankfully acknowledged.

The author specially remembers the encouragement provided by Late H.N. Bhattacharya during the preparatory period of this publication.

20th January 2013
Kolkata
Ph. 98304 34823

RANAJIT KUMAR GHOSH

PREFACE

(Essentials of Veterinary Embryology)

This book on Veterinary Embryology has been written on the basis of the approved syllabus of Veterinary Council of India in the under graduate level of Veterinary Science. In earlier days the subject was studied from the text books of some foreign authors who were mainly zoologists or general embryologists. Naturally they gave more emphasis on the philosophical aspect of the subject than that of practical aspect. Therefore this book has been designed on the basis of need based teaching of undergraduate and postgraduate veterinary students keeping aside the unnecessary details.

Being impressed upon the Chinese proverb "one picture is more than thousand words", sufficient schematic diagrams and sketches have been provided in the book. All the figures have been designed and drawn by the author himself on the basis of his experience in the teaching of anatomy for more than twenty five years.

The language of the text has been made as simple as possible to avoid complexity in understanding the subject. Most of the steps of development have been shown in a easy and simple manner to reduce confusion.

Although care has been taken, some errors or omissions would naturally occur. These shortcomings must be corrected in future editions with the help of constructive suggestions from my learned colleagues and professional brothers.

The author expresses his gratitude to his guide and teacher Prof. Asim Kumar Datta, Ex-Professor UCM, Calcutta University for his encouragement in publishing such book. He also thanks Prof. Shyamal Bose, Dr. Ranjit Guha, Dr. R.K. Das (Bhubaneswar) and Mr. C. Gupta for their active interest in this publication. The author thanks his colleagues Prof. M.M. Roy, Dr. S. Ray and Dr. P. Das for their co-operation and help in this publication.

The author expresses his thanks to the authority of W.B. University of Animal and Fishery Sciences, Kolkata – 700 037 for granting necessary permission to publish the book.

The efforts of M/s. S. Datta, 58/1, Vidyasagar Road, Kolkata – 700 077 printer of this book is thankfully acknowledged.

1st June 2002
Kolkata – 700 037

RANAJIT KUMAR GHOSH

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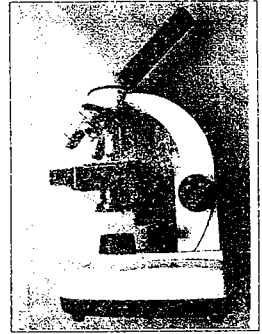
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GENERAL HISTOLOGY



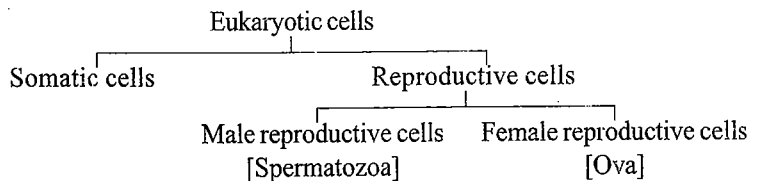
ANIMAL CELL

A cell is a mass of protoplasm enclosed in a semi-permeable membrane and forms the basic structural and functional unit of all tissues and organs in the animal body.

The cells which do not possess any organized nucleus are known as **Prokaryotic** cells and nucleated cells are called **Eukaryotic** cells. Some bacteria and blue-green algae are the examples of prokaryotic cells and most of the cells in the animal body are eukaryotic.

Functionally two types of cells are available in the animal body :

- (a) Somatic cells – These cells form various organs of the body and contain diploid ($2n$) number of chromosomes.
- (b) Reproductive cells – They take part in the reproduction and contain haploid (n) number of chromosomes. Reproductive cells are of two types – i) Male reproductive cells or male gametes or spermatozoa and ii) Female reproductive cells or female gametes or ova.



STRUCTURE OF A CELL

This structural unit of the living body may be of various shapes or sizes. They may be flat or cubical or pyramidal or columnar or irregular in shape. The size (diameter) ranges from 5 to 50 microns in most of the somatic cells. However, female reproductive cells and nerve cells are bigger in size.

Irrespective of shape and size each cell comprises of a cell membrane, cytoplasm and a nucleus.

Cell Membrane

Each cell is covered by a thin semi permeable membrane called cell membrane or plasma membrane. Generally it is 70Å thick and is composed of three layers of materials. Outer and inner layers are formed by protein and intermediate layer is composed of lipid. The cell membrane performs the following functions:

- i) Maintains the shape of the cell.
- ii) Helps in the selective interchange of inorganic ions.
- iii) It allows selective permeability to lipid molecules.
- iv) It accommodates various receptors.
- v) The membrane helps intake of fluid inside cell cytoplasm by the way of pinocytosis.

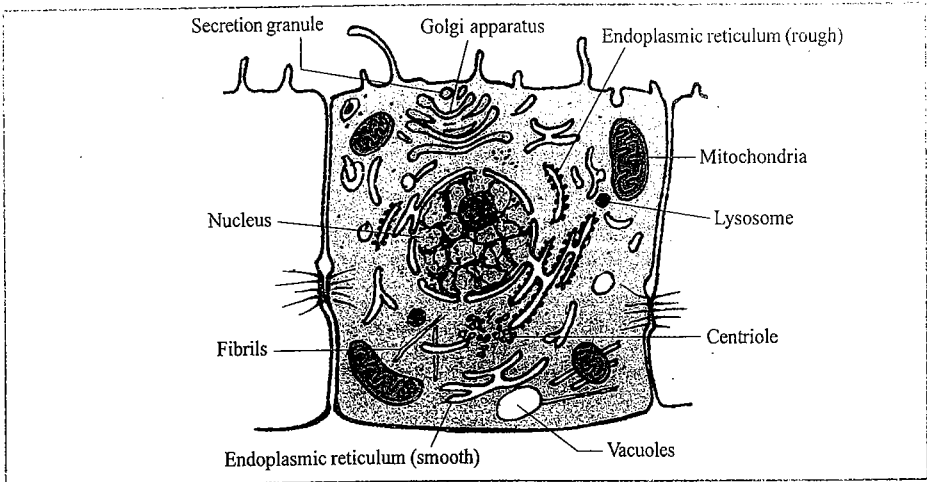


Fig. 1.1

Nucleus

This is a spherical dense body within the cytoplasm and composed of nuclear membrane, chromosomes, nucleolus and nuclear sap. Its shape, size and position and number may vary.

The **Nuclear membrane** is structurally similar to that of cell membrane but is thicker and have few pores. The outer surface of the membrane is sometimes blended with rough surfaced endoplasmic reticulum.

Chromosomes are thread like deeply stained (basic) structures remain in the form of a network within the nucleus at the resting stage. They become prominent during the time of cell division. The number of chromosomes is constant to the species. In somatic cells the number is 60 in cow, 64 in horse, 44 in rabbit, 38 in pig and 78 in dog and fowl. In mature germ cells these numbers will be half (haploid). The chromosomes become prominent with

the onset of prophase. But during the interphase i.e. the period between the cell divisions the chromosomes become uncoiled and extended to form a diffuse network. This is collectively called **Chromatin**. When the chromatin material is dispersed and stained poorly, called **Euchromatin**. On the other hand, when the chromatin material is condensed and deeply stained, called **Heterochromatin**.

Sex Chromatin or Barr body – It is a small chromatin material remains adjacent to nucleolus of nerve cell and other cells at the inner surface of the nuclear membrane of female animals.

Sex-chromosomes are a pair of chromosomes responsible for sex determination. In most of the animals they are designated as X and Y. Female animals have two X chromosomes and the males have one X and one Y chromosome.

Autosomes – Chromosomes other than sex-chromosomes are called Autosomes. They generally occur in pairs in somatic cells and singly in gametes.

The main component of a chromosome is DNA. The genes which are responsible for transmitting the hereditary character are located within the DNA molecule.

Nucleolus is another small body within the nucleus. The number of nucleoli may be more than one in one nucleus. It disappears during the cell division and is composed of irregular network of chromatin materials.

The **Nuclear sap** is the fluid component of the nucleus and serves as a medium for transport of RNA.

Cytoplasm

It is the semisolid jelly like substance which remains around the nucleus and enclosed by plasma membrane. This substance is colloid in nature and composed of water, salts, carbohydrates lipids and Ribonucleic acids. The main contents of the cytoplasm may be grouped as follows:

Active elements (organelles)

Endoplasmic reticulum
Golgi bodies
Mitochondria
Lysosomes
Ribosome granules
Centrioles
Fibrils

Cytoplasmic inclusions

Food granules - [Carbohydrate, Protein, Fat]
Pigments
Secretion granules

Endoplasmic Reticulum

These are membrane bound tubules or vesicles remain in the cytoplasm separately or in the form of network. They are of two types – Smooth surfaced and rough surfaced.

Ribosome particles are attached to the surface of the tubules or the vesicles of rough surfaced Endoplasmic Reticulum (rER) and helps in protein synthesis. The smooth surfaced Endoplasmic Reticulum (sER) helps lipid and steroid synthesis. An endoplasmic reticulum tubule may extend from cell membrane to nuclear membrane.

Golgi body / Golgi apparatus

This structure is composed of flat vesicles, secretory vesicles and micro vesicles. It is generally located close to the nucleus. The flat round vesicles are placed one after another and therefore in tissue sections it appears as a stack of tubules. The peripheral parts of these vesicles are little distended.

Actually the secretory vesicles are formed from these distended parts of the flat vesicles and move towards the peripheral surface of the cells. The micro vesicles are small in size and are generally located on the opposite surface of the stacked vesicles.

The protein molecules which are synthesized in the rER are carried by the micro vesicles to the flat vesicles. From the flat vesicles they go to secretory vesicles. The contents of the secretory vesicles are released at the cell surface as zymogen granules.

Mitochondria

These are small elongated double walled structures scattered throughout the cytoplasm. The inner membrane forms self like projections into the cavity of the organelle by making folds by itself. These selves are known as **Cristae**. The fluid which is filling the cavity of the mitochondria is known as matrix. The matrix contains enzymes of Krebs's citric acid cycle, respiratory enzymes, oxidative phosphorylase, etc. The number of this organelle is variable in different tissues. The number is more in Liver, Heart, and Kidneys due to requirement of more energy in these tissues.

Lysosomes

These are round or oval membrane bound bodies and contain hydrolytic enzymes like lipases, proteases, nucleases, phosphatases, etc. These enzymes can digest substances which enter the cell from outside and the substances which originate from its own cellular materials. They are absent in RBC. They are also called **suicidal bags**, because they will destroy the cell itself if their contents (enzymes) are released within the cell.

Ribosomes

These small granules having diameter of about $100\text{\AA}$ are scattered through cytoplasm either in free form or are attached to the surface of the endoplasmic reticulum. These are actually Ribonucleoprotein granules and help in the protein synthesis. They first appear in the nucleus and pass out to the cytoplasm through nuclear pores of nuclear membrane.

Centrioles

Centrosome is a dense zone of cytoplasm and remains close to the nucleus. It contains two dark particles known as centrioles. Each centriole is composed of an empty tubule formed by nine longitudinal bundles, each of which is made up of three microtubules.

Centrioles form spindle fibers during mitosis. Generally two centrioles are found in all cells which are capable of division.

Fibriles and filaments or Plasmosins

These are very fine filamentous structures form a network to give internal support to the cell. They are better developed in muscle cells, nerve cells and epithelial cells. They are formed by lengthwise joining of protein particles rich in Deoxyribonucleoprotein. These fibrils are called **Myofibrils** in muscle cells, **Neurofibrils** in nerve cells and **Tonofibrils** in epithelial cells.

TISSUE

The term tissue is derived from a French word which means texture or weave. Therefore anything looks like a woven material was called tissue. ***The tissue can be defined as a collection of similar cells perform similar type of function and united by intercellular substance.*** The animal body is composed of four elementary tissues

1. Epithelial tissue
2. Connective tissue
3. Muscular tissue
4. Nervous tissue

EPITHELIAL TISSUE

This tissue forms a membrane and covers free surfaces and lines hollow and tubular organs.

It possesses following characters –

1. The cells rest on a basement membrane which is attached to the basal surface of the epithelial cell and is composed of a basement lamina and a reticular lamina.
2. The cells are closely packed and the intercellular substance is minimum.
3. The non attached surface of the epithelium always remains free.
4. It is non vascular and gets nourishment from the blood vessels of the underlying lamina propria.

The epithelial tissue protects the animal body or an organ and helps in absorption, secretion and excretion.

According to the number of cell layers the epithelial tissue can be divided into different sub-groups.

- (a) Simple epithelium
- (b) Compound epithelium
- (c) Transitional epithelium

SIMPLE EPITHELIUM

When a single layer of cells are arranged on a basement membrane is called simple epithelium. According to the shape of these cells, the simple epithelium may be of following types

- A. Simple squamous epithelium
- B. Simple cuboidal epithelium
- C. Simple columnar epithelium
- D. Simple columnar ciliated epithelium
- E. Glandular epithelium

A. Simple squamous epithelium:

This epithelium is made up of single layer of flat cells placed tightly on a basement membrane. Other than protection it helps easy passage of liquid and gasses and has a dialyzing or filtering function. This epithelium forms serous membrane, alveoli of lungs, loops of Henle,

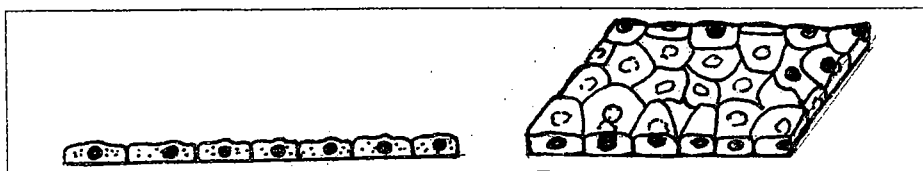


Fig. 1.2 Simple squamous epithelium.

Bowmans capsule, inner lining of heart and vessels. *Endothelium* is a term which is used for such an epithelium which lines vessels.

B. Simple cuboidal epithelium:

It is made up of a single layer of cube like cells placed on a thin basement membrane. Other than protection it has secretory and storage property. This epithelium is available in salivary glands, thyroid, terminal respiratory bronchioles etc. In the proximal convoluted tubule of this epithelium possess longitudinal striation at their free borders, and called brush bordered epithelium. The striation is due to the presence of finger like projections (microvilli) which is designed to increase absorptive surface.

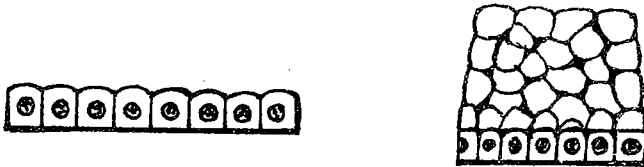


Fig. 1.3 Simple cuboidal epithelium.

C. Simple columnar epithelium:

It is formed by a single layer of cylindrical cells placed on a basement membrane. Each cell have a round nucleus at the centre or towards the basement membrane. The main function of this is absorption and secretion. They are found in stomach, intestine, gall bladder etc.

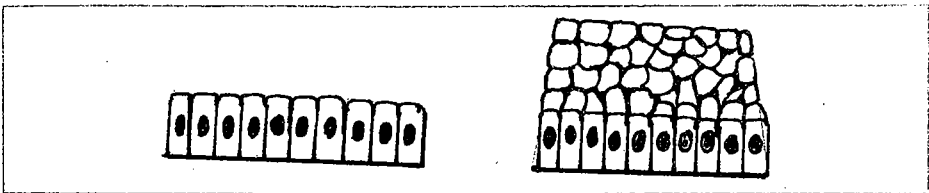


Fig. 1.4 Simple columnar epithelium.

The *goblet* cells are modified columnar cells. They contain mucinogen granules close to their free surfaces. When the number of granules increase the free end becomes swollen and finally burst out to discharge their secretions.

D. Simple columnar ciliated epithelium:

When the simple columnar epithelial cells have hair like processes (cilia) on their free surface, called columnar ciliated epithelium. Each of the cilia are attached to a particle present

in the cytoplasm of the cell close to the free border. These particles are called basal particles. This epithelium is found in the fallopian tube, trachea, vasa efferentia, ependymal cell, etc. Sometimes the cells may be low columnar or cuboidal type. These cilia help transportation of materials.



Fig. 1.5 Columnar ciliated.

E. Glandular epithelium:

The alveoli of many of the glands, such as thyroid, salivary glands, sweat glands, mammary glands, etc are lined by usually a single layer of cuboidal or low columnar cells. Ducts of some of these glands are also lined by similar epithelial tissue. These are known as glandular epithelium. These are mostly secretory cells of those glands.

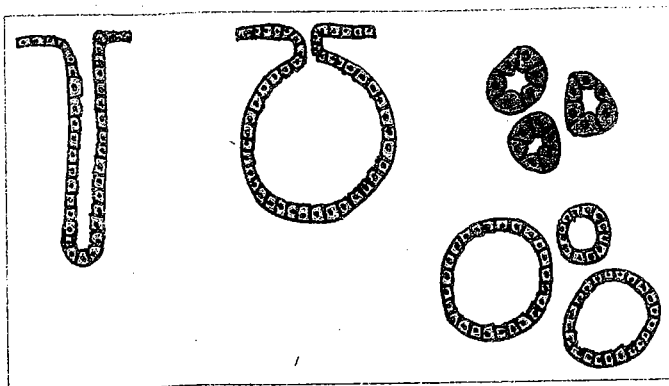


Fig. 1.6 Glandular epithelium.

COMPOUND EPITHELIUM

These epithelial tissues are formed by multiple layers (stratified) of cells arranged on a basement membrane. According to the shape of these cells, the compound epithelium is classified into following types :

- A. Stratified squamous epithelium
- B. Stratified columnar epithelium
- C. Stratified columnar ciliated epithelium

A. Stratified squamous epithelium

There are two types of such epithelium. - Stratified squamous cornified and stratified squamous non-cornified.

Stratified squamous cornified is present in such places where wear and tear is more and is exposed to atmosphere and friction. It is made up of multiple layers of cells and the superficial layer is

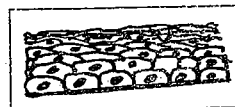


Fig. 1.7 Stratified squamous cornified.

covered by keratinized material. Skin is formed by this type of epithelium. Below the keratinized layer there remain few layers of flattened cells. However in the deeper layer the cells are polyhedral and in further deep layer they are columnar in shape. In this epithelium the surface cell layers (flat cells) die due to dehydration and lack of nutrition and subsequently become keratinized. Hoofs, horns and nails are modified stratified squamous cornified epithelium.



Fig. 1.8 Stratified squamous non-cornified.

Stratified squamous non-cornified epithelium is having similar histological characters to that of cornified but the keratinized layer is absent. This epithelium is present in mouth, pharynx vagina, anal canal, etc., where wear and tear is more and absorption is less.

B. Stratified Columnar epithelium

This epithelium is composed of several layers of columnar and fusiform cells. They are present only in some parts of pharynx, male urethra, fornix of conjunctiva etc.

C. Stratified columnar ciliated epithelium

Some parts of the laryngeal cavity and nasal surface of the soft palate is lined by multiple layers of columnar cells with cilia on the free surface of the superficial layer.

TRANSITIONAL EPITHELIUM

It is made up of three to four layers of cells – a) Superficial layer of polyhedral cells containing abundant cytoplasm, b) Intermediate pear shaped cells with their bases directed towards the superficial layer and tips directed towards the basement membrane and c) Next one or two layers of cuboidal cells. Transitional epithelium is found in the mucous membrane of urinary bladder, ureter, pelvis of kidneys and parts of urethra and therefore termed uroepithelium or urothelium.

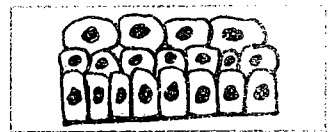
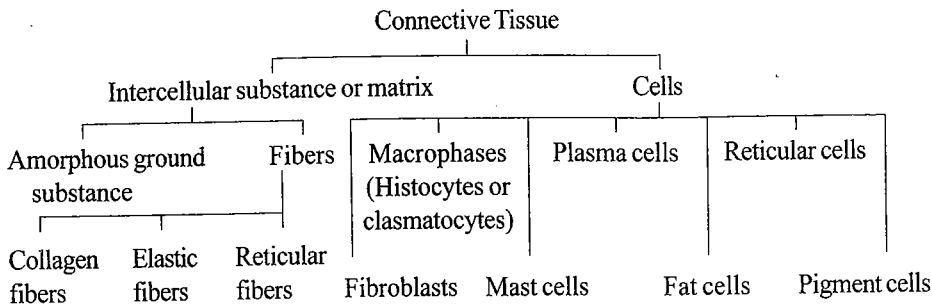


Fig. 1.9 Transitional epithelium.

The large superficial cells can withstand stretching of the distended urinary bladder by spreading themselves in a flat manner and are impermeable to fluid.

CONNECTIVE TISSUE

Tissues under this classification not only connect or bind or support other tissues of the body but perform many other functions. It also forms body fluids. This tissue is derived from mesoderm and composed of two types of substances – Cells and intercellular material.



The intercellular substance is composed of an amorphous ground substance and fibrous elements. The matrix is a nonliving material and is synthesized by connective tissue cells.

The **Amorphous ground substance** is mainly composed of water, electrolytes and mucopolysaccharides conjugated with proteins. The ground substance provides a framework of the tissue, helps in binding of cells as well as in the diffusion of metabolites. It acts as mechanical barrier to the cells and helps in preservation of water as tissue fluid. Formation of ground substance may be influenced by hormones. It diminishes with the advancement of age. It can be stained by PAS reagent and metachromically by toluidine blue or by alcian blue.

The **Fibrous elements** are collagen fibers, elastic fibers and reticular fibers. They are mostly derived from fibroblasts.

Collagen fibers

These are composed of bundles of white fibers. These fibers do not branch and do not run singly but in bundles. These bundles are wavy and run in different directions. These fibers are made up of collagen, a protein and produced by fibroblasts. Within the fibroblasts polypeptide chains are formed from amino acids including proline and lysine. They are hydroxylated to form procollagen with the help of Vitamin C. Three (3) procollagen chains unite to form triple helix tropocollagen molecule with the help of glycoproteins. These molecules are released by fibroblasts into the intercellular space and become polymerized to form collagen fibrils. These fibers stain **pink** with eosin, **red** in Van Gieson's stain and **blue** in Mallory's stain.

Elastic Fibers

These are also fibrous tissue and derived from fibroblasts and are little thicker. They are arranged singly or in small bundles but individual fibers may branch to form network. These fibers stretch and recoil easily. Some fibers may be yellowish in colour. They are found in various ligaments – Ligamentum nuchae, Ligamentum flava, in the wall of bronchi, in the wall of arteries etc. They are composed of a protein-tropo-elastin. They are resistant to chemical

treatment. These fibers may be stained with Weigert's resorchin fuchsin and with Verhoeff's stain.

Reticular Fibers

They are generally found in the reticular connective tissue particularly in association with the basement membrane. These are young collagen fibers and form a mesh work on which the cells of the organs rest. They branch and frequently anastomose with each other. The interspaces are small and are largely occupied by lymph and tissue fluid. The reticular fibers found in the lymph nodes, liver, spleen, bone marrow and in many other organs. They are stained with silver nitrate and PAS method.

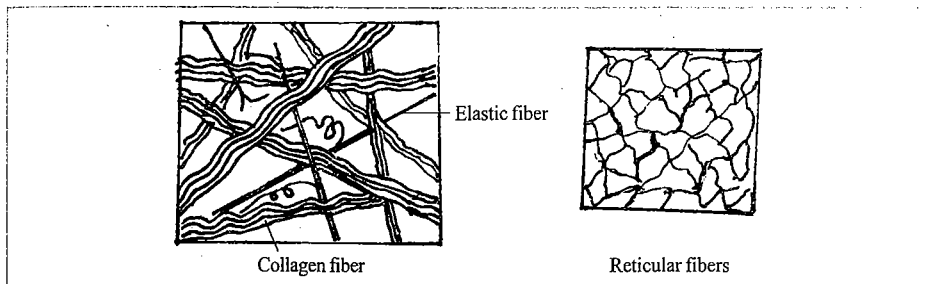


Fig. 1.10 Collagen, Elastic and Reticular fibers.

Cells of Connective tissue

FIBROBLASTS

These are young fibrocytes and are very active. These cells are fusiform or elongated in shape having numerous processes. Each cell contains an oval centrally placed nucleus. The cytoplasm is basophilic and contains rough surfaced ER, Golgi apparatus and Mitochondria. Old fibroblasts are called fibrocytes. They are inactive, elongated in shape and contain hyperchromatic nuclei. These cells help in the formation of collagen fibers by synthesizing tropocollagen protein. They also secrete mucopolysaccharide, reticulin and elastin. They help healing of wounds by continuous proliferation. They act as stem cells for other cellular components of connective tissue.

MACROPHAGES (Histiocytes or clasmatocytes)

They are large irregular cells containing one or more nuclei. The cytoplasm is basophilic. These cells belong to RE system. Active cells assume outline and move freely. The cells at rest are fixed to reticular fibers. These cells are phagocytic in nature and engulf foreign substances and therefore called big eaters or macrophages. They play role in antigen antibody reaction. They are

found in connective tissue as *histiocytes*, in blood as *monocytes*, in liver as *Kupffer's cells*, in lung as *alveolar phagocytes*, in lymphoid tissue as *reticular cells* and in CNS as *microglia*. They are stained as acidphosphatase (Lysosomal stain) and Aryl sulphate.

MAST CELLS

These are large round or oval cells with central nucleus and coarse intracytoplasmic granules. They are present in the fibrous capsules of liver and other organs, along the blood vessels and in synovial membrane. These cells produce heparin, histamine and small amount of serotonin. They also help in the formation of hyaluronic acid in the matrix. Occasionally the cytophelic antibodies (Ig E) are absorbed on the surface of these Mast cells. When specific antigen enters into the body an antigen-antibody reaction takes place on the surface of these Mast cells and histamin liberates. This event then leads to anaphylactic or allergic reaction. Mast cells may be stained with Anilin dyes.

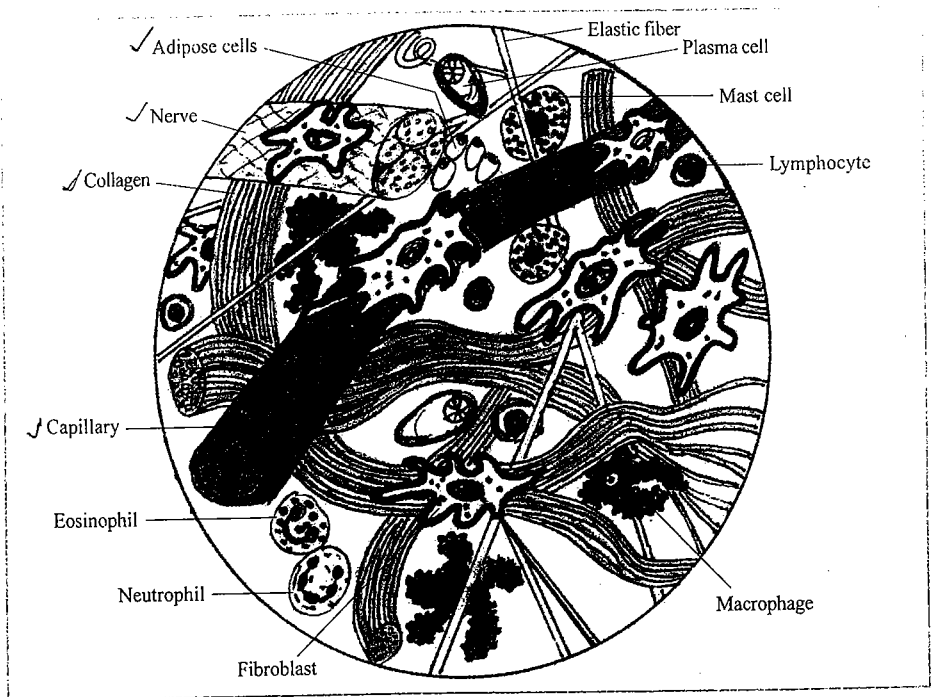


Fig. 1.11 Connective tissue cells.

PLASMA CELLS

These are large oval cells with eccentric nucleus. The chromatin materials of the nucleus give a cart wheel appearance. They are found in the lymphoid tissue and in the greater

omentum. The cytoplasm contains plenty of granular Endoplasmic Reticulum. The B-lymphocytes which are derived from the bone marrow through different lymphoid tissue, differentiate into plasma cells when exposed to specific antigen. The cytoplasm contains a Golgi complex which appear as an empty space in one side of cytoplasm under light microscope. Plasma cells liberate humoral antibody (IgG) and help in the defence mechanism of the body. These cells can be stained by basic dyes.

FAT CELLS

These are fat containing large rounded or polyhedral cells found in the adipose tissue. Due to presence of large number of fat granules, the cytoplasm is pushed peripherally and the nucleus is pushed to one side. Therefore it looks like a signet ring in H&E stained slides as the fat globules appear to be an empty space. The average diameter of fat cells is about 50 microns.

RETICULAR CELLS

In some glands fine network of reticulin fibers are produced by some branched flattened cells, called Reticular cells. It is difficult to differentiate these cells from fibroblasts. These cells are phagocytic in nature and act as stem cells for the cellular constituent of blood.

PIGMENT CELLS

Pigment containing cells are called Pigment cells. These cytoplasmic pigments are responsible for formation of colour. The pigment is called melanin and the cells are called *melanocytes*. These cells are found in the skin. In some lower vertebrates the pigment cells are yellow in colour. These pigments generally remain around the nucleus. But due to change of environment these pigments may disperse in the cytoplasm and therefore may lead to change in body colour. Melanocytes are generally stellate shaped cells with long processes and are derived from neural crest cells.

Classification of Connective tissue

On the basis of functional importance the connective tissues may collectively be classified into a) Areolar tissue, b) Adipose tissue c) White fibrous tissue, d) Yellow elastic tissue e) Reticular tissue, f) Mucoïd tissue g) Blood and hemopoietic tissue and h) Sclerous tissue.

AREOLAR TISSUE

This is a loose connective tissue and is present in the areas where mobility is required. It is found in the subcutaneous region of eye-lid, penis, submucous coat of alimentary canal, in

the subserous zone and within the wall of viscera. It is composed of **white collagen fibers**, **yellow elastic fibers**, **reticular fibers** and various types of cells such as **Fibroblasts**, **Histiocytes** **Plasma cells**, etc.

ADIPOSE TISSUE

It is situated in the zone where fat is deposited for the purpose of giving shape of the body parts like limbs, for positioning of some organs and viscera and for storing energy in the form of mesenteric or omental fat. It is composed of **fat cells**, which contain free fat inside, **supported by loose framework of areolar tissue**.

WHITE FIBROUS TISSUE

It is present in the region where tensile strength is needed. This tissue is found in the ligaments tendons and in sheaths. It is formed mainly by wavy bundles of **white collagen fibers** which run in different directions without branching. These fibers are derived from fibroblasts

YELLOW ELASTIC TISSUE

This tissue is found in hollow viscera where restoration of configuration is required. They are also found in some ligaments. They are yellowish in colour. The fibers are thinner than collagen fibers. The fibers branch and re-join freely, e.g. elastic lamina of aortic wall, ligamenta flava etc.

RETICULAR TISSUE

Already mentioned.

MUCOID TISSUE

These are semisolid substances and composed of abundant matrix and few cells with branching processes. They are found in the umbilical cord as **Whartons jelly**, in the eye ball as **vitreous body**, in the developing tooth as **pulp**, etc.

BLOOD AND HEMOPOETIC TISSUE

These are of two types – a) Myeloid tissue and b) Lymphatic tissue.

The Myeloid tissue produces RBC, granular WBC and platelets. These cells are phagocytic in nature.

Lymphatic tissue produces lymphocytes. This tissue may be i) noncapsulated or ii) capsulated. The lymphatic tissue in the form of aggregations in the loose connective tissue, such as Peyer's patches are the examples of noncapsulated lymphatic tissue. Lymph nodes, thymus, spleen, lymph glands, tonsils etc. are the capsulated lymphatic tissue.

SCLEROUS TISSUE

This is a specialized connective tissue and responsible for formation of general framework of the body as well as of some viscera to support soft structures. It is of two types (i) Cartilage and (ii) Bone.

CARTILAGE

This is a semi hard connective tissue which has a high tensile strength, rigidity, elasticity and resistance to compressive force. It has low vascularity and capacity for growth. Cartilage tissue is present on the articular surfaces of the long bones, walls of the thorax, in the larynx, trachea, bronchi, ear, nose, intra-articular discs, etc. The cartilage which is replaced by bones are known as temporary cartilage. The tissue is composed of abundant intercellular substance or matrix and less quantity of cells. The **Matrix** is composed an amorphous ground substance, made up of water, proteoglycans, lipids and collagenous fibers.

Cartilage cells – The young cells are small and irregular in shape. These cells are more active and are called Chondroblasts. The mature cells are large and more or less rounded in appearance. They are called Chondrocytes. These cells occupy small empty spaces within the ground substance called lacunae.

According to the number of cells and the characteristics of the ground substance the cartilage is classified into a) Hyaline cartilage, b) White fibro-cartilage and c) Yellow elastic cartilage.

Hyaline Cartilage – This cartilage looks like translucent glass and composed of cells and clear ground substance. The ground substance consists mostly of chondroitin sulphate and a few collagen fibers. Most of the cartilages of the body such as articular cartilage, costal cartilages, laryngeal cartilages (except epiglottis), tracheal and bronchial cartilages belong to this group. Excepting articular cartilages, all hyaline cartilages are covered by a fibrous membrane known as perichondrium. The cells are generally arranged in groups of 2, 4, etc. These cells are formed by multiplication of a single parent cell and are therefore found in close association. These cell groups are called cell nests. These cells are large with large nucleus and glycogen rich cytoplasm.

Articular hyaline cartilage covers the articulating ends of bones in the diarthrodial joints and provides smooth surface to create a wear resistant and friction free environment. This cartilage derives its nutrition from the synovial fluid by which its surface is bathed and from

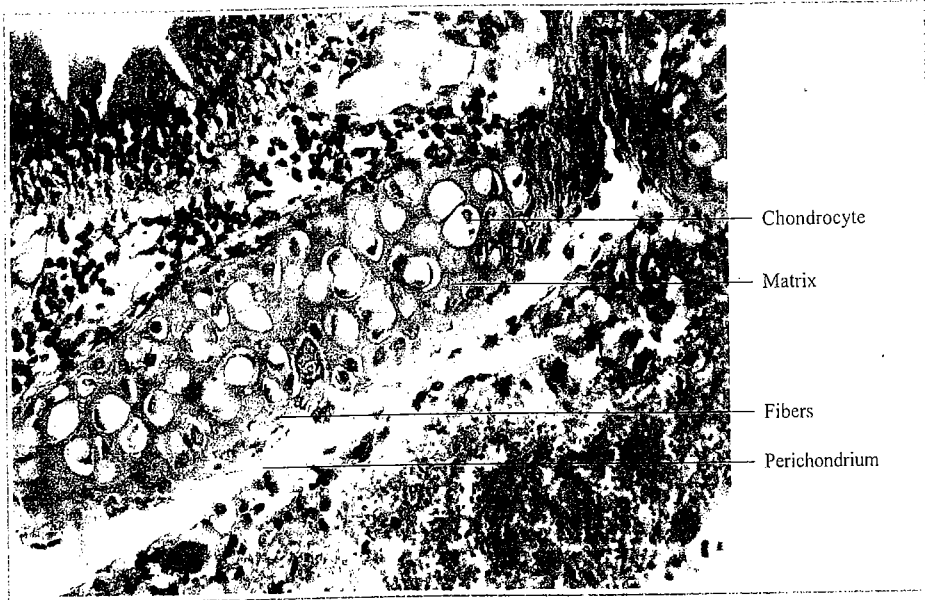


Fig. 1.12A Section of Hyaline cartilage.

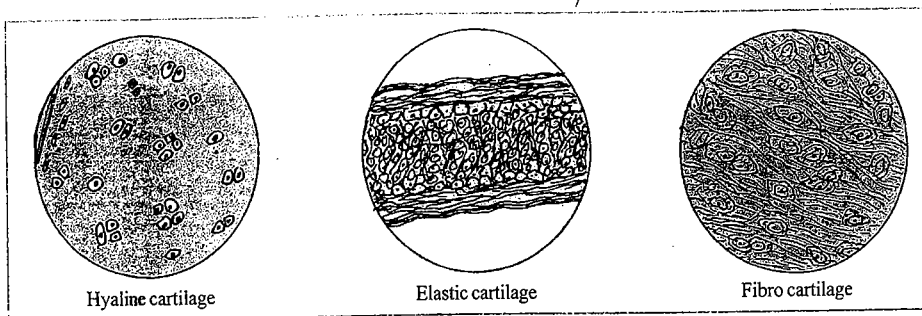


Fig. 1.12B

the vessels of synovial membrane and hypochondrium. The cells are generally arranged in four zones. The superficial cells (zone-I) are small ovoid or elongated and are arranged parallel to the surface. The intermediate cells (zone-II) are large round and most active. In the next layer (zone-III) the large round cells are arranged in a radiating manner, perpendicular to the surface. In the deep layer (zone-IV) the cartilage cells die and bone formation starts.

White fibro-cartilage – This cartilage is composed of bundles of white fibrous tissue in the matrix and scattered groups of cartilage cells. These cells are oval or round in shape and remain surrounded by fibers. These cartilages are present in the areas where maximum

tensile strength, flexibility as well as rigidity is necessary. They are found in the intervertebral discs, menisci, pelvic symphysis, etc.

Yellow elastic cartilage – The matrix of this cartilage is composed of amorphous intercellular ground substance which is traversed by yellow elastic fibers and typical chondrocytes. These fibers branch and anastomose with each other. It provides elasticity and at the same time rigidity to maintain shape of certain organs. They are present in the pinna / auriculum and in some laryngeal cartilages.

BONE

Bones are specialized hard connective tissue, made up of the followings:

- (a) Periosteum
- (b) Articular cartilage
- (c) Bone cells
- (d) Inter cellular substance
- (e) Bone marrow

(a) **Periosteum** – This is a membrane which covers the outer surface of the bone except articular surfaces. It's outer layer is composed of fibers and blood vessels and the inner layer contains osteoblasts which help in ossification and hence called osteogenic layer. Periosteum not only covers the bone but helps in its growth and repair. Periosteum is attached to the underlying bone by collagen fibers. Periosteum is not present on the sesamoid bones.

(b) **Articular cartilage** – These cartilages cover the articular ends of the bones to provide friction- free smooth surface. They are made up of hyaline cartilage. The cells of these cartilage are almost round or elongated and are arranged singly or in groups of even number of cells. These are presumed to be the offsprings of common parent cells.

(c) **Bone cells** – These are i) osteoblasts, ii) osteoclasts and iii) osteocytes.

i) **osteoblasts** are round or oval cells with processes and large nucleus. The cytoplasm is basophilic and contains large number of rER. The cytoplasm is rich in Alkaline phosphatase and helps in mineralization of bone matrix. These are very active cells and produce collagen fibers and organic materials.

ii) **osteoclasts** are large multinucleated cells with pale foamy eosinophilic cytoplasm which is rich in Acid-phosphatase. These cells do not have processes but are provided with branched borders. Osteoclasts are derived from mesenchymal cells like osteoblasts or formed by the fusion of few osteoblasts. They reabsorb bone salts and are active during growth and re-modelling.

iii) **osteocytes** are the mature bone cells and are derived from osteoblasts. Each of these cells are housed within tiny spaces surrounded by matrix known as lacunae.

These are flattened cells with numerous processes and centrally placed nucleus. The processes are accommodated within the minute canals which extend from the lacunae called canaliculi.

(d) **Intercellular substance** – The intercellular ground substance comprises of organic materials and inorganic bone salts. The organic materials are mainly protein polysaccharide complex and collagen fibers embedded in calcified matrix. Inorganic materials are calcium phosphate, calcium carbonate, magnesium phosphate, sodium carbonate etc.

(e) **Bone Marrow** – This is a soft, pulpy and vascular tissue accommodated in the medullary cavity of long bone, and in the marrow spaces of the spongy bones. There are two types of bone marrow – Red and Yellow.

i) Red marrow contains blood cells at their different stages of development, reticular connective tissues, fat cells, lymphoid cells, blood vessels and occasionally megakaryocytes.

ii) Yellow marrow contains connective tissue, blood vessels, fat cells and few mature and immature blood cells.

In infants bone marrow is generally red. With the advancement of age red bone marrow gradually replaced by yellow marrow.

Types of bone

There are two types of bone – compact and spongy.

1. Compact bone

It forms the wall of long cylindrical bones. There is a definite pattern of arrangement in the compact bone called **Osteones or Haversian System**. This system comprises of the following:

Haversian canals

These are parallel arranged small canals along the long axis of the bone and are situated at the center of the Haversian system. They accommodate blood vessels, nerves and lymphatics. These parallel canals are communicated by side branches. They communicate with marrow cavity as well as with surroundings through transverse **canals of Volkmann**.

Lamelle

They are bony layers concentrically arranged around the Haversian canals. These are made up of fine collagen bundles in calcified matrix. The number of these concentric lamellae generally varies from 5 to 10.

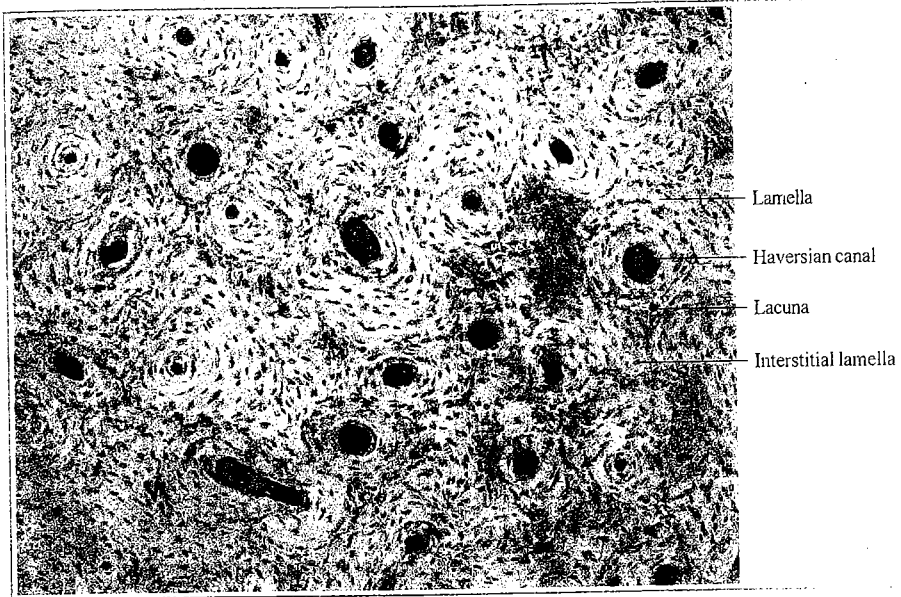


Fig. 1.13 Section of compact bone showing Haversian system.

At the superficial portion and along the circumference of the long bones few lamellae run parallel to the surface. These outer lamellae are called circumferential lamellae. In between the Haversian systems some irregular bony deposits are found. These are called interstitial lamellae.

Lacunae

These are spaces between these lamellae where osteocytes are housed. From these lacunar spaces very fine canals extend all around in a radiating manner which accommodate fine cytoplasmic processes of the osteocytes. These are known as **canaliculi**. Neighboring lacunae communicate through these canaliculi with each other and also with periosteal tissue spaces.

2. Spongy bone

The substance of all the bones other than shaft of long bones are composed of spongy bone. It looks like hard sponge and contains numerous small spaces between the bony trabeculae and spicules and therefore also called cancellous bone. However at the periphery these trabeculae merge with a thin layer of compact bone. The bony trabeculae or the spicules are arranged in such a manner that no osteone is formed.

Although the spongy substance appears to be an irregular network, there is some definite pattern of placement of the bony plates along the line of force which is to be exerted by the bone in living condition.

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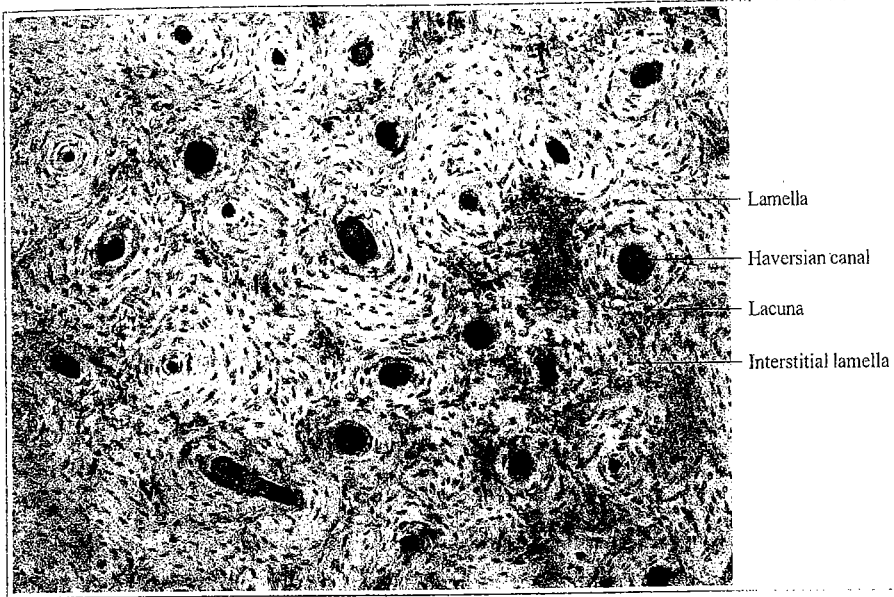


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MUSCULAR TISSUE

This is a specialized tissue having the property of contractility and designed for movements of the body. Excepting few, most of the muscles are derived from mesoderm. Only some small muscles, such as arrector pilorum muscles of iris are ectodermal in origin. Three types of muscles are available in the body as follows :

(I) Skeletal muscle, (II) Visceral muscle and (III) Cardiac muscle.

SKELETAL MUSCLE

These muscles are attached to the bones and therefore named skeletal. They are voluntary in nature and striated in appearance under microscope.

Composition

A number of fine myofibrils are enclosed in a connective tissue sheath called endomysium and form a muscle fiber. Many muscle fibers are enclosed by another connective tissue membrane or septa known as perimysium and form a muscle bundle or fasciculus. A good number of fasciculi are covered outside by a connective tissue coat called perimysium and a muscle is formed. The muscle fibers are considered to be units of muscle.

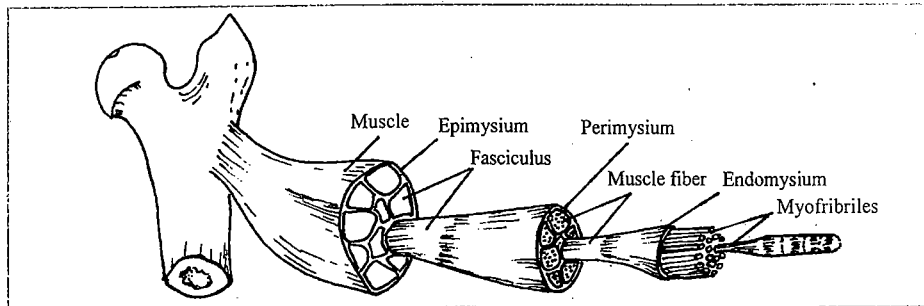


Fig. 1.14 Skeletal muscle.

Structure

A muscle fiber is composed of elongated tubular cells with multiple nuclei and extends along the of the muscle. A fiber may be 1 to 40 mm in length and 10 micron to 100 micron in breadth.

Sarcolemma

The outer transparent cell membrane of the muscle fiber, having a thickness of about 75Å is called **Sarcolemma**. Like other cell membrane it is composed of outer and inner protein

layers and an intermediate lipid layer. The sarcolemma maintains a higher concentration Na^+ and Cl^- outside and a higher concentration of K^+ inside which results a potential difference of -70 millivolts between them. With the arrival of a nerve impulse at the motor end plate the potential difference abolishes (i.e. depolarization occurs) and the muscle fiber contracts. Inside sarcolemma elongated myofibrils, multiple nuclei, mitochondria, a small golgi apparatus are embedded in the sarcoplasm.

Sarcoplasm

It is the semifluid non contractile cytoplasm of the muscle cell where other constituents of the cell are embedded.

Nuclei – Numerous elongated nuclei are found beneath the sarcolemma. Several hundred nuclei may be present in a single muscle fiber.

Mitochondria or sarcosomes are situated in rows in between the myofibrils and provide energy to the muscle.

Myofibrils

These are parallel thread like structures situated along the length of the muscle fibers. Each myofibril is composed of longitudinally arranged fine **myofilaments**. The myofibrils present along its length alternate dark band and a light band. This dark band is doubly refractive and anisotropic in nature and also known as A band. The light band is non-refractive and isotropic in nature and also called I band.

These A band and I band of adjacent myofibrils are aligned transversely and give a muscle fiber a cross striated appearance. At the middle of the I band, a thin dark transverse line is

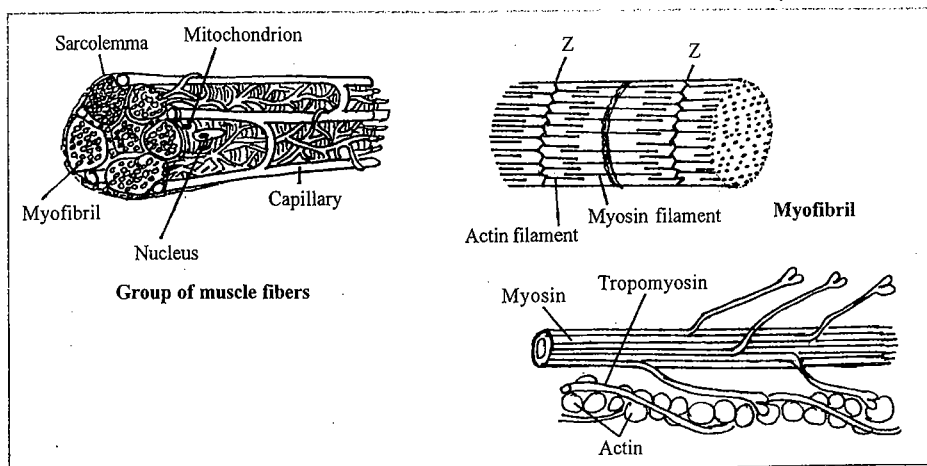


Fig. 1.15

present. This is known as Z line or Z disc. The portion of the myofibril in between two adjacent z discs is known as **sarcomere**. The sarcomeres are considered to be the contractile unit of a myofibril. Each sarcomere is about 2.5 micron long in a muscle at rest. The A band is bisected at the middle by a lighter zone known as H band. Within the H band a narrow dark line is seen called M band.

Myofilaments

These are fine thread like protein filaments, arranged longitudinally within the myofibrils. They are of three varieties—Myosin, Actin and Tropomyosin.

Myosin filaments – They are thicker and situated longitudinally parallel to each other in the dark A band. These filaments become more thick at the middle (M line) during contraction. They are composed of rods of myosin molecules with globular projection at one end and therefore appears as peripheral buds on the surface on EM.

The rod portion is called light meromyosin and the globular head portion is called heavy meromyosin. These myosin heads link with the actin filaments during contraction.

Actin filaments – These are thin and long filaments and extend from the Z band towards A band. During relaxation they fail to reach the middle of A band and therefore H band becomes prominent. The actin filaments are composed of globular subunits of G-actins in a double chain of a helix. The actin filament twist in opposite direction on either side of the Z disc and make the Z disc in a zigzag outline.

Tropomyosin filaments – These protein filaments originate at the groove between the two strands of helical actin filaments.

Sarcoplasmic reticulum

The myofibrils are surrounded by smooth surfaced circular and branching tubules derived as tubular ingrowths from the sarcolemma. These tubules are called sarcoplasmic reticulum. The circular tubules are known as centrotubules and extend around the Z disc and also called T system membrane. These tubules play a role of conveying the waves of depolarization from the sarcolemma to every sarcomere.

VISCERAL MUSCLES

These muscles form the wall of hollow visceral organs, ducts, glands, blood vessels, etc. and therefore called visceral muscles. They are involuntary in nature. These muscle fibers are not transversely striated and for this reason they are also called smooth muscle.

Composition – This muscle is composed of numerous spindle shaped muscle fibers of various length and are arranged in a compact manner in sheets or layers. The fibers are held

together by areolar tissue and are organized according to the function of the viscera. They may be longitudinal, circular, spiral or irregular.

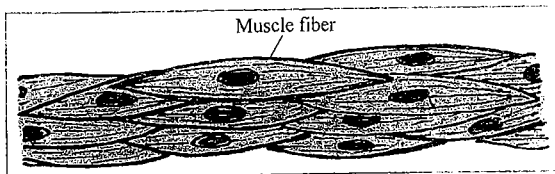


Fig. 1.16 Smooth muscle.

Structure – The structure of these muscle fibers are elongated and fusiform. The central portion is wide and the ends are tapering. The average length is about 200 microns and breadth of the central wide portion is about 6 microns. The cytoplasm contains longitudinally arranged myofibrils. The nucleus is elongated, oval and centrally placed. The fibers are arranged in such a way, that the thick middle portion remain in contact with the thin portion of the other. Mitochondria are present between myofibrils. The sarcoplasm is homogeneous. No band or cross striations are seen. Actin and myosin filaments are present. Sarcolemma is surrounded by a basement membrane and reticular fibers which join with the reticular fibers of adjacent cells.

CARDIAC MUSCLE

This muscle forms the wall (Myocardium) of heart and roots of large blood vessels attached to the heart. It is involuntary in nature and contracts rhythmically. The fibers exhibit striations.

Composition – The cardiac muscle is composed of numerous specialized types of muscle fibers which bifurcate and come in contact with neighboring fibers and appears falsely as a syncytial structure under light microscope. The cross striations are not prominent in these fibers. The cytoplasm shows a dark transverse line at certain intervals which make the limiting membranes of two adjacent cells called **Intercalated disc**.

Structure – These muscle fibers or myocytes are separated from each other by endomysium. Each fiber is about 80 micron in length and 16 micron in breadth. These muscle cells divide into two or more branches and come in contact with neighboring cells. Each cell contains a single centrally placed elongated nucleus. Perimysium is found between the fiber bundles. Mitochondria are more numerous and are arranged in rows in between the myofibrils. Sarcoplasmic reticulum is similar to those of skeletal muscles. T system is present at the level of Z line.

Myoglobin and glycogen are abundant in cardiac muscle. Myofibrils are more or

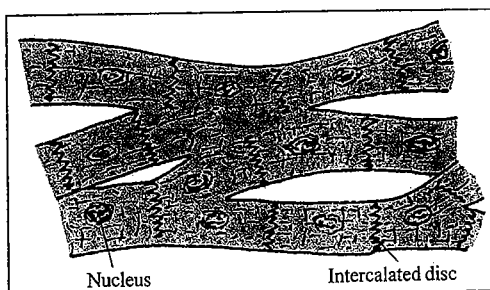


Fig. 1.17 Cardiac muscle.

less similar to those of skeletal muscles. The intercalated discs extend across the whole width of the fiber or its branches. The individual muscle cells join end to end by intercalated discs.

NERVOUS TISSUE

The nervous system receives information with regards to the change of environment (external and internal) of the body and in response regulates appropriate function. Therefore the tissue of this system is specialized in nature and complex in structure. Except the microglia the tissue of the system are ectodermal in origin. Microglia develop from mesoderm.

The morphological sub division of this system is as follows: A) Central Nervous System (CNS) – This part comprises of brain and spinal cord and remains covered by bones. B) Peripheral Nervous System (PNS) – This is composed of cranial and spinal nerves and their ganglia. C) Autonomic Nervous System (ANS) – This is the visceral component of the nervous system and composed of autonomic nerves, ganglia and specialized parts of CNS and PNS.

There are two types of basic cells in the nervous tissue. These are Neurons (main cells) and Neuroglia (supporting cells). Some other cells such as ependymal cells of CNS and Schwann cells of P N S are also important constituents of the nervous tissue.

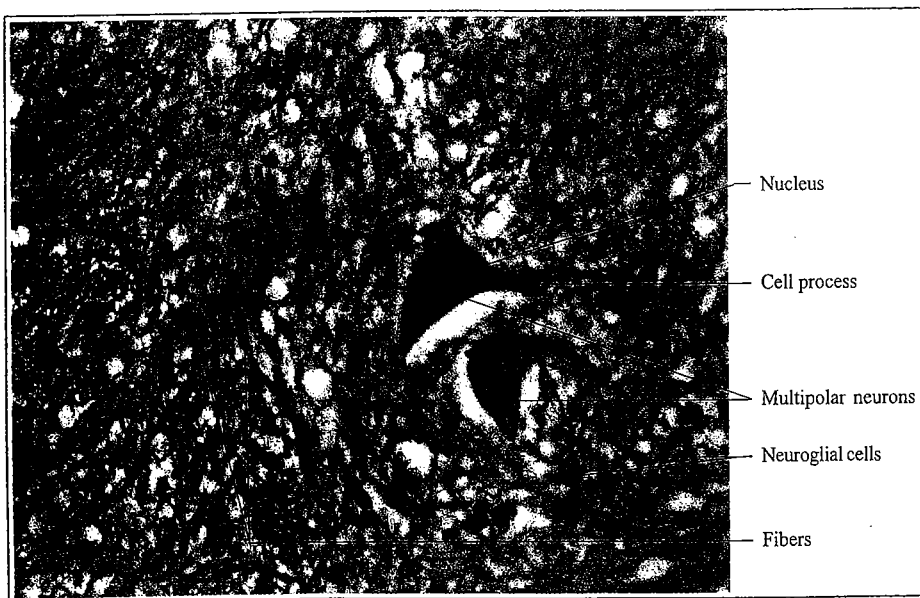


Fig. 1.18A Section of nerve tissue.

NEURONS

These are the excitable parenchymal cells and are the structural and functional unit of the nervous system. A neuron is composed of a cell body or soma and cytoplasmic extensions from the cell. These processes are of two types—one or more dendrites which convey impulses towards the cell body and a single axon conveying impulses away from the soma.

Cell body or soma

These are present in the grey matter, in various nuclei of CNS and in the ganglia of PNS and ANS. The **size** of the cells varies from 5μ to 130μ depending upon their situation. The **shape** of these cells depends on the number of dendrites. The multipolar cells are generally star shaped or pyramid shaped and the unipolar or pseudo-unipolar cells are round in shape. Some bipolar cells are fusiform or flask like in appearance. The Nucleus is mostly central in position. It is large vesicular and contains a prominent nucleolus. However in injury or in the fatigue state of the nerve cells the nucleus may be eccentric in position.

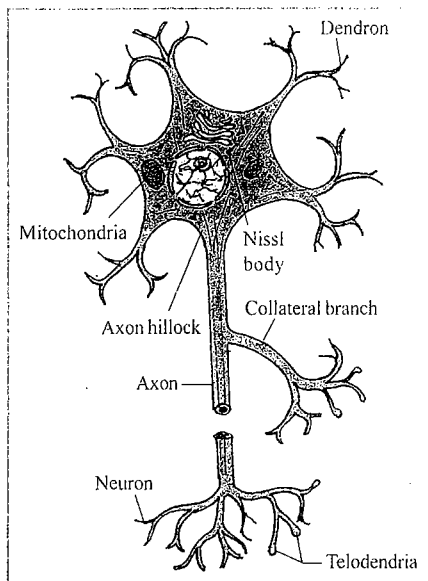


Fig. 1.18B

Plasma membrane

It contains integral membrane proteins and functions as ion-selective channels for K, Na, Ca cations and Cl anions. The plasma membrane of the cell body and dendrites contains receptor-protein molecules which become activated by neurotransmitters from other neurons.

The cytoplasm contains the following structures :

Neurofilaments – These are fine thread like cytoplasmic fibrils arranged in a plexiform manner within the cell body and processes. They provide mechanical support to the cell body. These filaments and microtubules crowd together at the axon hillock.

Nissl bodies – These are small triangular structures, present in the cytoplasm of the cell body and dendrites but absent in the axon hillock and axon as they cannot percolate through the crowded neurofibrils. Closely packed ribosome granules in combination with iron become attached to rough surfaced endoplasmic reticulum to form Nissl bodies. These bodies are associated with the synthesis of proteins and enzymes. These bodies degenerate and

disappear when the neurone is injured. This is called chromatolysis. They re-appear with the recovery of the neuron.

Mitochondria – These are oval elongated in shape and distributed throughout the cytoplasm of the cell body and processes.

Golgi apparatus – It is placed close to the nucleus in some neurons. In some neurons it helps in storing and releasing neurosecretions.

Lysosomes – These thick walled membranous vesicles with their enzymes hydrolyse Nissl bodies during chromatolysis.

Centrioles – Since the adult neurons do not divide it was believed that there is no centrioles in the nerve cells but its presence has been demonstrated by EM. They probably help regeneration of the cytoplasmic microtubules.

Inclusions – Neuro-melanin, a degradation product of catecholamine, found in the cell bodies of substantia nigra of mid brain. Lipochrome and senility pigments- Lipofuscin appear as clumps of granules in the neurons of old age. Metallic elements like Copper, Zinc and Iron may also be found in some neurons.

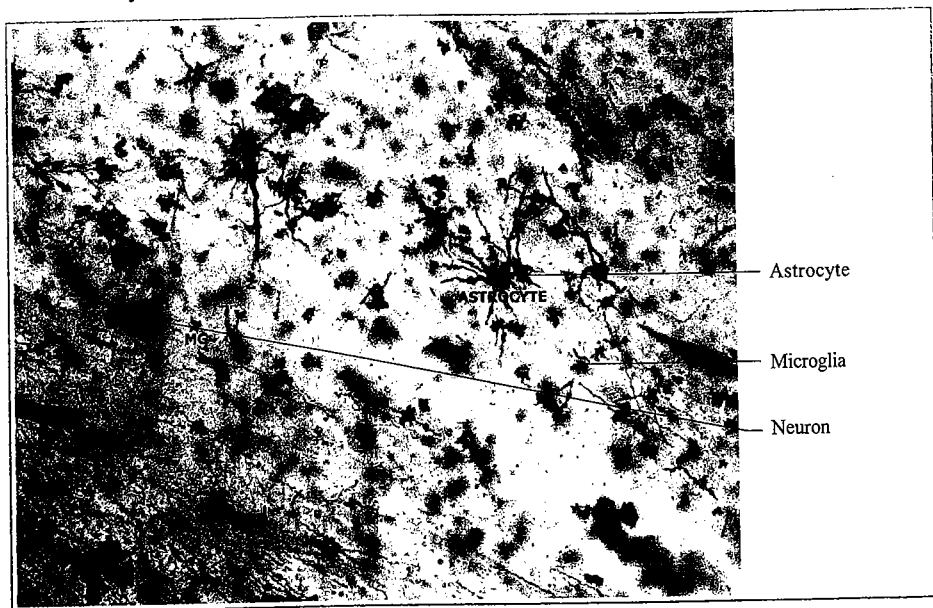


Fig. 1.18C Section of nerve tissue (Golgi cox).

Cell processes

Dendrites – These are afferent processes or cytoplasmic extensions of the cell bodies of neurons. They may be single or multiple. They receive and convey nerve impulses towards

the cell body. They may branch tremendously. The surfaces of these branches are studded with numerous projections called spines, which act as contact zones with other neurons. Dendrites of some peripheral nerves have structures similar to those of axons.

Axons – This is the single long process extends from cell body and generally carry nerve impulses away. The point of origin of this process from the cell body is known as **axon hillock**. Axon forms the structural basis of a nerve fiber. The axon is slender, long tubular structure of almost uniform diameter. The length of an axon may be more than one meter. It remains filled up by a fluid known as **axoplasm** which accommodates mitochondria and neurofilaments. The axon remains surrounded by a **myelin sheath**. The Schwann cells undergo spiralling around the axon and deposit concentric layers of lipid and protein to form myelin sheath. In somatic nerves the myelin sheath is covered by **neurolemma** – formed by the body of the Schwann cells. Post ganglionic autonomic fibers have no myelin sheath. The preganglionic autonomic fibers are myelinated. In the CNS the myelin sheath is derived from oligodendrocytes. In myelinated nerve collateral branches arise at right angles from the side of the axon at the node of Ranvier. The terminal branches of the axon or its collaterals are known as **Telodendria**. These terminals form bulber swellings at their ends known as **Terminal knobs** or boutons. A special form of termination of axon in a skeletal muscle is known as **motor end plate**. **Node of Ranvier** - At the myelinated nerve fibers, gaps occur at the junction between Schwann cells where the axon cylinder is exposed. These gaps are known as nodes of Ranvier.

Classification of Neurons

According to the number of processes

1. *Unipolar neurons*

When a nerve cell possesses only one process (axon), it is called unipolar neuron. True unipolar neurons are found only in the mesencephalic nucleus of trigeminal nerve.

The cells of the dorsal root ganglions of spinal nerves and of corresponding ganglia of cranial nerves have single process at the beginning. But it bifurcates into a peripheral

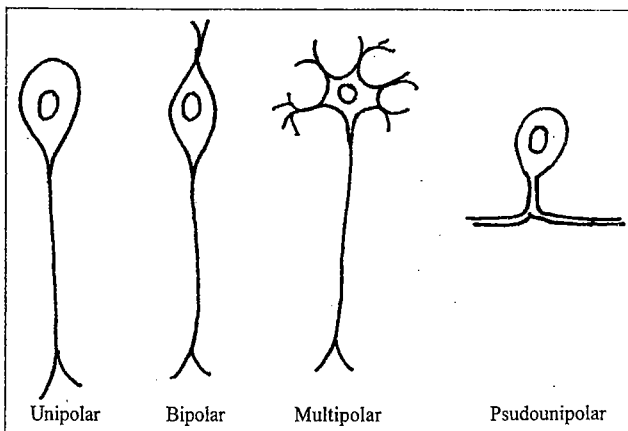


Fig. 1.19

part and a central part. The peripheral branches are long and extend to the muscles and skin and are dendritic in function. The central branches enter CNS through dorsal roots and are axonal in function. These neurons are called pseudo-unipolar neurons because developmentally these cells are bipolar and their two poles subsequently united to form a single process.

2. *Bipolar neurons*

Neurons with two processes are called bipolar neurons. They are generally spindle shaped cells and are found in the spiral ganglion of cochlea, olfactory epithelium and retina.

3. *Multipolar neurons*

The neurons having more than two processes are called multipolar neurons. Most of the neurons of CNS are multipolar.

According to the length of axon, these cells are divided into the following subgroups.

Golgi type-I neurons – They have long axons. They may form tracts or pass out of the spinal cord through peripheral nerves. Example – tract cells, ventral horn cells.

Golgi type-II neurons – These cells have short axon. They are generally confined in the CNS, Example – Association neurons.

According to the shape and size of the cell body

1. **Stellate** – star shaped
2. **Fusiform** – spindle shaped
3. **Basket** – A neuron whose fibrils of axon surround the cell body of another neuron.
4. **Flask shaped** – shape in like a flask
5. **Pyramidal** – pyramid in shape

Large neurons may be more than 100 μ in diameter; e.g., Purkinje cells and Golgi cells of cerebellum, spinal ganglionic cells etc. The neurons with a diameter less than 7 μ are called micro neurons; e.g., granular cells of cerebellum.

According to the function

1. *Sensory neurons (afferent)*

The cells are mostly pseudounipolar or bipolar. These cells carry sensations from periphery to the CNS and are situated outside CNS (except mesencephalic nucleus); e.g., cells of dorsal root ganglion.

2. Internuncial (connector) neurons

They are the connector or inter neurons. They are generally multipolar and remain confined within the grey matter of spinal cord or brain.

3. Motor neurons (efferent)

These are multipolar cells and are mostly situated in the CNS. However, post ganglionic autonomic neurons are situated outside CNS.

The motor neurons of the cerebral cortex and cranial part of brain stems are called upper motor neurons and those of spinal cord and caudal part of brain stem are called lower motor neurons.

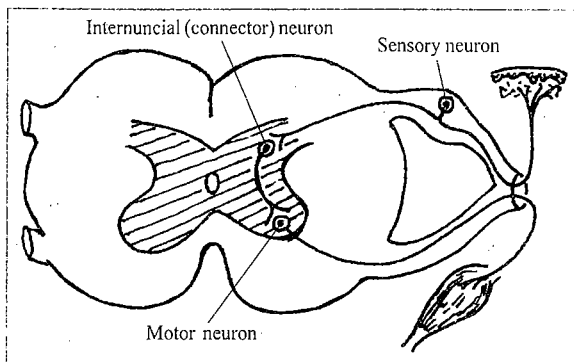


Fig. 1.20

Nuclei and ganglia

A group of neurons situated in a particular area of CNS, is called **nucleus** and such group of cells present in a particular structure out side CNS, is called **ganglion**. However, this rule is not always followed.

Nerve fibers

They are the axons or dendrons of a nerve cells. They are classified on the basis of myelin sheath.

a) **Myelinated (medulated) fibers** – Here the axons are enveloped by myelin or medullary sheath which is composed of lipoprotein complex containing unsaturated fatty acid and formed by many layers of modified cell membrane. It gives the white colour of the nerve. These are found in the peripheral

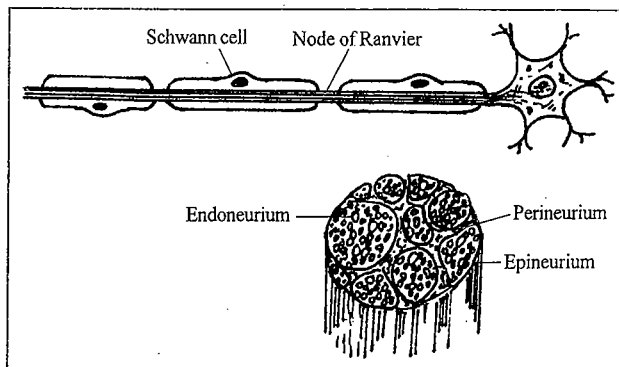


Fig. 1.20 Myelinated nerve fiber.

nerves and in the white matter of the CNS. Myelin sheath is derived from the Schwann cells in the peripheral nerves and oligodendrocytes in CNS.

b) **Unmyelinated nerve fibers** – They are found in the postganglionic autonomic fibers and in some smaller axons in the CNS. In the PNS the *fibers are enveloped within simple clefts of Schwann cells* without any spiraling. The *nodes of Ranvier are absent*. In the CNS the fibers are not ensheathed and run free among the processes of other neurons and glial cells.

c) **Naked nerve fibers** – They are found in the grey matter of CNS and in the free nerve endings. They are devoid of myelin sheath and sheath of Schwann cells.

Supporting cells of the nervous system

- C N S a) Neuroglia
 b) Ependyma
- P N S a) Schwann cells
 b) Satellite cells

Neuroglia

These supporting cells of CNS are nonconducting elements and form a framework in between the neurons. The number of these cells are many times more than the number of neurons. They are of following types:

i) **Macroglia** – They are moderately large cells and include astrocytes and oligodendrocytes.

Astrocytes – These are star shaped cells with numerous branched processes and contain large round or oval nucleus. They are developed from the embryonic

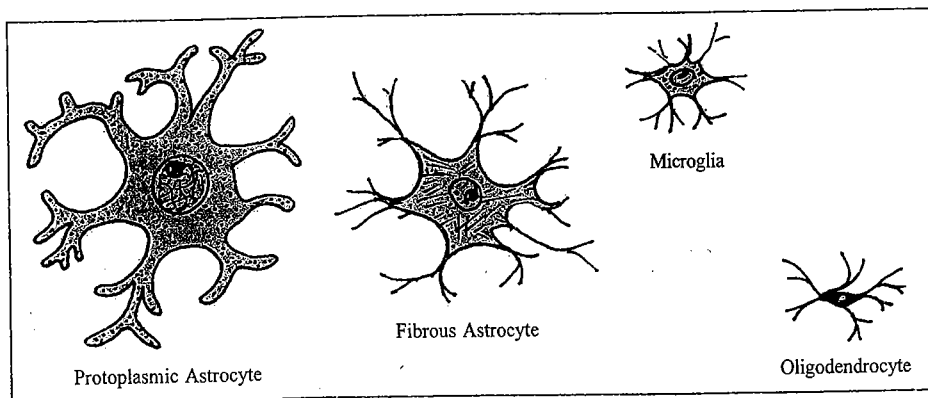


Fig. 1.22

neuroectoderm. The astrocytes with short and thick processes and remain confined in the **grey** matter are called **Protoplasmic astrocytes**. Other variety of astrocytes have thin and long processes and remain in the **white** matter. These are known as **Fibrous astrocytes**.

Some processes of astrocytes become attached to the outer surface of the capillaries of the brain and help establishing blood brain barrier. They also provide nutrition and framework support to the nerve tissue.

Oligodendrocytes – They are small cells with few processes and found in both grey and white matter. They form satellite cells in grey matter and peri-fascicular cells in the form of rows in the white matter.

ii) Microglia – These are small cells with thorny projections. They are found more in the grey matter and less in white matter. *Microglia are derived from mesoderm*. They are the macrophages of CNS.

Ependyma

This is the epithelial lining of the ventricles of the brain and central canal of spinal cord. It is composed of a single layer of columnar ciliated cells. Some ependymal cells lining the floor of the 3rd ventricle possess long cytoplasmic processes which extend in to the nerve tissue are called **Tanycytes**.

Schwann cells

These are flat cells undergo spiraling around the axons outside the CNS. Each axon comes with the contact of many Schwann cells and form myelin sheath by depositing concentric layers of lipid and protein. The sheath is interrupted at regular intervals in between the covering of the Schwann cells and this exposed part of axolemma is called nodes of Ranvier. Schwann cells are derived from neural crest cells.

Satellite cells

These are small flat cells derived from neural crest cells and form a capsule around each ganglion cell. Some oligodendrocytes also serve the purpose of satellite cells around the cells of grey matter

Nerve ending – The peripheral nerve fibers whether sensory or motor end in arborization either on some other neurons to form synapse or in the components of some organs like skin, muscle, glands, joint capsule etc. Close to the termination a nerve fiber loses the neurolemma first, then the myelin sheath.

Synapse

It is the junction, where one neuron ends and another neuron begins. The terminal branches of one axon come in contact with the cell body or dendrites of the next neuron and conduct the impulse in one direction. The terminals of an axon form small swellings called terminal bouton. In synapse, there are closely applied to the dendrites or the all bodies of other neurons. The minute gap between the two neurons at the point of contact is called ***synaptic cleft***, which is about 20 nm wide. The chemical substances like acetylcholine, norepinephrine, dopamine, serotonin etc are released from the nerve terminals of presynaptic neuron which flow towards the postsynaptic neuron. These substances are called neurotransmitters. Generally a single type of neurotransmitter is released in the form of secretory vesicle.

Motor nerve endings

They terminate in the muscles or glands. The naked axon divides into a number of terminal branches. The small swellings at the end of these terminals knobs contain several mitochondria and vesicles. The sarcolemma of the muscle fiber forms depressions or gutters, where the terminal knobs are inserted. The endoneurium is extended over the nerve terminals to the surface of a muscle fiber and fuse with the endomysium. The neurotransmitter in such nerve endings is acetylcholine.

One muscle fiber receives one terminal knob called **motor end plate**. One axon form several terminal branches and therefore innervate many muscles fibers. All these muscle fibers innervated by the terminals of a single axon is called a **motor unit**.

One or more terminal knobs of nonmyelinated nerve fibers end on the surface of the plasma membrane of cardiac and smooth muscle fibers. In glands they end among the epithelial cells.

Sensory nerve endings

These are also called receptors. These nerve endings may be naked or encapsulated.

Naked (Free) nerve endings are devoid of any covering and receives pain and tactile (touch) sensations. Touch sensation may also be felt by the hairs indirectly when these free nerve endings become associated with hair follicles.

Encapsulated nerve endings – Here the naked nerve terminals are covered by capsules of connective tissue. There are several varieties of these nerve endings.

a) Pacinian corpuscle – Here the naked terminal is covered by a concentric layers of lamellae and therefore it looks like a knob and receives touch and pressure sensation. They are present in dermis, ligaments, etc.

b) Meissner's corpuscle – The type of capsule is like a irregular cylinder. It receives fine touch sensation and found in the dermis of hands, lips, teat, etc.

Nerve ending in the form of specialized cells

Here actually the nerve endings are attached to some specialized cells who act as receptors. e.g. Rods and cones of retina, Hair cells of organ of Corti.

Some receptor cells in association with surrounding cells form a cell group or sense organ. e.g. Taste bud.

Muscle spindle

This is the sensory organ of skeletal muscle. It is the receptor of stretch reflex and proprioception. Muscle spindles are fusiform structures, comprise of 10–12 small modified muscle fibers remain encapsulated by a fibrous sheath. These spindles are situated within the ordinary muscle fibers and their capsules merges with the connective tissue sheath of the adjoining fibers. The ordinary muscle fibers are called **extrafusal** fibers and the muscle fibers remaining within the spindle are called **intrafusal** fibers. These are two types of intrafusal fibers

– (a) Neuclear bag fibers and (b) Nuclear chain fibers. In the bag type fibers the nuclei are aggregated in a bag type swollen middle portion and in chain type fibers the nuclei are arranged in a single row. Contractile elements are present only at the ends of these intrafusal fibers. Sensory nervendings spiral around the mid portion and the motor fibers supply the ends of these intrafusal fibers.

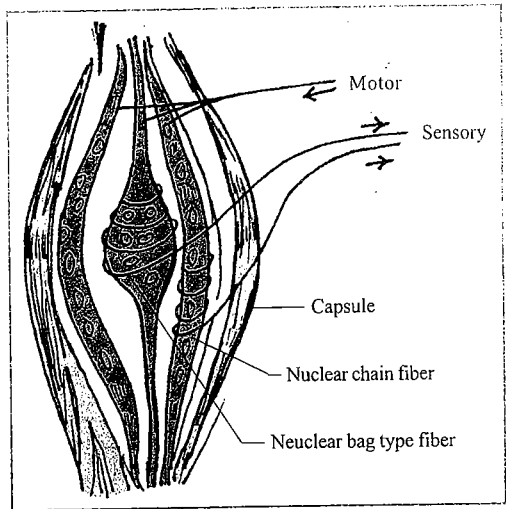


Fig. 1.23 Neuromuscular spindle.

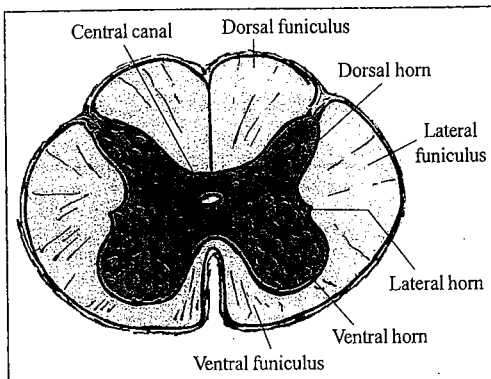


Fig. 1.24 Spinal cord.

Spinal cord

It is composed of a central grey matter and peripheral white matter. Along the central axis of the spinal cord a canal exists, which extends from the 4th

ventricle at the caudal half of the medulla oblongata to the conus medullaris in the form of a minute tube. It contains cerebro spinal fluid during life and is lined by a single layer of ciliated columnar epithelium called **ependyma**. The ependyma is continuous with that of ventricles of the brain.

White matter

This component occupies the spaces at the periphery of the spinal cord and almost surrounds the butterfly shaped central grey matter. It is composed of bundles of nerve fibers, neuroglia and blood vessels. The nerve fibers are mostly thick and myelinated and that is why it is white in appearance. However large number of small calibered and non-myelinated fibers are also present in the white matter. Each half of the white matter is divided into dorsal, lateral and ventral regions, popularly known as funiculi.

The **ventral funiculus** extend from the ventral median fissure to the region of ventral nerve roots. Ventral white commissure connects the ventral funiculi of both the sides and intervenes between the ventral grey commissure and the roof of the ventral median fissure. The **Dorsal funiculus** extends from the dorsal median sulcus to the dorso-lateral sulcus. Cranial to the mid thoracic region the dorsal funiculus is subdivided into a medial part, the **faciculus gracialis** and a lateral part, the **faciculus cuneatus**.

The **Lateral funiculus** is situated in between the dorsal and ventral funiculi and lateral to the grey matter.

Grey matter

It is the centrally placed H shaped column of dark or grey substance which extends throughout the length of spinal cord. It is composed of neurons and their processes, neuroglia and blood vessels. Each half of the grey matter comprises of a dorsal horn, a ventral horn and in some specific zone a lateral horn.

Dorsal horn

This is narrow, directed dorsolaterally towards the dorsolateral sulcus. It is separated from the surface by a narrow band called dorso lateral fasciculus. The end of the dorsal horn is capped with translucent mass of nerve tissue, known as **substintia gelatinosa**. It forms the sensory part of the grey matter and accommodates small multipolar nerve cells. These neurons receives the sensory fibers from the dorsal root ganglion and give rise to second order fibers.

Ventral horn

It is broad, short and directed ventrolaterally. It does not extend up to the surface and accommodates large multipolar neurons. Axons of these cells form the ventral roots of the spinal nerves.

Lateral horn

It is found at the level of thoracic and cranial lumbar part of the spinal cord in the form of a lateral projection. It contains the preganglionic neurons of autonomic nervous system.

Cerebellum

The cerebellar mass is composed of a central core of white matter and peripheral layer of grey matter called cerebellar cortex. Four pairs of cerebellar nuclei are embedded into the white matter of the organ. These are nucleus **Fastigi**, nucleus **Globosus**, nucleus **Emboliformis** and nucleus **Dentate**. The cortex is covered by thin layer of pia mater.

Cerebellar Cortex

It exhibits an uniform histological organization in all parts of the structure and arranged accordingly as per the depressions and infoldings of the surface. It is composed of three layers of cells.

(a) *Outer molecular layer* – It is composed of small molecular cells and two types of neurons – Stellate cells and basket cells. It contains plenty of unmyelinated fibres derived from stellate cells, basket cells, sensory climbing fibers and dendrites of Purkinje cells and Golgi cells.

(b) *Intermediate Purkinje cell layer* – This is composed of a single layer of large flask shaped cells. The dendrites of these cells are in the form of a bush and distributed in the

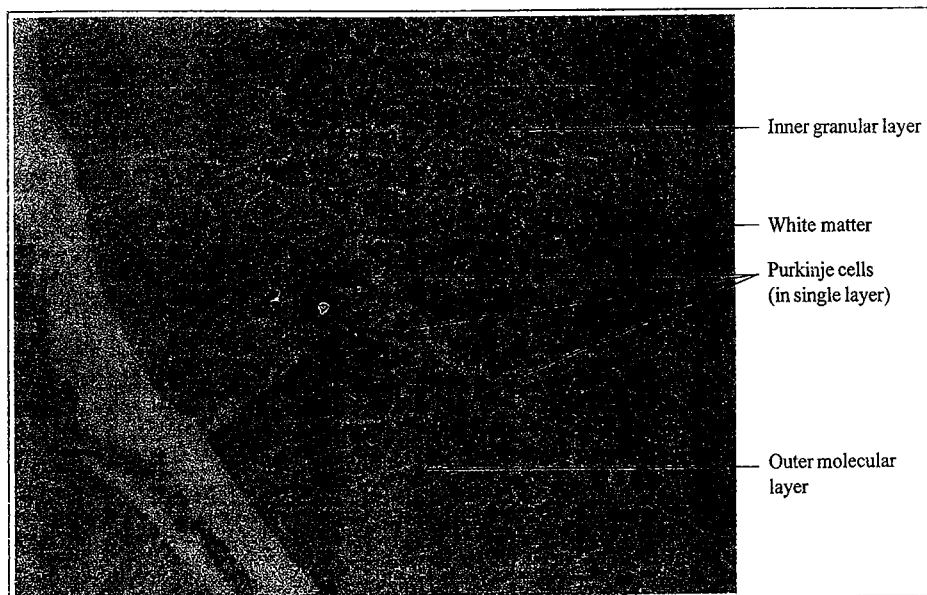


Fig. 1.25 Section of cerebellar cortex.

outer molecular layer. Their axons pass downward and synapse with the deeper cerebellar nuclei.

(c) *Inner granular layer* – It is a thick zone, covers the white matter and composed of closely packed small granule cells. This layer also contains dendrites of Golgi cells and sensory fibers.

Cerebrum

It comprises of a layer of grey matter called cerebral cortex, which remains covered by pia mater and a central core of white matter. The basal ganglia are embedded within the white matter.

Cerebral cortex

The thickness of the cerebral cortex is variable according to different zones. The thickness ranges from 2 to 5 mm. It is composed of six layers of cells as follows :

1. *Outer molecular layer* – This thin layer comprises of mainly fibers and few horizontal cells of Cajal.

2. *Outer granular layer* – It contains granule cells and some small pyramidal cells.

3. *Outer pyramidal cell layer* – This layer accommodates small and medium sized pyramidal cells.

4. *Inner granular layer* – Its upper part contains granule cells and some medium sized pyramidal cells. The deep part contains the outer band of Baillarger, which is composed of some transverse fibers.

5. *Inner pyramidal cell layer* – The superficial part contains medium sized pyramidal cells and the deep part accommodates large pyramidal cells and inner layer of Baillarger.

6. *Fusiform cell layer* – It comprises of fusiform and stellate cells of different shapes and sizes along with plenty of fibers.

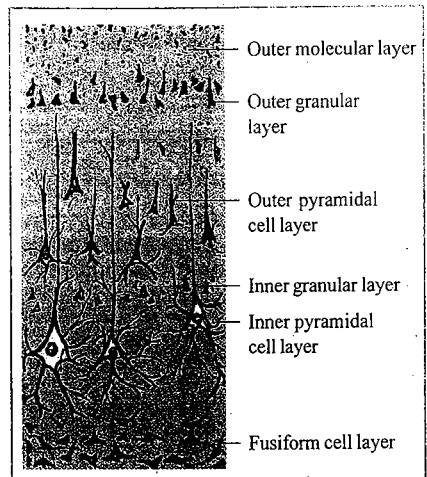


Fig. 1.26 cerebral cortex.

Hippocampus and dentate gyrus

This is phylogenetically older part of the brain and comprises of only three layers. These are molecular layer, pyramidal cell layer and pleomorphic layer.

CARDIOVASCULAR AND LYMPHATIC TISSUE

This system comprises of the following components :

Heart	Lymph vessels
Artery	Lymph node
Vein	Spleen
Capillary	Thymus
	Tonsils

HEART

The wall of the heart is composed of three layers of tissues.

a) Epicardium, b) Myocardium, c) Endocardium.

Epicardium

It is a serous membrane and the visceral layer of pericardium, that immediately envelops the heart. It is composed of a superficial layer of mesothelium over a thin layer of connective tissue. This layer contains blood capillaries, lymphatic capillaries and some nerves. Its deeper layer contains blood vessels and fats and is continuous with endomysium of the underlying cardiac muscle.

Myocardium

This is the thickest layer and composed spirally arranged cardiac muscle.(already described).

Endocardium

It is the innermost tunic of heart and is composed of endothelium, a single layer of squamous cells and sub-endothelial connective tissue. It not only lines the atrial and ventricular chambers, but covers all the structures that extend from the heart walls such as chordae tendinae, valves, papillary muscle etc. The deep (outer) layer may contain some smooth muscle fibers in some places. Generally its thickness has a inverse relation with the thickness of myocardium.

Valves of heart are formed by the foldings of endocardium with a core of dense fibroclastic tissue.

Skeleton of heart

The skeleton of heart comprises of a) four fibrous rings at the wall of four orifices (2 atrio-ventricular orifices, aortic orifice and pulmonary orifice); b) membranous part of interventricular septum and c) two fibrous trigones those connect the fibrous rings.

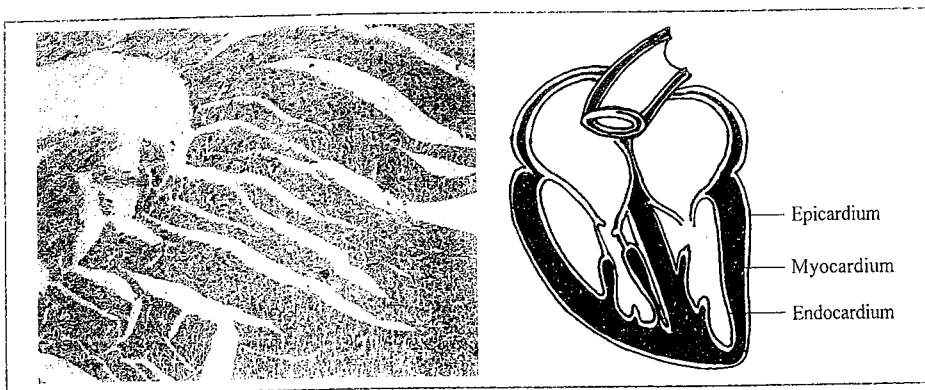


Fig. 1.28 Low power photomicrograph showing disposition of cardiac muscle.

ARTERY

These are the musculo-membranous tubes, receive the blood from the heart and carry it to the capillaries. Arteries have been classified into three groups: a) Elastic artery b) Muscular artery c) Arteriole.

However the wall all of these vessels have the following common structure of variable proportions.

i) *Tunica adventitia* – This is the outermost thin coat of the wall and composed of fine elastic and collagen fibers. The collagen fibers are generally arranged parallel to the long axis of the vessels. This layer attaches the vessels with the surrounding connective tissue and retains the tunica media and intima during distension.

ii) *Tunica media* – This forms the bulk of the wall and composed of circularly arranged smooth muscle fibers and some elastic fibers. The concentration of elastic fibers is much

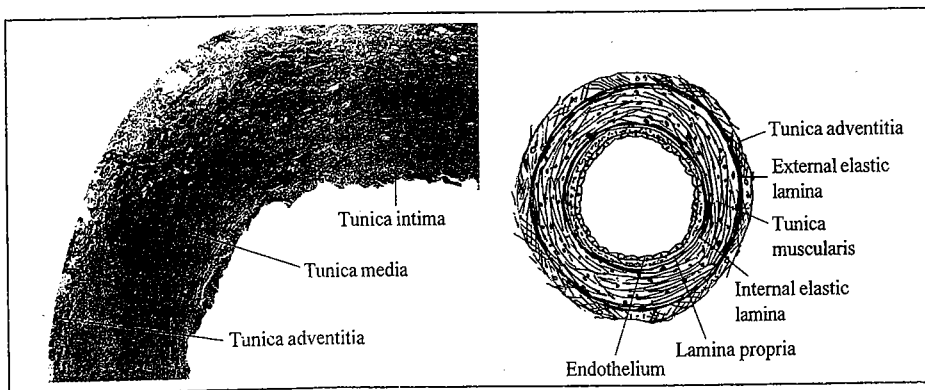


Fig. 1.29 Cross section of a medium-sized artery.

towards the periphery and forms an external elastic lamina which separates this layer from the tunica adventitia.

iii) *Tunica intima* – This is the innermost coat of the wall and composed of a) single layer of squamous cells (endothelium), b) Lamina propria, composed of longitudinally arranged delicate collagen and elastic fibers and c) Internal elastic lamina, formed by the condensation of elastic fibers. This layer of tunica intima maintains the potency of the lumen of the arteries.

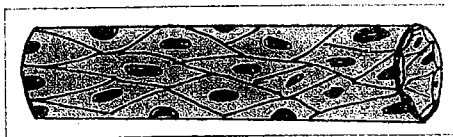


Fig. 1.30 Capillary.

Structural variations amongst the three type of arteries.

	<i>Elastic artery</i>	<i>Muscular artery</i>	<i>Arteriole</i>
	Large arteries, close to heart. (conducting artery)	Large and medium artery (Distributing artery)	Small muscular, arteries about 100 μ . in diameter (Resistance arteries)
Tunica Adventitia	Thin	Thicker	Very thin
Tunica Media	Thick Elastic fibers are more in amount	Very thick Smooth muscle fibers are more in amount	Thick elastic fibers disappear and smooth muscles are prominent
Tunica Intima	Smooth small folds are absent. Lamina propria is thick. Internal elastic lamina is very thin	Exhibits small folds. Lamina propria is thin. Internal elastic laminae is prominent	Exhibits small folds. Internal elastic lamina is thin.

Capillaries

These are the finest blood vessels, form diffuse network by branching and anastomosing within themselves and link between arterioles and venules. The capillaries have the following characteristics :

- These are microscopic vessels with an average diameter of about 8 to 10 microns.
- The wall is composed of a single layer of endothelial cells with elongated nucleus and surrounded by a thin basal lamina. Some flat mesenchymal cells with long cytoplasmic processes remain associated with the basal lamina, known as *pericytes*.
- In muscle and nerve tissue, the wall of the capillaries are uniform and without any pore. These are called *Muscular capillaries*.

The capillaries of the glomerulus of kidneys and those of endocrine glands possess small pores. They are known as ***Fenestrated Capillaries***.

Veins

These are the thin walled blood vessels and more numerous. They start from periphery, gradually increase in caliber along their course towards heart. Although the wall is thin, the lumen is large in comparison to the arteries.

The wall of the veins have the following characteristics :

i) *Tunica adventitia* – It is composed of longitudinally arranged collagen fibers, some elastic fibers and some smooth muscle fibers. This layer is thickest of the three coats.

ii) *Tunica media* – This is thin and is composed of collagen fibers, elastic fibers and some smooth muscle fibers,

iii) *Tunica intima* – The structure of this layer is almost similar to that of arteries but the elastic lamina is absent. The veins of limbs have valves in their lumen which are inclined towards the direction of the flow of blood and prevent back flow. These valves are formed by the foldings of tunica intima.

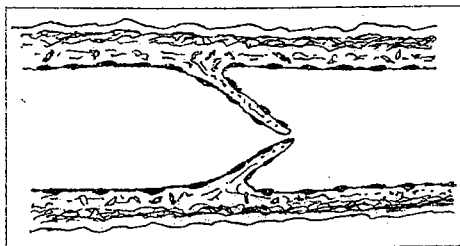


Fig. 1.31 Vein.

Smooth muscle fibers are absent in the veins of CNS and bone marrow. However some veins like uterine veins during pregnancy, pulmonary veins and veins of penis contain little amount of smooth muscle fibers in tunica media.

Sinusoids

These are dilated vascular channels lined by an incomplete layer of endothelium and basal lamina and therefore allow the blood to come in direct contact with the cells of the tissue. These are found in *liver, spleen, bone marrow* and in *some endocrine glands*.

The lining membrane contains some phagocytic R.E cells or fixed macrophages. Since the wall of the sinusoids have gaps in some places and flow of blood through these spaces is slow, considerable exchange of metabolites between the blood and surrounding tissue takes place in the sinusoids.

The sinusoids may connect an arteriole with a venule, e.g spleen and a venule to another venule, e.g. liver.

Vasa Vesorum

These are the vessels for large blood vessels. They supply and drain the outer part of tunica media and tunica adventitia of large and medium blood vessels.

Arterio – Venous anastomosis

By passing the capillary network, some direct communication between arterioles and venules, are found in some places of the body. The wall of this communicating zone of the vessels is thick and richly supplied with sympathetic nerves. They are found in skin, erectile tissue of external genitalia and in G.I tract. Some such anastomotic vessels are tortuous and thick walled and contain modified muscle (epitheloid) cells called Glomus.

Lymph Vessels

The excess tissue fluid which do not return via capillaries and velules, are carried through separate channels are known as lymph vessels.

Lymph is a colourless fluid which contains small amount of plasma protein and lymphocytes. These lymphocytes are added to the fluid while it circulates through lymph nodes.

The lymphatic vessels are small, delicate thin tubes possess numerous valves which allow the lymph to flow in one direction. These are mainly distributed in the mucous, serous and synovial membromes, glands and in the skin but ***not found in the nervous tissue***. The flow of the lymph is very slow. The vessels pass through lymph nodes and finally end at the thoralic duct and right lymphatic duct which open into the venous system.

Lymph capillaries

These are blind ended small vessels originate from the tissue spaces and are lined by a single layer of endothelial cells.

Larger lymph Vessels

Lymph capillaries join to form larger vessels. The wall of these vessels is composed of three coats like that of venules., These vessels come and enter lymph nodes on their way as afferents.

Lymphocyte

It is one type of agranular white blood cells having a dark spherical large nucleus that occupies almost the entire cell. Some lymphocytes are large and some are small in size. They can identify foreign antigens and help in the production of antibodies. Functionally two types- T-lymphocytes and B-lymphocytes are present in the body. In routine histology these two types of cells cannot be identified separately but can be identified with the help of immuno-histochemistry.

T- lymphocytes (Thymus dependent) after their origin in the bone marrow, go to the tymus. Here they differentiate further, become mature and transported to the circulation and other lymphoid organs. Lymphatics leave the node as efferent vessels.

B-Lymphocytes (Bursa dependent) -- The name of these cells is derived from the Bursa of Fabricius of birds, where they differentiate. But in mammals, there is no bursa of Fabricius and these cells differentiate only from bone marrow.

Lactials – The villi of small intestine contain a lymph capillary in their cores, known as lacticals. These are useful at the time of absorption of fatty acids from the intestine.

Thoracic duct- The structure of this largest lymph vessel resembles that of a vein but contains more muscle fibers in the tunica media.

Lymphoid tissue

This is the aggregation of lymphocytes within a network of reticular tissue. The lymphocytes may be matured or in the different stages of maturation.

When these aggregation is found diffusely below the epithelium of G.I tract or Respiratory tract in little irregular manner called Diffuse lymphoid tissue.

In some places these lymphoid tissue remain in the form of a small rounded masses. They are called **limph follicle or limph nodule**.

Some of these lymph nodule contains a central zone of loosely packed lymphoblasts and a peripheral zone of densely packed small lymphocytes. The central loose area is called germinal center. These lymphoid tissues are very much prominent in the ileum. Since the functions of spleen is shared by other organs like liver and bone marrow in adult life, the organ is not essential for life.

Lymph nodes

They are oval or bean shaped nodular brown or reddish black structures of variable sizes ranging from very minute bodies to the size of a lemon. The hilum is in a depressed area where blood vessels and efferent lymph vessels enter or leave the gland. The afferent vessels are found at different points along the convex surface of the node. The nodes are covered by a connective tissue capsule. The capsule sends septa or trabeculae inside the node. The trabeculae form compartments at the cortical area. The compartments accommodate cortical nodules. The central portion of a nodule is known as **germinal center**. The germinal center is lighter in colour and production of lymphocytes occurs in these germinal centers. The cortical nodules are separated from the capsule as well as trabeculae by lymph sinuses. The medulla is composed of lymph cords which extend from the nodules, lymphocytes, RE cells, meshwork of trabeculae and lymph sinuses. In ox some large pigmented branching cells are found in the medulla. The lymph enters the nodes through afferent lymphatics, percolates through sinusoids and the filtered lymph emerges via the efferent lymphatic through the hilum.

Although variable in number, the lymph nodes are constantly found in certain definite areas of the body, such as axilla, inguinal region, mesentery, pre-scapular area, supra-mammary region, etc.

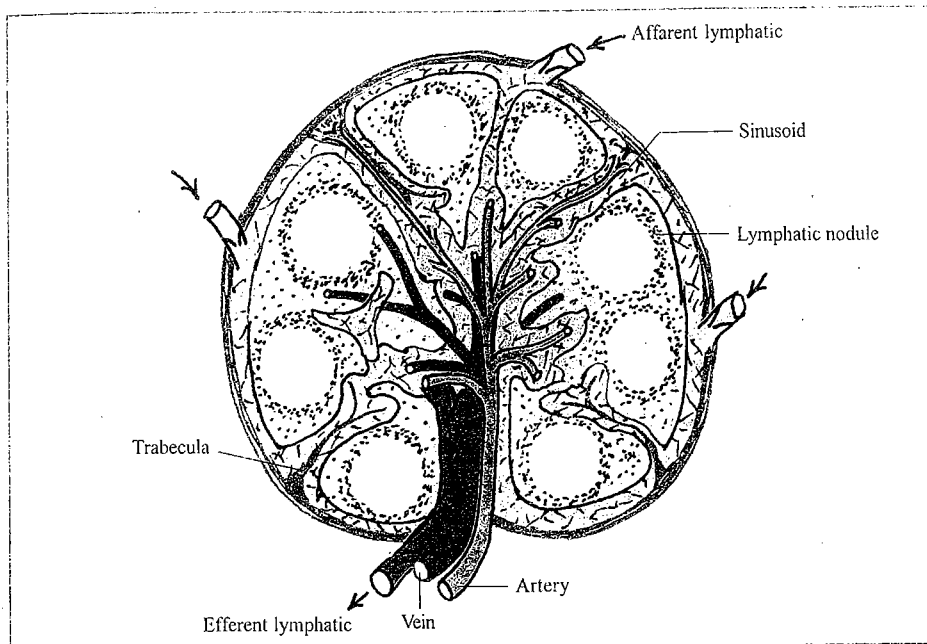


Fig. 1.32 Section of a Lymph node (Diagramatic).

Spleen

This is the largest lymphoid organ. It forms erythrocytes in fetal life and lymphocytes after birth and therefore it is also called an hemiolymp organ. It filters blood and remove foreign particles from circulating blood.

Framework of the organ

(a) Capsule – The spleen is covered by a thick capsule which is composed of collagen and elastic fibers and some smooth muscle fibers. The capsule remains covered by visceral peritoneum.

(b) Trabeculae – These are the septa which extend from the capsule and hylum towards the interior. These trabeculae branch and join each other and divide the gland into a number of lobules. Composition of these septa is similar to that of the capsule.

(c) Connective tissue network – The spaces between the trabeculae has a net work of reticular connective tissue to hold the lymphoid tissue in position. There is no cortex and medulla in this organ.

In freshly cut large tissue pieces of spleen exhibit pale and red zones at the surface on naked eye observation. The pale zones which remain scattered in a red background is called white pulp and the background red zone is called red pulp.

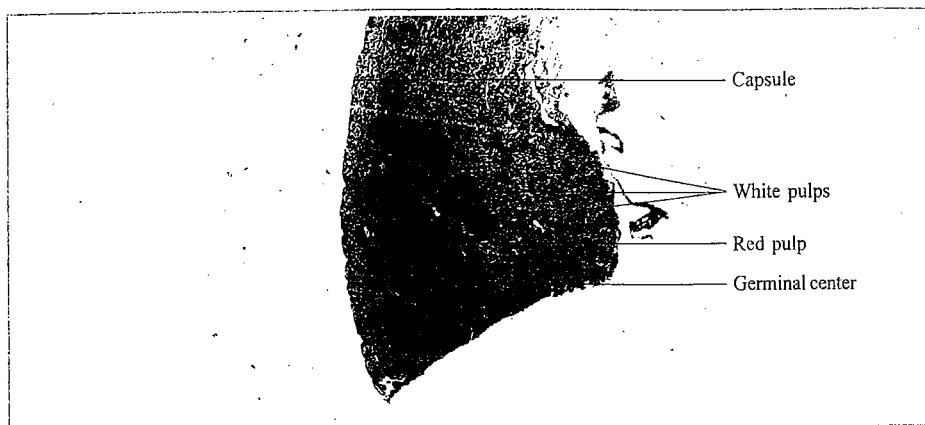


Fig. 1.33 Section of spleen.

Lymphoid tissue of spleen

The substance of the spleen comprises of lymphoid tissue and blood vessels within reticular framework.

White pulp

In histological sections (H&E) it is found that numerous deep stained round or oval masses of lymphoid tissue are scattered unevenly within the background of lighter zone. Each such mass contains a minute artery at the center. Some of them have germinal centers. These circular masses are known as white pulps. The blood vessel may sometimes be eccentric in position. In the germinal center B-lymphocytes proliferate.

T-lymphocytes are found in the periphery.

Red Pulp

The rest of the zone comprises of venous sinusoids, spongy net work of connective tissue elements, lymphoid tissue, circulating blood cells and some macrophages. Both B and T lymphocytes are found in red pulp.

Splenic circulation

Branches of splenic artery leave the trabeculae and subdivide to form arterioles. Each arteriole passes through the white pulp and again divide into smaller but straight vessels within the red-pulp area. These are known as **Penicillar arteries**. The tunica adventitia was lost in the white -pulp. The penicillar arteries loose their tunica media in the red-pulp and become ensheathed by reticular cells and form spindle shaped thickening called

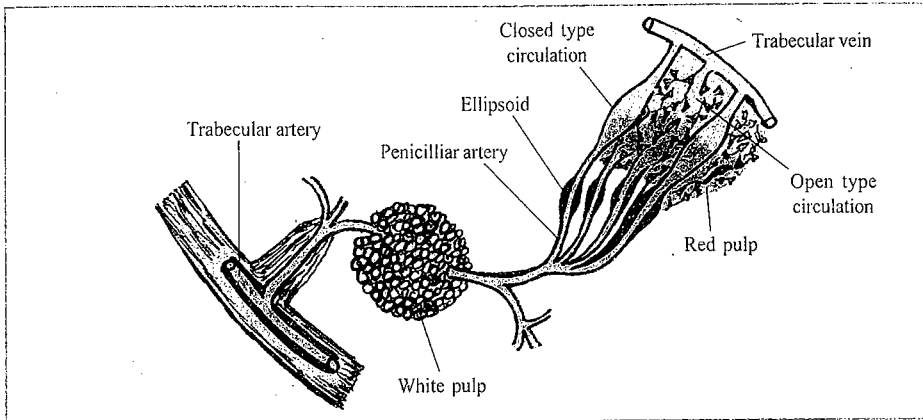


Fig. 1.34 Spleenic circulation.

Ellipsoids. The lumen at the ellipsoid zone become narrow. The extensions of the penicillar arteries after ellipsoids, become narrow and form the arterial capillaries. These capillaries may be directly continuous with the venous sinusoids as per close theory of circulation. As per open theory of circulation the capillaries open directly into the splenic cords of red pulp and from there the blood cells percolate into the venous sinusoids. However, there is a general agreement that the sinusoidal endothelium has large gaps in them and when the organ remain in relaxed condition, allow the blood to go in and out of the sinusoids to the surrounding red pulp. During contraction, these gaps are closed and blood flows from capillaries to veules directly.

Thymus

This is an irregular bi-lobed structure situated in the cranial mediastinum in front of the aortic arch. It is a lympho-epithelial organ. Its epithelial part is derived from the 3rd pharyngeal pouch and the lymphoid part is derived from mesoderm. This is an important organ for body defense mechanism.

Capsule – The structure is encapsulated by a thin layer of connective tissue which is composed of collagen and elastic fibers. Thin septa extend form the capsule and divide the cortex into numerous incomplete lobules.

Parenchyma – In the cortex lobules are situated. The lobules are incomplete. Each lobule has a peripheral more condenced zone called the cortex of the lobule and a loose central zone with scanty thymocytes and more epithelial cells, called medulla of the lobule.

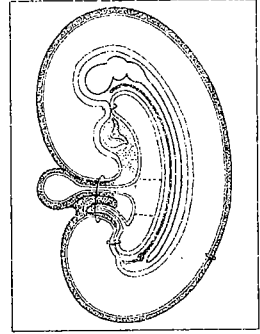
Medulla of the organ contains lightly packed lymphocytes, blood vessels and epitheloid mesh. Actually the original medulla of the organ branch towards the periphery and invaginated into the incomplete cortical lobules to form the medulla of the lobules. Therefore the medulla

of the lobules are the extensions of the original medulla of the organ like the white matter of cerebellum. Degenerated epithelial cells form mest-like structures, consist of several layers of concentrically arranged flattend cells around a central hyaline necrotic mass called **Hassall's corpuscles**. These corpuscles increase in number with the advancement of age.

Tonsils

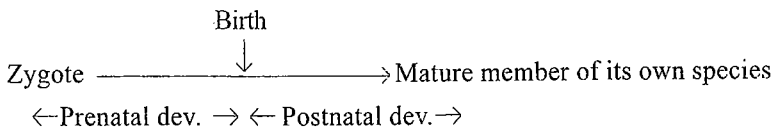
These are the lumps of lymphoid tissues in the form of nodules situated under the epithelium and are partly covered by capsule. They are mostly situated in the proximal parts of digestive and respiratory system. They remain separated from the surrounding tissue by a distinct connective tissue layer.

GENERAL EMBRYOLOGY



Developmental Anatomy is the Science which deals with the formative history of an individual from the time of fertilization of ova which is unicellular, to its proper transformation into the mature member of its species.

Therefore this process can be divided into two parts – (a) Pre-natal development and (b) Post-natal development.



Embryology deals with the pre-natal stages of development, i.e. from fertilization of ovum to the birth of the new individual.

This subject may be studied in different ways as follows :

Morphological Embryology

Orderly progress of development is studied by observing morphological changes those take place during the course of time.

Functional Embryology

In this method various physiological changes those occur in the embryo are studied at different stages of development.

Experimental Embryology

In this study experiments are conducted by surgical removal and / or by transplanting an organ during the process of development to know various events of it.

Comparative Embryology

This is the study of embryology on comparative basis to ascertain process of development in various species.

This book would deal with the basic principles of Morphological Embryology with some comparative points on domestic animals and birds.

Reasons for studying Embryology

1. It gives a rational understanding of the various organs of the body.
2. It throws light on how a single cell zygote gives rise to various systems in a creature.
3. It explains the position and relation of a normal structure in an adult subject.
4. Placentation in various species is well understood by studying the subject.
5. It provides knowledge to know the causes of congenital pathological conditions.
6. The subject works as a good co-relator of different morphological structures.
7. It helps in better understanding of teratology.

Some Introductory Definitions

Reproduction – This is the production of continuous stream of new generation of specific species.

Gonad – It is the primary sex organ of an animal or bird. Testes are the male gonads and ovaries are the female gonads.

Gametes – These are the specialized sex cells which are produced by the gonads. Spermatozoa are the male gametes and ova are the female gametes.

Fertilization – It is the union of a spermatozoon and an ovum.

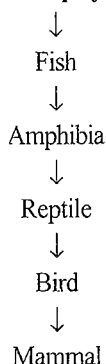
Zygote – The single celled fertilized ovum is known as zygote.

Deutoplasm – The reserve food materials within ova (yolk) is called deutoplasm.

Ontogeny – It is the development of one's own self, i.e individual development. It embraces complete life cycle of an organism which consists of pre-natal development, post-natal growth and maturity. This is a gradual process of expression of the blueprint of life which is stored in the genes of zygote.

Phylogeny – This is the historical development of a species. The evolutionary or ancestral histories of a group of organisms are expressed in this process.

Vertebrate phylogeny



The ontogeny repeats phylogeny – This is best understood by observing sequences of the development of the kidneys in fishes reptiles, birds and mammals.

The **Pronephric kidney** appears at the early stages of development near the upper thoracic region. It completely disappears in the mammals but persists in adult forms of some fishes. The **mesonephric kidney** appears by replacing pronephric kidney in lower thoracic region and persists in adult forms of most of the fishes and amphibian. **Metanephric kidney** appears in the lumbo –sacral region by replacing mesonephric kidney and persists as permanent kidney in reptiles, birds and mammals.

This chronology of development shows that at first mammals are in **fish** stage and then passed into **amphibian** stage and finally reached the **mammalian** stage and proved that ontogeny repeats phylogeny.

Totipotent Character – Normally one out of the two cells, which are formed after the first cleavage division in a zygote, produces an embryo and the other cells gives rise to protective covering of the embryo and provides nutrition to it. But in case of the formation of identical twins each of those two cells forms a separate embryo. This character may be retained up to 8-cell stage of development. Therefore the capability of these newly formed cells to form a new individual separately is called totipotent character. However, this character is variable in different species of animals.

Pluripotent Character – Groups of cells in the morula are capable of giving rise to several different cell types. This is called pluripotent character. However, they may still differentiate into various specialized types of tissue elements.

Amniotes – In reptiles, birds and mammals spermatozoa pass from the body of male to that of female during coitus and fertilization takes place inside the body of female. The amniotic cavity develops and the embryo of these species floats within the fluid filled amniotic cavity and therefore called amniotes.

Anamniotes – In fishes and amphibian the ova are fertilized outside the animal body. The embryos grow in external environment without being surrounded by amniotic cavity. These species are known as anamniotes.

Oviparous -- The reptiles and birds when lay fertilized eggs, the whole of the prenatal development takes place inside the egg on getting nourishment from the yolk. Therefore these species of animals and birds are called oviparous animals/ birds.

Viviparous Animals – The mammalian embryo have small yolk sac with meager supply of nutrition. The embryos develop within the uterus on receiving nutrition from mother through placenta. These mammals are called viviparous.

Incubation Period – It is the duration of time through which the embryos are hatched within eggs of birds and reptiles outside the body.

Gestation Period – It is the duration of retention of the embryos within the uterus in mammals until fully developed young individuals are born.

Decidua – It is the modified form of endometrium just after implantation. The endometrium remains at secretory phase when the morula reaches the uterus. But with the implantation the secretory phase is intensified, the stromal cells enlarge, vacuoles appear within this layer and it stores glycogen and lipids. This change is called **decidual reaction**.

Fundamental processes in development

During conversion of zygote (single celled) into a complex body (multi cellular), two processes are involved. These are (a) Growth and (b) Differentiation.

Growth

Growth takes place by increase in bulk. It occurs by (i) cell division, (ii) increase in cell size and (iii) increase in intercellular substance.

Cell division or multiplicative growth occurs by successive mitotic division in most of the tissues and organs in pre-natal life. However some cells (Neurons) do not divide in post-natal life. On the other hand epidermis of skin, intestinal epithelium, blood cells, are continuously lost by wear and tear and are replenished by production of new cells by mitosis from stem cells. Again cells (hepatocytes) do not usually divide but undergo mitosis in altered conditions.

Increase in cell size occurs in oocytes and in some neurons by the increase of cytoplasmic volume. This is called **auxetic growth**.

Differentiation

In this process groups of cells acquire special characteristics and undertake specific function. Tissues and organs are laid down in the developing embryo in a methodical and sequential manner by the process of differentiation.

When differentiation in a local area of an embryo occurs by liberation of some chemical substance, the process is known as **Chemo-differentiation** and the chemical substance is known as **organizer**. **Histo-differentiation** is a process when anatomical characteristics of the tissues are detected. It generally occurs after the chemo-differentiation. At this stage organogenesis starts and the organs take their specific shape depending upon their functional characteristics. Therefore final structural re-modelling which occurs in the functional period is known as **functional differentiation**.

ORGANS OF REPRODUCTION

Male Reproductive System

It comprises of the following organs :

- (a) Two gonads – the testes
- (b) A copulatory organ – the penis
- (c) Duct system
- (d) Accessory sex glands

TESTIS

The **testes** (left and right) are two solid glands housed in the scrotal sac and are situated in various disposition in different mammals. In bull they are suspended in vertical direction, in stallion they are horizontally placed, in dog they are situated obliquely below anus, in boar the tail of epididymis is directed upward. However in birds they are situated in the abdominal cavity at the sublumbar region. The weight, volume and other dimensions are highly variable depending upon the age, breed and species. The average weight of an adult bull testis is about 250-300 gms ; length is about 12 cm and thickness is about 5 cm. The medial surface is flat and lateral surface is convex. The upper end, caudal border and the lower end are occupied by the head, body and tail of epididymis respectively.

Next to tunica vaginalis, a thick fibrous membrane invests the whole testis known as **tunica albuginea**. Internal to albuginea there is a areolar and vascular membrane, known as tunica vasculosa. Along the central axis, deep into the gland a mass of tissue is extended, known as **mediastinum testis**. From the mediastinum, numerous fibrous septa radiate and divide the gland into a number (more than 100) of chambers or lobules of testis. Each of

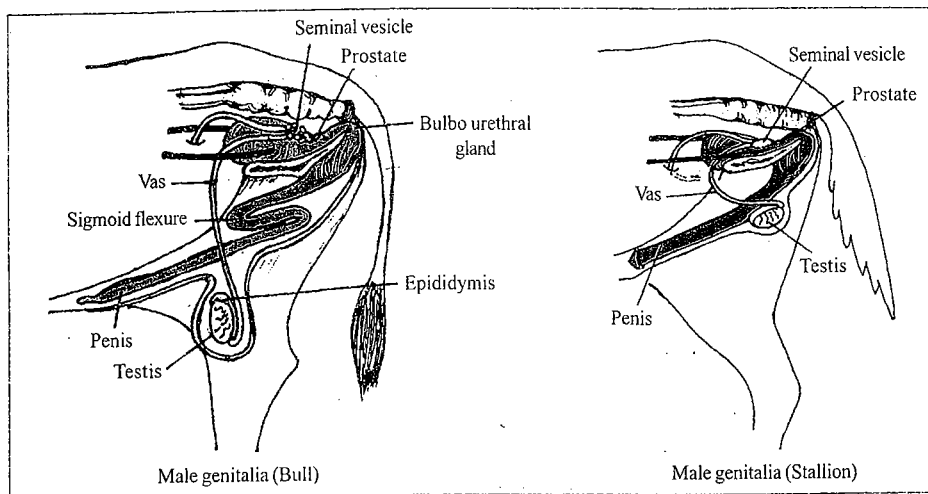


Fig. 1.35

these small chambers are filled with seminiferous tubules, which are connected by interstitial cells. The convoluted parts are placed at the fundus of these small chambers. The convoluted portion is known as **tubuli contorti**. From the tubuli contorti straight tubes proceed towards the mediastinum testis. They are called **tubuli recti**. The tubuli recti from different lobules reach the mediastinum testis and join with each others to form a network, called **rete testis**. About a dozen of efferent ductules arise from the upper end of the mediastinum and enter into the head of epididymis. They are known as **vasa efferentia**. These ductules unite in the head of epididymis to form a single duct, the duct of epididymis.

PENIS

The **Penis** is a cylindrical structure and the organ of copulation. It consists of three parts – root, body and glans. The **root** begins at the ischial arch. Here the urethra is enclosed between the two crura. The crura arise from the lateral part of ischial arch and are made up of erectile tissue. The **body** is the largest part of the organ between the root and the glans. Before passing between the spermatic cords, in bull, ram and boar it experiences a ‘S’ shaped curve – the **sigmoid flexure**. This flexure is absent in dog and horse. It then passes between the spermatic cords at the base of the scrotum along the midline of the ventral abdominal wall and then continues as glans and remains within the prepuce. The glans is the free conical end of the penis. This is slightly twisted and presents a groove at the tip in the bull. The external urethral orifice is situated at the end of this groove. In stallion at the base of the glans there is a border, known as **corona glandis**. The urethral process is situated in the depression at the tip of the glans known as **fossa glandis**. In dog, at the cranial portion of the body, a bone is embedded along the length of penis, known as **os penis**. The caudal

part of the glans is enlarged to form **bulbus glandis**. In boar the terminal part of penis is spiraled. In small ruminants the terminal 2 to 3 cm length of the urethra projects beyond the glans penis in a twisted manner. The copulatory apparatus in birds is placed at the ventral aspect of the caudal end of a cloaca. It is composed of two papillae of vas deferens, two vascular bodies, a phallus and two lymphatic folds.

The duct system comprises of (i) a dozen of **vasa efferentia**, (ii) **duct of epididymis**, (iii) **Vas deferens** and (iv) **Urethra**.

About a dozen of small ductules originate from the upper end of mediastinum testis, enter into the head of the epididymis, are called vasa efferentia. Here they unite together to form a single tube and pass through the body and tail of epididymis in a highly tortuous manner and continue outside as vas deferens.

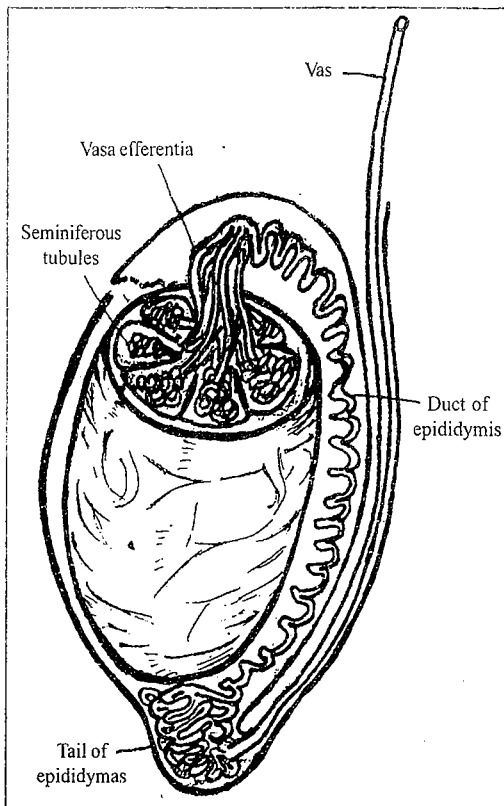


Fig. 1.36

The vas deferens is a thin tube starts from the tail of epididymis, passes upward along the caudal border of the testicle in a slight tortuous manner at the beginning and gets incorporated into the caudal bundle of the spermatic cord. The tube passes through the inguinal canal, enter the abdomen and ultimately opens at the roof of urethra on either side of colliculus seminalis. The terminal portions of both the tubes are little dilated and close in apposition. This part is the ampulla of the tube.

The urethra extends from the neck of the bladder to the glans penis and serves as a common passage for urine and semen. The pelvic part lies along the midline of the pelvic floor, arrives at the ischial arch bends downward and then forward and becomes continuous at the penile part.

The accessory sex glands are (i) **Seminal vesicles**, (ii) **Prostate** and (iii) **Bulbourethral gland**. Seminal vesicles are two lobulated and elongated glands situated at the caudodorsal aspect of the bladder. The lump of the gland is formed by the irregular coiling of a single thick walled tube. The single duct of each gland opens on either side of colliculus seminalis

lateral to the opening of the corresponding vas. The seminal vesicles are absent in dog. They are large in boar and in horse and rabbit they are in the form of elongated sacs.

Prostate is a fibromuscular gland situated at the neck of the bladder. It is composed of glandular alveoli in the fibromuscular meshwork. A number of prostatic ducts drain the secretion of the gland into the urethra at the roof behind the colliculus seminalis.

The bulbourethral glands are two small round structures situated on either side of the dorsal part of urethra at the level of ischial arch under the covering of a layer of fibrous tissue. Each gland is composed of small lobules. A single duct from each gland opens on the roof of urethra close to its situation. In dog prostate glands are well developed but bulbourethral glands are absent.

Female Reproductive system

This system consists of the following organs :

- (a) Two ovaries
- (b) Two oviducts
- (c) Uterus
- (d) Vagina and Vulva
- (e) Accessory sex glands (Mammary gland)

★ OVARY

The ovaries are two oval bodies one on each side, situated a little above the middle of the pelvic inlet and is attached to the broad ligament by a fold of peritoneum.

The size is highly variable from amlinal to animal. In cow the average length is 2-3 cm ; width is 2 cm and thickness is 1 cm. The organ is richly supplied with blood vessels. The attached mesovarial border is considered as the hilus of the ovary.

The ovary undergoes maximum histological variations at different phases of life. A normal mature ovary is externally covered by germinal epithelium which is continuous with the peritoneum. Tunica albugenia is a fibrous layer below germinal epithelium. The stroma is composed of connective tissue network, spindle shaped cells and few involuntary muscle fibers which give support to other important structures and vessels of the ovary. Graafian follicles are round bodies scattered mostly at the peripheral part of the ovary and found in different stages of development. According to the maturity they are called primary, secondary and mature follicles. When ovulation occurs the remnants of ruptured follicle reorganize to form Corpus luteum. It remains as a reddish yellow coloured outgrowth from the surface of the ovary for a restricted period of time.

Instead of a solid mass the ovary in case of birds looks like loose bunch of grapes containing oval follicles of various sizes.

OVIDUCT

The **oviducts** are two narrow flexuous tubes which are continuous with the pointed end of the corresponding uterine horns. Each has a length of about 20-30 cm in cow. It is attached to the free cranial border of the broad ligament. The diameter is about 2-3 mm. The uterine part is narrow and thick walled and called isthmus. The middle part is thin walled, little dilated and called ampulla. The terminal part is funnel shaped and is very close to the ovary and called infundibulum. The margin of the infundibulum is fimbriated. The abdominal opening of the tube is small and situated at the center of the funnel. The intramural part of the tube which is inserted within the tip of horn is narrow and its lumen forms the uterine opening of the fallopian tube.

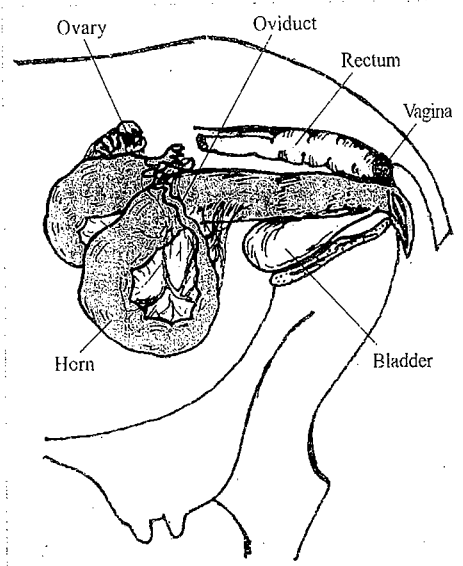


Fig. 1.37 Female organ of reproduction.

The tube is composed of serous, muscular and mucous coats. Presence of good amount of circular muscle fibers at the intramural part of the tube suggests the existence of a sphincter at this junction. The mucous membrane is composed of ciliated columnar epithelium.

The basic pattern of structural arrangement of the fallopian tube in various domestic mammals is more or less same.

Great modifications are observed in the oviduct of birds. In nonlaying hens the length is about 15 cm. At laying stage it increases much in length as well as in width. However in the birds the right set undergoes degeneration in early stage and only the left set persists throughout the life. Its different parts are Infundibulum, Magnum and Isthmus respectively from the ovarian end to the uterine end. It is continuous with the tubular uterine and vaginal parts of the genitalia.

UTERUS

The uterus has three main parts – a) horn, b) body and c) Cervix.

In cow the **horns** are well developed and the body is small and narrow. The horns (left & right) are thick walled muscular and tubular organs remain almost in the abdominal cavity between the oviduct and the body of the uterus. Each horn is 30 cm long is non pregnant condition and is directed forward, downward backward and upward in a curved manner. The broad ligament is attached to the lesser curvature of the horn. The horn is narrow

towards the tip and broad towards the body. The **body** is only 4 to 5 cm in length and thick walled. Cranially the body is bifurcated to continue as horns and caudally connected to the vagina through cervical canal. The **cervix or neck** of the uterus is a highly thick walled tube, about 8 cm in length and is composed of mainly circular muscles of the wall. The cervical canal is narrow and contains spiral folds of mucous membrane. The wall of the uterus is composed of serous, muscular and mucous coats from outside inwards, popularly known as perimetrium, myometrium and endometrium respectively.

The endometrial epithelium is columnar ciliated at the horn, columnar in the body and neck and stratified at the external os.

In the endometrium of the horn and body of cow, a large number (about one hundred) of raised pitted surfaced button like structures are present in a scattered manner, called uterine **caruncles** or **cotyledons**.

The uterus in mare has short horns and comparatively large body where as in case of bitch the body is practically absent and the horns are very long. In sow the horns are very long and coiled. The vagina and vestibule are tubular caudal continuation of the genitalia. In cow it is about 10 to 20 cm in length and presents a suburethral diverticulum just caudal to the opening of the urethra. In rabbit the horns of the uterus are individual tubes and open separately in to the cranial end of vagina.

MAMMARY GLANDS

The number of mammary glands is variable from species to species. In cow they are four in number, two at the left side and two on the right side. But all these glands are closely set in the inguinal region and the whole mass is popularly known as udder. In mare and goat these glands are two in number and both are situated in the inguinal region. In bitch they are five in each side- two pectoral two abdominal and one inguinal in position. Whatever may be the position is, the basic structure of the organ is same. Each gland is covered except the

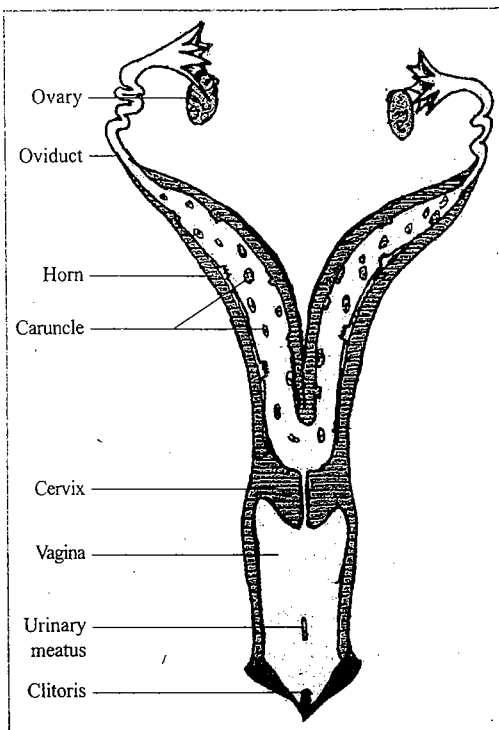


Fig. 1.38 Schematic diagram of genitalia of cow.

base by a thick capsule from which fibrous septa deep inside and divide the gland into several lobes. Each lobe contains the glandular parenchyma. The lobular ducts unite a little above the base of the teat and open in the milk sinus. In bitch the united ducts open independently through teat canals. Number of teat canals varies in different species.

GAMETOGENESIS AND FERTILIZATION

Female Germ Cells

Primitive sex cells are developed by the proliferation of endodermal cells of dorsal wall of yolk sac close to the allantoic canal of the developing embryo. Probably between 5th to 6th weeks of gestation the primitive sex cells migrate through dorsal mesentery of the gut and reach to the developing gonad. If the sex cells appear at the cortex of the genital ridge,

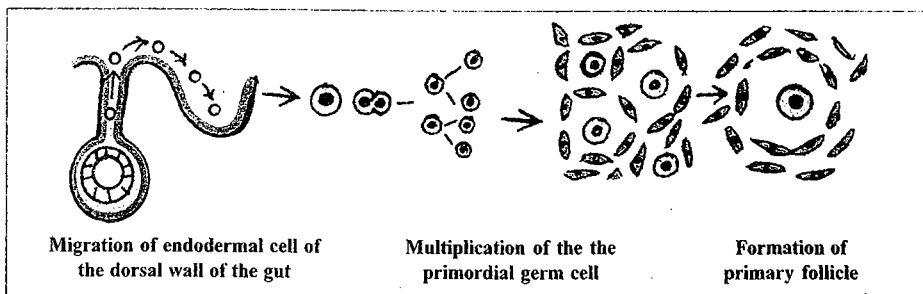


Fig. 1.39

the medulla regresses and the cortex is converted into ovary. When the sex cells reach of the medulla, the cortex regresses and testis develops. These primordial germ cells multiply to form numerous oogonia. When the foetus attains the age of 7 to 8 months the multiplication stops. Each oogonium increases in size and differentiates into primary oocyte. Then a layer of flattened epithelial cells surrounds a primary oocyte and form a primordial follicle (primary ovarian follicle). Most of the follicles degenerate at the early stage and only few thousand follicles persist at puberty. All mature ova are direct descendants of primordial germ cells of the embryonic stage of the animal.

OOGENESIS

In this process the primary oocyte develops to form mature ovum.

The primary oocytes complete the prophase of the first meiotic division at birth and then take rest for a prolonged period. Shortly before ovulation a primary oocyte completes the first meiotic (reduction) division and the secondary oocyte is formed.

In each estrus 5-10 follicles mature but only one follicle develops fully, ruptures and shed the secondary oocyte from the ovarian surface. Rest of the maturing follicles become atretic.

Maturation process

The oocyte completes the prophase of first meiotic division at birth. At puberty next changes occur.

This primary oocyte have eccentric nucleus and contains diploid number (xx) of chromosomes.

The following changes are observed at this stage.

- (a) The primary oocyte enlarges.
- (b) The follicular cells become cuboidal and multiply into several layers.
- (c) Zona pellucida a striated membrane is formed around the oocyte. This layer is formed by the fusion of the processes of primary oocyte, follicular cells and locally available glycoprotein.
- (d) The follicle enlarges, fluid filled spaces appear between the follicular cells and subsequently coalesce to form antrum folliculi. Therefore the follicular cells separate to form stratum granulosum and cumulus oophorus or cumulus ovaricus.
- (e) The theca externa (fibrous layer) and the theca interna (vascular and cellular layer) are developed outside the stratum granulosum by the stroma cells of the ovary and thus a mature Graafian follicle is developed
- (f) The primary oocyte completes the first meiotic (reduction) division which started during prenatal life. As a result two daughter cells each with haploid (n) number chromosomes are formed.
- (g) In this process the nuclear division is equal but the cytoplasmic division is unequal.

Therefore one daughter cell becomes large with abundant cytoplasm from the mother cell.

This is called Secondary oocyte. The small cell is the first **polar body** and becomes accommodated in the **perivitelline space**.

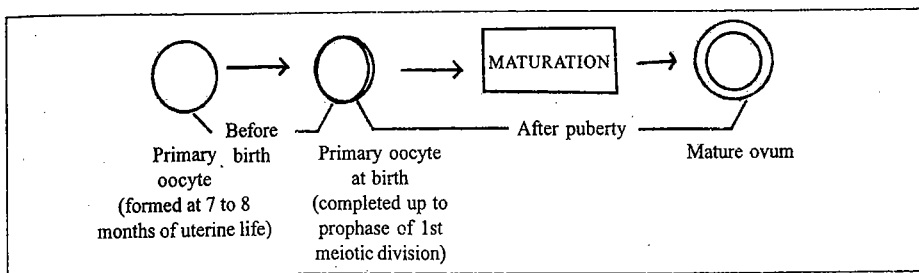


Fig. 1.40

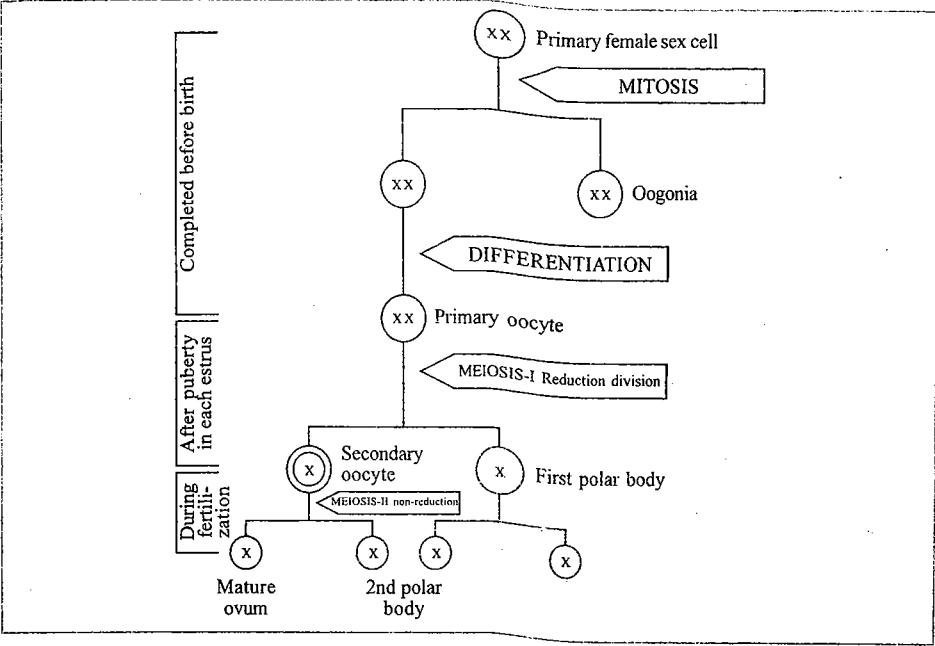


Fig. 1.41

OVULATION

Ovulation occurs when a mature Graafian follicle ruptures at the surface of the ovary. The ovulation can take place at any point of the surface excepting the hilus. In this process the secondary oocyte surrounded by zona pellucida and cumulus ovaricus cells, is shed from the ovary. Whether the ovulation occurs from alternate ovaries or randomly is not clearly known.

Characteristics of Secondary oocyte

- (a) It is larger than other cells. Diameter is about 150μ .
- (b) The cell membrane is known as **Vitelline membrane**. It is covered by **zona pellucida**.
- (c) The space between vitelline membrane and zona pellucida is known as **perivitelline space**.
- (d) The nucleus is large, eccentric and contains half number of chromosomes.
- (e) The ooplasm or yolk is similar to that of other cells in most of the mammals. This type of egg is known as **microlecithal eggs**. The eggs of birds contain abundant nutritive yolk (deutoplasm) and therefore called **macrolecithal eggs**. The oocytes of higher mammals contain little yolk and is dispersed almost uniformly and therefore called **isolecithal eggs**. The eggs of birds are also called **telolecithal eggs** because yolk tends to concentrate in one hemisphere. In the eggs of arthropods the yolk is located at the center and is surrounded by a peripheral layer of cytoplasm and therefore called **centrolecithal eggs**.

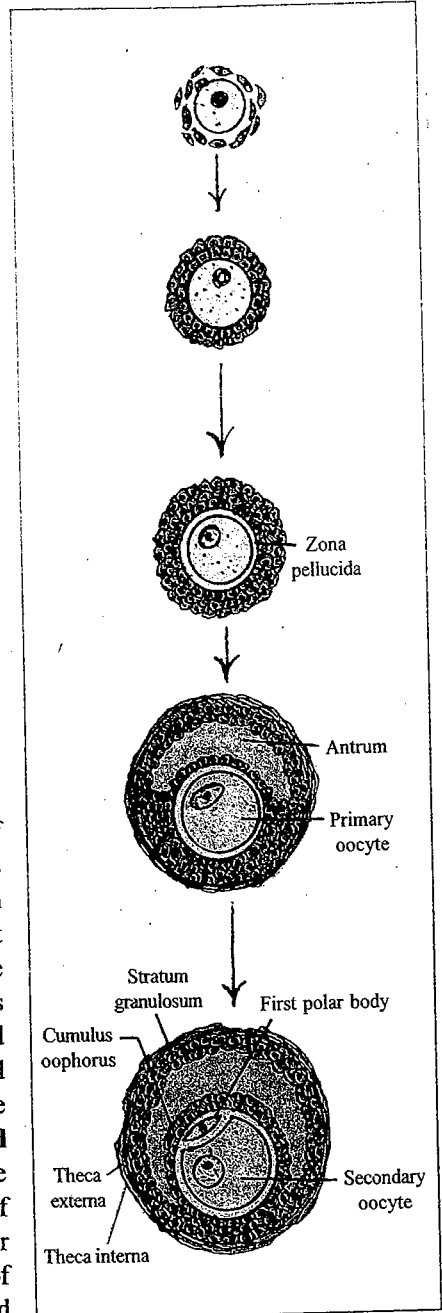


Fig. 1.42

- (f) The cells surrounding the oocyte are attached to the zona pellucida in a radiating manner. This cellular arrangement is called **corona radiata**.
- (g) The centrosome with two centrioles is situated close to the nucleus.

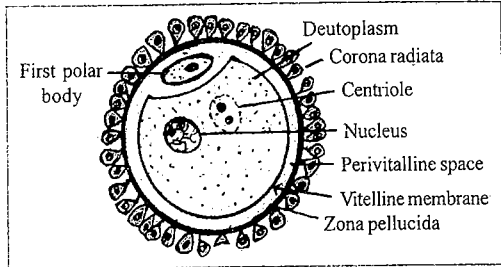


Fig. 1.43

Male Germ Cells

The primitive sex cells migrate from the endodermal cells of the hind gut through dorsal mesentery of the gut and reach the medulla of genital ridge. The medulla is converted into

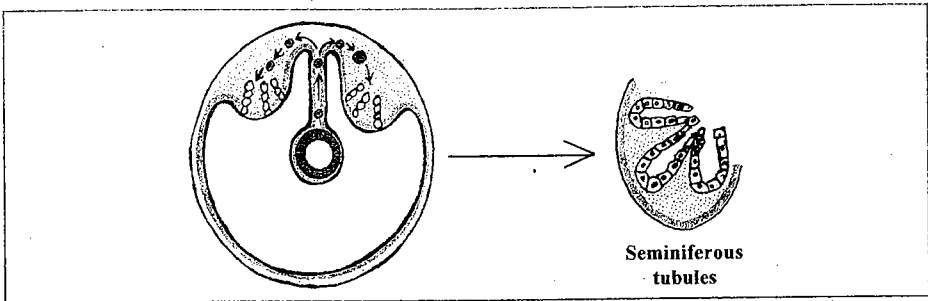


Fig. 1.44a

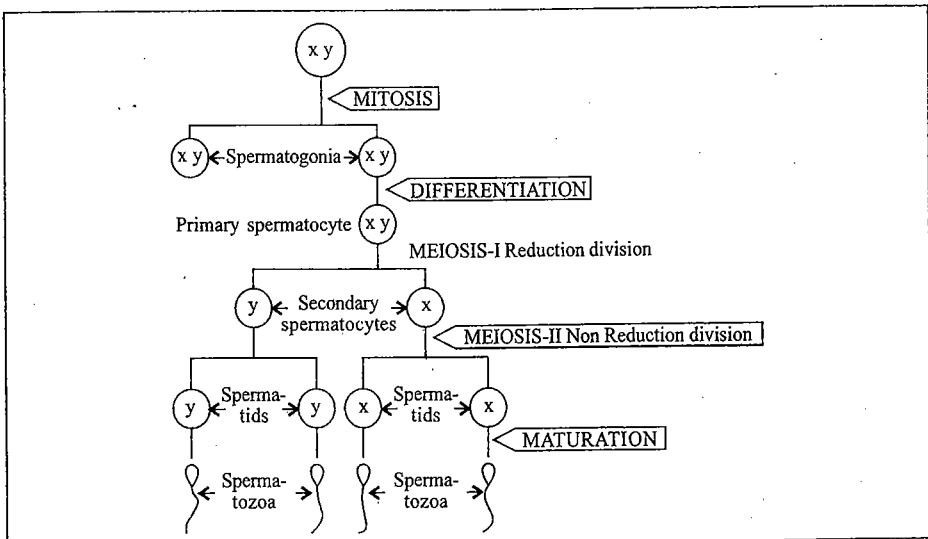


Fig. 1.44b

components of testis and the sex cells are ultimately transformed into spermatozoa.

From the surface epithelium of genital ridge numerous cellular testis cords project into the interior of the ridge. All the primitive sex cells are incorporated into these testis cords. These cords become canalized and seminiferous tubules are developed.

The tubules are the essential structural units of the testis. The epithelium contains (a) male germ cells and (b) Sertoli cells. The sustentacular cells of Sertoli are large long cells and extend from basement membrane to the lumen of the tube. They give support and nourishment to the spermatogenic cells.

In seminiferous tubules the germ cells are arranged in layers. (i) The outer layer consists of **spermatogonia** which are produced by mitosis of primitive sex cells, (ii) The intermediate layer is having an outer zone comprising of **primary spermatocytes**, produced by mitosis of spermatogonia. The inner zone of the intermediate layer contains **Secondary Spermatocytes** which are produced by 1st meiotic (reduction) division of the primary spermatocytes. Therefore the secondary spermatocytes contain haploid number of chromosomes. (iii) The inner layer consists of spermatids. These are produced by 2nd meiotic (non-reduction) division of secondary spermatocytes. Spermatozoa are produced from these spermatids by metamorphosis.

Spermatogenesis

It is a process of conversion of primitive male germ cells into spermatozoa through a series of chemical and physical changes. This process starts at puberty. The primary male sex cells divide by mitosis and form **spermatogonia**, they differentiate to form **primary spermatocytes** and each of them contains as usual diploid ($2n$) number of chromosomes. Each primary spermatocyte undergoes reduction division (Meiosis - I) and form two daughter cells – the **Secondary spermatocytes**. Therefore secondary spermatocytes contain haploid (n) number of chromosomes. Each secondary spermatocyte divides again through a non-reduction division (Meiosis – II) and form **spermatids**. Metamorphosis of Spermatids leads to the formation of **spermatozoa**.

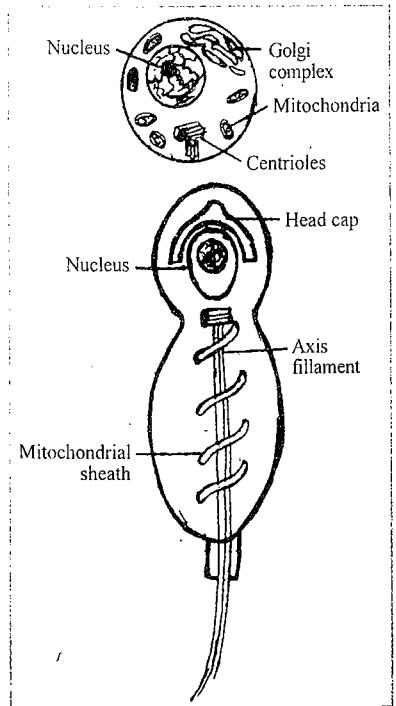


Fig. 1.45

Spermiogenesis

By this process the spermatids undergo metamorphological transformation into spermatozoa without any cell division. The Golgi vesicles coalesce to form head cap. The posterior centriole form axis filaments of the body and tail. The mitochondria are rearranged in a spiral manner and form mitochondrial sheath. The spermatid elongates.

FERTILIZATION

This is a process, when two mature germ cells, i.e. a spermatozoon and an ovum fuse together and form a single cell, the zygote. Therefore zygote is an undifferentiated diploid cell which is formed by the fusion of two highly specialized haploid gametes. Fertilization occurs in the uterine tube.

The process involves the following stages :

Approach of Gametes

By this process the male and female gametes reach the uterine tube and become close with each other. At the time of coitus or artificial insemination, the semen is deposited in the vagina close to the cervix. The transportation of spermatozoa is facilitated with the prostaglandin of the semen by induction of contraction of uterine muscle. Coital reflex also play a role for the release of oxytocin by the pituitary which helps in the contraction of the uterine muscle. Inside the uterine horn the spermatozoa mix up with the secretion of the uterine glands. The mixture enters the fallopian tube by aspiration. The motility of spermatozoa play little role in transportation process. Since the beginning (uterine end) of the fallopian tube is narrow, a remarkably reduced number (about 500) of spermatozoa can reach to the site of fertilization.

The oocyte moves from the ovary to the uterine tube by the activity of the fimbriated end of the infundibulum, ciliary beats and by the rhythmical contraction of the musculature of the tube.

Fusion Gametes

At the time of ovulation the secondary oocyte (haploid) is released after being produced from the primary oocyte by the process of first meiotic reduction division. The secondary oocyte reach the uterine tube and come in contact of spermatozoa.

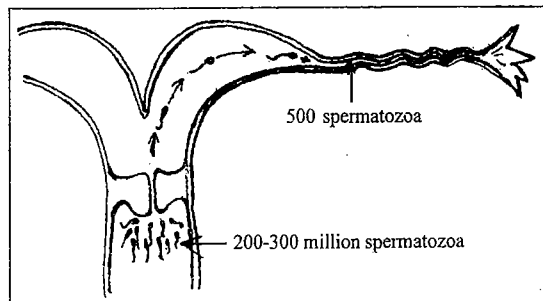


Fig. 1.46

In one ejaculation about 200 to 300 million spermatozoa are released. Out of them about 500 spermatozoa reach the fertilization site. Only one spermatozoon fuses with the oocyte after crossing the barrier of corona radiata, zona pellucida and the vitelline membrane of the secondary oocyte. Other spermatozoa which reached the ovum, become engaged in disintegration of corona radiata cells by the secretion of an enzyme **hyaluronidase**. Rest of the spermatozoa die within 24 hours after ejaculation.

After the contact between the male and female gametes, there is a brief period (about 5-7 hours) of resting when the anticapacitation factors like glycoprotein, seminal plasma, etc. are removed from the acrosomal region of the spermatozoa. This period is called **capacitation period**.

A bilamellar membrane which covers the anterior two-third of the nucleus of the spermatozoon is known as **Acrosome** or **head-cap**.

When the spermatozoon come in close contact to the secondary oocyte, a series of enzymes are released in succession from the acrosome for penetration to the barriers. This process of releasing of enzymes is known as **Acrosomal reactions**.

Fusion of sperm head with the oocyte occurs when a spermatozoon crosses the first barrier (corona radiata) by the activity of hyaluronidase, second barrier (zona pellucida) by the activity zona lysine and another trypsin like substance. During acrosomal reaction, the bilamellar plasma memberame of the acrosome disappears and the spermatozoon touches the third barrier – the vitalline membrane and two plasma membranes are fused. Immediately after the entry of head inside the oocyte, the ruptured entry point is blocked by cytoplasmic granules to prevent entry of other spermatozoa. This process is called **vitelline block**.

Results of fertilization

1. The moment the spermatozoon enters the secondary oocyte, it completes the second meiotic (maturation) division and forms a mature ovum with extraction of the second polar body outside the vitelline membrane (perivitelline space)
2. The nucleus of the mature ovum is called the **female pronucleus**. At the same time the head of the spermatozoon sweels to form **male pronucleus**. Both the pronuclei fuse together and the diploid number of chromosome is restored in the zygote.
3. The chromosomal sex is determined. If X-bearing spermatozoon fertilizes the ovum the off-spring becomes female and if a Y bearing spermatozoon fertilizes an ovum, a male animal is formed.

PERIODS OF EMBRYOLOGY

The changes, those occur during the whole gestation period are subdivided into the following stages.

- I. Germinal stage
- II. Embryonic stage
- III. Foetal stage

The **Germinal stage** includes cleavage, formation of morula and blastocyst, implantation of blastocyst and appearance of three germinal layers.

The **Embryonic stage** comprises of differentiation of the three germinal layers and formation of most of the tissues and organs.

The **Foetal stage** is characterized by growth of various systems of the embryo without much tissue differentiation and development of placenta. The gestation period is variable in different species as shown in the table.

Animals	Period of Gestation
Cow	280 to 290days
Mare	330 to 340days
Dog/Cat	60 to 65days
Sow	110 to 130days
Goat/Sheep	140 to 160 days
Human	270 to 290 days
Elephant	600 to 650 days
Rabbit	30 to 35 days
Rhinoceros	520 to 560 days
Rat	20 to 25 days
Monkey	160 to 175 days
Hen	(incubation period) 20 to 25 days

GERMINAL STAGE

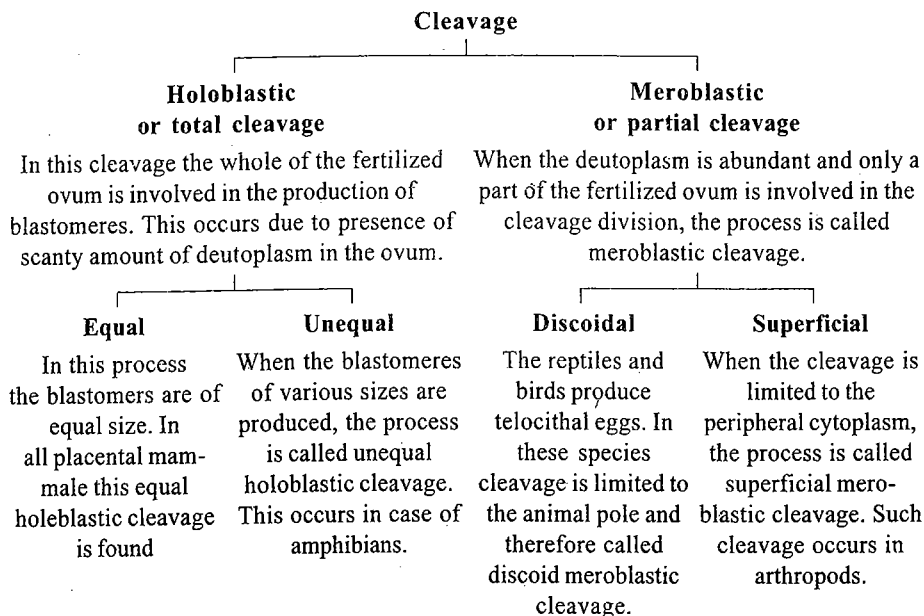
CLEAVAGE

This is a process of rapid successive mitotic division of an ovum immediately after its fertilization, resulting in production of increasing number of smaller cells within the zona

pellucida, called **blastomeres**. The rate of cleavage division is inversely proportional to the amount of yolk present in the ova. The results of the cleavage are as follows:

- (a) Zygote is segmented into smaller cells – blastomeres.
- (b) Mobility of the blastomers is increased due to their smaller size.
- (c) The size of the cells becomes characteristic to the species.

The nature of cleavage those occur in different species is tabled below.



MORULA

It is a stage of cleavage where the number of cells (blastomeres) is 12 to 16 and remain closely packed without formation of any cavity inside. Since the pack of blastomeres looks like a mulberry fruit, it is called morula.

In case of chick embryo it appears as a disc shaped mass of cells, several layers in thickness and remains closely applied to the yolk.

The central cell mass of the morula generally gives rise to embryo proper and the peripheral cells form protective and nutritive covering of the embryo. Even in this stage the blastomers remain within the covering of zona pellucida and the cells change their positions within the central and peripheral cell mass.

With the continuation of cleavage the zygote migrates from ampulla of the fallopian tube and subsequently reach to the cavity of the uterus, either in the horn or in the body depending

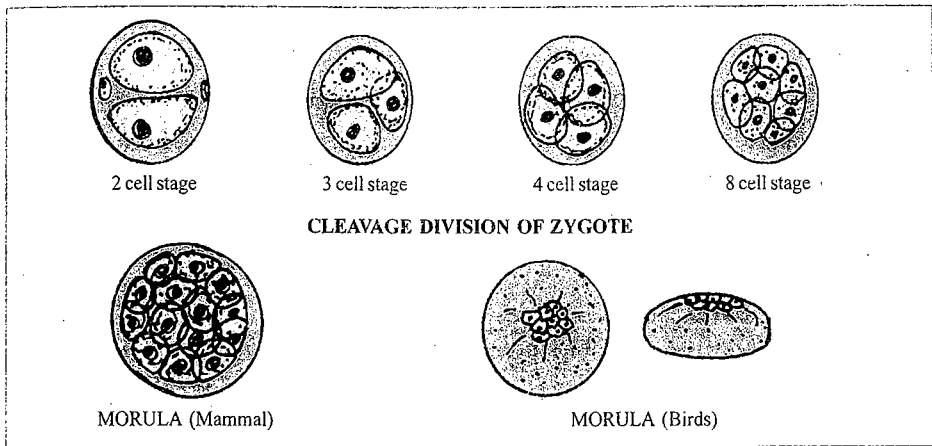


Fig. 1.47

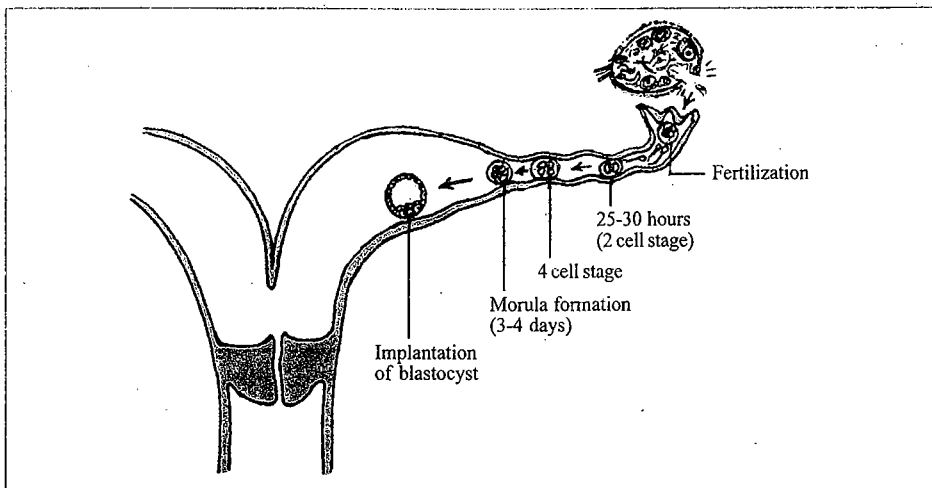


Fig. 1.48 Changes during 1st week of gestation in cow (approx).

upon the species. During this period the zygote is transformed into morula stage. This migration is facilitated by the cilia of the mucous membrane of the tube and by its muscular contraction.

BLASTOCYST

In the uterine cavity the blastomeres continue to divide and fluid forms the lumen of the uterus enters inside the morula through zona pellucida and forms a central cavity. This fluid gradually separates the blastomeres into an inner cell mass and an outer cell mass.

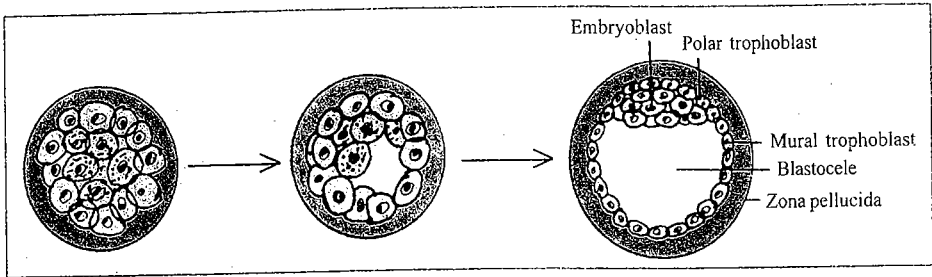


Fig. 1.49

The fluid filled cavity is called **blastocoele** and the whole structure is known as **blastocyst**. The outer cell mass which form the wall of the blastocyst, is called **trophoblast**. The inner cell mass is called **embryoblast**.

Blastocyst is generally formed between 4th to 5th day after fertilization in cow and man. The part of the trophoblast which covers the embryonic pole of blastocyst is known as **polar trophoblast** and the remaining part of the trophoblast forming the wall of the cavity is known as **mural trophoblast**.

Implantation of blastocyst

The zona pellucida disappears on 5th or 6th day of fertilization in human and 7th to 9th day in cow. In man and rodents the polar trophoblast is implanted on the decidual wall of uterus by proteolytic action. The blastocyst is embedded gradually in the decidua of uterus by histolytic action of trophoblast. By the end of second week the blastocyst is completely embedded in the endometrial stroma in human. Therefore in human it is totally an invasive process. In domestic animals implantation is not an invasive process but it occurs by adhesion and apposition between trophoblast and uterine epithelium. However in **pigs** the process involves invasiveness. In this species blastocyst starts its attachment to the uterine surface

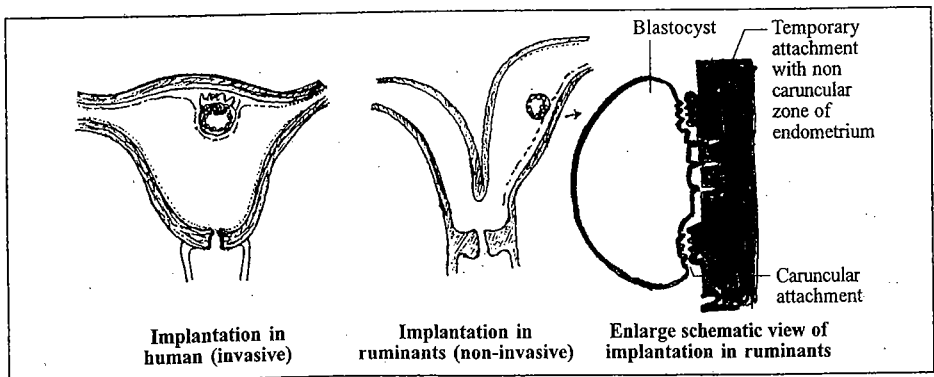


Fig. 1.50

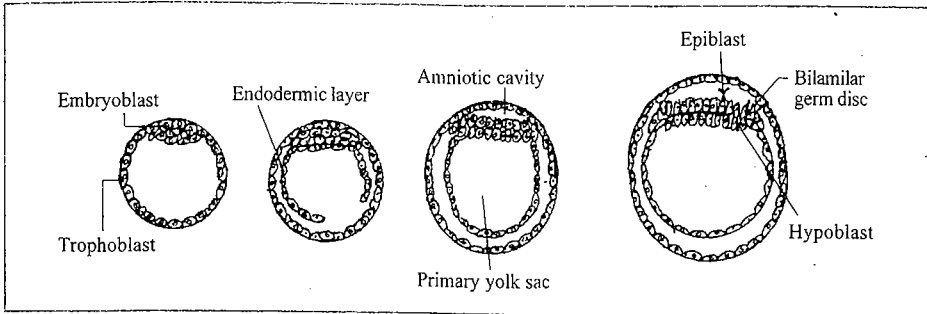


Fig. 1.51 Formation of primary Yolk Sac, amniotic cavity and differentiation of endoderm and ectoderm.

on 13th day and finishes on 18 to 24th day. In **ruminants** the placental attachment involves both caruncular and inter-caruncular areas of endometrium. As a short time measure the trophoblast develops finger like projections which extend into the uterine gland and provide a temporary anchor for absorption of nutrition during implantation and in the meantime caruncular attachment progresses.

During the process of implantation some uninucleated trophoblastic cells give rise to **binucleated** cells on about 17th day of gestation. These cells persist throughout the gestation period and subsequently involve in immunologic protection. In **mare** implantation takes place on 24 to 40 days of gestation. The growth and development of blastocyst becomes rapid after the disappearance of zona pellucida. The trophoblast differentiate into an inner layer known as **cytotrophoblast** and an outer layer called **syncytiotrophoblast** or **syncytium**. The embryo gives rise to an inner endodermic layer of cells and enclose the blastocoele gradually. Thus a bilaminar blastocyst is formed. The primary endoderm enclose a cavity at the opposite side of the embryonic (abembryonic) pole known as **primary yolk sac**. The endodermic layer of the embryo is known as **hypoblast**. The cells close to the polar trophoblast of the embryo are transformed into tall columnar cells. This layer is called **epiblast** or **primary ectoderm**. In between epiblast and hypoblast an extracellular basement membrane appears. The cytotrophoblast and the epiblast are separated with each other to form a fluid filled cavity – the **primary amniotic cavity**. Therefore a bilaminar plate is formed between the primary yolk sac and primary amniotic cavity. This bilaminar plate gives rise to the development of embryo and is known as bilaminar germ disc.

Appearance of germ layers

The germ disc is circular at the first stage. Subsequently it becomes elongated and future axis of the embryo is indicated. One end becomes broad (cephalic end) and the other end becomes narrow (caudal end).

Three functional zones are differentiated in the ectodermal layer of the germ disc.

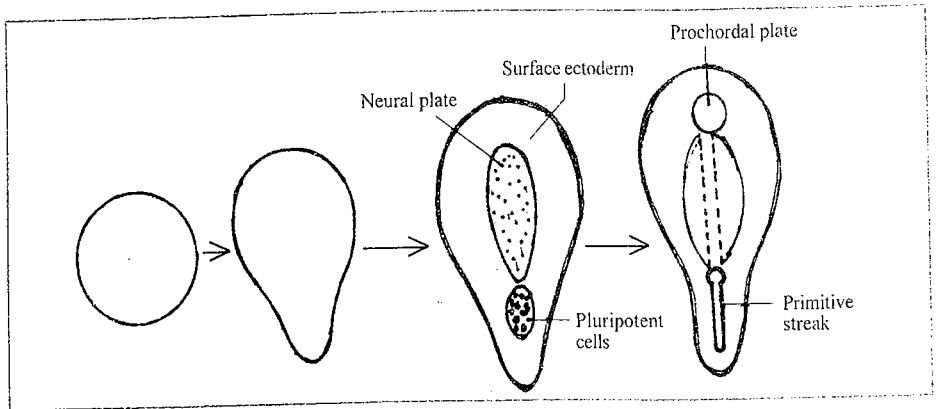


Fig. 1.52

These are as follows :

- Surface ectoderm** – The cells of cephalic end and the peripheral margin constitute the surface ectoderm. It gives rise to epidermis of skin.
- Neural plate** – The cells on a depressed area at the central part of the surface ectoderm form an elongated plate which gives rise to future nervous system. This part is called neural plate.
- Pluripotent cellular zone** – A group of fast proliferating cells are accommodated at the caudal part of the germ disc. They differentiate very rapidly and form a linear opacity in the midline, called **primitive streak**. These cells are known as pluripotent cells.

At the end of first month of gestation a narrow median groove appears, with slightly raised lateral margins. The pluripotent cells migrate and invaginate into the space between the epiblast and hypoblast and this invagination procedure is known as **Gastrulation**. Formation of three germ layers by the rearrangement of blastodermal cells is necessary for organogenesis. This cellular rearrangement by the process of invagination is the chief event of gastrulation.

The definitive **endoderm** is formed by the replacement of primary endodermal cells with some cells of the primary ectoderm or the epiblast by invading through hypoblast. Again some cells of epiblast migrate bilaterally through the primitive streak, reach between the

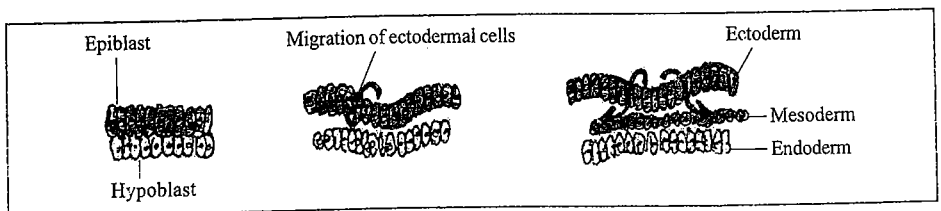


Fig. 1.53

epiblast and definitive endoderm to form **mesoderm**. Now the epiblast is called the definitive **ectoderm**.

Therefore all the three components of the tri-laminar germ disc, ectoderm, mesoderm and endoderm are derived from pluripotent epiblast.

Formation of Notochord

The cephalic end of the primitive streak becomes swollen by the proliferation of cells. This is called **primitive knot** or **Henson's node**. A central depression appears at the Henson's node called **primitive pit** or **blastopore**. The pit goes downward and forward and the cells surrounding the primitive pit gradually extend in the form of a solid tube cranially along the midline between the ectoderm and endoderm up to the prochordal plate. The cavity of the primitive pit also extends through the cellular extension and converts it into a canal called **notochordal canal**. Subsequently the floor of the canal breaks down and communicates with the yolk sac. It also becomes continuous with the amniotic cavity through the primitive pit. Therefore at this stage the amniotic cavity and yolk sac become continuous. This occurs probably to supply nutrition to the ectodermal surface of germ disc. Gradually the notochordal wall becomes flat to form a notochordal plate. This plate forms a fold along the long axis at the roof of the yolk sac which is now lined by endodermal layer. This fold becomes deep to form a tube. This tube is converted into a solid chord of cells which is now known as **definitive notochord**. The notochord acts as a fore-runner for the development of the vertebral column. The notochord elongates, gets separated from the endoderm and takes a midline position. However, with the formation of vertebral column, the notochord disappears but parts of it persist as nucleus pulposus of intervertebral disc.

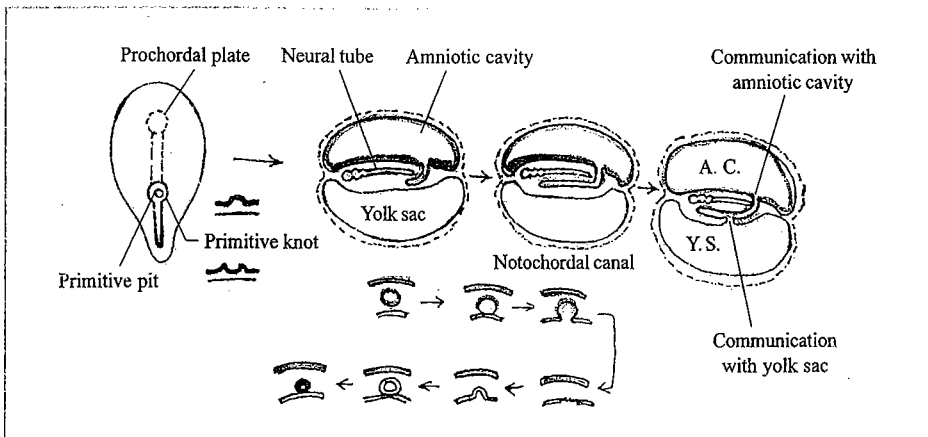
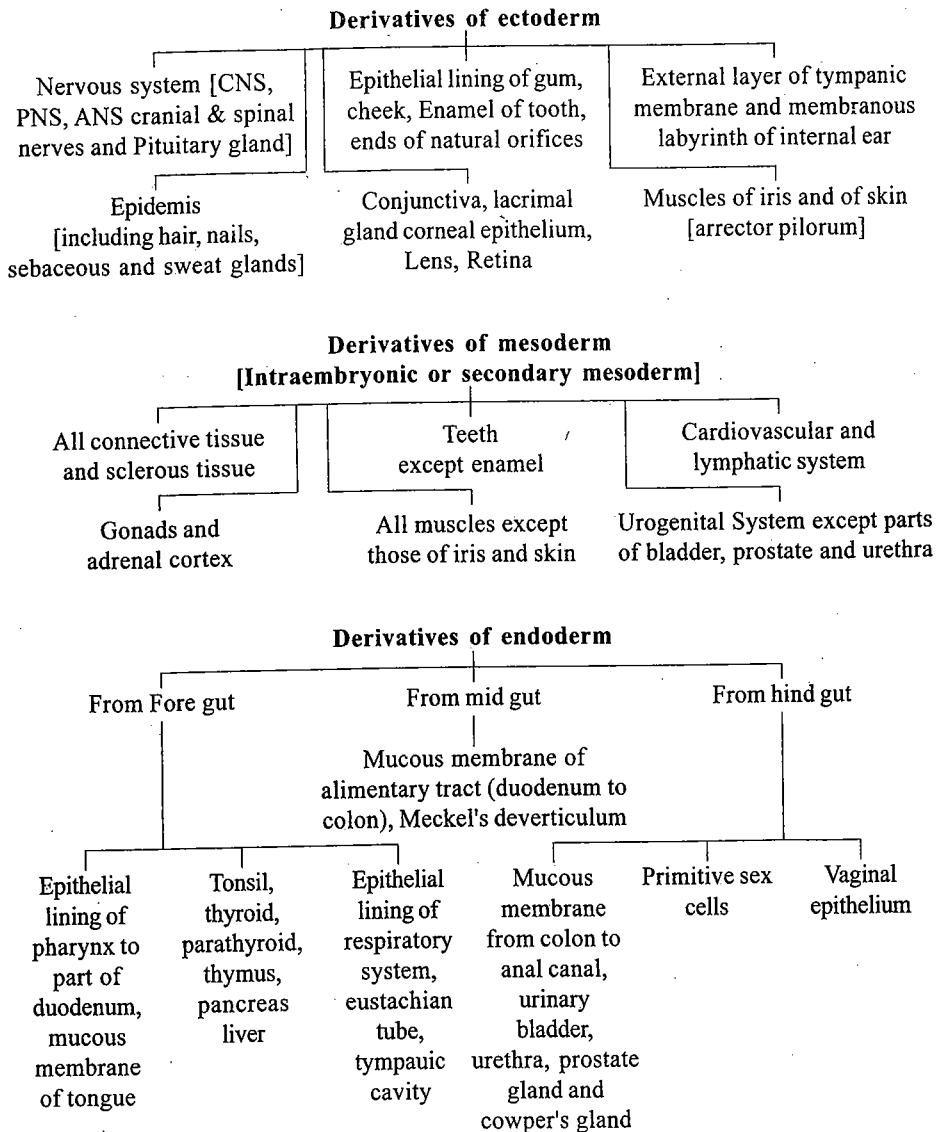


Fig. 1.54

EMBRYONIC STAGE

In this period each of the three germinal layers lay down most of the organs and tissues. The ectoderm forms covering of the body and nervous system, the endoderm forms mucous membrane of gut and the mesoderm gives rise to skeletal tissue, muscles and blood vascular system.



Differentiation of ectodermal layer

The neuroectoderm gives rise to the entire central and peripheral nervous system including cranial, spinal and autonomic ganglia. The surface ectoderm forms outer protective covering of the embryo and helps in the development epidermis, hair, nails, sebaceous and sweat glands. The other derivatives have been mentioned in the chart.

Differentiation of mesodermal layer

The intra-embryonic mesoderm which is formed by the proliferation of the cells of primitive streak, at first appear as loose sheet on each side of the median plane in between the ectoderm and endoderm. At the periphery of the embryonic disc the intra-embryonic mesoderm is continuous with extraembryonic mesoderm. Now the loose sheet of intra-embryonic mesoderm of each side becomes divided longitudinally into three zones.

- (i) **Paraxial mesoderm** – This is a thick layer and placed just at the lateral side of notochord.
- (ii) **Intermediate cell mass** – This part is placed lateral to the paraxial mesoderm. This is thinner at the beginning but becomes bulky later.
- (iii) **Lateral plate mesoderm** – This thin part is placed further laterally and extends to the periphery of the germ disc to be continued with the extra embryonic mesoderm.

The **paraxial mesoderm** becomes subdivided into a number of cubical blocks of tissue masses and are called **SOMITES** or **METAMERES**. The somites do not appear all at a time. They start appearing at the end of first month of gestation. The somites are formed in cranio-caudal direction and their time of appearance is variable depending upon the species. In this somite period the approximate age of the embryo may be assessed by counting the number and matching with standard table.

As example it may be stated that in case of chick embryo the somites begin to start only on 22 hours of incubation. Eight pairs of somites appear by 27 hours of incubation. Subsequent number of somites appear with the progress of incubation period. Each cubical somite subdivides into a ventromedial part called **sclerotome** and a Dorsolateral part known as **dermomyotome**. The Sclerotome moves ventromedially around the notochord and forms primitive vertebra. The dermomyotome again divides into a **dermal plate** and a **muscular plate**. The dermal plate forms the dermis and subcutaneous tissue and the muscular plate (myotome) gives rise to spindle shaped cells of skeletal muscle.

The **intermediate cell mass** which remains in between the para-axial mesoderm and lateral plate, projects into the dorsal wall of the coelom on each side and gives rise to the development of nephric system and sex glands.

In the **lateral plate mesoderm** small cavities appear. They coalesce to form a large cavity, the **intraembryonic coelom**. This intra-embryonic coelom forms the pericardial sac, plural sac and peritoneal sac.

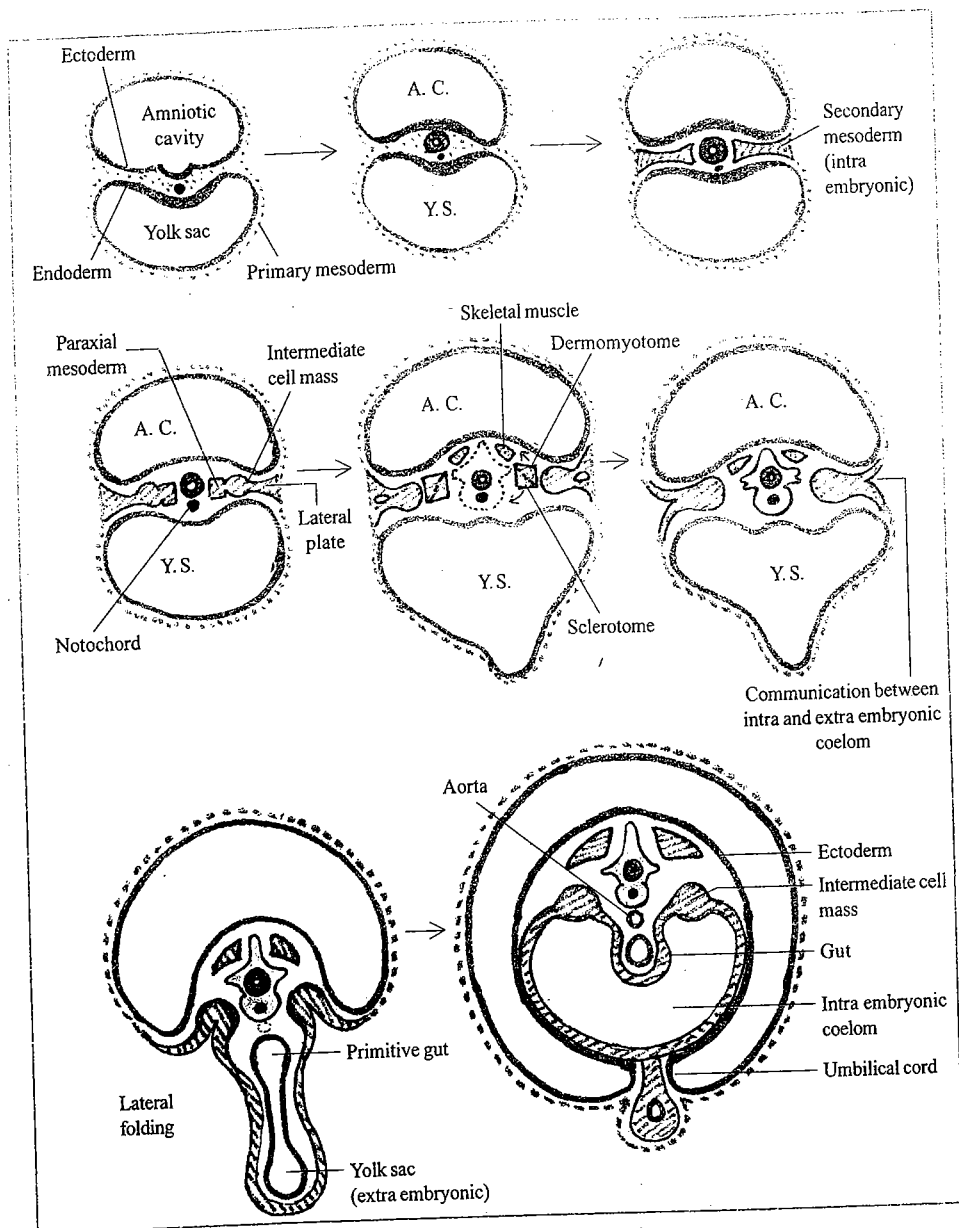


Fig. 1.55 Stages of embryonic development.

With the development of intra-embryonic coelom the lateral plate mesoderm divides into a parietal layer called the **Somatopleure** and the visceral layer called **splanchnopleure**. A communication develops between the intra and extra embryonic coelom after breaking through

the continuity between somatopleuric and splanchnopleuric layers. The mesoderm situated at the cephalic aspect of embryonic area does not split and forms a plate, called **septum transversum**. This septum contribute to the formation of diaphragm.

Differentiation of endodermal layer

The derivatives of this layer has already been mentioned. Other details of the endodermal development would be discussed in the alimentary system.

Folding of embryo

As the cells at the center of the flat germ disc proliferate rapidly than those of periphery, the embryonic area develops a head fold, a tail fold and two lateral folds at the end of first month. Therefore a cylindrical shape of the embryo is formed.

During the folding, growth of the yolk sac slows down and the **amniotic cavity** enlarges. It surrounds the whole embryo so that the latter floats in the amniotic fluid.

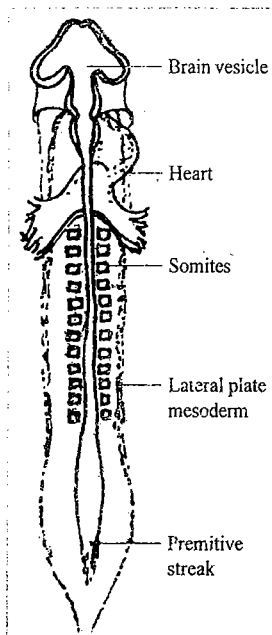


Fig. 1.56 A chick embryo with 12 pair of somites at 34 hours of incubation.

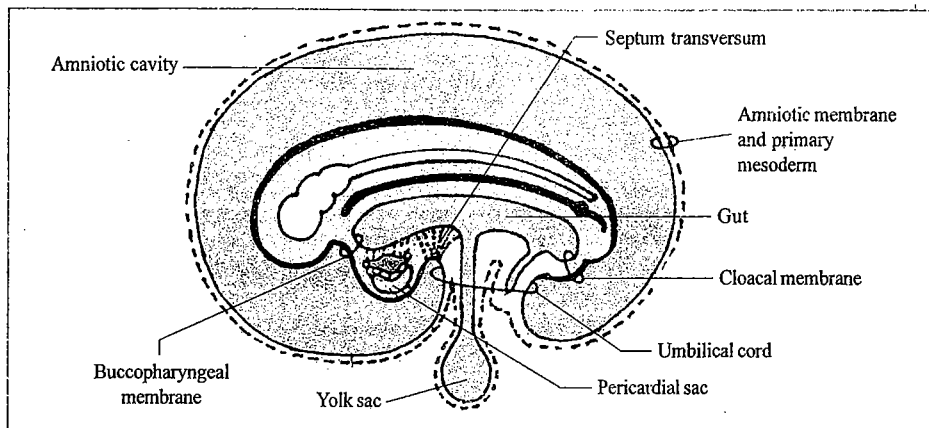


Fig. 1.57 Sagittal section of developing embryo.

FOETAL STAGE

Growth of the foetus occurs in this period rapidly due to maturation of various tissues and organs. In this stage complete development of placenta takes place along with umbilical

cord and foetal membranes. This period extends from 3rd to 4th months of gestation to the termination of pregnancy.

The foetus gains more weight, volume and the contour due to deposition of subcutaneous fat. However fat deposition mainly occurs at the second half of pregnancy. At the 7th or 8th month of gestation, alveoli grow within the lung buds and the capillaries are established. Therefore 8th month onwards foetus may survive if the pregnancy terminates early.

At birth a full term foetus have complete descended testes in the scrotum, attachment of umbilical cord in the center of the ventral abdominal wall and appearance of epiphysal center at the lower end of femur take place. Although growth is more predominant in this period, the differentiation to some extent continues throughout pre and post-natal life.

Approximate age of an embryo may be determined by measuring the **crown rump length**. It is the distance between the fore head and sacral prominence. The data is variable in different species.

PLACENTA AND ITS DEVELOPMENT

The placenta can be defined as an area where a close apposition or fusion takes place between the uterine wall and embryonic tissue for exchange of materials.

Placenta develops from two sources : (a) Foetal part from chorio-allantoic membrane ; (b) Maternal part, the decidua basalis.

The chorionic villi attached to the embryonic pole of the blastocyst proliferate more rapidly and are called **Chorionic frondosum**.

When the blastocyst is embedded in the endometrial wall, the endometrium is changed to **decidua** due to decidual reaction. In this phase the secretory activity of the endometrium is intensified, glycogen and lipids are stored and vacuoles appear into the stroma

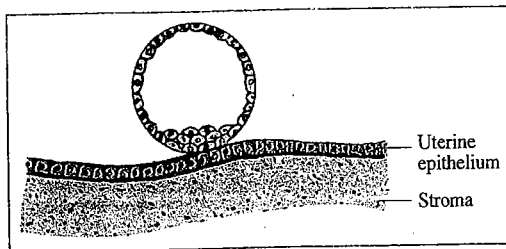


Fig. 1.58

Stages of development

- (a) **Zona pellucida** disappears at the time of implantation.
- (b) The trophoblastic layer differentiates into an inner layer of **cytotrophoblast** and an outer layer of **syncytiotrophoblast**.
- (c) The syncytiotrophoblast proliferates into a multilayered and multinucleated protoplasmic mass.

- (d) The cytotrophoblast differentiates internally into a layer of **primary mesoderm**.
- (e) **Primary mesoderm, cytotrophoblast** and **syncytotrophoblast** together form the **chorion**.
2. Within the syncytotrophoblast, a number **lacunar spaces** appear. Syncytal cells form cords between the lacunar spaces, called **trabeculae**.
 3. The lacunae enlarge and erode branches of uterine arteries and veins and become filled with maternal blood.
 4. Cords of cytotrophoblast invade the trabeculae and convert them into **primary chorionic villi**. Lacunar spaces are now called **intervillous spaces**. An outer

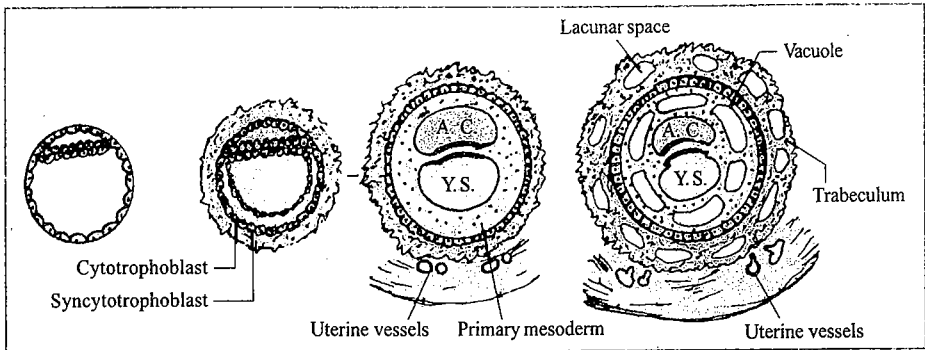


Fig. 1.59

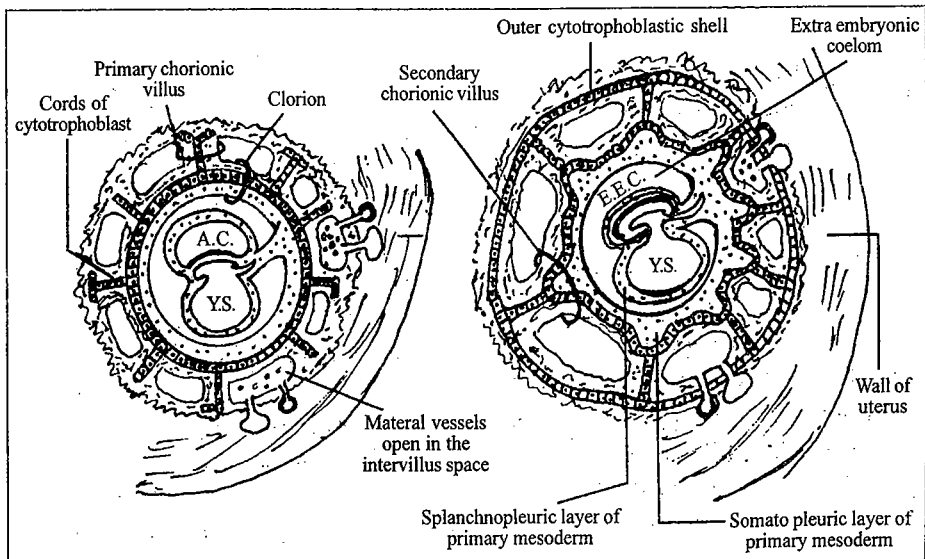


Fig. 1.60

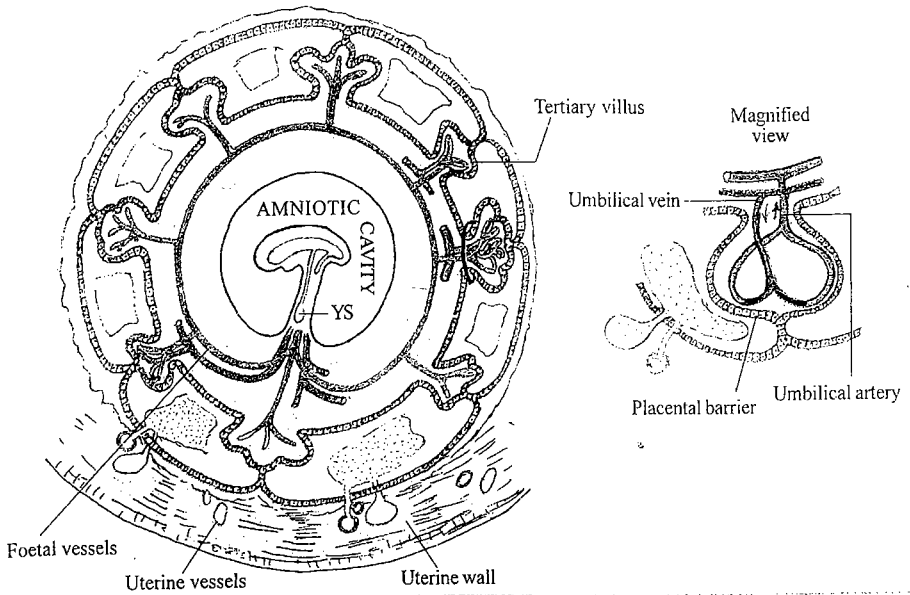


Fig. 1.61

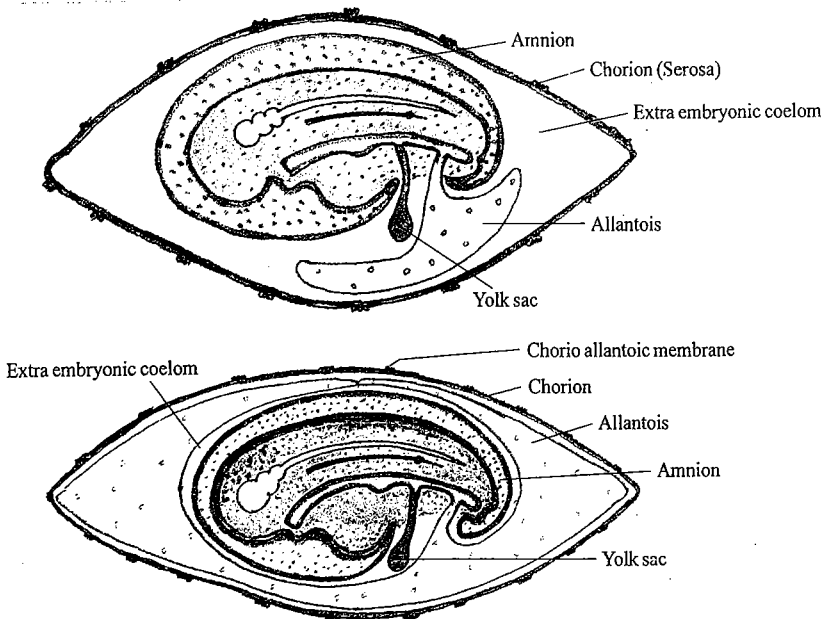


Fig. 1.62

cytotrophoblastic shell is formed due to spreading of cytotrophoblast outwards from the tip of the cytotrophoblastic cords on either sides in the form of **T of Y**.

5. Primary chorionic villi are transformed into **secondary chorionic villi** when primary mesodermic layer invade into the primary villi along the axis.
6. When the foetal blood vessels appear within primary mesoderm and their branches project into secondary villi, these are converted into **tertiary villi**. Subsequently these tertiary villi become branched and project into the intervillous space.
7. Vacuoles also appear within the primary mesoderm. Subsequently they coalesce to form extra-embryonic coelom between the amniotic cavity and primary mesoderm.

In **birds** and in **some farm animals** (cattle, sheep, goat, pig), the allantoic vesicle expands into the extraembryonic coelom very rapidly and ultimately surrounds the whole amniotic cavity. It occupies the space between the amnion and the chorion (serosa). The outer wall of the allantois fuses with chorion and forms **chorioallantoic type of placenta**. The amniotic cavity contains **amniotic fluid** within which the embryo floats and gives protection to it by neutralising shock and pressure. During parturition it works as a lubricant. The fluid contains salts, water, protein and sugar.

In **bovines**, attachment between maternal and foetal membranes occurs throughout the endometrium of the horn in a sporadic manner as per distribution of cotyledons. In **human** the chorionic villi develop rapidly at the embryonic pole and are called **chorionic frondosum**. Rest of the villi attached to the abembryonic pole degenerate and disappear. In **carnivores**, the villi occupy on a girdle like band around the middle of chorionic sac.

Therefore placenta formation (contact between foetal membrane and endometrium) occurs in various zones which differs characteristically depending upon the species.

According to the distribution of chorionic villi placental classification is made as follows:

Type of Placenta	Animal	Characteristics
Diffuse	Horse, Pig, Camel	Villi are scattered all over the surface of chorion
Cotyledonary	Cow, Goat, Deer	Villi are present on multiple button like caruncles
Zonary	Dog, Cat	Villi are situated on a strip or band around the middle of the sac
Discoid	Human, Rabbit	Villi are placed on a large flattened area in the form of a disc
Bidiscoid	Monkey	Villi are distributed in two discs

Placental barrier

Between the maternal blood and foetal blood, there remains a composite layer of tissue, called placental barrier. These layers are generally composed of (a) Syncytiotrophoblast,

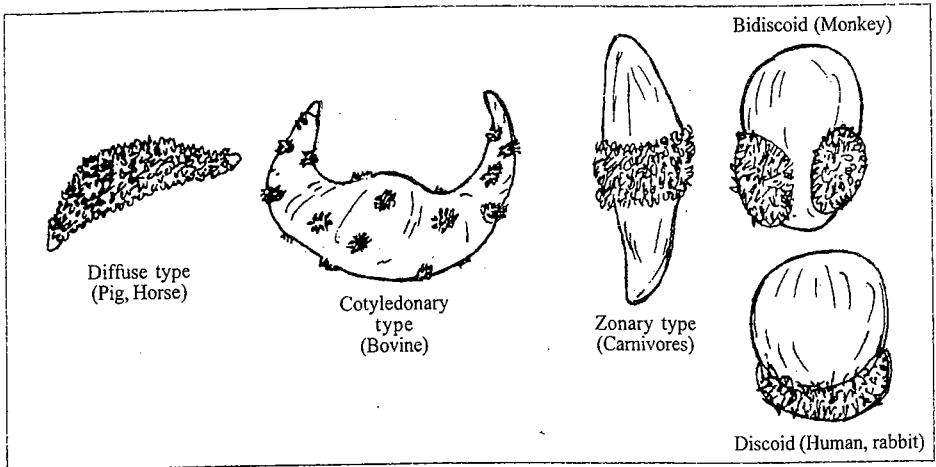


Fig. 1.63

(b) cytotrophoblast, (c) primary mesoderm, (d) Endothelium of foetal and maternal blood vessels, (e) endometrium etc. ; but variable in different species as shown in the table. According to this barrier, another classification has been made. However many authors have recorded different types of classifications on the basis of other structural characters which are not mentioned here.

Classification according placental barrier

Present – ✓ Absent – ×

Type of placenta	Animal	Endo-metrial epithelium	Endo-metrial stroma	Syncyotrophoblast	Cyotrophoblast	Primary mesoderm	Endothelium of foetal vessel	Endothelium of maternal vessel
Epithelio-chorial	Pig Horse Camel	✓	✓	✓	✓	✓	✓	✓
Syndesmo-chorial	Cattle Sheep Deer	×	✓	✓	✓	✓	✓	✓
Endothelio-chorial	Dog	×	×	✓	✓	✓	✓	✓
Hemochorial	Man	×	×	✓	✓	✓	✓	×
Haemo-endothelial	Rabbit	×	×	×	✓	✓	✓	×

Umbilical cord

It is a thick cord like structure which extends from center of the abdominal wall of the foetus to the centre of the foetal surface of placenta. It is composed of **two umbilical arteries, one Umbilical vein, duct of the yolk sac and distal part of allantoic diverticulum**. All these structures are surrounded by **Wharton's jelly** and finally enveloped by **amniotic membrane**. The Wharton's jelly is formed by the mucoid degeneration of the mesodermal cells of the connecting stalk.

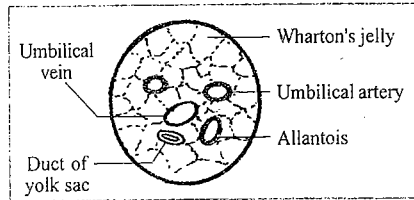


Fig. 1.64

FETAL CIRCULATION

The umbilical vein carrying placental (oxygenated) blood, enters the abdomen of the fetus at the umbilicus and enters the liver. At the early part of embryonic life two umbilical veins are present. Latter only the left vein persists. It then joins the portal vein, hepatic vein and finally opens into the abdominal venacava through ductus venosus. The blood is then conveyed to the right atrium. Through the foramen ovale maximum blood passes into the left atrium and thereby to the left ventricle. The foramen ovale closes at birth. Through the aorta most of the blood goes to the head and fore limbs and a small amount passes into the abdominal aorta. From the cranial aspect blood returns through anterior venacava to the right atrium. This blood along with a small amount of blood form the abdominal venacava

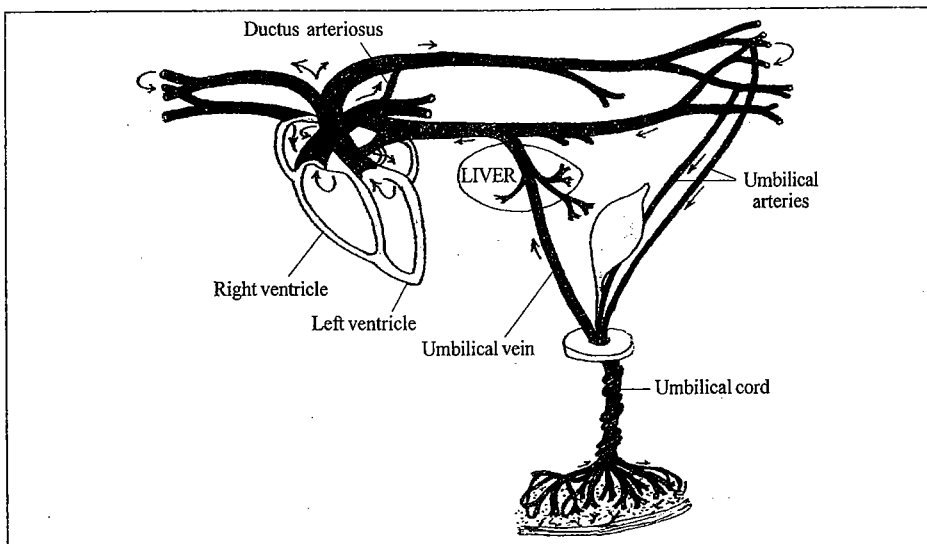


Fig. 1.65 Fetal circulation (Schematic).

passes into the right ventricle. The right ventricular blood goes *via* pulmonary trunk but instead of going to the inactive fetal lungs most of the amount passes into the descending aorta through ductus arteriosus. **Ductus arteriosus** is a arterial duct which connects the pulmonary artery with the aorta. At birth it becomes occluded and in adult it persists as a ligament (Ligamentum arteriosum). This blood mix with a small amount of blood which is transmitted from the left ventricle through the aorta, passes backward, supplies to some extent to the viscera and hind limbs and the maximum amount finally passes out to the placenta through the umbilical arteries.

DEVELOPMENT OF SKELETAL SYSTEM

AXIAL SKELETON

Vertebral column

The sclerotome of the somites form the bones of vertebral column. The cells of the sclerotome are loose at the beginning. A group of these cells from each segment (somite) migrate ventro-medially around the notochord. These migrated cells form a segmented uniform but loose distribution at first. Soon at the middle of this segment, cells become compact in a transverse manner. This condensed zone is called **perichordal disc**, which subsequently forms **intervertebral disc**.

In the less condensed areas on either side of condensed zone the notochord disappears. Now, the less condensed areas of two adjoining segments fuse together to form the

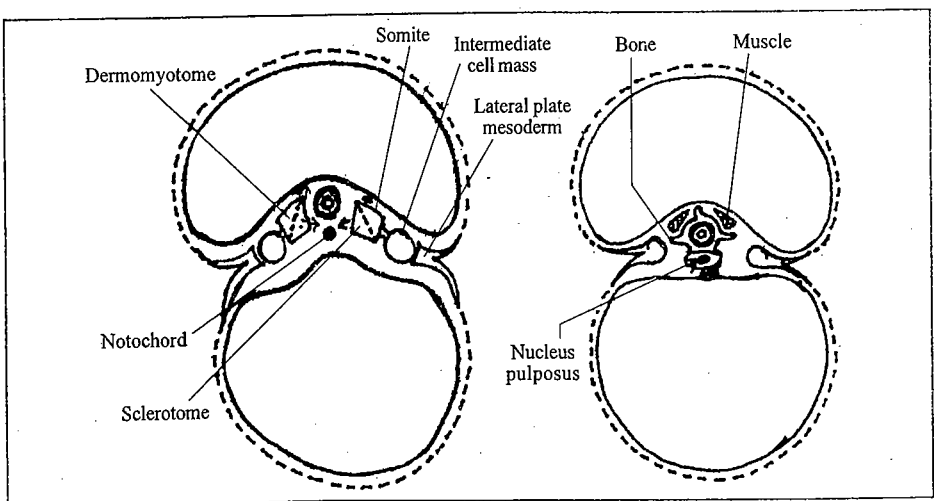


Fig. 1.66 Cross section of an embryo, showing differentiation of the secondary mesoderm.

primordium of the body (centrum) of a vertebra. The portions of notochord which did not disappear in the condensed zone expands to form **nucleus pulposus**.

The other cells of sclerotome migrate dorsally and medially to form neural arches, spine and transverse process in the similar manner. Interspinous ligaments are also developed in a manner, similar to those of intervertebral disc. These primordial zones formed by the migration of cells from the sclerotome become converted to cartilage by the appearance of chondrification centers in the centrum as well as on the neural arches.

The cartilaginous vertebra become ossified by the appearance of three primary and some secondary ossification centers. The primary ossification centers generally appear on the 8th week of development – one in the centrum and one in each neural arch. The Secondary ossification centers appear after birth.

Therefore a vertebra is an inter-segmental structure and formed by parts of two adjacent somites.

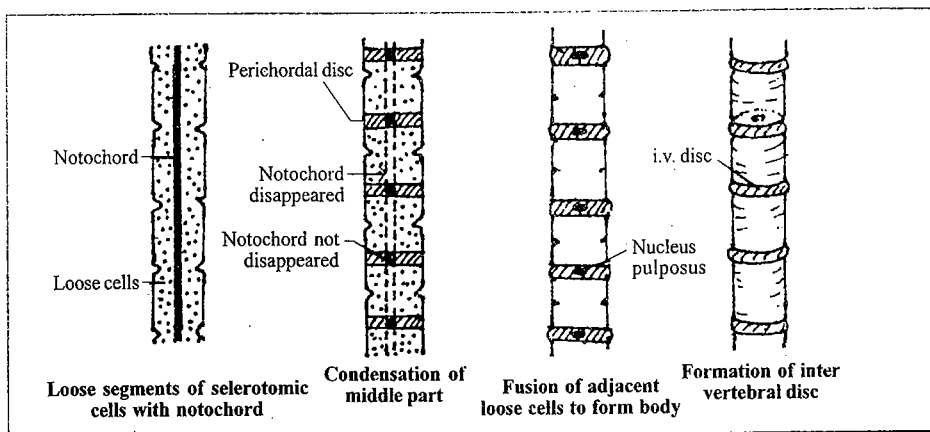


Fig. 1.67

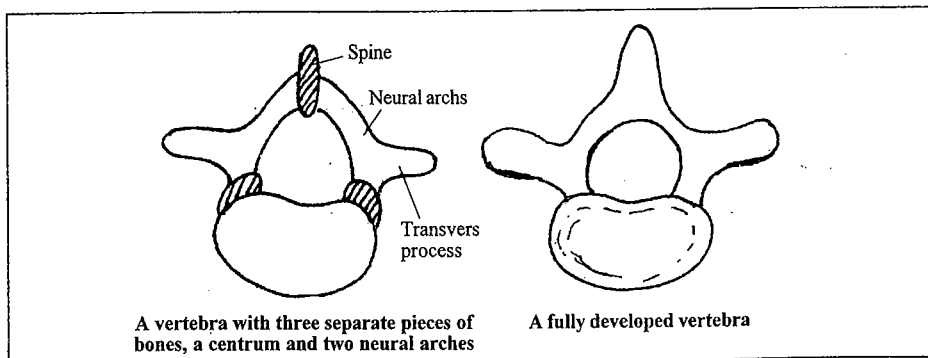


Fig. 1.68

Anomalies

Spina bifida – This condition occurs when the neural archs fail to fuse at the midline. It may be unilateral or bilateral. When bilateral, the spine would be absent.

Hemivertebra is a condition which occurs due to defect in the process of development resulting in the development of only half of the body.

Fusion of two or more vertebrae may also occur.

The **number** of vertebrae may increase or decrease than the stipulated number during the complexity of development.

Ribs

Vertebral arches are formed from ventral extension of sclerotomic mesenchyme. They are present in all the regions (cervical, thoracic, lumbar and sacral) of the vertebral column. The bones formed from the arch is fused to the transverse process and called **costal elements**. In the cervical region it contributes to the formation of foramen transversarium. In the lumbar vertebra it helps in formation of transverse process and in the sacral region it fuses to form the wings.

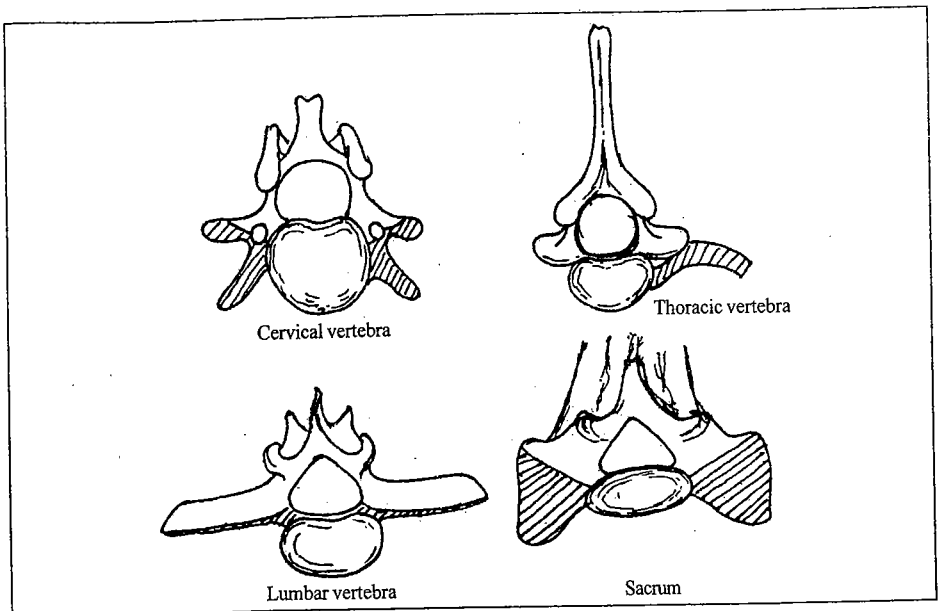


Fig. 1.69

 Marked area shows contribution of costal elements for the formation of various parts of vertebrae of different regions.

The ribs are formed from the condensation of **costal elements**. These costal elements are developed in the neural archs close to the centrum from separate centers. They extend laterally through the segmental myotomes. In the thoracic region the costal elements grow independently and form the **costal arches**. First the arches become chondrified and subsequently ossified to form one primary ossification center. After birth secondary ossification centers are developed for head and tubercle. The ventral part remain cartilaginous.

Anomalies

There may be development cervical rib or lumbar rib in addition.

Some ribs may be missing.

There may be abnormal fusion between two ribs.

Sternum

The ventral ends of cranial 7 or 8 costal archs fuse on each side to form cartilaginous **sternal plate**. These plates unite at the midline in cranio-caudal direction. The fused cranial part forms the manubrium, middle part forms the body and the caudal part forms the xiphoid process. The body and manubrium are ossified separately. The xiphoid process do not ossify in pre-natal life.

Anomalies

Sternal cleft occurs due to incomplete fusion or failure in the fusion between the sternal plates or costal arches.

Skull

The surrounding mesenchymal tissue of the developing brain and mesodermal derivatives of the branchial arches take part in the formation of skull.

The **base of the skull** in the occipital region is formed by the sclerotomes which are derived from the **occipital somites**. The occipital somites appear in front of first cervical somite.

The **temporal region** is formed by the mesenchyme around the otic vesicle.

The first branchial arch which gives rise to **maxillary** and **mandibular processes** forms some facial bones of the skull. The **maxilla**, **palatine** and part of **temporal bone** develop from maxillary process. The mandibular arch forms the body of **mandible**.

A pair of **polar cartilages** appear by the side of the pituitary gland. They fuse to form posterior part of the body of the **sphenoid bone**. The wings of the sphenoid bone are formed from a pair of cartilaginous elements known as **alisphenoid**.

The **cribriform plate** of ethmoid bone is formed from a cartilaginous plate, the **trabeculae cranii** which appears in the median plane.

The membrane around the nasal capsule ossify to form **nasal lacrimal** and **vomer** bones. The **parietal** and **frontal bones** are developed from the mesenchyme surrounding the developing brain.

Anomalies

Congenital **hydrocephalus** may occur when bones forming the cranial cavity are widely separated by the expansion of cranial cavity.

When the greater part of the cranial vault is missing, it would lead to **anencephaly**. Occipital bone may be fused with Atlas.

Appendicular Skeleton

Limb buds appear at the end of 1st month of uterine life. At first they appear in the form of elongated buds. The fore limb buds appear from few caudal cervical and few cranial thoracic somites opposite to pericardial sac. The hind limb buds appear little later from lumbo-sacral somites, a little above and behind the umbilical cord.

The buds are externally covered by ectoderm and contain a core of mesoderm. This mesoderm is derived from the somatopleuric layer of lateral plate by the influence of adjacent somites.

Bones	}	Derived from core mesoderm.
Ligaments		
Joints		
Vessels		

Muscles

Muscles are derived from mesodermal somites, which migrate into developing limb bud at the beginning of 2nd month of gestation.

The bones of limbs develop first by condensation of mesenchyme and successively followed by chondrification and ossification. Except some carpal and tarsal bones the primary ossification centers appear in the intra-uterine life. Secondary ossification centers appear after birth. The successive order of development of bones is as follows :

Pectoral girdle → Humerus → Radius & ulna → Metacarpals → Phalanges
 Pelvic girdle → Femur → Tibia & fibula → Metatarsals → Phalanges

The **joints** are developed from the mesenchyme in between two developing bones. This mesenchyme differentiates into fibrous tissue or cartilage to form various components of

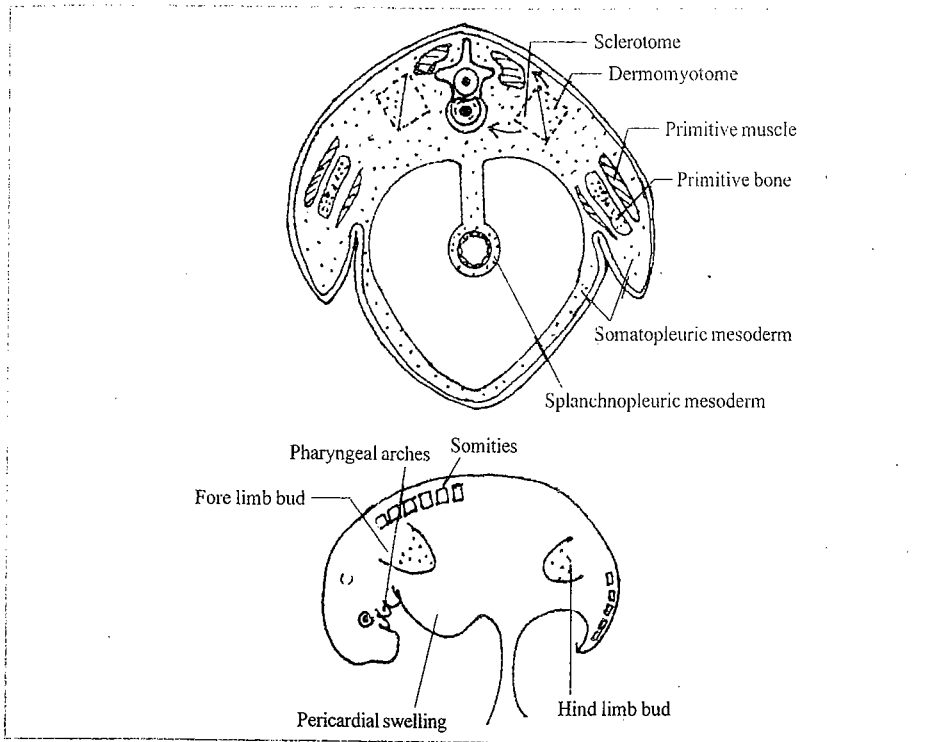


Fig. 1.70

joint. At the time of formation of a synovial joint, the mesenchyme gives rise to an outer layer of membranous structure, which become continuous with perichondrium and a middle layer, which is loose. The capsule is derived from the outer layer. A cavity appear in the middle loose tissue and becomes lined by a mesothelium which subsequently form synovial membrane.

Anomalies

Amelia – complete or partial absence of one or more limbs.

Micromelia – All the segments of limbs are unusually short.

Syndactyly – Fusion between digits.

Phocomelia – Rudimentary limbs are directly attached to the trunk. This condition along with amelia occurs when mother take thalidomide group of drugs during pregnancy.

DEVELOPMENT OF NERVOUS SYSTEM

Excepting few neurological components and the outer covering (duramater), the nervous system as a whole is developed from the ectoderm.

Along the longitudinal axis an elongated **Neural or medullary plate** appears on the dorsal aspect of the embryonic disc. This plate overlies the notochord. It becomes depressed at the middle along the length and a **groove** is formed. As the groove deepens further, the two edges (**Neural crests**) come closer to each other and ultimately fuse to transform the groove into the **Neural tube**. At first the fusion of neural crests takes place at the middle and then it progresses on either direction- anteriorly and posteriorly. Therefore the neural tube presents two openings. The anterior enlarged one is called the **Cranial neuropore** and the posterior narrower one is known as **caudal neuropore**. These pores communicate the neural tube with the amniotic cavity and for a temporary period amniotic fluid circulates through the lumen to provide nutrition to the cells of the tube. Subsequently the pores are closed and the neural tube becomes closed one. The dorsal surface of the tube is detached from the surface ectoderm and become embedded in the mesoderm. The cells of the neural crest are also detached from the ectodermal layer and occupy the space within the mesoderm and between the tube and ectoderm at the dorsolateral aspect. The cranial part of the neural tube forms the brain and the caudal part forms the spinal cord.

The wall of the enlarged cranial part of the tube develops three successive dilatations due to difference in the growth and expansion. These brain vesicles are called **Prosencephalon**

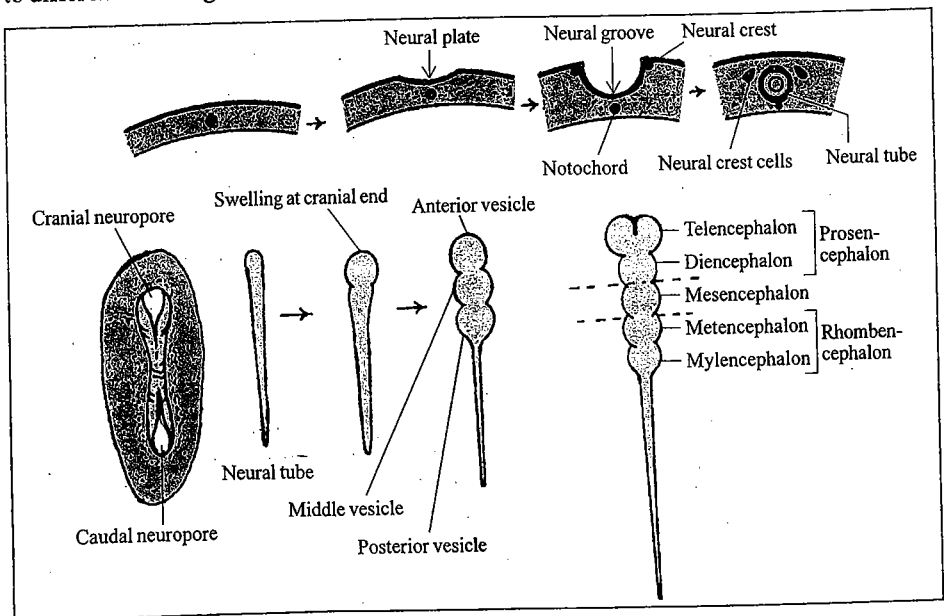


Fig. 1.71

or the fore brain, **mesencephalon** or the mid brain and **rhombencephalon** or the hind brain. The derivatives of various components from these vesicles is presented in the table.

Vesicles of neural tube	Derivatives
Prosencephalon	
(a) Telencephalon (proximal part)	Cerebral hemisphere, lateral ventricles, anterior part of 3rd ventricle
(b) Diencephalon (distal part)	Thalami, Optic nerve, Pineal body, Posterior part of 3rd ventricle, Pituitary body, Interpeduncular structures
Mesencephalon	Acqueduct of Sylvius, Corpora quadrigemina, Crura cerebri
Rhombencephalon	
(a) Metencephalon (proximal part)	Cerebellum, pons
(b) Myelencephalon (distal part)	Medulla oblongata

The vesicle of telencephalon divides into a left and a right part. These two vesicles form lateral ventricles. The cavity of diencephalon together with that of central part of telencephalon form the **third ventricle**. **Aqueduct of Sylvius** is formed by the cavity of the mesencephalon and the **fourth ventricle** is derived from the cavity of the rhombencephalon.

The **neural crest cells** being separated from ectoderm appear within mesoderm as a cluster of cells along the dorsolateral aspect of the neural tube and subsequently form the following :

- Neurons of dorsal root ganglia.
- Neurons of sympathetic ganglia.
- Neurons of parasympathetic ganglia (ciliary, pterygo-palatine, mandibular and otic).
- Schwann cells.
- Chromaffin cells of the adrenal medulla.
- Melanoblasts
- Odontoblasts

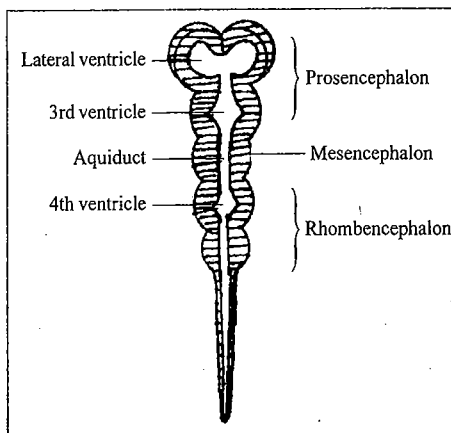


Fig. 1.72

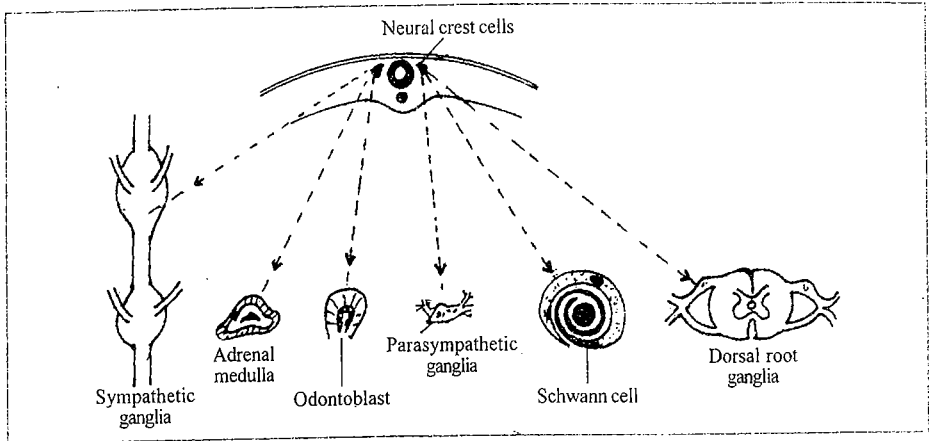


Fig. 1.73

- (h) Piamater and Arachnoid.
- (i) Neurons of sensory ganglia of 5th, 7th, 8th, 9th, and 10th cranial nerves.

HISTOGENESIS OF NEURAL TUBE

The lining cells of the neural tube proliferate and make the wall of the tube multilayered and becomes arranged in three zones.

(i) Zone of the ependymal or germinal cells –

They are germinative in character and form neurons, neuroglial cells and more germinal cells. Most of these cells move to the outer zone. Rest of the cells remain in position and persist as **ependymal cells**. They line the ventricles of brain and the central canal of spinal cord.

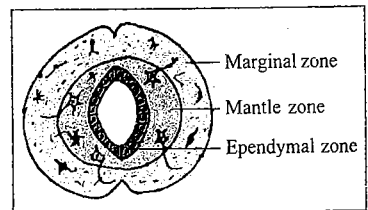


Fig. 1.74 Neural tube and its various regions.

- (ii) **Mantle zone** – The developing neurons (**neuroblasts**) and neuroglial cells (**spongioblasts**) are found in this layer.
- (iii) **Marginal zone** – This zone forms the white matter of the CNS. At the beginning, the cytoplasmic process of the primitive ependymal cells occupy this layer. Subsequently the axonal processes of neuroblasts and neuroglial cell invade this zone. This becomes white due to myelination of the nerve fibers.

Development of a Neuron

- (a) From the germinal (ependymal) layer cells migrate to the mantle zone. There are the **apolar neuroblasts**.

- (b) They become **bipolar neuroblast** with the appearance of two cytoplasmic processes on either side.
- (c) They lose one process and become **unipolar neuroblast**.
- (d) The remaining process elongates and on the other side several small processes are developed to transform the cell into a **multipolar neuroblast**.
- (e) The long process passes to the marginal zone and becomes converted to **axon**. It elongates further and may or may not remain within the CNS. If it goes out, forms an efferent nerve fiber of a peripheral nerve.

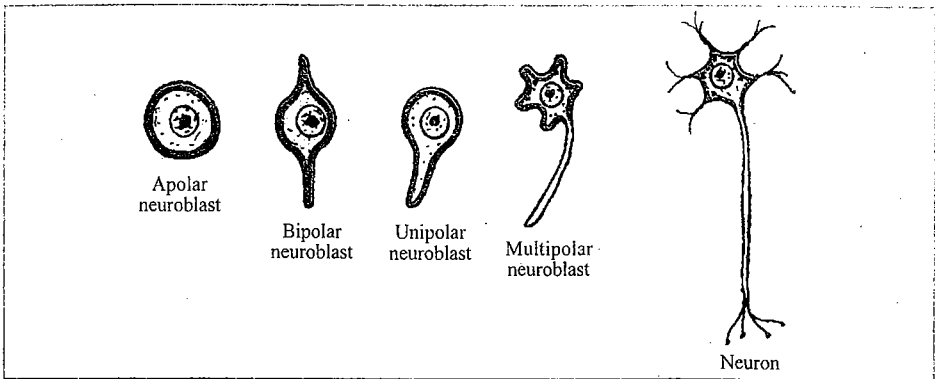


Fig. 1.75

- (f) Small processes ramify to form **dendrites**.
- (g) In the homogeneous cytoplasm of the neuroblast **Nissl granules** appear. The cells lose the power of multiplying and become converted to a **Neurons**. Nerve fibers are ensheathed in the CNS by neuroglial cells and outside CNS by Schwann cells. The **myelin sheath** is developed in the CNS by neuroglial (oligodendrocytes) cells and outside CNS by Schwann cells.

Process of myelin sheath formation by Schwann cells.

- (a) The axon is **invaginated** in the body of the Schwann cells.

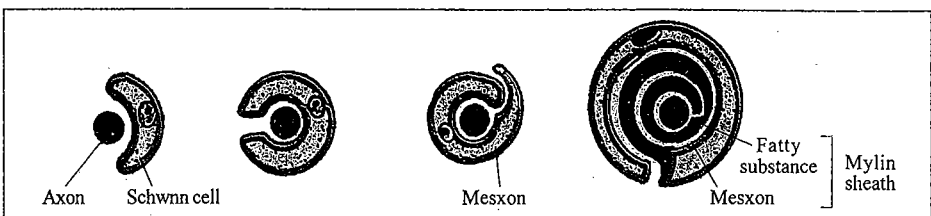


Fig. 1.76

- (b) The cell membrane of the S.cell become drawn to form a double layered membrane, similar in disposition to that of mesentery and therefore called **mesaxon**.
- (c) The Schwann cell wind around the axon in a spiral manner.
- (d) Some fatty substance is deposited between the layers of mesaxon.
- (e) Myelin sheath is formed together with the mesaxon and the fatty layer.

Full function of a nerve fiber starts when it gets its myelin sheath. In some cases several axons may invaginate in a single Schwann cell as shown in the figure.

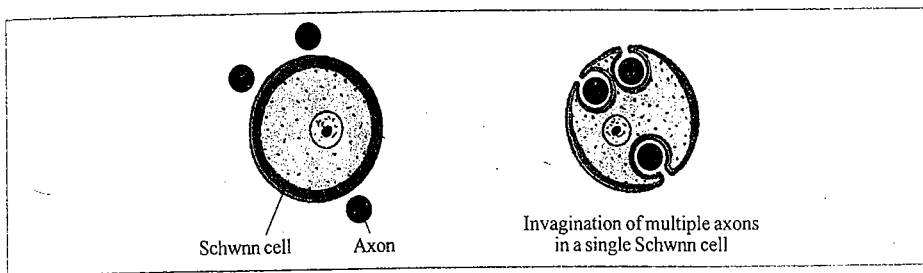


Fig. 1.77

Formation of Neuroglial cells

They are formed from the same germinal (ependymal) cell layer. These cells (**spongioblasts**) pass to the mantle zone and marginal zone and differentiate into **astroblasts** or **oligodendroblasts**. The astroblast form the **astrocytes** and the oligodendroblasts form **oligodendrocytes**. However the **microglial cells** do not develop from the ependymal zone but are believed to be derived from mesoderm.

After the completion of the differentiation of neuroblasts, the neuroglial cells are formed.

The **Duramater** is developed from the surrounding mesoderm.

The **Piamater** and **Arachnoid mater** are believed to be derived from neural crest.

DEVELOPMENT OF BRAIN

The components of fore-brain are derived from prosencephalon. The mid-brain is developed from mesencephalon and the hind-brain is formed by the rhombencephalon.

FORE BRAIN (Prosencephalon)

Cerebral hemisphere

The prosencephalon is subdivided into the telencephalon and the diencephalon. The telencephalon forms two lateral vesicles which give origin to the cerebral cortex and corpus striatum on either side. The diencephalon forms thalamus and hypothalamus.

The telencephalic vesicles, which were small at the beginning expands rapidly in all directions and extend forward, upward and backward and therefore they cover the dorsal and lateral aspects of diencephalon. The vesicles come in close apposition and each of them assumes an oval outline with a convex supero-lateral surface and a flat medial surface. A longitudinal cleft separates the medial surfaces of both the vesicles. The bottom of the cleft forms the roof of the third ventricle which subsequently forms the **Corpus callosum**.

The falx cerebri is derived from the mesodermal tissue which occupies the cleft between the growing telencephalic vesicles. The cavities of the telencephalic vesicles form **lateral ventricles** and the cavity of the diencephalic vesicle forms the **third ventricle**. Initially the wall of the vesicles were composed of cell layers which were similar to that of neural tube; *i.e.* inner ependymal zone, intermediate mantle zone and outer marginal zone.

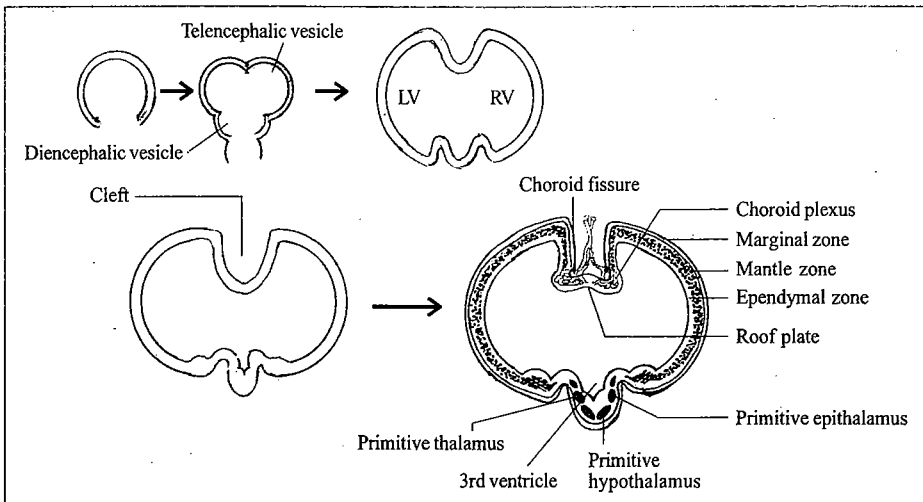


Fig. 1.78

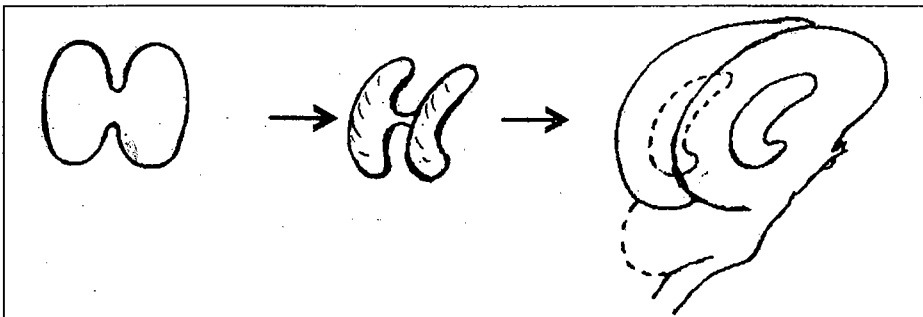


Fig. 1.79 Elongation of Lateral Ventricles.

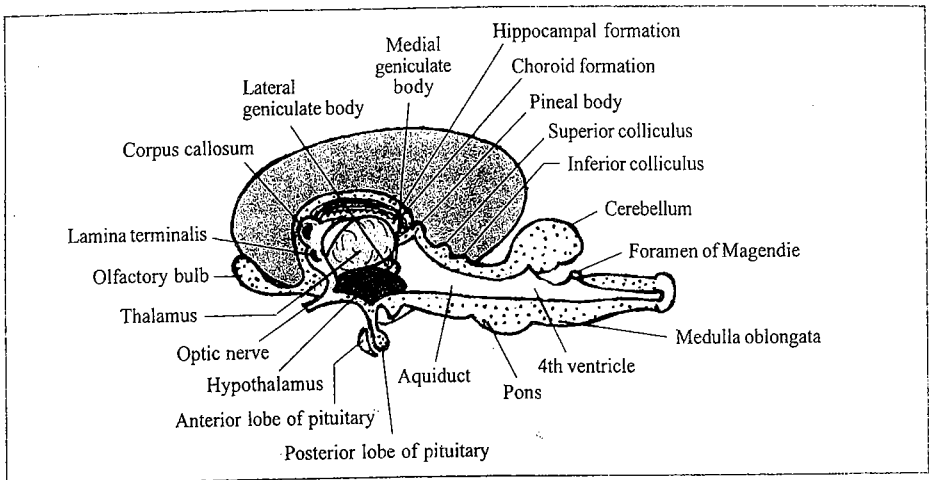


Fig. 1.82 Developing brain (sagittal section).

The Alar lamina forms the **superior colliculus** and **inferior colliculus**. It is believed that the **red nucleus** and **substantia nigra** are also developed from the alar lamina. The **Basal lamina** gives rise to **oculomotor nucleus**, **trochlear nucleus** and **Edinger westphal nucleus**.

The basis of the formation of cerebral pudences is the invasion of cortico-spinal, cortico-bulbar and cortico-pontine fibers into the marginal zone of basal lamina.

HIND BRAIN (Rhombencephalon)

The hind brain (Rhombencephalon) is subdivided into **metencephalon** and **myelencephalon**. The metencephalon forms the pons and cerebellum and the myelencephalon forms the medulla oblongata.

Medulla oblongata

At the early stage the development of this part of CNS is similar to that of spinal cord as it's lateral wall also divides into a **dorsal or alar lamina** and a **ventral or basal lamina** by the **sulcus limitans**.

The position of the dorsal lamina changes at the expense of 4th ventricle. At first it becomes dorso lateral and later becomes ventrolateral in position.

The roof-plate of the myelencephalon comprises of a single layer of ependymal cells, which is covered outside by vascular mesenchyme. These two layers jointly form **telachorida**. Choroid capillary plexus develops in the tela-choroida and projects in the roof as **Choroid plexus of 4th ventricle**. The ependymal roof of the 4th ventricle bulges outwards and

finally ruptures to form a central perforation — the **foramen of Magendie** and two bilaterally placed perforations — **foramina of Luschka**. The cells of the alar lamina develop vestibular nucleus, olivary nucleus, nucleus of tractus solitarius (which receives taste sensation) and part of dorsal nucleus of vagus. The nucleus Gracialis and nucleus cuneatus persist in the cells of the basal lamina. Inferior salivary nucleus, hypoglossal nucleus, nucleus ambiguus and part of dorsal nucleus of vagus are also developed in the basal lamina.

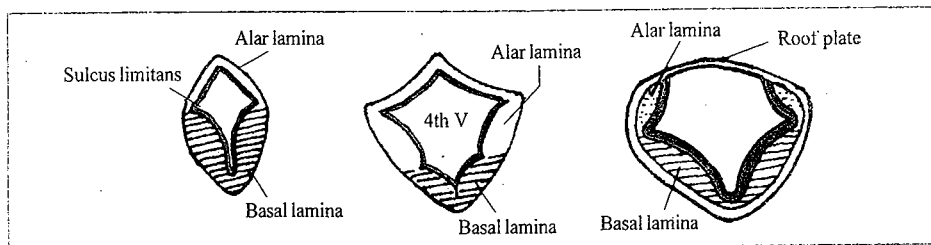


Fig. 1.83 Medulla oblongata during development.

The white matter of myelencephalon is composed of ascending and descending tracts and by the fibers of cells which are forming nuclei in this part of CNS.

Cerebellum

Two **Rhombic lips** develop in the alar lamina bilaterally on either side of the roof plate (see figure). These lips form the primordium of cerebellum. Some cells of the lip proliferate on the roof of 4th ventricle and other cells grow outside.

These lips approach each other and meet at the middle. Thus a dumb-bell shaped primitive cerebellum is developed. Later the middle constricted part forms the vermis and bilateral expanded parts form lateral lobes.

Eventually a number of fissures appear on the dorsal surface of the developing cerebellum and divide it to form various folia. At first **flocculonodular lobe** is formed at the posterior aspect. This is known as **archi cerebellum**. The archicerebellum is phylogenetically oldest part of cerebellum and this part is only present in aquatic vertebrates. It establishes connection with vestibular nucleus. Gradually other fissures appear one by one and in the next sequences uvula and pyramid are developed. The anterior lobe, uvula and pyramid form **Paleo**

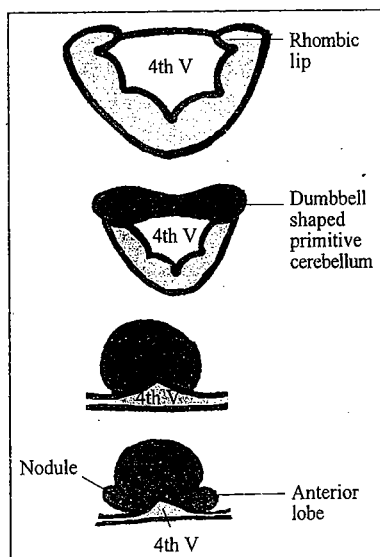


Fig. 1.84

cerebellum. It establishes connections with spinal cord to regulate tone and posture of limbs and phylogenetically first appear in **terrestrial vertebrates**. The remaining parts of the cerebellum form **Neo-cerebellum** which establishes connection with cerebrum. It helps in co-ordination of voluntary movement of the body so that skilful movement is made. This is phylogenetically present in higher vertebrates. As the development progresses the neuroblasts migrate from the mantle zone to the marginal zone. They proliferate and differentiate to form **Purkinje cells, Golgi cells, basket cells, granule cells**, etc. The neuroblast of the mantle zone which do not migrate outside forms various nuclei (dentate, emboliformis, fastigi and globosus).

Pons

It is developed at the ventral part of metencephalon. It forms **pontine nucleus** on getting contribution from alar lamina of myelencephalon. It also forms **middle cerebellar peduncles** by the axons of the cells of pontine nucleus which extend in transverse direction. As in the the medulla, the alar lamina of metencephalon is also situated ventrolaterally. The alar lamina forms the nuclei of 8th and sensory component of 5th cranial nerves. The basal lamina forms motor nuclei of 5th, 6th and 7th cranial nerves as well as superior salivary nucleus.

Anomalies

Anencephaly – The anterior neuropore fails to close and the brain substance is exposed to surface.

Hydrocephalus – It occurs due to excess accumulation of CSF in the skull. Ventricles become enormously distended with CSF due to obstruction of the passages of the fluid.

Microcephaly – Formation of small sized brain.

SPINAL CORD

It is developed from the neural tube caudal to the brain vesicles. At the beginning it is short but gradually increases in length with the elongation of vertebral column.

The wall of the tube possesses as usual three zones – inner ependymal zone, middle mantle zone and the outer marginal zone. The cells of the mantle zone proliferate fast and the wall becomes thickened. With the appearances of **sulcus limitans** at the lateral aspect of the lumen of the tube the lateral wall of the growing spinal cord divides into a dorsal alar lamina and a ventral basal lamina. The wall of the roof and the floor become comparatively thinner. At this stage the central canal appears to be diamond shaped in cross section.

The **alar laminae** of both sides grow medially, and obliterate the dorsal part of the central canal. The median septum is formed at the same time. The **basal laminae** grows ventro laterally and a ventral median groove is formed. Later this groove is occupied by the ventral spinal artery. The diamond shaped canal is reduced and become triangular in out line. Development of the mantle layer of alar lamina gives rise to the **dorsal horns** of grey matter and similar development of basal lamina forms the **ventral horns** of grey matter. The neuroblasts of the dorsal horns form the **sensory neurons** of second order and the neuroblasts of ventral horn differentiate into **motor neurons**. The cells of the mantle layer close to sulcus limitans grow to form lateral horn of grey matter. These neuroblasts are differentiated to form preganglionic neurons of sympathetic system of Autonomic nervous system.

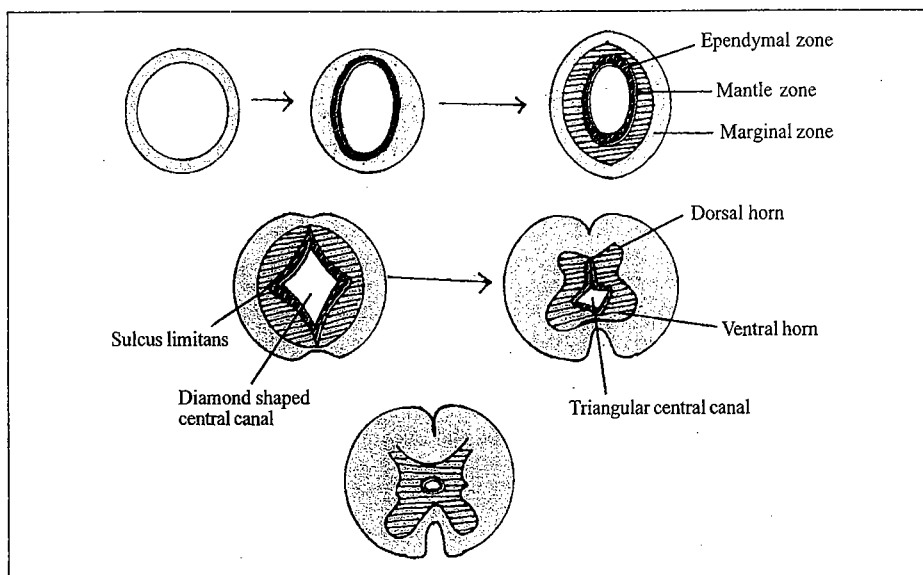


Fig. 1.85 Stages of developing spinal cord.

The central processes of the axons of the dorsal root ganglionic cells (derived from the neural crest) form dorsal root and the axons of the ventral horn cells grow out to form ventral root.

The white matter of the spinal cord is formed by the axons pass through marginal zone. These axons form ascending and descending tracts. With the development of gray matter the white matter is also divided into dorsal column ventral column and lateral column.

At first the spinal cord grow in the same speed to that of vertebral column. Latter the vertebral column increases more and the caudal end of the cord terminates at the level of 2nd to 3rd sacral vertebra.

Anomalies

Rachischisis – Neural groove fails to close completely.

Spina bifida oculata and **Meningocele** – The arachnoid and piamater of the spinal cord protrude through the opening of bifid spine and form a cystic swelling.

DEVELOPMENT OF CARDIOVASCULAR SYSETEM

The components of the heart and blood vessels are (i) Endoethelium. (ii) Muscle and (iii) Connective tissue. All these components are derived from mesoderm.

When supply of nutrition to the developing embryo by the way of diffusion from the uterine wall is not sufficient, a separate blood vascular system develops at the end of 3rd week. **Extraembryonic** blood vessels are developed from the angioblastic cells of mesoderm. **Vitelline vessels** are developed from the capillary network of the wall of yolk sac and the **Umbilical vessels** are derived from the chorion.

In the meantime the intraembryonic mesoderm divides into a parietal – somatopleuric layer and a visceral – splanchnopleuric layer. Heart develops in the splanchnopleuric mesoderm out of the **angioblastic** tissue situated ventral to the foregut. This area is known as **cardiogenic** area. At the beginning two longitudinal vessels appear in the flattened embryonic area along the dorsal wall of yolk sac. But when the head fold is established, the developing heart comes ventral to the fore gut which was dorsal to the foregut earlier.

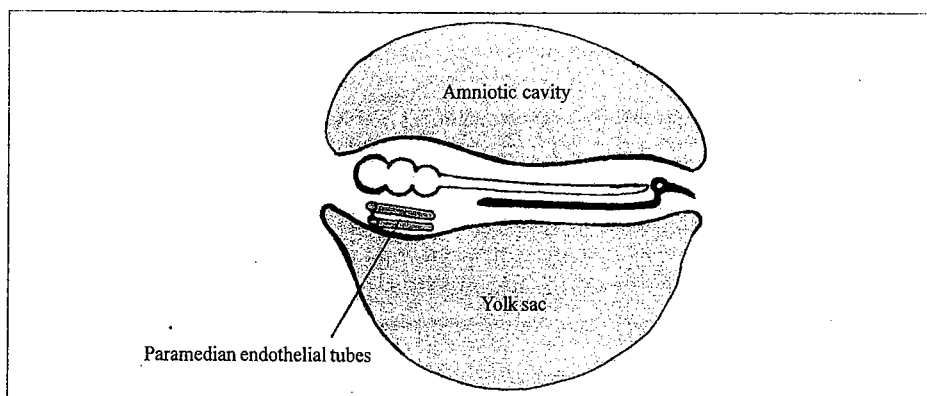


Fig. 1.86 Embryo before head folding.

Development of heart

The two endothelial tubes which appeared dorsal to the foregut comes ventrally with the head folding of the embryo. Soon they fuse in craniocaudal direction and form a single dilated tube – the primitive heart. It develops a series dilatations. The cranial end is the arterial end and the caudal end is the venous end of the tube. These dilatations from cranial to caudal end are (1) **Bulbus cordis**, (2) **Ventricle**, (3) **Atrium** and (4) **Sinus venosus**. Later on Truncus arteriosus develops from bulbus cordis. With the formation of truncus arteriosus the primitive heart tube presents **five** saccular dilatations which are interconnected with each other. The truncus arteriosus bifurcates into left and right branches, called first pair of aortic arch (pharyngeal arch arteries) and subsequently five pair more aortic arches

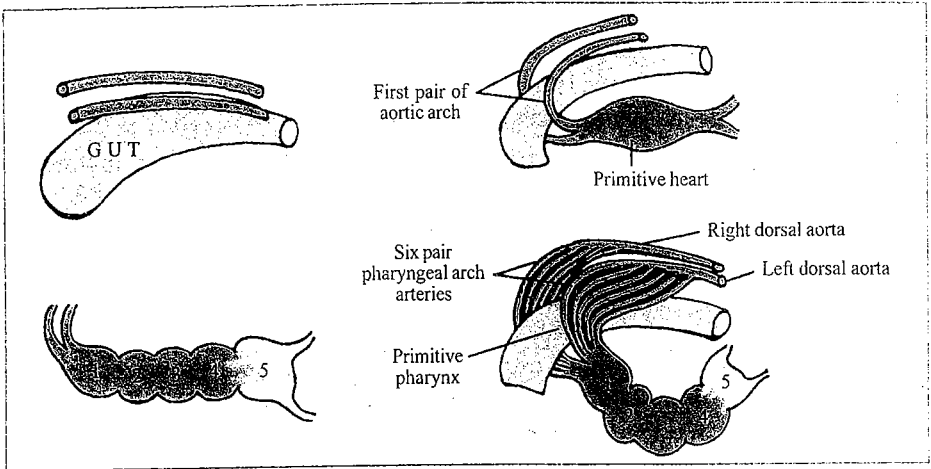


Fig. 1.87 Developing heart.

1. Truncus arteriosus ; 2. Bulbus cordis ; 3. Ventricle ; 4. Atrium ; 5. Sinus venosus.

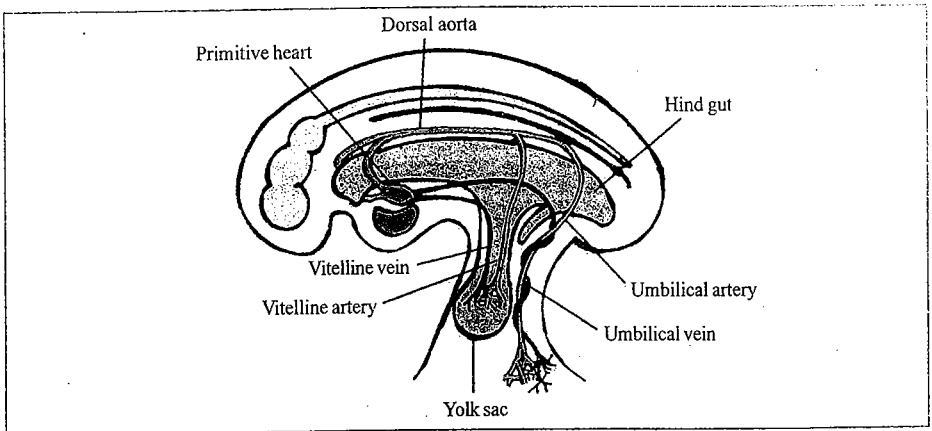


Fig. 1.88 Embryo after establishment of head fold.

appear and all of them become continuous with the corresponding dorsal aorta as shown in the figure.

The venous end which represents the sinus venosus of developing heart becomes little dilated receives one common cardinal vein (ccv) from the body wall, one vitelline vein from the yolk sac and one umbilical vein from the placenta on either side, called left and right horns of sinus venosus. The derivatives of the components of the primitive heart tube are as follows :

The body of the SV gives rise to major part of **Right atrium**.

The right CCV forms the **terminal part of cranial vena cava**.

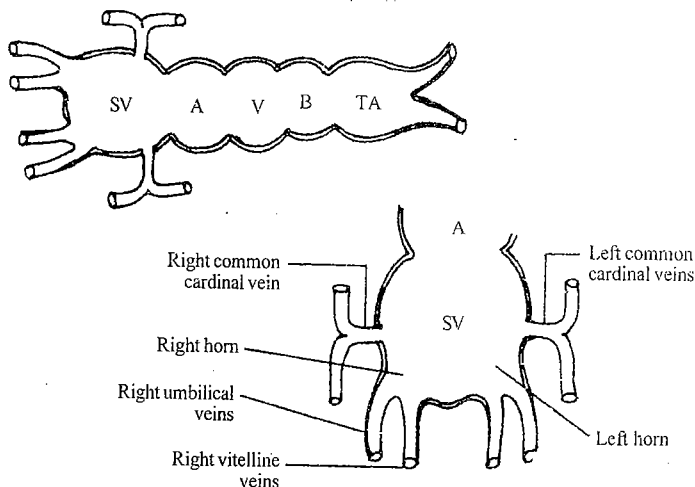


Fig. 1.89 Derivatives of heart tube.

SV – Sinus venosus ; A – Atrium ; V – Ventricle ; B – Bulbus cordis ; TA – Truncus arteriosus.

The Right vitelline vein forms the **terminal part of caudal venacava**.

Left horn is reduced to form **part of coronary sinus**.

The atrium gives rise to a part of **right and left atria**.

The ventricle and bulbus cordis form **left and right ventricles**.

The TA gives rise to **ascending aorta and Pulmonary trunk**.

Formation of the wall and cardiac loop

The sacculated heart tube invaginates into the pericardial sac from superior aspect and the splanchnopleuric mesoderm of the dorsal part of the pericardial sac proliferate to form **myocardial mantle**. Subsequently after total invagination this mantle surrounds the heart tube is transformed into **myocardium** as well as **epicardium**.

The dorsal mesocardium disappears and the heart tube become free within the pericardial sac and remains suspended by its two ends. However the caudal end components i.e. atrium and sinus venosus remain embedded within the septum transversum. The sacculated heart tube develops fast within the limited space of the pericardial sac and therefore an **'U' shaped loop** is formed with the bulbus cordis and ventricle. This is now called **bulbo-ventricular loop**.

Subsequently the atrium and sinus venosus become free from the septum and drawn within the pericardial cavity. They reach behind and above the ventricle and the U loop becomes converted to **'S' shaped loop** at this stage. The atrium shifts slightly towards the bulbo-ventricular cavity.

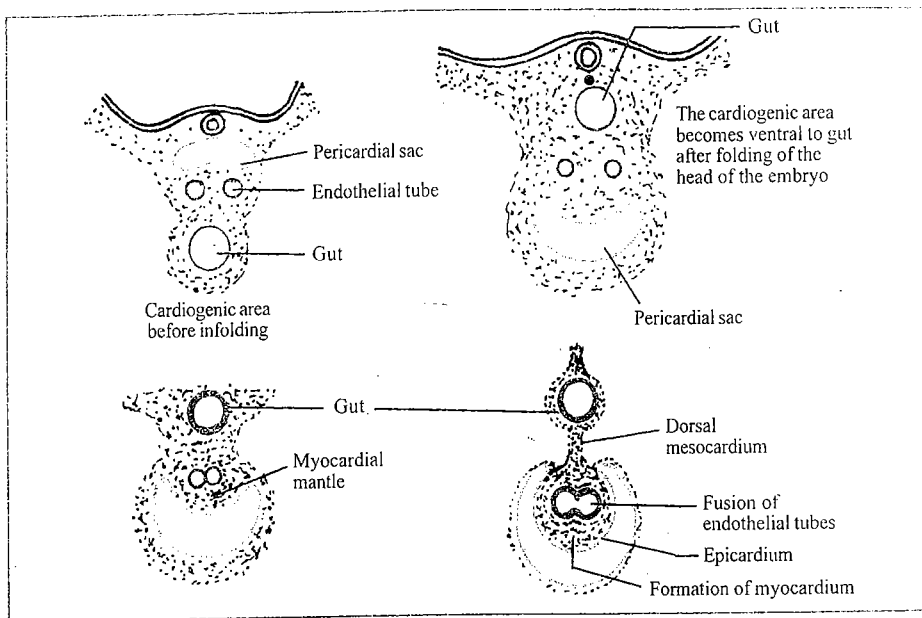


Fig. 1.90

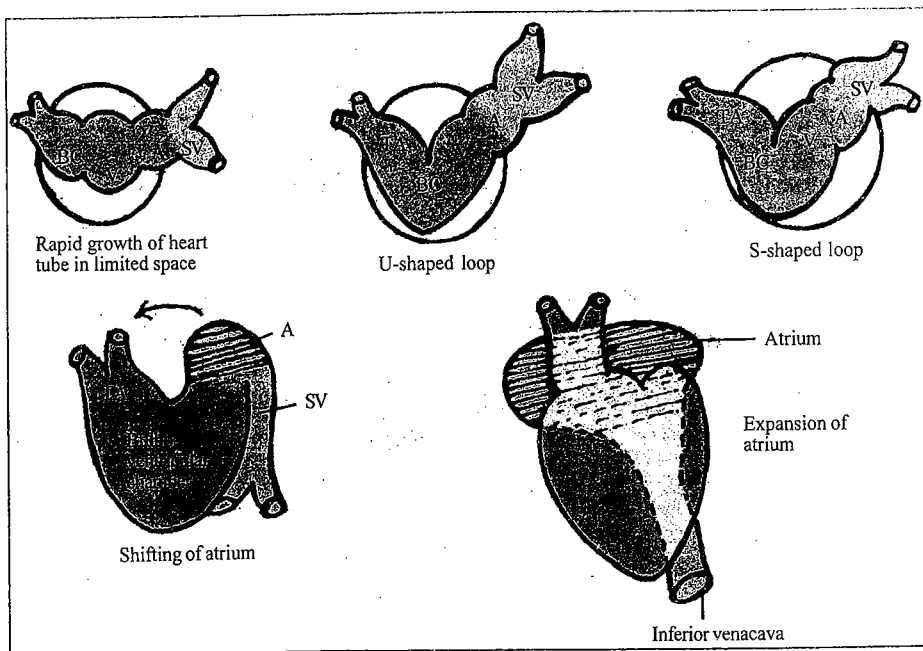


Fig. 1.91

The groove between the bulbus cordis and ventricle becomes shallow and therefore these two sacculations form a single chamber which communicates with truncus arteriosus at one end and atrium at the other end.

The atrium shifts further and reach behind the truncus arteriosus and bulbus cordis. The sac being compressed grows in a transverse manner between the fore gut (pharynx) and bulbus cordis and expands on each side to form atrial appendages. Thus a definitive exterior shape is achieved by the primitive heart.

Changes in the sinus venosus

Due to the foldings the communication between the chambers of atrium and sinus venosus becomes narrow gradually. The left groove between these chambers becomes deep and the left horn of the sinus venosus is partially separated from the atrial chamber. At the same time right horn of the sinus venosus enlarges and the **left horn with its tributaries regresses**. Finally the whole left horn persists only as coronary venous sinus. The sinu-atrial orifice

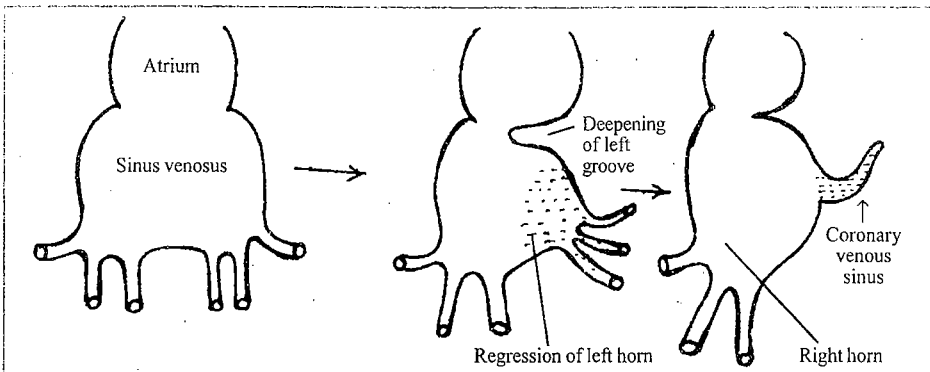


Fig. 1.92 Changes in the sinus venosus.

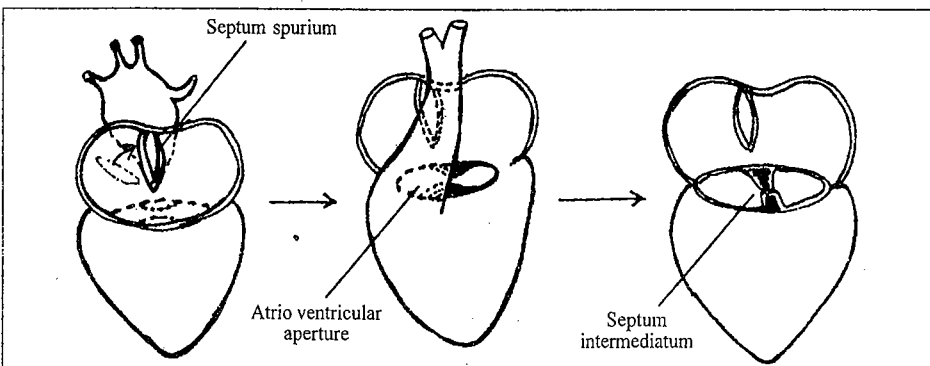


Fig. 1.93 Formation of septum intermediatum at the atrioventricular aperture.

which was at the middle, to the right side and becomes vertical in position. The right and left venous valves appear at the margin of the orifice. These two valves meet at the upper end and appears as a septum. This is called **septum spurium**.

Changes in the atrio-ventricular aperture

Two atrio-ventricular **cushions** (thickenings) appear at the dorsal and ventral walls of the atrio-ventricular opening. They grow, fuse and divide the opening into right and left halves. This partition is known as **septum intermedium**.

Development of inter-atrial septum

At the left side of the opening with the sinus venous (septum spurium), another septum appears. This is called **septum primum**. It grows down towards septum intermedium of atrioventricular cushion and the **foramen primum** is formed between the growing septum

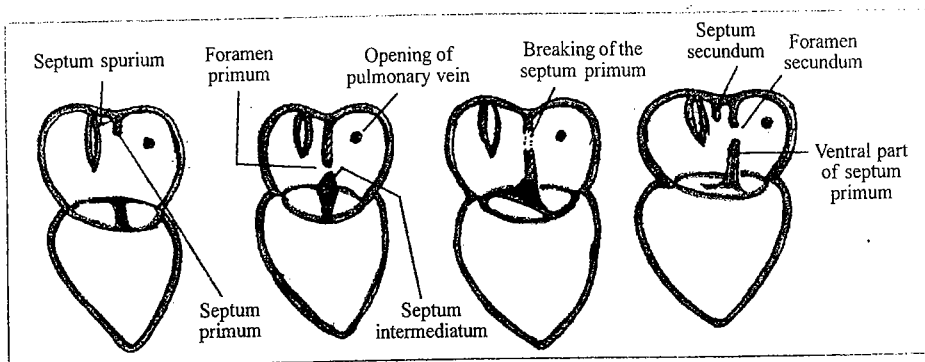


Fig. 1.94 Inter-atrial septum.

primum and septum intermedium. With further growth of these septa, the foramen primum is closed but at the same time another opening appears by breaking the upper part of the septum primum. This breaking of the wall occurs due to **programmed cell death** of that particular part of the wall. This second foramen is called **foramen secundum**. From the roof in between the septum spurium and septum primum, a second septum appears, known as **septum secundum**. This partition grows further downward and overlaps the foramen secundum and thus converts the straight opening into a valvular opening. This is now called **foramen ovale**.

The lower edge of the septum secundum becomes strong and the upper edge of the ventral part of septum primum which is attached below to septum intermedium, becomes thin. Therefore, the flow of blood from the right atrium to left atrium get no obstruction since the thin edge of septum primum moves away due to pressure. But if the blood tends to flow from left to the right, the foramen ovale closes due to the apposition of the thin edge of

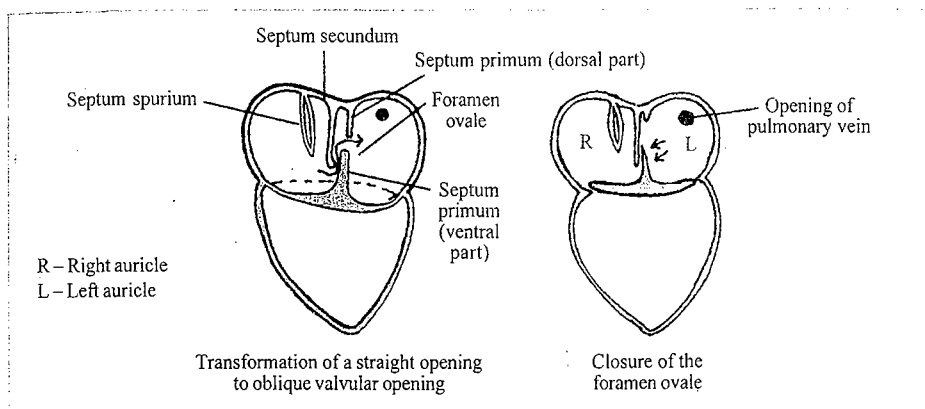


Fig. 1.95

the septum primum with the thick margin of the septum secundum. Throughout the fetal life the foramen ovale remains potent. After birth the left atrium receives blood from lungs and the pressure inside the left atrium increases. This causes close apposition between septum secundum with the septum primum and the foramen closes completely leaving a depressed mark, the **fossa ovale**.

Fate of sinus venosus

The sinus venosus is absorbed into the right atrium after formation of interatrial septum and forms a part of the body of right atrium. The right vitelline vein forms the end part of posterior (inferior) venacava and the right common cardinal vein forms the end part of anterior (superior) venacava. The left horn forms part of coronary sinus. They all open into the right atrium.

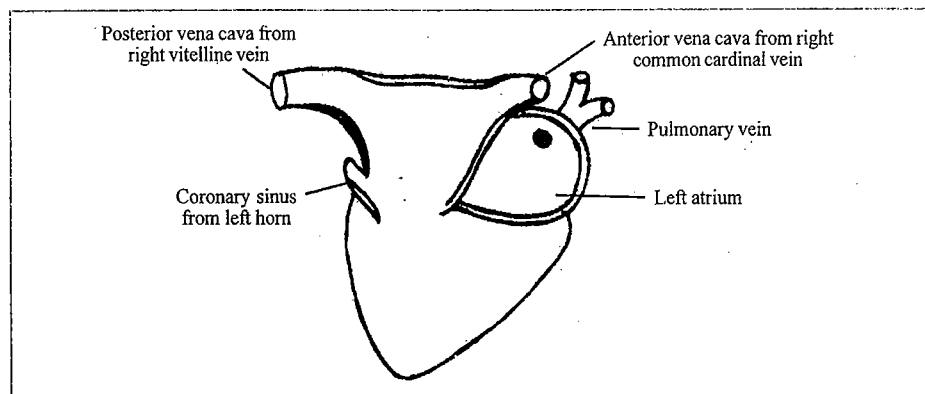


Fig. 1.96

Formation of Pulmonary veins

The left atrium at its dorsal wall receives a single pulmonary vein at the time of development of septum primum. The vein is formed by the union of two branches, one from each lung. Each branch is again formed by two second order branches. All these four branches gradually become connected to the left atrium directly due to absorption and incorporation of the venous walls into the wall of the left atrium and therefore four separate veins, two from each side open into the left atrium.

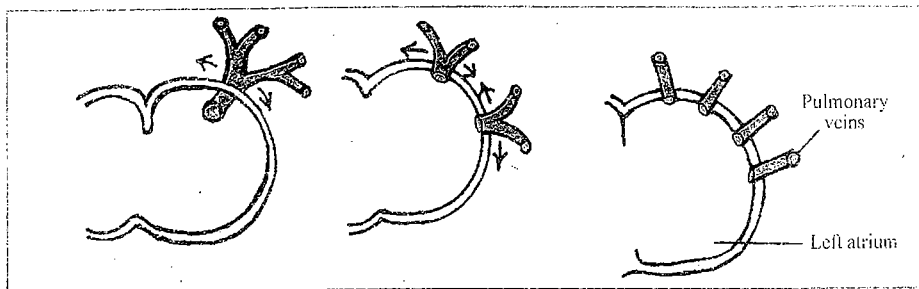


Fig. 1.97

Transformation of bulbus cordis

The bulbus cordis gives rise to an upper part – Truncus arteriosus and a lower part – the conus.

Within the truncus arteriosus a spiral valve appears and divides the truncus into two. One division forms the **Aorta** and other forms **Pulmonary trunk**. The pulmonary trunk is placed in front of the aorta. This division occurs after shortening of truncus. At first four endocardial cushions appear at the beginning of the common aortic trunk. Out of them the left and the right are larger in size. Other two are anterior and posterior in position. The right and left cushions subdivide and at the same time become included individually within each division of truncus as shown in figure. With the separation of aorta and pulmonary trunk, the divisions of each left and right cushions become

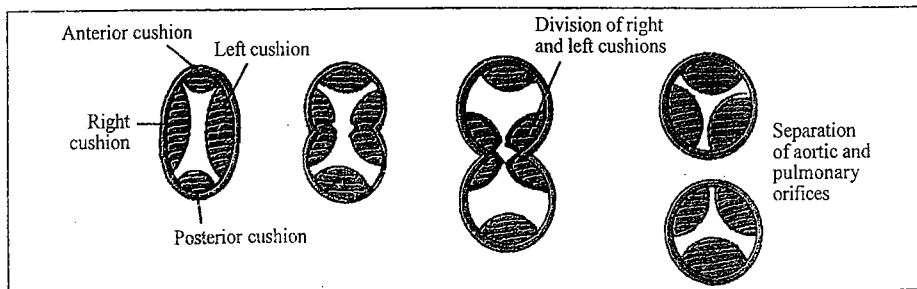


Fig. 1.98

incorporated into each orifice. Therefore the aortic and pulmonary openings each get three cushions. From these cushions cusps of the concerned pulmonary and aortic valves are developed.

As the truncus arteriosus divides, the bulbus cordis gets incorporated into the ventricle at the right side. This occurs due to atrophy of the invaginated wall (bulboventricular sulcus) between bulbus cordis and ventricle.

Formation of Interventricular septum

From the floor of the bulboventricular cavity a septum grows upwards. Its upper margin is concave and free and the lower border is thick, convex and attached to the floor. Gradually the septum grows and finally meet the atrio-ventricular cushion (septum intermedium). However the I.V septum grows ventrally due to active downward enlargement of right and left ventricular cavities.

The conduction system of heart develops by differentiation of some parts of developing cardiac muscle. The myocardium starts beating as early as 4th to 5th week of embryonic life before nerves reach the heart. The A.V node appears first (6th week) in the dorsal endocardial cushion of the atrio-ventricular canal. S.A node appears later in the 3rd month of gestation close to the origin of anterior vena cava.

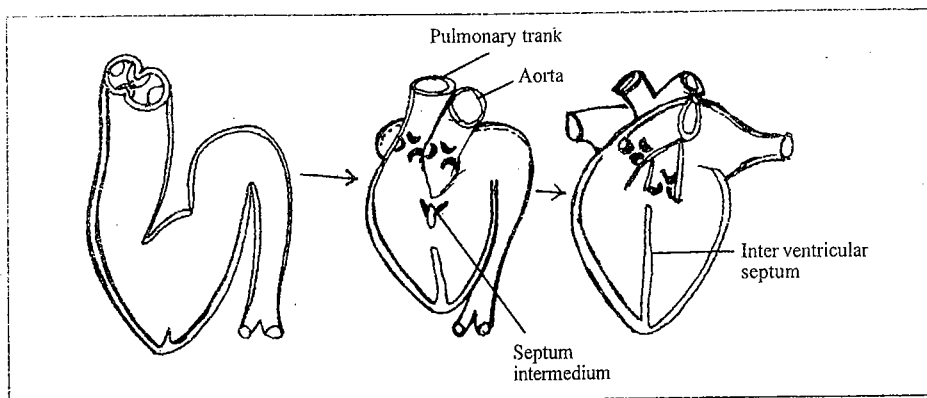


Fig. 1.99

Cardiac loop is formed at the 5th week.

Interatrial septum is formed within 6th or 7th week. Conduction system also appear at the same time. However, all these timings are variable in different species due to the variation in their gestation periods.

Anomalies

Septal defecets

- (a) Septum primum defect – The septum primum fails to reach atrio-ventricular cushion.
- (b) Septum secundum defect – The septum secundum fails to develop and foramen secundum persists.
- (c) Potent foramen ovale – The valvular passage of ovale may persist even after birth although septum primum and secundum are developed. This defect does not create problem until blood shunts through it.
- (d) Inter ventricular septal defect – The septum fails to reach A. V. cushion

Stenosis or atresia

Opening of any orifice may be very narrow (stenosis) or not at all developed (atresia). Hypertrophy of right ventricle is another anomaly.

Development of other arteries occurs gradually from the two endocardial tubes which form the heart.

Umbilical arteries appear before fusion of the two dorsal aortae.

The **vitelline veins** (Omphalo mesenteric veins), right and left are developed from the yolk sac.

Right and left umbilical veins develop from placenta. But when liver develops in the septum transversum, the vitelline as well as umbilical veins break down inside the developing liver parenchyma and help in the formation of sinusoids.

The **Lymphatic system** develops with the appearance of lymphatic sacs which are lined by endothelium. The **lymph nodes** are formed by invasion of connective tissue and lymphocytes into these sacs. The sac represents **cisterna chyli** is not filled up. The lymphatic channels are formed by the extension from these sacs.

2

INTEGUMENTARY SYSTEM



Integument is a multilayered covering of the body and composed of skin and subcutaneous tissue. Integument is responsible for i) Providing protection from mechanical objects as well as from entry of micro organisms and from ultraviolet rays, ii) Regulation of body temperature, iii) Excretion of some waste products, iv) Providing sites for synthesis of vitamin D and v) Acting sensory perception. The complexion of integument depends on the absence and presence of Melanin. Presence of breakdown products of hemoglobin in the circulation may also influence skin colour.

SKIN

The skin comprises Epidermis and Dermis.

Epidermis

The Epidermis is a stratified squamous keratinizing epithelium and composed of the following layers of cells.

- (a) Stratum basale
- (b) Stratum spinosum
- (c) Stratum Granulosum
- (d) Stratum lucidum
- (e) Stratum corneum

The **Stratum Basale** is the innermost layer of epidermis and composed of a layer of moderately large columnar cells. The basal cells are anchored in the basement membrane by fringe like processes and adhere with each other by desmosomes. In some places dendritic **Melanocytes** are present in between the basal cells. These cells provide pigment granules to the basal cells. During proliferation the melanocytes carry pigment to the higher cells. Frequently this layer invaginates into the depressions of dermis. These finger like invaginations are called epidermal papillae and therefore this layer of cells gives a wavy appearance in histological sections.

The **Stratum Spinosum** is a thick zone and composed of multiple layers of polyhedral cells. The cells have spine like processes in their surfaces and therefore called **Prickle cells**.

These spines are actually tonofibrils which randomly occur in the cytoplasm, radiate from the surface and make intercellular bridges in between the cells.

Mitosis occur both in the cells of stratum basale and stratum spinosum and therefore these two layers together are called **stratum germinativum**.

Stratum Granulosum is composed of one to few layers of flattened granule containing cells. Actually, as a result of growth process at the stratum germinativum, the cells of the peripheral zone are pushed towards the surface. These cells become flattened, move further away from the dermal capillaries, get less nutrition and therefore synthesise highly basophilic keratohyaline granules by recycling nucleic acids.

Stratum Lucidum – This is an inconstant layer and found only in the thick epidermis. It is composed of dying or closely packed dead cells of the periphery of the granulosum cells and therefore the nuclei are not apparent. This layer appear as a thin homogenous refractive (Lucid) zone in between the stratum granulosum and stratum corneum and thus named Lucidum.

Stratum corneum – Several layers of flattend cornified plates of dead cells form this most superficial layer of epidermis. Here the cells are transformed into a horny material called keratin.

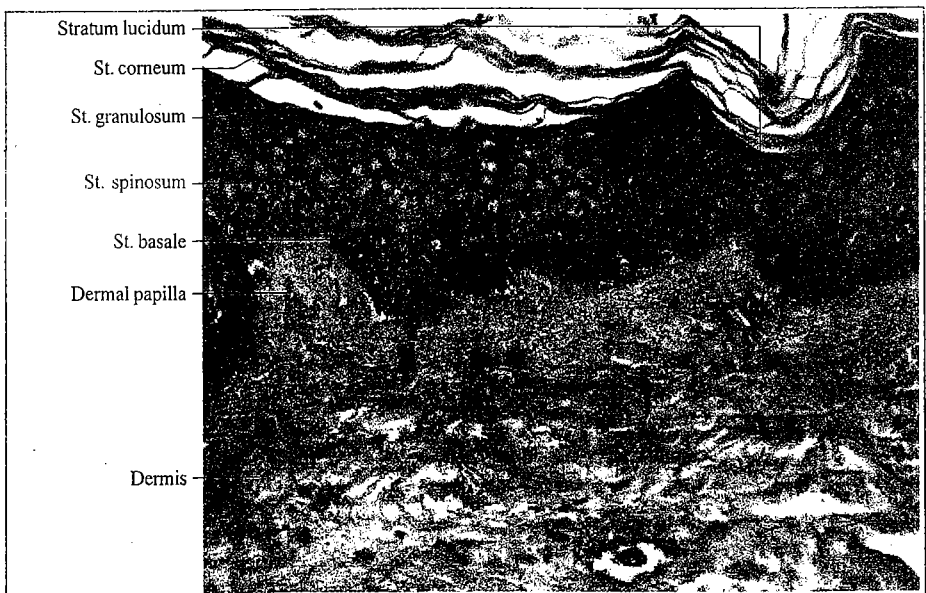


Fig. 2.1a Skin.

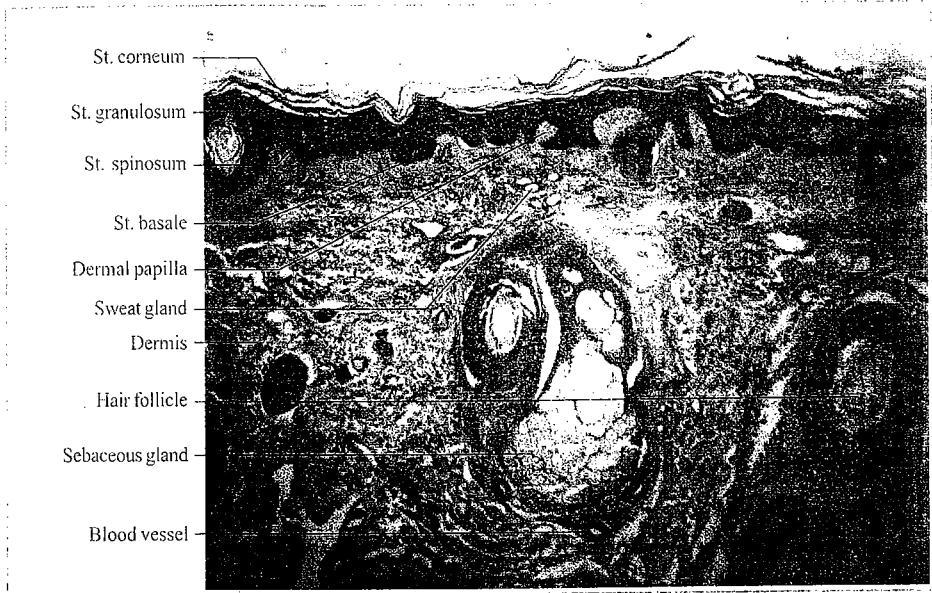


Fig. 2.1b Skin.

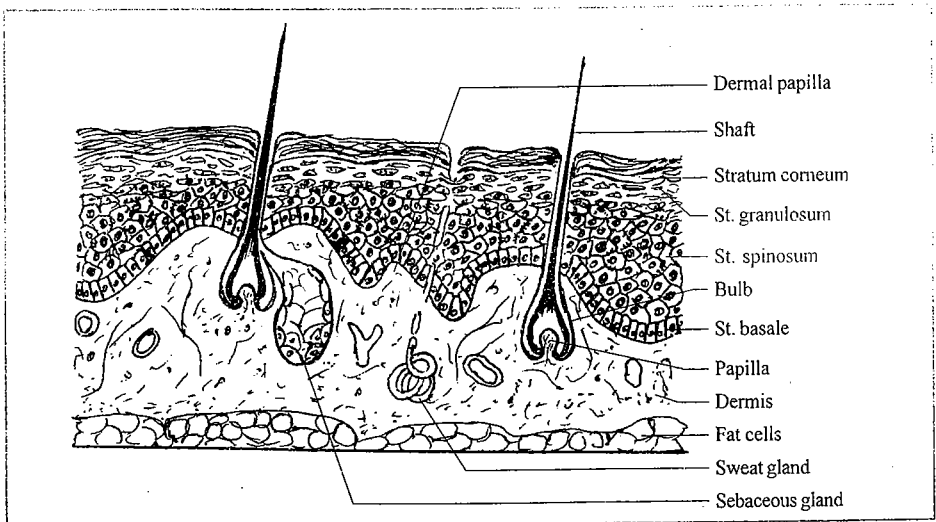


Fig. 2.2 Skin (schematic diagram).

Keratin is an albuminoid protein in the form of fibers derived from stratified squamous epithelia. This is hard, elastic and resistant to friction. In some places like nails, hoofs, claws, the keratin is hardest. The hardness is due to more sulfur content of the tissue.

Dermis (corium)

The connective tissue layer below epidermis is the dermis. It contains blood vessels, lymphatics, nerve fibers, hair follicles, sebaceous glands, sweat gland, bundles of collagen fibers and network of reticular fibers. There are two layers of the dermis – outer papillary layer and inner reticular layer.

Papillary layer

It is the superficial layer and forms finger like projections of different shape and sizes which interdigitate with the downward projections of epidermal papillae. The dermal papillae contain blood vessels and nerve endings (touch receptors).

Reticular layer

This is the deep layer and contains bundles of collagen fibers and network of elastic fibers. Some connective tissue cells such as fibroblasts, macrophages, plasma cells etc. may also be found. Smooth muscle fibers (erector pilorum or erector pili) are present in relation to the hair follicles. These muscle fibers are present mainly in the areas of scrotum, teat and penis. In some animal, skeletal muscle fibers of the cutaneous muscle which is popularly known as *panniculus carnosus*, penetrate the dermis and for this reason voluntary movement of skin is possible. Some collagen fibers are arranged in this layer, parallel to the line of tension of the skin.

Subcutis

This is a layer of connective tissue attaches the dermis with the underlying muscles or sclerous tissue. It is composed of loose collagen and elastic fibers. Adipose tissue in the form of clusters may be present. This layer allow movement of skin in animals.

Appendages of skin

These are the specialized structures generally derived from the epidermis and serve specific function. These are i) Sweat glands, ii) Sebaceous glands, iii) hair, iv) hoof / nail, v) Arrector pili muscles.

i) *Sweat gland*

These are simple coiled tubular glands and Merocrine in nature. The secretory portion of the coiled gland is situated deep to the reticular layer of the dermis. The coiled tube is lined by a single layer of high cuboidal secretory cells. Some spirally arranged cells remain in between the epithelial cells and basement membrane are the myoepithelial cells.

The duct of the gland experience a helical course through the epidermis and is lined by a double layer of cuboidal cells.

Apocrine type of sweat glands are found in the domestic animals in plenty. The secretory cells stain dark and vary in shape from low cuboidal to high columnar depending upon the stage of activity. They are found throughout the skin but more in amount in the axilla and external auditory meatus. They help formation of cerumen with the secretion of sebaceous gland. Sweat is a clear fluid and helps in thermo regulation of the body. It contains sodium chloride, urea, lactose and helps in water and electrolyte metabolism. Sweat also serves as a media for disposal of waste products from the body.

ii) *Sebaceous gland*

These are simple or branched alveolar glands and Holocrine in nature. The alveoli open into a common duct and release the secretion, sebum, into the hair follicle. They are mostly associated with the hair follicles and invade the dermis. However in hairless zone the duct of the gland open directly into the skin.

Each alveolus is surrounded by a basal lamina upon which a layer of cuboidal cells are present. These cells enlarge, become polygonal in shape, pushed towards the center and finally disintegrate to form sebum. The duct of these gland is short and lined by stratified squamous epithelium.

The population of these glands is highly variable in different zones of the body and are absent in soles or foot pads.

iii) *Hair*

Hairs are flexible filamentous thread like keratinised structures and distributed all over the body except foot pads, hoofs, horns, glans penis etc. They grow from the hair follicles, situated in the dermis. The hairs are sensory in nature and act as heat insulators.

Structure of hair – It has mainly two parts – a) shaft b) root.

- (a) *Shaft* is the free part of the hair which remains above the surface of the skin. It is composed of an outermost layer called cuticle, a layer of densely packed keratinised cells called cortex and a central zone of loose cells known as medulla. The cells of the medulla are mostly cuboidal in shape and have spaces in between them.

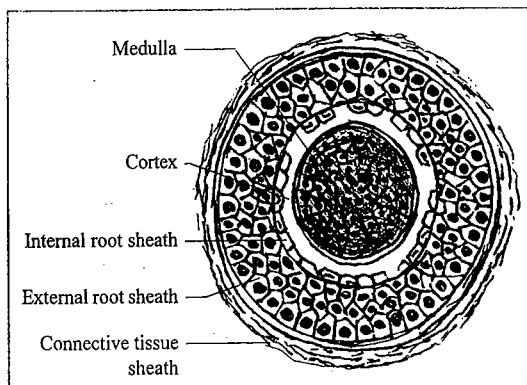


Fig. 2.3 Hair follicle (Transverse section).

- (b) *Root* – The part of the hair which remains embedded within the skin in a tubular sheath is known as root.

The deep end of the embedded root expands like a cup, known as hair bulb. The bulb is invaded by a papilla of connective tissue, called hair papilla. The down growth of the epidermis which encloses the root of the hair is known as external root sheath. At the deeper part another layer appear close to the root is called Internal root sheath. The hair bulb, hair papilla, the internal root sheath and the external root sheath together form the Hair follicle.

The external hair sheath is derived from stratum corneum and stratum spinosum of epidermis. During the formation of a hair follicle, growth of the cells of epidermis occurs into the dermis as well as into the subcutaneous tissue. The internal root sheath is composed of an inner cuticular layer, middle granular epithelial layer and an outer pale epithelial layer.

The cluster of epithelial cells at the deepest part of the down growth of epidermis which gets tissue fluid from the hair papilla and is responsible for the formation and growth of the hair is known as germinal matrix.

iv) *Hoof*

It is the hard keratinized (horn) portion of dermis and form the digital organ in animals. The wall of the hoof is composed of three layers a) Stratum externum, b) stratum medium and c) stratum internum.

Stratum externum is the outermost thin layer of the hoof. It originates from the germinal layer of epidermis of the periople.

Stratum medium is the thickest part and remain between the stratum externum and stratum internum. It is the main supportive structure of the hoof. It is composed of tubular and inter tubular horn and the horny tubules are arranged parallel to the outer surface of the hoof. It

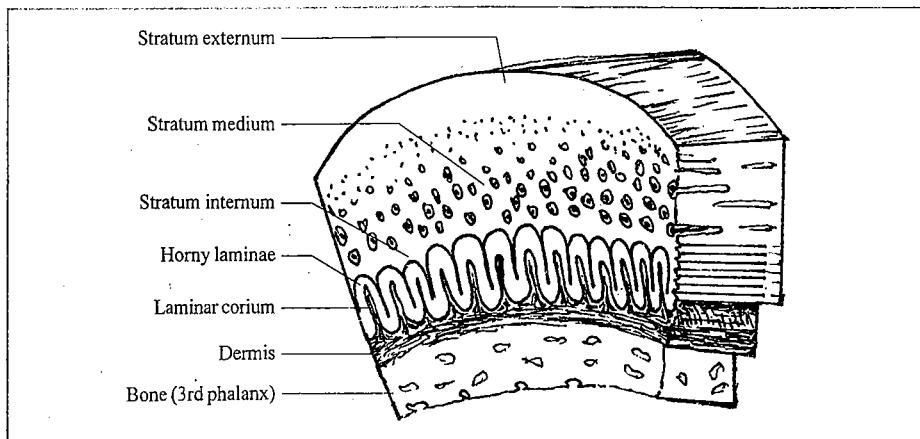


Fig. 2.4 Hoof.

originates from the stratum germinativum of the epidermis lining the coronary groove of the hoof.

Stratum internum is formed by numerous vertically arranged keratinized laminae. This layer is also originated from the stratum germinativum of the coronary groove. In equines each lamina is composed of 100 – 200 secondary laminae which project at right angle from the main structure. This layer remains in contact with the laminar corium which remains in between the horny laminae and bone (3rd phalanx). The laminar corium is composed of connective tissue, bundles of collagen fibers and network of arteries and veins.

The **claws** of dogs and cats are composed of a shield of hard keratin. Few rudimentary laminae are found at the inner surface, close to dorsal ridge. The wall is thick at the dorsal aspect and thin along the sides. This keratinized covering is developed from the epidermis. Stratum lucidum and stratum granulosum are present. The corium is composed of plenty of blood vessels and collagen and elastic tissue fibers.

Nail is developed from stratum lucidum of epidermis. It consists of several layers of flat transparent cornified cells which has been transformed to keratin. The nail bed which supports the nail consists of stratum granulosum of epidermis and the dermis. The body of the nail is free part and the root is the proximal part which remains covered by skin. Nail matrix is the part of the nail bed near the root.

Horn – The cornual processes are covered by the hard and keratinized horn developed from the epidermis and a corium developed from dermis. The basal layer of epidermis interdigitate with the connective tissue papillae of corium. Up to certain small distance from the root, a thin outermost layer of horn extends called *epikeras*. It becomes flaky and desquamated as the horn grows. The space between the periosteum of corneal process and the epidermis is filled by the corium which is composed of net work of blood vessels and connective tissue.

v) *Arrector pilli muscles*

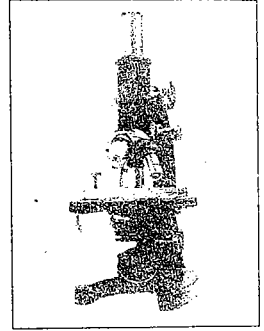
These are very small bundle of muscle fibers which extend from the papillary layer of dermis to the fibrous sheath of hair follicle. These muscles are innervated with the sympathetic nerves. Contraction of these muscles leads to the rise of hairs.

Nerves and vessels of skin

Since the skin is an important sensory organ, it is richly supplied with nerves. Sensory nerve fibers from free nerve endings are innervating the dermis as well as epidermis. Efferent sympathetic fibers supply the arrector pilli muscles, sweat glands and smooth muscles of blood vessels.

Numerous fine blood vessels are distributed within the dermis. Epidermis is avascular and therefore the cells of this layer derive their nutrition from the vessels of dermis.

DEVELOPMENT OF SKIN



The ectoderm and mesoderm together form the skin. The epidermis is formed by surface ectoderm and dermis is formed by underlying mesoderm.

Epidermis

At the beginning the epidermis is formed by a single layer of ectodermal cells. It differentiates into an outer and an inner layer. The inner layer is the **germinative layer**. This layer proliferates and differentiates to form **stratum basale**, **stratum spinosum**, **stratum granulosum**, **stratum lucidum** and finally **stratum corneum**. The outer (superficial) layer is shed off and mix with secretions of sebaceous glands to form a pasty substance called vernex caseosa.. This substance serves as a protective layer to the foetus at the latter part of the intrauterine life. Some neural crest cells migrate into the basal layer of epidermis and differentiate to form **melanoblast cells** during 3rd month of gestation.

Dermis

The mesodermal component of skin condense and differentiate to form dermis. This mesoderm is derived from the dermatome of paraxial mesoderm (somites). Subsequently

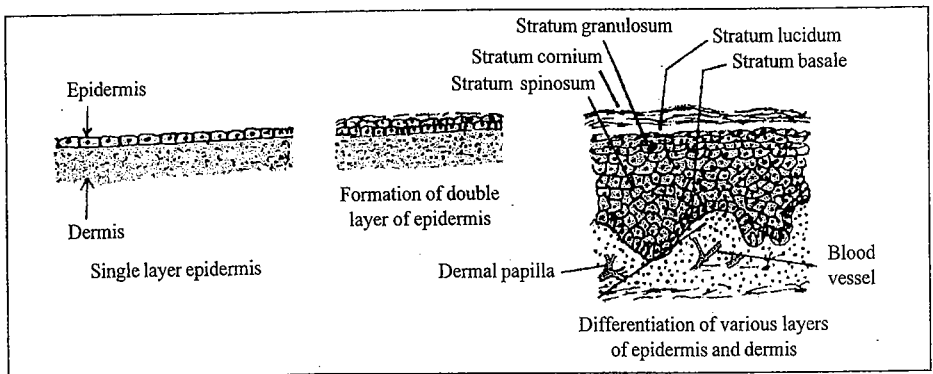


Fig. 2.5

dermis, which is straight at the beginning from numerous projections, towards epidermis and gives rise to **dermal papillae**. The layer below the dermis is called **hypodermis**. The subcutaneous fibro-fatty tissue is derived from this layer.

Hair

The germinative layer (ectodermal in origin) of the epidermis develops a down growth into the dermis. The lower end of this down growth expand to form the **hair bulb**. This bulb is invaginated by a condensed mesoderm in the form of a projection called **papilla**. The germinal cells overlying the papilla become spindle shaped and get keratinized to form the body of the hair. The **root sheath** is formed by the cells which are remaining at the parietal layer of the down growth close to the bulb.

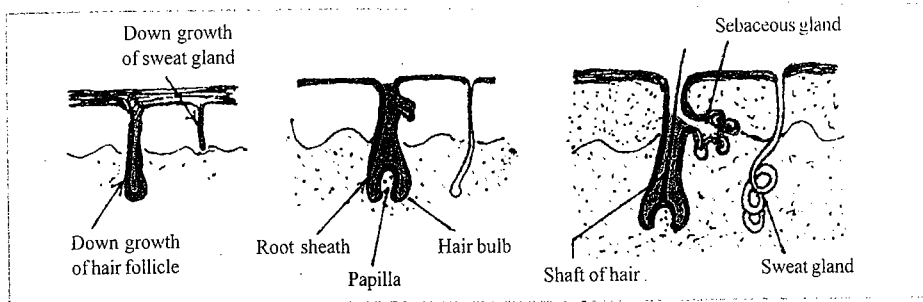


Fig. 2.6

Sebaceous glands

From the lateral wall of the epidermal down growth of hair follicle the sebaceous gland appear in the form of a bud. This bud gives rise to the formation of sacculations. Subsequently proliferation and degeneration of the germinative cells of this layer form this gland.

Sweat gland

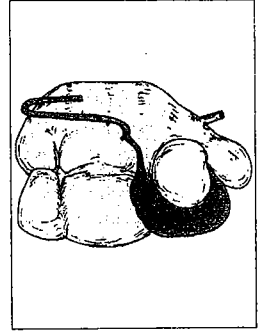
The ectodermal layer of the skin form a solid down growth. Subsequently the cord become canalized and extend upto dermis. The distal end undergo coiling to form the gland. It opens on the surface at the late stage of intrauterine life.

Hoof

They appear just before mid term pregnancy at the tips of the digits. It is developed in the stratum lucidum of epidermis. The epidermis becomes keratinized first at the tip and subsequently extends up to the dorsal aspect of 3rd phalanx. The germinal layer of the root of hoof proliferate and form a matrix. The matrix is transformed into hoof substance.

3

DIGESTIVE SYSTEM



This system is associated with the ingestion, digestion and absorption of food and elimination of waste products. Basically this system is formed by a muscular tube which starts at the mouth, undergoes regional modification and specialization according to the functional need and terminates at the anus.

The components of this system are as follows :

Mouth	Salivary glands
Pharynx	Pancreas
Esophagus	Liver
Stomach	
Small Intestine	
Large Intestine	

Mouth (oral cavity)

Lips – The main bulk of the lip is contributed by the tunica muscularis, which is composed of the striated muscle fibers of Orbicularis oris.

Externally the lips are covered by skin and internally lined by mucous membrane. At the junction of the skin and mucous membrane, the hair follicles are absent but the epidermis is thick. The mucous membrane is generally made up of keratinized stratified squamous epithelium in most of the herbivorous animals but non-keratinized in

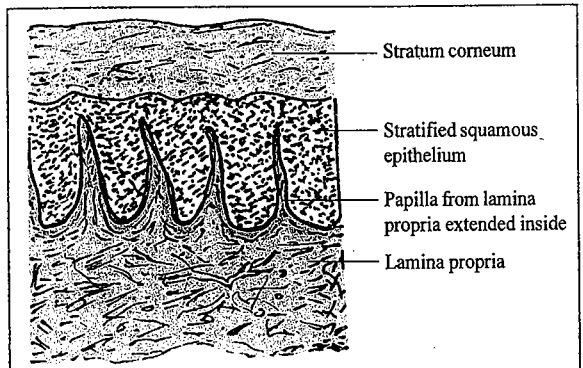


Fig. 3.1 Dental pad.

carnivorous animals, depending upon the food habit. Demarcation between lamina propria and submucosa is indistinct. Labial glands are serous or seromucous type.

Cheeks – Histological structure of the cheeks are more or less similar to that of lips. They are also composed of skin, muscles, glands and mucous membrane. Skin is continuous with the other part of the face. Muscular layer is formed by buccinator, levator and depressor muscles of the face. Buccal glands are minor salivary glands situated at the submucosa as well as within the muscle bundles. These glands are serous or mucous or mixed type. In most of the mammals the lining mucous membrane is made up of non keratinized squamous epithelium but in ruminants it bears a large number of cornified pointed papillae, which are directed backward.

Gum (Gingiva)

It is composed of a thick layers of collagen and elastic fibers which are closely attached to the periosteum of the alveoli bearing bones and surrounds the neck of the tooth. Many fibers of gingival lamina propria are continuous with the periodontal membrane and are inserted into the cementum.

Hard Palate

The mucous membrane is composed of keratinized stratified squamous epithelium. The stratum corneum is very thick at the **dental pad** in ruminants. Lamina propria is well developed and papillary processes from this layer extend into the thickness of the stratified squamous epithelium. The submucosa is composed of dense network of collagen and reticular fibers. This layer blends with the periosteum.

Soft Palate

The mucous membrane is made up of stratified squamous noncornified epithelium. The mucous membrane of the nasal surface is composed of ciliated pseudostratified columnar epithelium. Branched tubulo acinar mucous and seromucous glands are present in the lamina propria and submucosa. The bulk of the soft palate which remain between two mucous membranes, is composed of longitudinally oriented striated muscle fibers and connective tissue.

TONGUE

This highly movable muscular structure. This structure is covered at its dorsal aspect by a specialized mucous membrane and contains plenty of vessels, nerves, connective tissue,

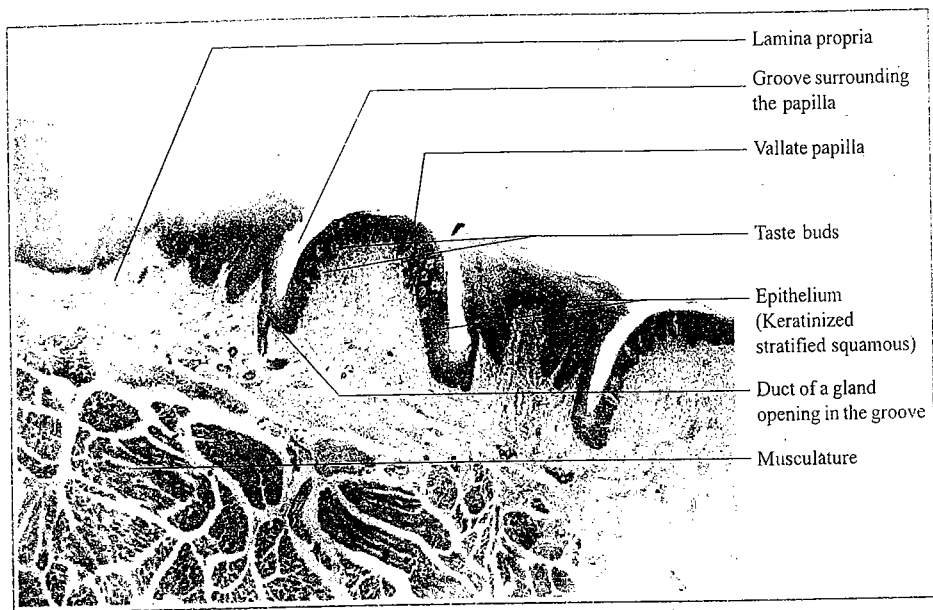


Fig. 3.2 Tongue.

glands and some spindle shaped Neuro-epithelial (taste) cells. These taste cells have microvilli at their tips which project through a small opening on the surface of the tongue, called taste pore. The base of these cells are associated with the sensory nerve terminals.

The tunica mucosa of the dorsal surface is formed by keratinized stratified squamous epithelium. The thickness of the keratinization is variable amongst different zones. Thin surface contains many macroscopic papillae which either serves mechanical or gustatory function. These are a) filliform, b) fungiform, c) lenticular and d) vallate. Foliate papillae are found in equines and conical papillae are present on the tongue of dog and cat.

Filliform papillae – These are numerous fine variety blunt cone shaped papillae and are distributed throughout the dorsal surface of the tongue rostral to transverse groove. The tips of these papillae project above the surface and are covered by keratinized stratified squamous epithelium. The stratum corneum is thick. Each papilla has a connective tissue core which is highly vascular. Cornified thread like structure extend from the tip of these filiform papillae in equines. In dog these papillae sometimes have two or more apices.

Fungiform papillae – They are larger in size and remain scattered among the filliform papillae on the dorsal surface of the tongue. The shape of these papillae look like young mushroom and hence called fungiform papillae. Non keratinized stratified squamous epithelium covers the surfaces of these papillae. The epithelium contains few taste buds in cow and horse. However, the number of taste buds is more in sheep, pig and in carnivores. The connective tissue core contains adequate blood vessels.

Lenticular Papillae – These are in the form of flattened projection of low height and are situated at the caudal part of the dorsal surface of tongue. They are prominent on the torus linguae. These papillae are covered by stratified squamous epithelium.

Vallate papillae – They are the largest variety of papillae of tongue and each of them is encircled by a wall and therefore also called circumvallate. They are situated at the caudo-dorsal aspect of the tongue, 10-15 in number in cow and 2 to 3 in equines, pigs and carnivores. The tips of these papillae, although do not project but fairly exposed to the surface. They are covered by stratified squamous epithelium. Good number of taste buds are present at the sides of these papillae. Ducts of some small gustatory serous glands open in the inner surface of the surrounding wall. The connective tissue core is dense and rich in blood vessels and nerves.

Foliate papillae – These papillae are absent in ruminants and are present in horse, cat and rabbits. These are parallel folds of the mucosa situated on either side of root and in front of anterior pillars. Stratified squamous epithelium covers these papillae. Some taste buds are found in the epithelium.

Conical papillae – These are cone shaped small papillae found on the root of the tongue in dog, cat and pig. There are also found at the cheek and floor of the oral cavity. They are covered by keratinized stratified squamous epithelium. Connective tissue core is narrow.

Taste buds

These are oval elongated structures situated within the covering epithelium of fungiform, vallate and foliate papillae of tongue and extend from the basement membrane to the surface. The buds are flask shaped structures with a base, wide body and neck which opens at the **taste pore**. Each bud is composed of spindle shaped taste cells or the gustatory cells at the

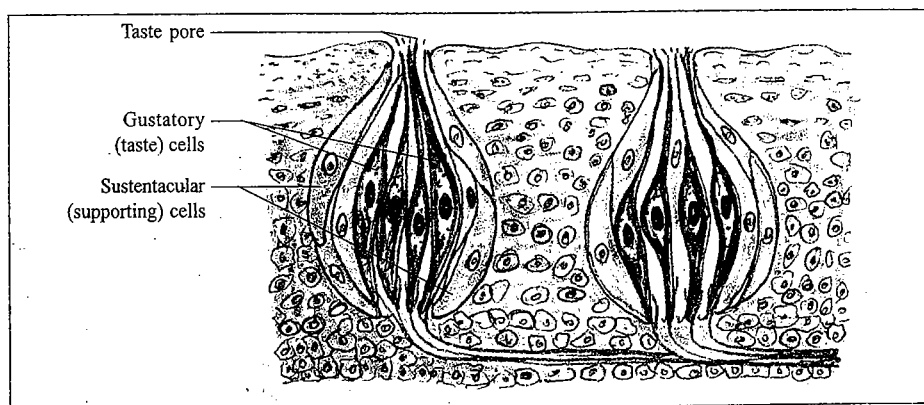


Fig. 3.3 Taste buds.

center and crescent shaped supporting cells. The taste cells are neuro-epithelial receptor cells and are connected to sensory fibers. It is evident that the life span of those taste cells is less and the degenerated cells are regularly replaced by peripheral germinal cells. The taste buds are also found in the soft palate, epiglottis and in other areas of mouth.

Musculature

The bulk of the tongue is formed by the intrinsic muscles mainly and extrinsic muscles partly. All are striated muscle fibers. The intrinsic muscles fiber bundles are arranged longitudinally, transversely and vertically. The dorsal longitudinal fibers are situated below the mucosa. Due to excessive mobility of the organ, the muscle fibers are arranged in multiple directions.

Ventral surface of the tongue – This surface is smooth and is covered by non keratinized stratified squamous epithelium. This epithelium is highly vascular

Glands

Some seromucous lingual glands are present between the bundles of muscle fibers in a scattered manner. These are small lobulated glands and part of minor salivary glands of the tongue.

Lingual tonsils are some aggregations of lymphoid tissue around epithelial pits which invaginate deep at the root of tongue. The pits are lined by stratified squamous epithelium.

Lyssa – It is a fibro-elastic cord extends along the mid line of the ventral surface of the tongue of dog. It is composed of fibrous connective tissue, adipose tissue, striated muscle fibers, vessels and nerves. In cat it is mainly composed of adipose tissue. In other animals (Pig and horse) it remains in the form of a thin fibro- elastic cord.

TOOTH

Teeth are highly mineralized and hardest structure of the body and implanted into the alveolar sockets of the upper and lower jaw bones. A tooth is composed of a pulp cavity, dentin enamel and cementum.

Pulp cavity

It is a small cavity inside the body of the tooth. It is little dilated towards the crown and narrow towards the root. The narrow portion open at the tip of this root in the form of a canal known as root canal. The cavity is lined by a layer of tall cells called *odontoblasts*.

The pulp is composed of connective tissue cells, blood vessels, nerve and collagen fibers. The vessels and nerves pass into the pulp cavity through the root canal.

Dentin

The bulk of the tooth is formed by dentin which also encloses the pulp cavity. Dentin contains numerous parallel arranged dentinal canaliculi in which dentinal fibers or processes extend from the tall odontoblastic cells of the pulp cavity towards the periphery in a radiating manner. These processes may sometimes be branched. Around or in between the odontoblastic processes organic intercellular substance is deposited which is composed of reticular and collagenic fibers at first. This uncalcified intercellular substance of dentin subsequently become calcified to form the hard dentin. The recently formed intercellular substance of dentin which is naturally close to the odontoblasts, remain uncalcified for a short period, called pre-dentin. Due to the presence of cytoplasmic processes of odontoblast in the dentin, the tooth is very sensitive to stimuli.

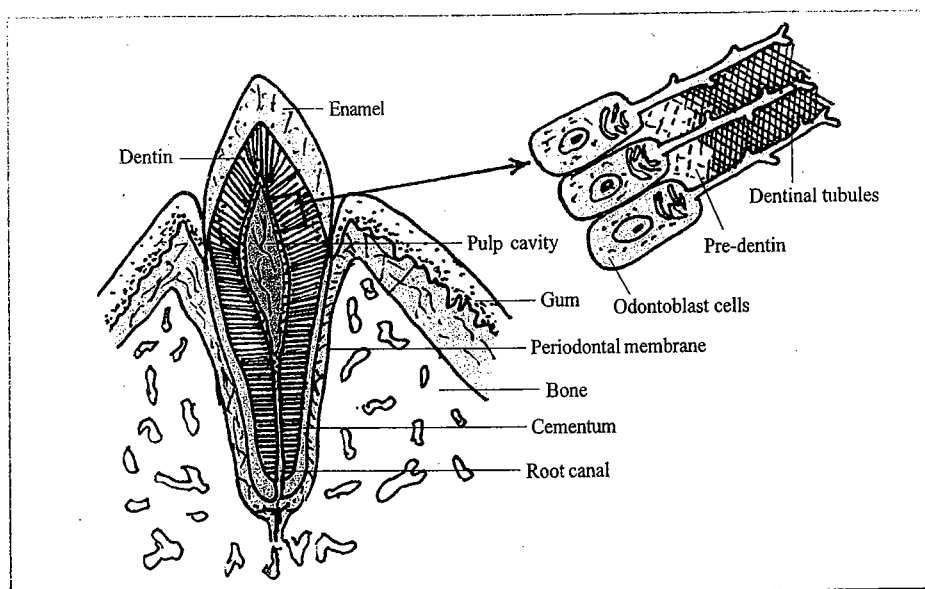


Fig. 3.4 Tooth (longitudinal section).

Enamel

The projected part of the tooth above the level of gum is known as crown. Crown has an external covering of hard translucent material is known as enamel. It is composed of radially arranged hexagonal rods the enamel prisms derived from **Ameloblast cells**. These enamel prisms are held together by cement substance. Generally each ameloblast cell produces one

enamel rod. The enamel is composed mainly of calcium phosphate in the form of apatite $\text{Ca}_{10}\text{F}_2(\text{PO}_4)_6$ and very small amount of protein and carbohydrate. Enamel is the hardest substance of the body.

Cementum

The narrow part of the tooth which remains implanted into the alveolar socket is known as root. Cementum is a hard substance which covers the root.

It is slight yellowish in colour and composed of modified bone tissue. The upper part (close to crown) is devoid of cells. Rest part of the cementum has cells in the lacuna, called **cementoblasts**. The periphery of the cementum contains some bundles of collagen fiber and extend to the bony socket to form **Periodontal membrane**. This membrane is similar to periosteum, lines the alveolus and attaches the cementum to the alveolar socket.

In domestic animals two different types of teeth are available. These are Brachydonts and Hypsodonts.

Brachydonts

These are generally short in size and do not grow further after eruption is complete. E.g. teeth of man and carnivores, incisors of ruminants.

Hypsodonts

These are longer in size and grow throughout the most part of life; e.g. teeth of horse, cheek teeth of ruminants, tusks of boar, elephant etc.

PHARYNX

This funnel shaped part of G.I. tract is common to digestive and respiratory passages and has three parts – Nasopharynx, Oropharynx and laryngopharynx. The wall of the pharynx is composed of following layers.

(a) Inner mucous coat

Lining epithelium – It is nonkeratinised stratified squamous epithelium in the Oropharynx and laryngopharynx and pseudostratified columnar ciliated epithelium in the nasopharynx.

Lamina propria – Other than serous and mucous glands, it contains collections of lymphoid tissue. These are known as pharyngeal tonsils. Such collections of lymphoid tissue at the lateral wall of oropharynx are known as palatine tonsils.

(b) Muscular coat

Bundles of ill-defined skeletal muscle fibers are arranged in a thin layer intermingled with fibro elastic connective tissue.

(c) Outer fibrous coat

It is a fibro elastic layer and attaches the pharynx to the surrounding structures.

GENERAL HISTOLOGICAL CHARACTERISTICS OF G.I. TRACT

From esophagus to rectum of the Gastro-intestinal tract exhibits a common histological feature as follows, with regional variations:

1. Mucous coat

It comprises of a) Lining epithelium, b) Lamina propria and c) Muscularis mucosae.

The **lining epithelium** is stratified squamous in the esophagus and in the anal canal. The epithelium of the rest portions of the G.I tract is of simple columnar type. These columnar cells perform absorptive or secretory functions.

The **lamina propria** is composed of loose connective tissue, glands, blood vessels and nerves. It supports the lining epithelium.

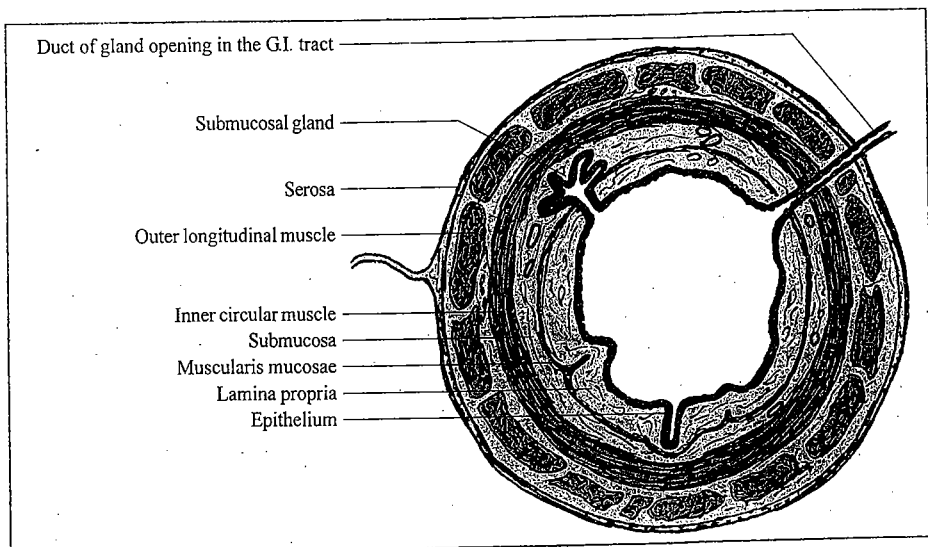


Fig. 3.5 General pattern of histological features of alimentary canal.

The *muscularis mucosae* generally very thin and comprises of an outer layer of longitudinal and an inner layer of circular muscle fibers. Some fibers from this layer may extend in to the lamina propria which invaginated into various foldings of mucous membrane or in to the villi. In anal canal it is absent. This layer helps localized movement of the mucous membrane.

2. Submucous coat

It is composed of loose connective tissue and contains vessels, nerves, lymphatics and sometimes submucosal glands. This coat connects the muscular coat with the mucous coat.

3. Muscular coat

This is the bulky part of the wall and is composed of inner circular and outer longitudinal muscle fibers. The thickness of the circular muscle fibers is highly increased at the sphincters. This coat accommodates parasympathetic ganglion cells or plexus.

4. Serous coat

It is the outermost layer and generally composed of a single layer of squamous cells and a small amount of underlying connective tissue. In esophagus rectum and anal canal the layer is substituted by fibrous coat.

ESOPHAGUS

This tube is composed of all the four coats but the outermost coat is fibrous instead of serous.

Mucous coat

The *lining epithelium* is made up of squamous stratified non-keratinized cells in carnivores. It is keratinized in herbivores. *Lamina propria* may or may not contain few branched tubular glands. It is made up of fine collagen and elastic fibers. The *muscularis mucosae* is composed of longitudinally arranged smooth muscle fibers. They are indistinct or absent at the cranial part and prominent at the caudal part.

Sub mucous coat

It is composed of loose connective tissue, large vessels and nerves. It contains mucous or seromucous glands. Specially at the cranial part in most of the animals. However in dogs, these glands are distributed in the submucous coat throughout the length of esophagus.

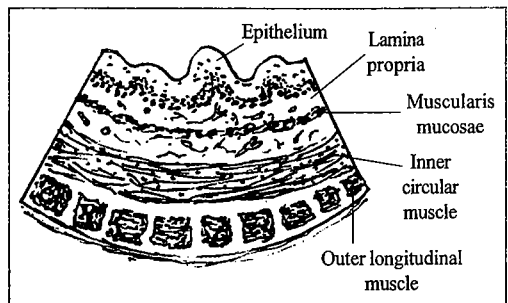


Fig. 3.6 Esophagus.

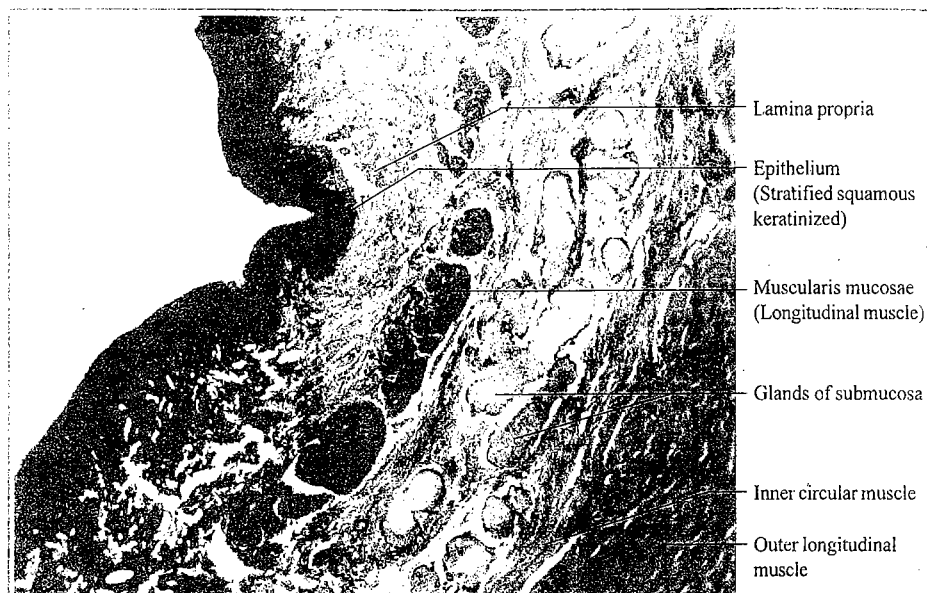


Fig. 3.7 Esophagus (Transverse section).

Muscular coat

It is composed of inner circular and outer longitudinal muscles. But at the cranial part of the tube these two layers mix together. The thickness of the circular muscle fibers increases caudally in most of the animals but is more thicker in horse. The characteristics of the musculature is highly variable in different mammals as follows :

<i>Animal</i>	<i>Striated</i>	<i>Smooth</i>
Ruminants and dog	Entire length	—
Horse and pig	Cranial 2/3rd	Caudal 1/3rd
Cat	Cranial 4/5th	Caudal 1/5th

Fibrous coat

The outermost coat is made up of connective tissue containing many elastic fibers, blood vessels and nerves in the cervical region. In the thoracic part the tunica muscularis is invested by mediastinal pleura. The abdominal part is very small in most of the animals and is covered by peritoneum.

STOMACH

This is the dilated part of the G.I. tract and is designed for the breakdown of the food materials to make it suitable for enzymic activity. Therefore this organ is variable in structure in different mammals and birds depending upon their food habits. However, the wall of the stomach is composed of all the usual layer of the G.I. tract in all the domestic mammals. These are a) serous coat, b) Muscular coat, c) Sub mucous coat and d) Mucous coat. The serous coat is made up of a single layer of squamous cells with a small amount of underlying connective tissue.

The muscular coat has an extra oblique layer at the innermost part. The sub mucous layer is as usual. The mucous coat is composed of epithelium, a lamina propria and a muscularis mucosa. The mucous coat exhibits two different parts – a) glandular and b) non-glandular; in most of the domestic mammals.

In dogs and rabbits the stomach is simple and the non glandular part is absent. In horse, the stomach is of single chamber but the mucous coat is having two different zones (non glandular and glandular) separated by an irregular rough line – the *Margoplicatus*. In pig a small part around the cardia in non glandular and rest portion is glandular. In ruminants the stomach comprises four compartments connected to each other – rumen, reticulum, omasum and abomasum. The first three are non glandular and fourth one is glandular. The glandular part exhibits similar histological character to that of simple stomach.

Mucous coat of glandular part is thick and has three histologic portions – i) cardiac part, ii) fundic part and iii) pyloric part.

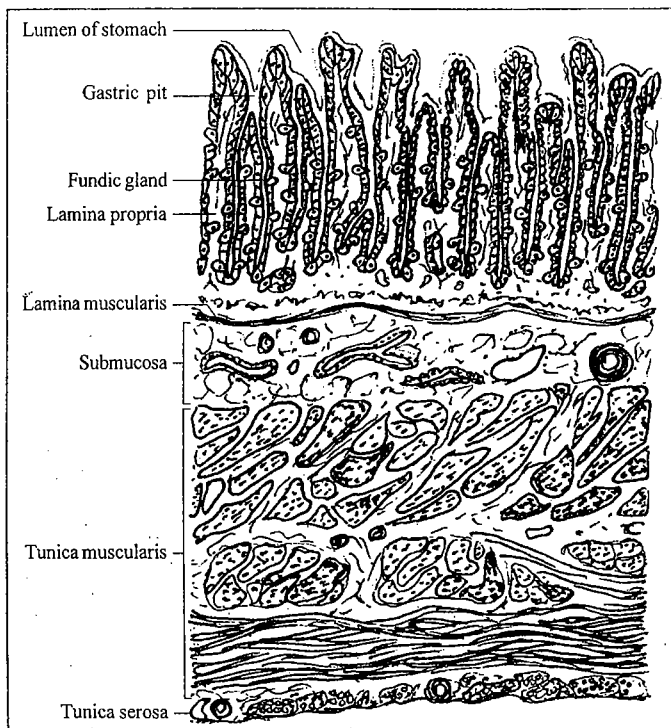


Fig. 3.8a Section of the wall of stomach.

The surface epithelium is lined by a single layer of tall columnar cells and secretes mucous. The Goblet cells are absent. When the stomach is empty, it shows numerous longitudinal folds called rugae. They become flat when the stomach is filled.

Gastric glands

These are –
 a) Cardiac glands,
 b) fundic glands and
 c) pyloric glands.
 They are accommodated in the thick mucosa and are

bordered at their bases by muscularis mucosa. Actually the epithelium dips into the lamina propria to form long tubular glands. The bases of this invaginated tubes are rounded and appear as acini. These glands open at the depressions on the surface called gastric pits.

Cardiac glands

These glands are situated in the lamina propria of the area around the entrance of the esophagus into the stomach. These are branched tubulo alveolar short mucous glands and composed of the cells of pale cytoplasm.

Fundic glands

These are the main gastric glands and are found in the fundus or body of the stomach. They are simple branched tubular glands with long and straight secreting tubules which open at the bottom of the short gastric pits. Each gland comprises of a blind dilated end called base, a long body and a neck.

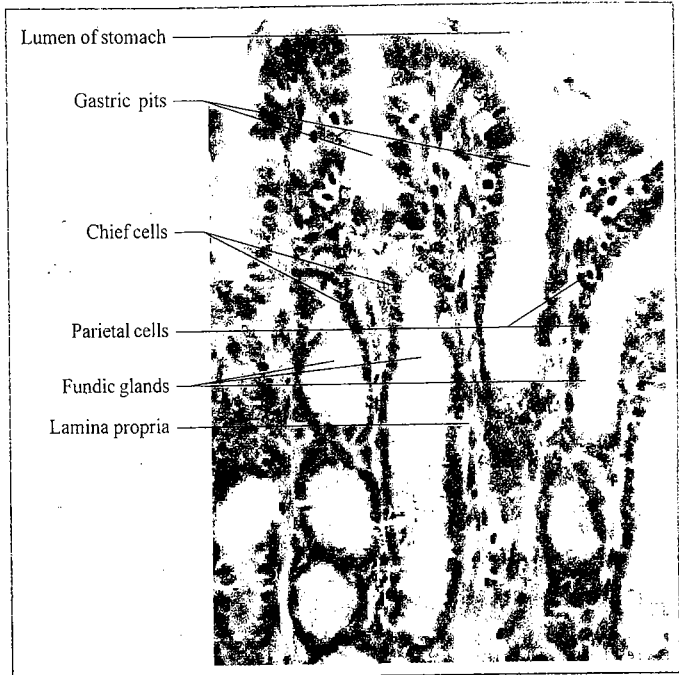


Fig. 3.8b Section of gastric epithelium.
 (By Courtesy : Dr. Pawan Kumar, Hissar)

The secretory epithelium is composed mainly of four structurally and functionally different types of cells. These are a) *Chief cells*, b) *Parietal cells*, c) *Mucous neck cells* and d) *Argentaffin cells*.

CHIEF CELLS (peptic cells or zymogene cells)

These cells are numerous and are cuboidal, pyramidal or spherical in shape. They are situated at the base and body of the gland and contain zymogen granules in the cytoplasm between the nucleus and free surface. They secrete pepsinogen which forms pepsin on hydrolysis.

PARIETAL CELLS (oxyntic cells)

They are less in number, large in size, placed between chief cells but pushed towards periphery of the gland. These cells have a spherical nucleus and the cytoplasm stains deeply with Eosin. The cytoplasm contains no secretory granules but possesses numerous mitochondria and microvilli. These cells secrete Hydrochloric acid. A good number of canaliculi which are formed due to invagination of cell membrane end at the lumen of the gland.

MUCOUS NECK CELLS

These are large columnar cells mainly situated at the neck of the gland with basal nucleus and pale cytoplasm. They secrete mucous.

ARGENTAFFINE CELLS

These are also less in number and remain interposed between the basement membrane and chief cells. They are demonstrated with silver stain and secrete serotonin which stimulates the muscle to contract. They are also called entero-chromaffin cells because they have affinity to chromium salts.

Pyloric glands

These are simple but branched and coiled, relatively shorter in size and located at the pyloric part of the stomach. The gastric pits are more deeper than those of fundic glands. The cells of these glands are similar to those of mucous neck cells of fundic glands. Some cells of these glands which are present between the mucous cells secrete Gastrin and are called G cells. Gastrin stimulates secretion of HCl in fundic glands.

Ruminants – Glands are found only in the abomasum.

Horse – Cardiac gland region is narrow and located after the marginalis.

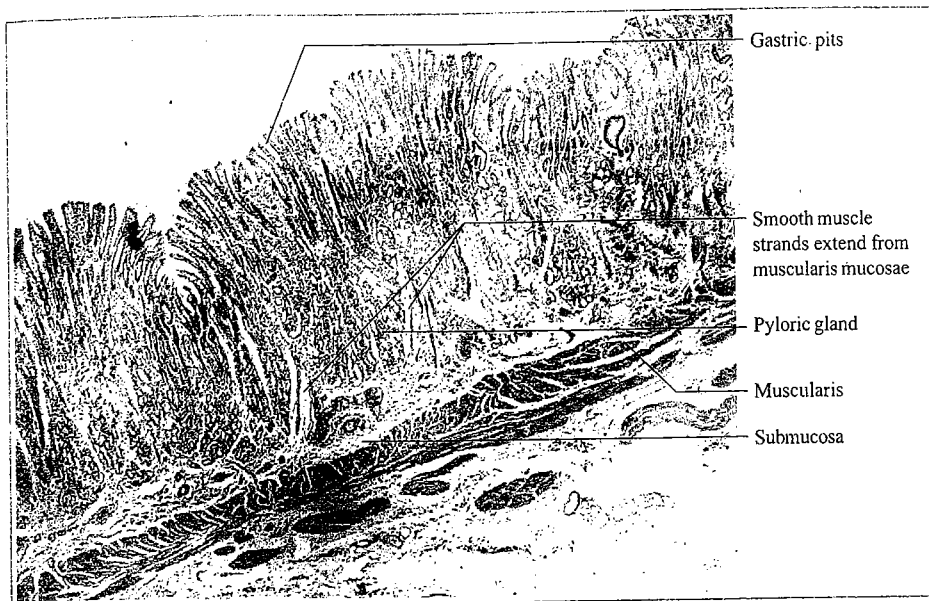


Fig. 3.9a Simple stomach (Pyloric part).

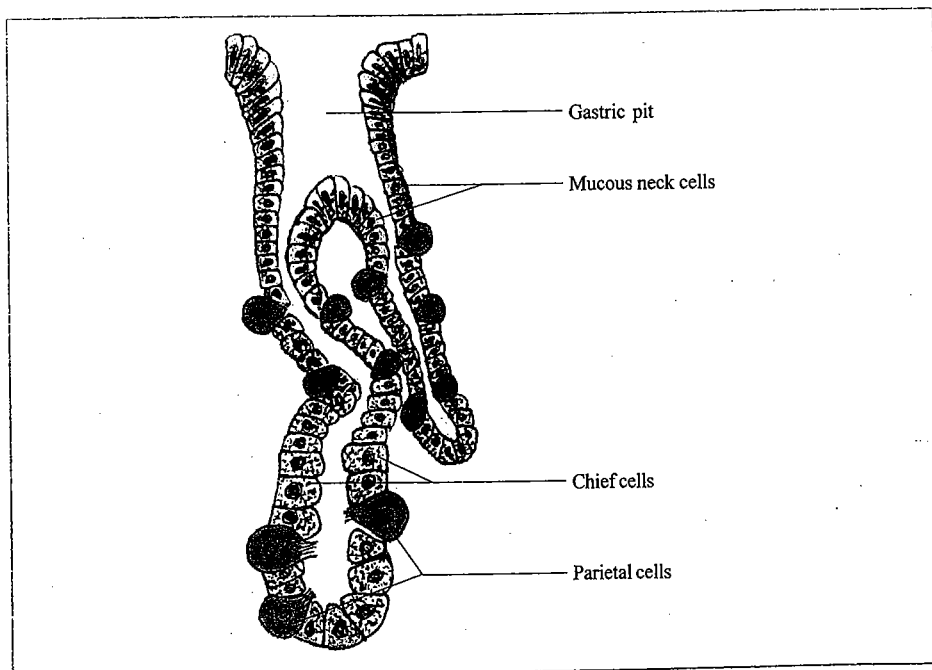


Fig. 3.9b Gastric pit and gland.

Dog – Cardiac gland region is comparatively narrow and the fundic gland region is divided into a light zone (having thin mucosa and few parietal cells) and a dark zone (with thick mucosa and more parietal cells).

Pig – Cardiac region is large and parietal cells in the fundic region some times remain in clusters.

Stomach of Ruminants

Out of the four compartments (Rumen, Reticulum, Omasum and Abomasum) the last compartment is glandular. First three portions are non glandular and are lined by stratified squamous epithelium. The abomasum is glandular and is similar to that of simple stomach as has been described earlier.

The non glandular compartments transform the course and fibrous feed to absorbable nutrients by mechanical and chemical action. The micro-organisms which remain in these non glandular chambers act on these fragmented feed and produce volatile fatty acids and absorbed through the mucosa. The remaining ingesta pass to the abomasum for enzymic digestion.

Rumen

The mucous membrane of rumen comprises of large number of small papillae. They are smaller in young and infants but may be as large as 1.5 cm. in adult animals.

The epithelium is made up of stratified squamous cells which protect the wall from the rough and coarse feed materials and also helps in metabolism and absorption. The wall of this non glandular compartment is composed of the following layer and having some similarity to that of skin. *Stratum corneum* – It is made up of squamous cells of variable thickness (1 to 15 cell thick). *Stratum granulosum* – It is composed of 1 to 3 cell thick flattened cells. These cells contain keratohyaline granules. *Stratum spinosum* – This layer is made up of 1 to 10 cell thick slightly large polyhedral cells. The cytoplasm contains numerous mitochondria and ribosomes. Desmosomes are also numerous. *Stratum basale* – It consists of columnar cells placed on a basement membrane.

The *lamina propria* consists of a compact network of collagen, reticular and elastic fibers. It extends into the center of each papilla.

Muscularis mucosae and glands are absent.

The *submucosa* is as usually composed of loose connective tissue and blends with lamina propria. It contains vessels and nerve fibers. It blends with lamina propria without junction.

The *tunica muscularis* is made up of circular, longitudinal and oblique muscles and contains myoenteric plexuses. The *tunica serosa* is covered by mesothelium, contains collagen and elastic fibers blood and lymph vessels, nerves and some amount of fat.

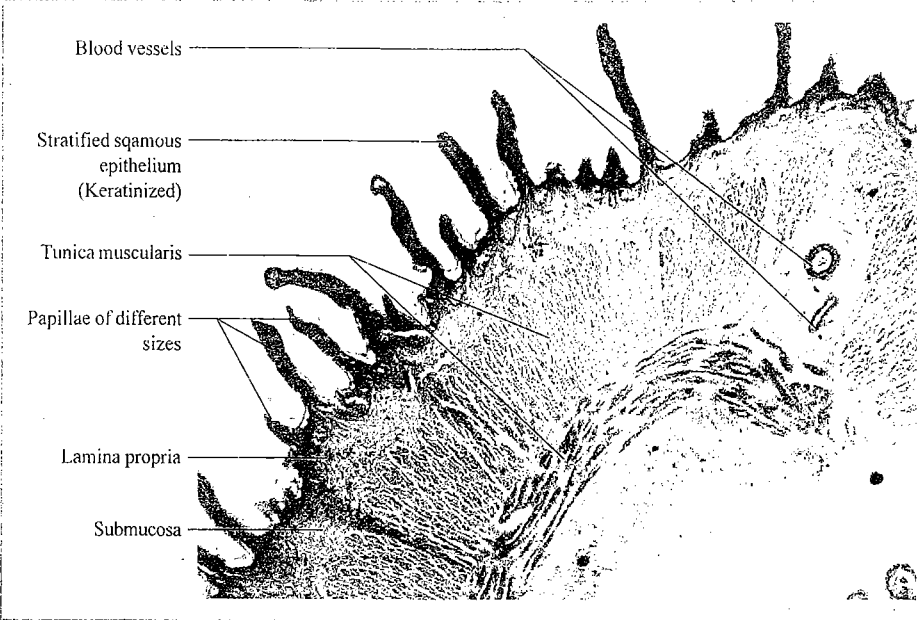


Fig. 3.10 Rumen.

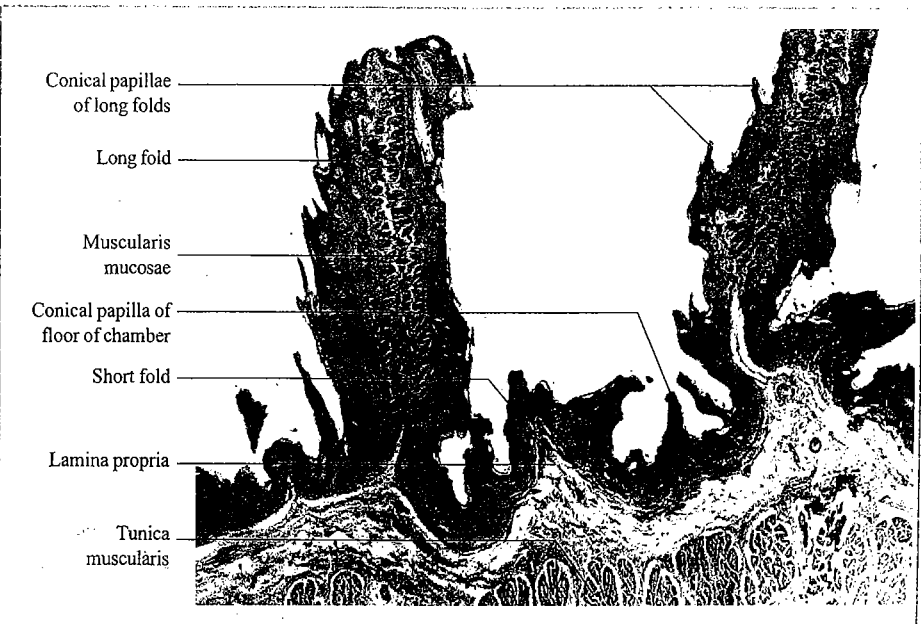


Fig. 3.11 Reticulum.

COMPARATIVE HISTOLOGY OF DIFFERENT COMPARTMENTS OF RUMINANT STOMACH

Compartment	Appearance	Epithelium (keratinised stratified squamous epithelium)				Lamina propria	Tunica sub-mucosa	Tunica muscularis	Tunica serosa
		Stratum corneum	Stratum granulosum	Stratum spinosum	Stratum basale				
RUMEN	Papillated. Numerous papillae of varying sizes. Turkish towel appearance.	1-15 cell thick stratified squamous cells.	1-3 cell thick flattened cells containing keratohyalin granules.	1-10 cell thick large polyhedral cells with numerous desmosomes.	Single layer columnar cells placed on a basement membrane.	Network of collagen elastic and reticulin fibers. It extends into papillae. Muscularis mucosae absent.	Loose connective tissue with vessels and nerves. It blends with lamina propria.	Circular longitudinal and oblique muscles. Myoenteric plexus present.	Collagen and elastic fibers and covered by mesothelium.
RETICULUM	Honey comb. Numerous hexagonal or pentagonal chambers are subdivided into smaller chambers with walls of low height. Floor and walls bear papillae.	As above.	As above.	As above.	As above.	Contains collagen and elastic fibers. Muscularis mucosae is present and extends inside the folds which form walls of the chambers of honey comb structure.	As above.	Inner oblique layers cross with outer layer at right angles.	As above.
OMASUM	Engorged with about 100 crescent shaped laminae of variable heights (upto 5th order). Outer surfaces of the laminae are studded with numerous rounded horny papillae.	As above.	As above.	As above.	As above.	Similar to that of reticulum but contains dense subepithelial capillary network. The extended muscularis mucosae is thick and present on either side of the central sheet of muscle which extends from the inner circular layer of tunica muscularis.	As above but may contain nerve plexus with ganglia.	Composed of inner circular and thin longitudinal muscles. A thin sheet from inner circular layer extends inside large laminae.	As above.
ABOMASUM	Glandular.	Structures are similar to those of simple stomach.							

Reticulum

The permanent anastomosing folds of the mucosa form small polygonal (Hexagonal/pentagonal) chambers and give rise to honey-comb appearance. These chambers are subdivided by other folds of low height. The floor of these chambers are covered by numerous conical papillae. The margin of these folds bear vertical ridges. Structural variations have been presented in the table.

Omasum

The cavity of this compartment is occupied by about a dozen of large sickle shaped folds which spring from the greater curvature of the organ. In between large folds 3-4 orders of similar folds of low height are accommodated and therefore total number of folds is about 100. The surfaces of these folds are studded with numerous round horney papillae. Structural differences have been given in the table.

Abomasum

The fundus of this compartment presents 10-12 oblique thick glossy mucosal folds. It is the true stomach and its microscopic structure is similar to that of simple stomach.

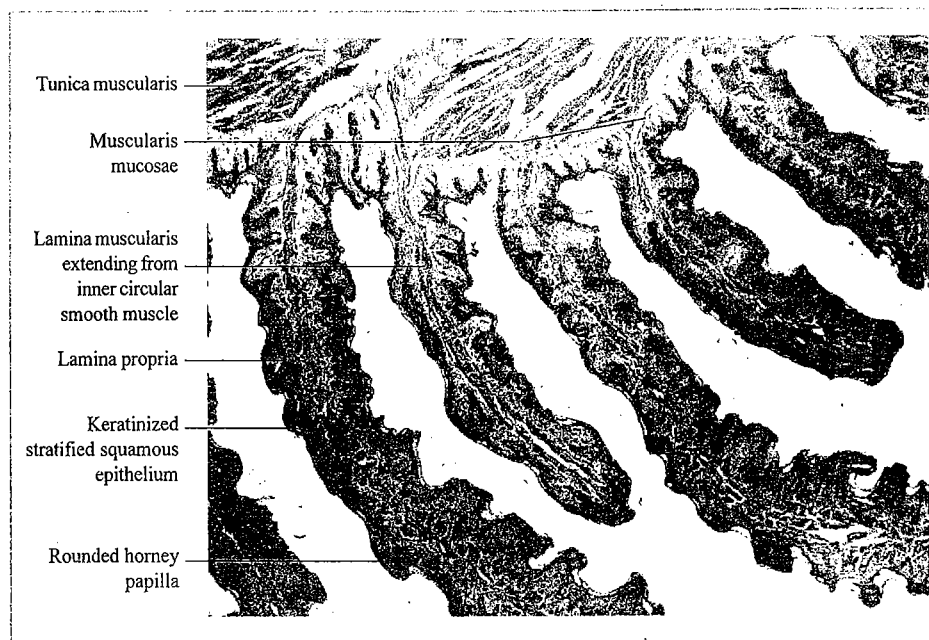


Fig. 3.12 Omasum with various orders of laminae.

SMALL INTESTINE

The components of small intestine are Duodenum Jejunum and Ileum. There is a general pattern of histomorphological organization because all the components are responsible for absorptive function by enhancing the surface area as well as digestive function by secretion of considerable amount of digestive enzymes from mucosa, submucosa and from glands outside the intestine. Secretion of mucus for lubrication and protection of living cells from mechanical injury is also another important function.

The common structures of small intestine are mucous, submucous, muscular and serous coats.

Tunica mucosa

Components

Lining epithelium, lamina propria, lamina musculars (muscularis mucosae).

The **lining epithelium** is composed of simple columnar epithelium with numerous goblet cells. The surface of the mucosa is studded with finger or leaf like projections which take major part in absorption are called villi.

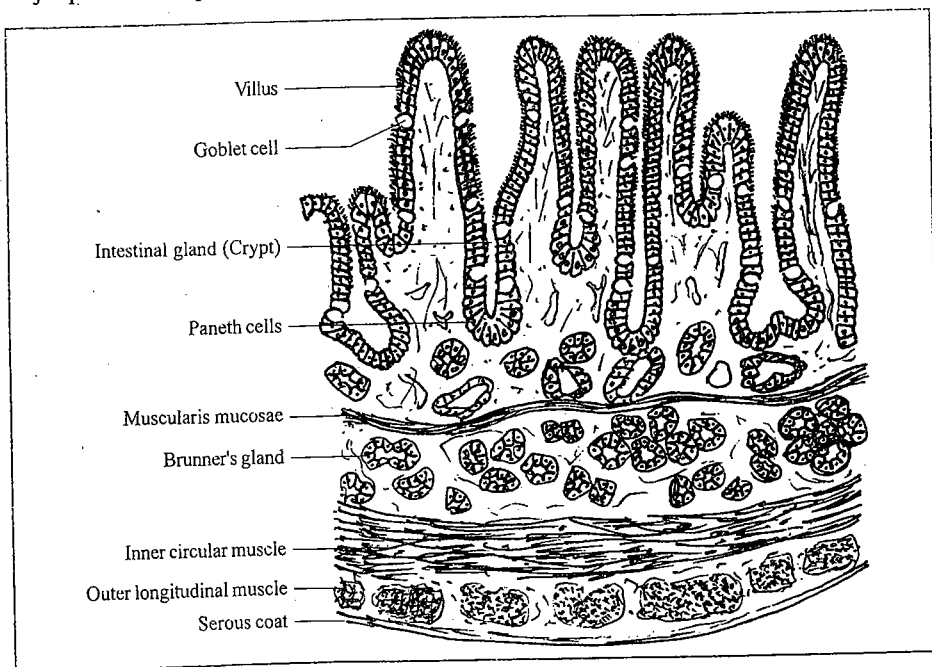


Fig. 3.13a Duodenum (Transverse section).

Villus

This finger like projection is composed of (a) a central blind lymph vessel – the Lacteal, (b) few muscle fibers, (c) plexus of blood vessels and (d) epithelium covering the surface of the villus.

Epithelium

The tall columnar cells line the villi and surface. The free surface of these cells bear tightly packed micro villi which facilitate absorption. The cytoplasm is finely granulated. The nucleus is generally oval in shape and situated close to base. The **Goblet cells** (unicellular mucous secreting glands) are sporadically distributed in the epithelium of the villi and glands. The number increases at the distal part of the intestine.

Plica circularis are the circularly disposed mucosal folds which increase the surface area, situated at the upper two third of the intestine. These folds are permanently present in the ruminants but in other domestic animals they are found to be in relaxed condition.

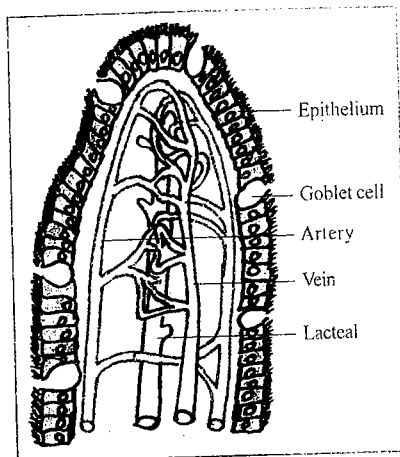


Fig. 3.13b An intestinal villus.

Glands

These simple tubular glands have been formed by the downward extension of the grooves between the bases of the villi up to the lamina muscularis. These are also called **Crypts of Lieberkuhn**. The lining epithelium is continuous with that of surface but have short microvilli. Goblet cells are present. Some undifferentiated stem cells are present in the epithelium which proliferate by mitosis to form goblet and columnar cells. These cells are responsible for continuous replacement of the epithelium of small intestine. There are pyramidal shaped cells present at the base of the glands called **paneth cells**. These cells contains large acidophilic granules above nucleus and produce digestive enzymes. At the bottom of many glands some secreting cells are found called **argentaaffin cells**. They are identified by silver stain only. They contain granules at the subnuclear part.

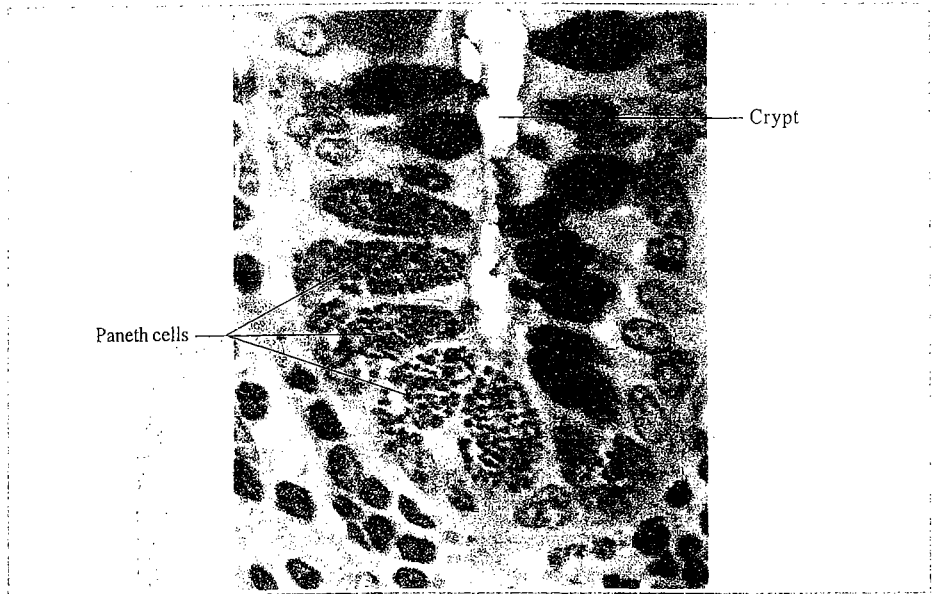


Fig. 3.14 Crypts of Lieberkuhn showing paneth cells.

	Duodenum	Jejunum	Ileum
Common features	Present	Present	Present
Brunner's glands	Most numerous at the proximal part than distal part and absent at the distal end.	Absent	Absent
Villi	Absent in the proximal end. Broad leaf like	Long and narrow	Short and club shaped
Peyer's patches	Present	Present	More characteristic
Plicae circularis	Glands are found in the core of the plicae	Present	Decreased in size an number
Taenia	Absent	Absent	Absent

Lamina Propria

The core of the villi and spaces between the glands are occupied by loose connective tissue. This connective tissue which contains diffuse and solitary lymphoid nodules in places

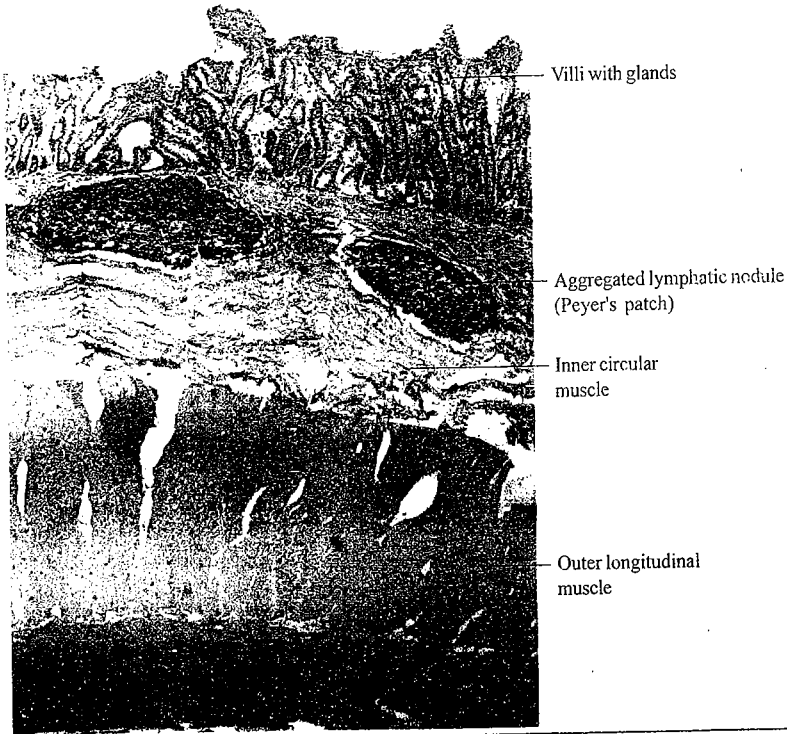


Fig. 3.15a Ileum (Transverse section).

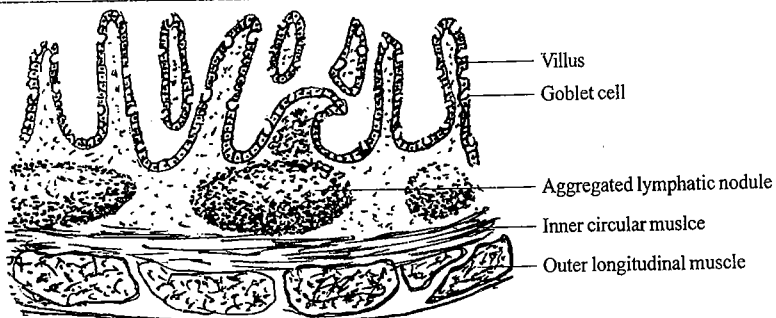


Fig. 3.15b Ileum (Transverse section).

in the lamina propria of small intestine. Externally it is limited by lamina muscularis. This is a thin layer of smooth muscle remains after the lamina propria and composed of an inner circular and outer longitudinal fibers. Some of its fibers extend into the villi. In dog this layer is thick and in most of other domestic animals it is thin and incomplete.

Tunica submucosa

A layer of connective tissue composed of elastic and collagen fiber bundles situated between the lamina muscularis and tunica muscularis form the tunica submucosa. This layer contains ***glands of Brunner***, ducts of which pierce the muscularis mucosae and mostly end in the intestinal glands (crypts of Leiberkutin). These glands are mucous in dog and ruminants, seromucous in cat and serous in horse and pig. It also contain ***Peyer's patches*** (aggregated lymph nodules) which are most characteristic in ileum. Along with the glands there are blood vessels and nerve plexuses.

Tunica muscularis

Tunica muscularis is composed of inner circular and outer longitudinal bundles of smooth muscle fibers. These layers are of variable thickness in different species. Between the two layers, a coarser variety of nerve plexuses are lodged. They contain cell bodies of parasympathetic neurons and fibers of autonomic nervous system and are called Myoenteric Plexus.

Tunica Serosa

This is a layer of loose connective tissue composed of collagen and elastic fibers and continuous with that of mesentery.

LARGE INTESTINE

The parts of large intestine are cecum, colon, Rectum and Anus. The lumen of large intestine is wider and more fixed in position than that of small intestine. It is more volumnus in grass eating animals and is a site for microbial action on the cellulose containing ingesta, secretion of mucus and absorption of water, electrolytes and vitamins.

Common histological features of large intestine amongst domestic animals.

1. Villi are absent
2. Intestinal glands are more straight, long and compact.
3. Paneth cells are absent
4. Goblet cells are numerous
5. Plica circularis are absent.
6. Lymphatic nodules are numerous
7. Longitudinal mucosal folds are present.

	Cecum	Colon	Rectum	Anus
1. Surface epithelium of mucous coat	Simple columnar	Simple columnar	Simple columnar	Stratified squamous. Anal glands and anal sacs are present
2. Brunner's gland	Absent	Absent	Absent	Absent
3. Villi	Absent	Absent	Absent	Absent
4. Glands	Straight & numerous. Paneth cells absent	Numerous	Longer	Absent
5. Peyer's patches	Present	Present	Present	Absent
6. Plicae	Absent	Absent	Absent	Absent
7. Taenia	Present in horse, pig	Present	Absent	Absent

Cecum

Since this is a capacious compartment and site for microbial action on cellulose containing ingesta, the shape size and orientation of this organ is highly variable in different herbivorous animals. On the other hand in carnivorous animals it is small. In general the wall accommodates plenty of lymphatic nodules arranged in a scattered manner. In some animals, ruminants, dog and pig the lymphatic nodules are found around the ileocecal opening. However, in cat and horse they are located at the wall of blind end of cecum. The muscular coat presents few longitudinal bands extended along the length in some animals (Horse) known as *taenia ceci*. Since the length of the *taeniae* are shorter than the length of the cecum, the wall become sacculated. These bands are formed by the condensation of outer longitudinal muscle fibers along with numerous elastic fibers. Other structures are similar to that of small intestine.

Colon

1. The mucosa is thicker due to the increased length of intestinal glands.
2. Villi are absent and therefore the lumen is smooth.
3. Goblet cells are numerous.
4. The submucosa remains distended by the presence of lymphatic tissue.
5. The outer longitudinal muscle fibers form *taenia coli* like that of *taenia ceci*, in pig and horse.

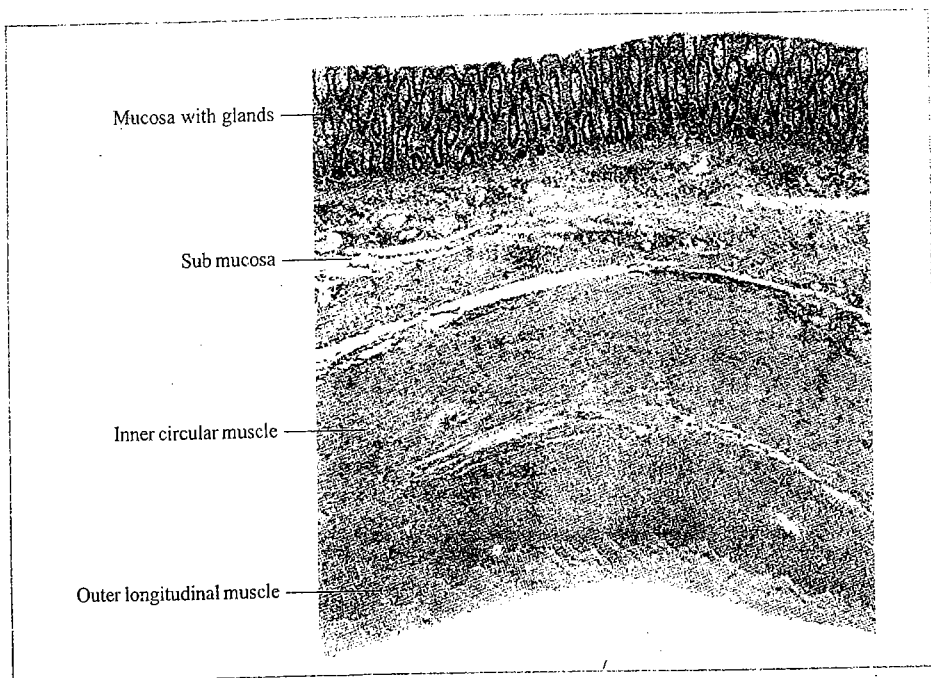


Fig. 3.16 Colon (Longitudinal section).

Rectum

1. The surface epithelium is simple columnar.
2. Villi are absent.
3. Goblet cells are numerous.
4. The wall is thicker. Taenia are absent and therefore no sacculations are found.
5. Serosa is absent at the distal part.
6. Close to the ano-rectal junction the mucous membrane is thrown into longitudinal folds called **rectal columns**.
7. Presence of large venous plexus at the lamina propria at the level of ano-rectal junction.
8. In dog plenty of (about 100) solitary lymph nodules are found in the mucous or sub mucous coat.

Anus

1. The simple columnar epithelium of rectum changes to stratified squamous non keratinized epithelium. Distally it is continuous with skin.
2. Glands are absent

3. In the columnar zone the depressions between the columns are called sinus.
4. In dog, anal glands, (modified tubuloalveolar sweat glands) are present in the sub mucosa. These glands secrete lipid substance in dog and cat but mucous in pigs. **Anal sac** are bilateral cutaneous diverticulum situated between inner (smooth) and outer (striated) muscles and the ducts of which open into the anus at the level of ano-cutaneous junction. The walls of these sacs contain sebaceous and sweat glands. Occasional occlusion of the ducts of anal sacs in dogs frequently lead to infection and associated complications.
5. Sphincter ani internus muscle is formed by the inner circular muscle fibers of tunica muscularis and therefore smooth. The external sphincter muscle is striated. Longitudinal muscles which remain between these two layers are smooth and striated.

Digestive system associated Glands

Glands associated with the Digestive system are – **salivary glands, liver and pancreas.**

SALIVARY GLANDS

The major salivary glands are parotid, sublingual and mandibular in most of the domestic animals. However in carnivores zygomatic salivary gland and in cat molar salivary gland are available. These are branched tubuloacinar glands secrete saliva which keeps the mouth cavity moist and lubricated. They also secrete ptyalin – a digestive enzyme.

According to the type of secretory cells the salivary glands are classified into (a) serous salivary glands, composed of serous secretory cells only e.g parotid. (b) Mucous salivary glands containing mucous secreting cells only e.g sublingual (in cow, sheep and pig). However this gland is of mixed variety in dog and cat. (c) Mixed salivary gland contains both mucous and serous cells, e.g Mandibular.

Serous cells

Shape – pyramidal

Size – Comparatively small

Nucleus – Round and placed close to the base.

Cytoplasm – Contains zymogen granules at the supra nuclear part. Basal part takes basic stain due to presence of rough E.R.

Myoepithelial cells (basket cells) are spindle shaped cells with many long cytoplasmic processes and located between basal lamina and bases of the secretory cells. These cells contain fibrils and help in expulsion of secretion.

Mucous cells

Shape – polyhedral

Size – Comparatively larger

Nucleus – Flattered and placed close to the base

Cytoplasm – Light staining and foamy in appearance. It contains large granules of mucinogen.

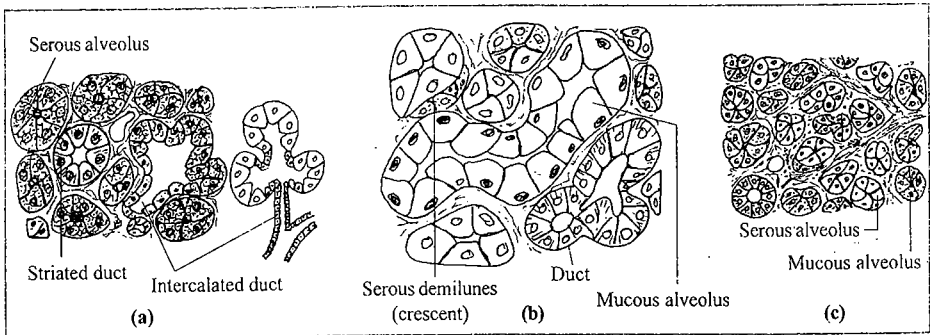


Fig. 3.17 (a) Parotid salivary gland; (b) Sublingual salivary gland; (c) Mandibular salivary gland.

Parotid salivary gland

This *serous* tubuloacinar salivary gland is enveloped by connective tissue capsule from which septa enter inside the gland and divide the parenchyma into numerous lobules. These lobules accommodate a number of alveoli or acini of various shape and sizes, small ducts, blood vessels and nerves.

Parenchyma

It is composed of closely packed acini which are lined by single layer of serous cells. The lumen of an acinus is small or sometimes obliterated and open into short **intercalated duct**. These ducts are lined by low cuboidal epithelium.

Ducts

The intercalated ducts which are lined by a single layer of low cuboidal cells join with the striated ducts which are also intralobular in position. These striated ducts are lined by cuboidal or columnar cell with striations at their bases.

These striated cells play role in transportation of water, ions and excretion of salts. These ducts join with the inter lobular duct at the septa which are also lined by simple

columnar epithelium. The lining cells are not striated and changes to stratified columnar when they join with similar ducts. Further union of such ducts leads to the formation of main parotid duct which opens in the mouth where it is lined by stratified squamous epithelium.

Sublingual salivary gland

It is a branched tubuloacinar gland, *entirely mucous in cow, sheep and pig* but mixed in dog and cat. Intercalated ducts are less in number. The capsule of the gland is not distinct but connective tissue septa are well developed. Terminal alveoli are mostly elongated and often open directly in the larger intra lobular duct.

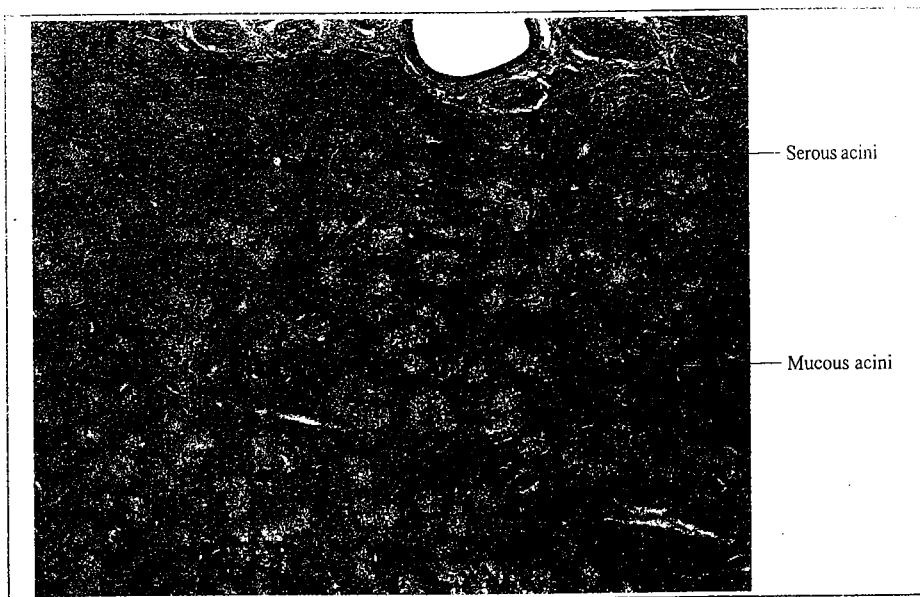


Fig. 3.18 Salivary gland. Mixed type (Mandibular/Sublingual in dog).

Mandibular salivary gland

It is a compound branched tubuloacinar gland of *mixed type*. The connective tissue frame work is similar to that of parotid. Some alveoli are completely serous and some are purely mucous with prominent lumen. However some alveoli contains both serous and mucous cells. Some other mucous alveoli have serous crescents associated with them. These crescent or half-moon shaped clusters of cells are called *serous demilunes*. Duct system is similar to that of parotid.

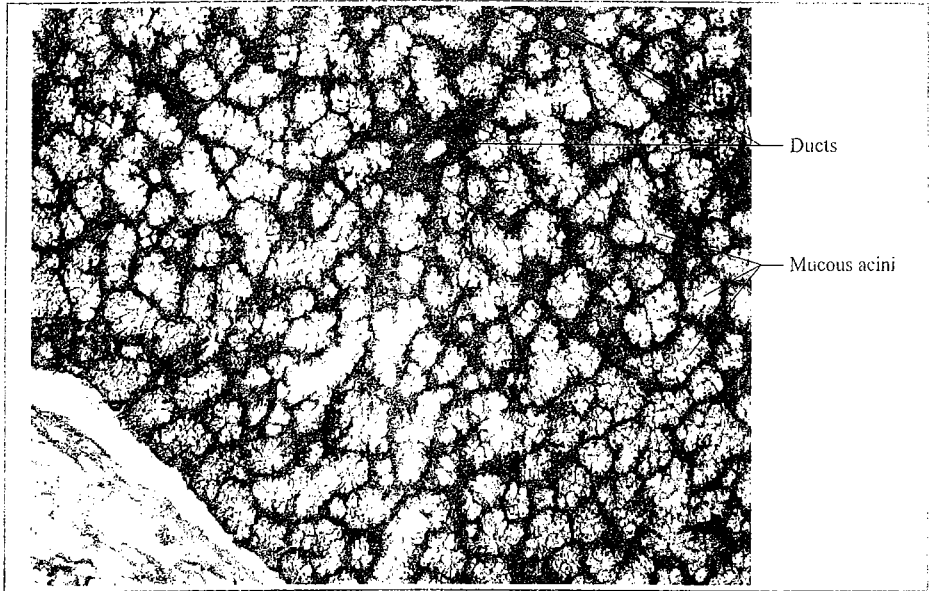


Fig. 3.19 Salivary gland. (Mucous type).

LIVER

It is the largest gland in the body which performs multiple complex functions. Beside production of bile liver is involved in metabolism of nutritional substances, viz., fat, protein, carbohydrate, vitamins and minerals. It is also associated with synthesis of various proteins, phagocytosis and detoxification. This solid gland is composed of several lobes, the number of which is variable in different animals. Each lobe comprises of numerous small lobules. The whole of the gland is covered by a connective tissue sheath is called Glisson's capsule. This fibrous capsule enter the gland and form incomplete septa between the lobules.

Liver cells

The main cells of the hepatic parenchyma are the hepatocytes. Beside the hepatocytes there are specialized macrophages, called Kupffer cells and few endothelial cells.

The hepatocytes are polyhedral cells with large round nucleus and prominent nucleolus. These cells are arranged in the form of plates with single cell thickness. The shape and sizes of the liver cells depends on the location. Due to such disposition these cells have few contact surfaces and some free surfaces. With the contact surfaces they are attached to the adjoining cells by zona occludens (tight junction) and macula adherences (desmosomes) and the free or exposed (sinusoidal) surfaces are studded with short broad microvilli.



Fig. 3.20 Liver of pig.

Hepatic lobules

Each lobule having an approximate length of 2 mm and a diameter of 1 mm. Each of them is surrounded by connective tissue septa. This is prominent in the liver of pig. The center of the lobule is occupied by the central vein along the axis from which the hepatocytes in the form of cords or plates are arranged in a radiating manner towards periphery. The spaces in between the plates (laminae) are called sinusoids. The small triangular space between adjoining three such lobule accommodates branches of hepatic artery, portal vein and bile duct and are collectively known as Portal triad. The radiating plates of hepatocytes has, on one side a bile capillary going out of the lobule to join larger ducts at the portal triad and on the other side, a vascular capillary towards the center to join with the central vein.

Portal lobule

In this concept the portal lobule is demarcated between three adjacent central veins around a portal triad. This area is drained by interlobular duct and supplied by interlobular branch of portal vein. The flow of blood in this area is opposite to that of bile and lymph.

Hepatic laminae

The one cell thick radiating irregular branching and anastomosing plates formed by the hepatocytes are called hepatic laminae. The adjoining laminae are interconnected by bridges

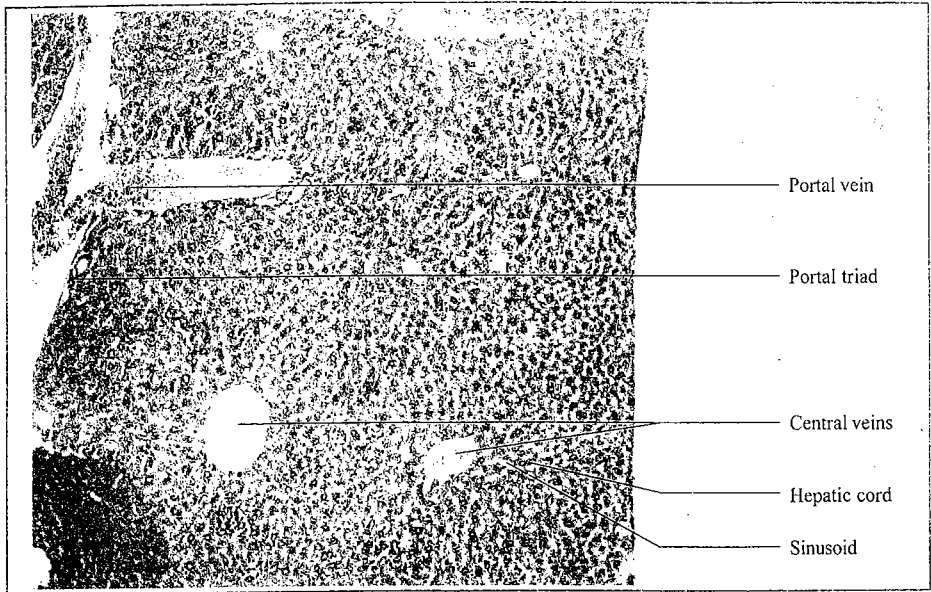


Fig. 3.21 Liver of rat. Lobulations are not distinct.

of liver cells. Presence of perforations at the laminae make an intercommunicating system between adjacent sinusoids.

Hepatic sinusoids

These are the spaces between the hepatic laminae which anastomose with each other by perforations. These sinusoids are lined by endothelial cells and **Kupffer's cells**. The Kupffer's cells are large, having processes and are phagocytic in nature. They also help in formation of bile pigments. There is a space between the sinusoid and hepatic laminae called perisinusoidal space or *space of Disse*.

Gall bladder

It is composed of a) Outer fibrous coat, b) Middle fibromuscular coat and c) Inner mucous coat. Submucosa is absent.

The outer layer is composed of fibrous connective tissue. The middle layer is made up of smooth muscles mixed with fibrous tissue and mostly arranged in circular manner. The inner mucous layer is thrown into a numerous folds which branch and anastomose with each other. This orientation give honey comb appearance in empty condition. The lining epithelium is formed by simple tall columnar cells with striated border composed of microvilli for

absorption of water. There is a areolar and vascularised lamina propria beneath the lining epithelium.

Biliary apparatus

It consists of biliary duct and gall bladder. These structures carry bile, store it and expel to the intestine at the time of need.

Bile duct

The biliary passage starts with bile canaliculi (sinusoid) which empty into interlobular ductules and then to wider ducts. The intrahepatic ducts are lined by cuboidal cells and the extra hepatic ducts are lined by columnar cells. All these cells have striated borders due to presence of microvilli. Occasionally small mucous glands are present in the submucosa which open into the depression of the mucous membrane. Externally these ducts have a fibro elastic coat with some smooth muscle fibers.

PANCREAS

It is a compound tubulo acinar gland and has an exocrine and an endocrine portions. The exocrine part produce digestive enzymes which helps in the digestion of carbohydrate, protein and fats. The endocrine portions produce insulin and glucagon, the hormones responsible for regulation of carbohydrate metabolism in the body.

The whole of the gland is covered by a thin connective tissue capsule from which septa pass inside and divide it into a number of lobules. Each lobule contains numerous alveoli and interacinous cell islets. This lobular arrangement is better developed in cat.

Exocrine part

This is composed of alveoli or acini and their ducts. The acini are lined by a single layer of serous cells with broad bases and narrow apices. The apex is directed towards the lumen and contains numerous coarse zymogen granules. The basal portion contains round nucleus and is basophilic due to presence of granular endoplasmic reticulum (rER). In some acini one or more cuboidal cells remain in contact with the apices of the secreting cells are called

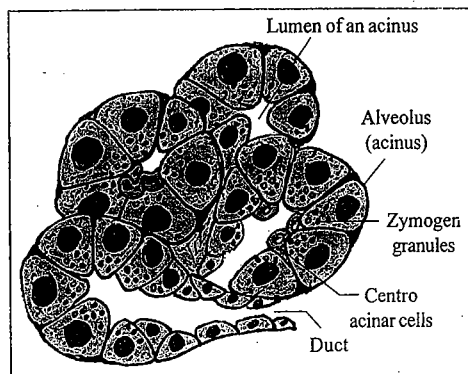


Fig. 3.22 Pancreas.



Fig. 3.23 Pancreas.

centro-acinar cells. These cells do not have secretion granules and are continuous with the epithelium of intercalated ducts.

The ducts are intercalated and intra lobular but are less in number in comparison to salivary glands. These ducts are long and branch many times before entering the acini. Numerous intra-lobular ducts join to form inter-lobar ducts. The wall of the larger ducts contains elastic fibers and muscles and thereby control flow of pancreatic juice into duodenum.

Endocrine part

Within the exocrine part and in between the acini some roughly spherical light stained cell islets of varying sizes are found. These are called **islets of Langerhans**. These are composed of irregular cords of cells, numerous blood capillaries and few fine connective tissue fibers. By special staining three types of cells can be distinguished. These are α cells, β cells and δ cells. α (alpha) cells contain numerous fine red coloured granules and secrete glucagon. The cell has distinct membrane. The β (beta) cells contain coarse dark blue coloured granules and secrete insulin. The membrane of these cells are indistinct. The δ (delta) cells are few in number and secrete somatostatin, which regulates insulin and glucagon secretion.

All these cells are smaller than the acinar cells. The α cells are generally peripherally placed and β cells are centrally situated.

DEVELOPMENT OF ALIMENTARY SYSTEM

This system develops from the endoderm. Actually the endodermal layer forms the mucous lining of the gut and the structures which are derived from the gut. But in the region of mouth and anal canal some portions of the epithelial covering are derived from the ectoderm of the stomatodaeum and proctodaeum. The musculature, fibrous stroma and serous coat are derived from the splanchnopleuric layer of lateral plate mesoderm.

The primitive gut tube extends along the midline from the cephalic end (buccopharyngeal membrane) to the caudal end (cloacal membrane). The primitive gut tube is actually the intra-embryonic part of the yolk sac. It is divided into fore gut, mid gut and hind gut.

Fore gut

It is the cranial part of the gut tube. It is separated from the stomatodaeum or the primitive mouth cavity by buccopharyngeal membrane at the early stage. This bilaminar membrane is

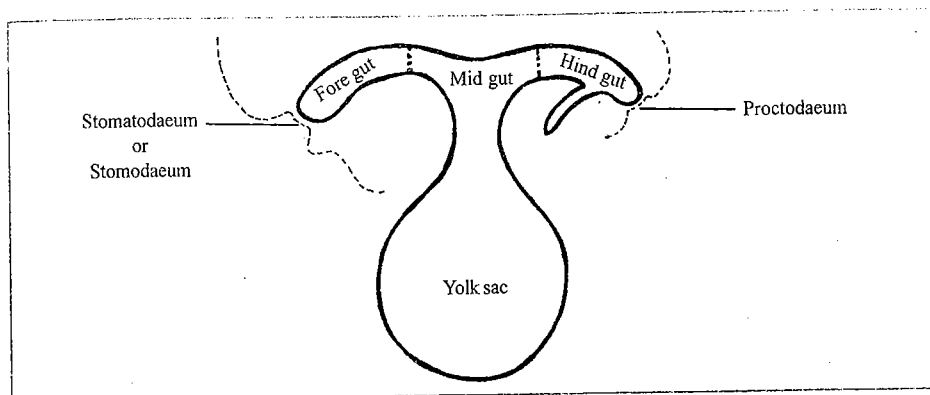


Fig. 3.24

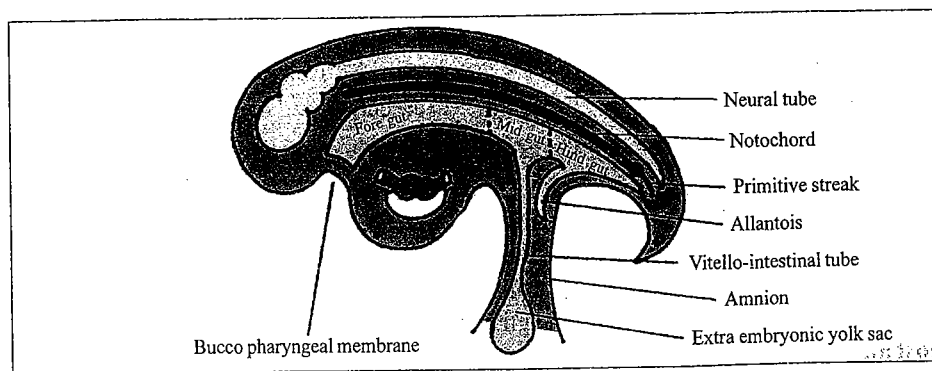
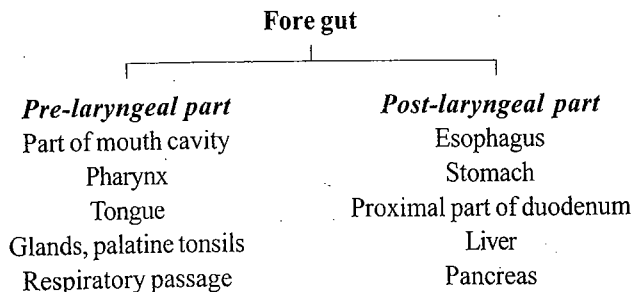


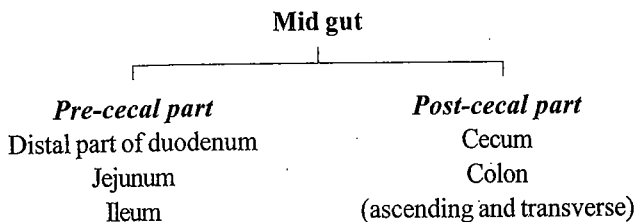
Fig. 3.25

formed by the ectoderm and endoderm and disappears at about 4th week of development. At this stage the junction between the ectoderm and endoderm is not recognized. Caudally the foregut extends up to the second part of duodenum, at the level of the opening of the bile duct. For the purpose of description the fore gut is divided into a **pre-laryngeal** part and a **post-laryngeal** part at the level of laryngotracheal groove. These two parts give rise to the following structures.



Mid gut

This is the middle part of the primitive gut tube which extends from the corresponding aspect of duodenum to transverse colon in adult. Mid gut is connected with the extraembryonic part of the yolk sac by vitello-intestinal tube. The mid gut may also be divided into a **pre-cecal** part and a **post-cecal** part at the level of the appearance of cecal diverticulum. They give rise to the following structures.



Hind gut

It is the caudal part of primitive gut tube. Like that of fore gut it is separated from the ectoderm by cloacal membrane. This membrane is also bilaminar. It disappears at about in the 6th week of development. The hind gut is also divided into a **pre-allantoic** part and a **post allantoic** part at the level of attachment of allantoic diverticulum. The derivatives of these parts are as follows :-

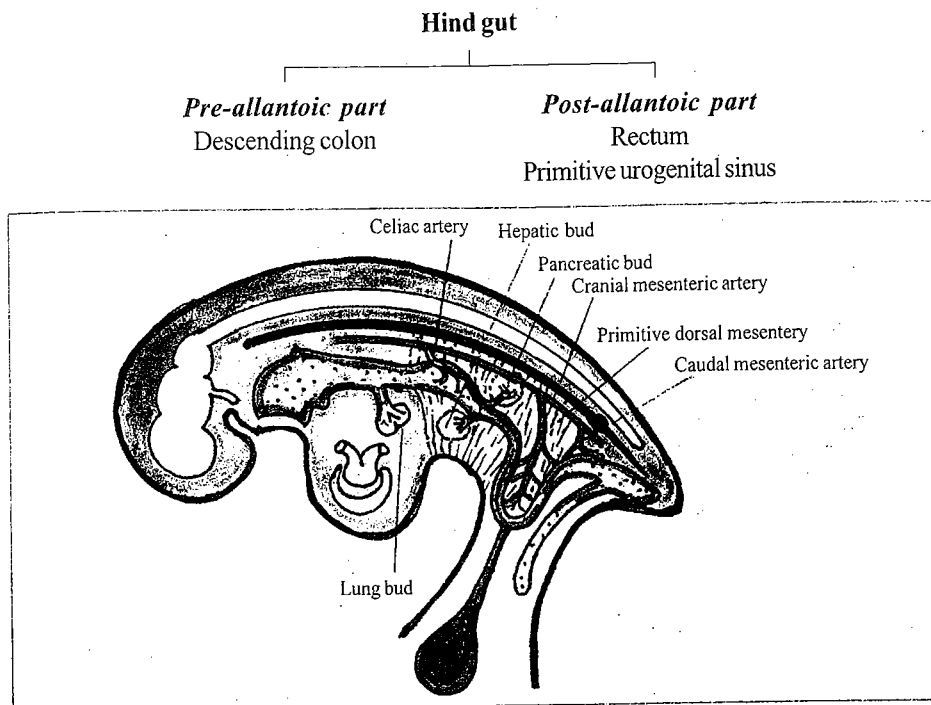


Fig. 3.26

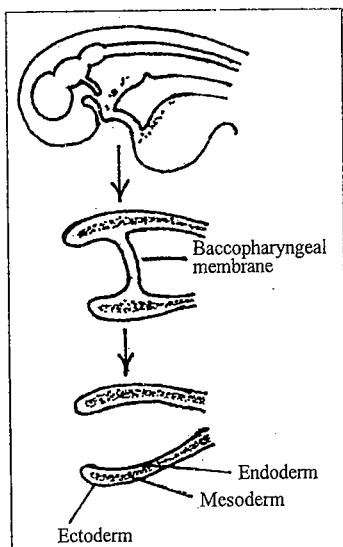


Fig. 3.27

The splanchnopleuric layer of the mesoderm after enclosing the gut with its muscular, fibrous and serous layers, forms primitive dorsal mesentery by its lateral apposition. This dorsal mesentery suspends the gut from the dorsal wall and gives passage to blood vessels. Thus celiac artery supplies the abdominal part of fore gut, cranial mesenteric artery supplies the mid gut and the caudal mesenteric artery supplies the hind gut.

PRE-LARYNGEAL (Cranial most) PART OF THE FORE GUT

The cephalic part of the fore gut remains at first separated from the stomatodaeum by buccopharyngeal membrane. With the reupture of buccopharyngeal membrane the cephalic part of fore gut opens to the exterior through stomatodaeum. Now primitive pharynx

is formed and is composed of three layers – ectoderm at the external surface, mesodermal layer at the middle and endoderm at the luminal surface. The mesoderm of the lateral wall of this part of fore gut undergoes thickening at intervals and form a series of (**six pairs**) bars, known as **branchial or pharyngeal** arches. Each of these bars grow ventrally and joins with the corresponding bar of the opposite side at the floor of the developing pharynx and take the shape of arch. Therefore they are called pharyngeal arches. These arches are externally covered by ectoderm and internally lined by endoderm. The grooves which appear outside between the bars as shown in the figure are known as **branchial clefts** and the grooves which develop internally in the similar way are known as **Pharyngeal pouches**. The branchial arches, branchial clefts and pharyngeal pouches are collectively called **branchial apparatus**. It is responsible for the development of face, neck, mouth, pharynx and larynx.

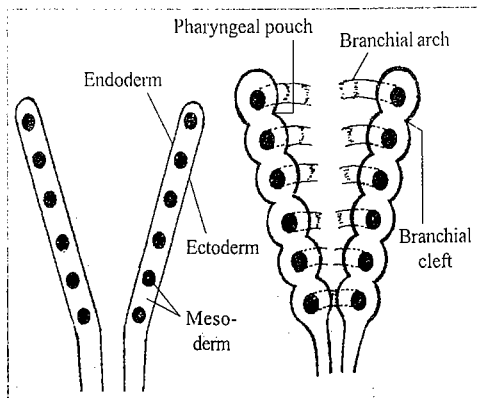


Fig. 3.28

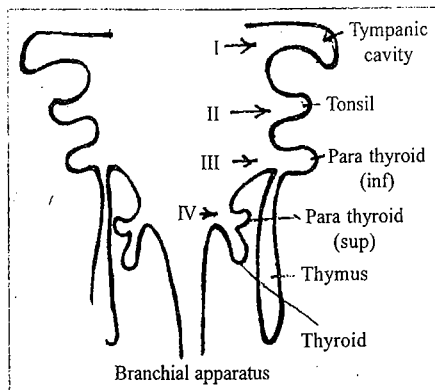


Fig. 3.29

Fate of Clefts

The first cleft gives rise to the lining membrane of external acoustic meatus. Dorsal ends of 1st, 2nd, and 4th clefts invaginate into the mesenchyme and form placodal vesicles. These embedded ectodermal vesicles become associated with the development of ganglia of 7th, 9th and 10th cranial nerves. Others clefts generally disappear.

Fate of Pouches

The 1st and part of 2nd pouch give rise to auditory tube and tympanic cavity. The 2nd pouch (part) contributes to the formation of tonsil. 3rd pouch forms inferior parathyroid and thymus. 4th pouch gives rise to superior parathyroid and thyroid gland. 5th pouch is seen for a brief period and form Ultimobranchial body. This body probably gives rise to parafollicular cells of the thyroid gland with some contribution from fourth pouch.

The derivatives of arches are tabled below :

ARCHES	Arteries	Nerves	Skeleton	Muscles
1st arch (Mandibular arch)	Part of maxillary artery	Mandibular (part), Chorda tympani (part)	Maxillary process Mandible Malleus, Incus	Tensor tympani, Muscles of mastication
2nd arch (hyoid arch)	Not significant	Facial	Body of hyoid bone, Stapes	Stapedius, Stylohyoid and muscles innervated by facial
3rd arch	Common carotid	Glossopharyngeal	Great and other cornu of hyoid bone	Stylopharyngeus
4th arch	Arch of aorta	Superior laryngeal	Thyroid cartilage	Cricothyroid
5th arch	Disappears early			
6th arch	Pulmonary artery, Ductus arteriosus	Recurrent laryngeal	Cricoid and arytenoid cartilage	Intrinsic muscles of larynx except Crico-thyroid

DEVELOPMENT OF TONGUE

A swelling appears at the midline on the floor of the developing mouth between the ventral ends of the mandibular (1st) archs, known as **tuberculum impar**. On each side of the tuberculum impar and on the mandibular archs two other swellings appear. These are called **lingual swellings**. Just behind the tuberculum impar a depression develops, called **foramen caecum**. The epithelium of the floor of mouth proliferates as a down growth through the foramen caecum to form thyroid gland.

At the same time another swelling appears on the midline in relation to the medial ends of 2nd, 3rd and 4th arches known as **hypobranchial eminence**. It divides into a cranial and a caudal part. Cranial part forms the posterior one-third of the tongue and the caudal part forms the epiglottis. Actually the 2nd arch mesoderm goes deep and 3rd arch mesoderm spreads over it. The anterior two-third of the tongue is formed by the fusion of two lingual swellings and tuberculum impar. This is why anterior two-third is innervated by lingual branch of mandibular nerve and chorda tympani of 7th nerve.

These are the nerves of 1st arch. Glossopharyngeal nerve being the nerve of 3rd arch innervates posterior one-third of the tongue. The tongue musculature is innervated by hypoglossal nerve because those muscles are derived from occipital myotome. The epithelium of tongue at the beginning is made up of single layer which subsequently becomes stratified.

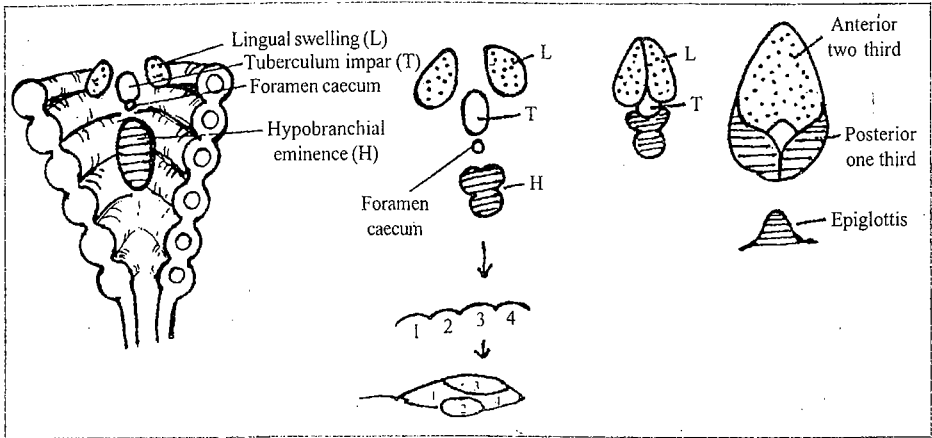


Fig. 3.30

DEVELOPMENT OF TEETH

The epithelial lining of the mouth is partly ectodermal and partly endodermal in origin because the mouth is developed from stomatodaeum as well as from the fore gut.

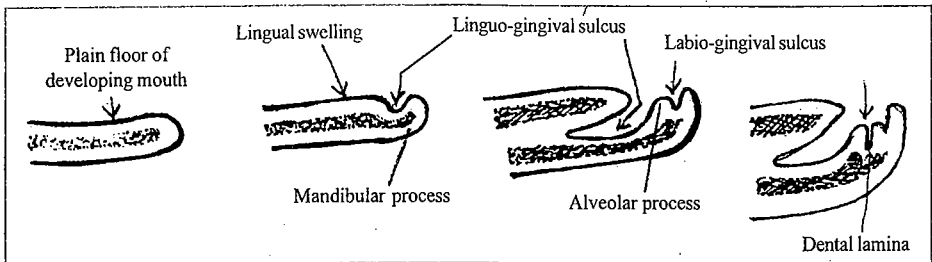


Fig. 3.31

The buccopharyngeal membrane disappears and the line of junction between the two vanishes.

However the epithelial lining of lips, cheeks, teeth, gum and palate is developed from ectoderm but the a tongue is derived from endoderm.

At the beginning the floor of the developing mouth remains plane. Now the tongue swellings appear and become separated from the mandibular process by the appearance of **linguo-gingival sulcus**.

Another groove in the mandibular arch appears peripherally called **labio-gingival sulcus** and thereby the lip is formed. Both the sulci deepens to form a raised arch shaped process. Gradually it becomes prominent and now called **alveolar process**. The lower jaw and its teeth develop from this alveolar process.

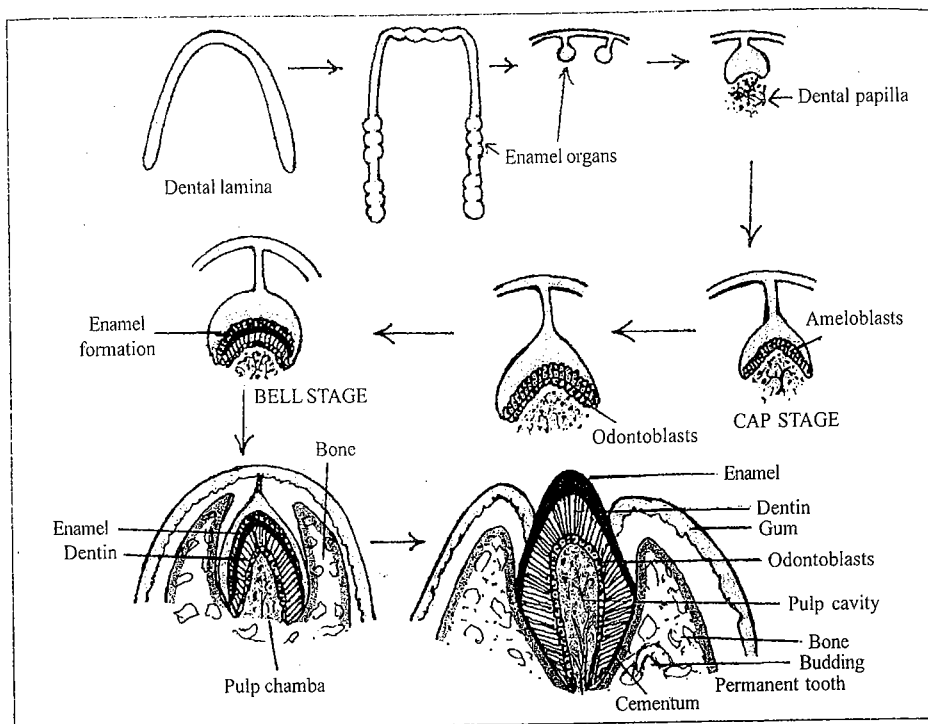


Fig. 3.32

A thickening develops on the convex border of the alveolar process and invaginates deep into the surrounding mesoderm. This invaginated mark is known as **dental lamina**. A series of thickenings appear on dental lamina due to its local cell proliferation. These thickenings are called **enamel organs** and each of these organs gives rise to one milk tooth. Therefore the number of such organs is variable depending upon the species of animals. Each enamel organ which invades the mesenchyme assumes a rounded shape. Soon a depression appears at its free surface and the round enamel organ takes the shape of a cup. The cavity of the cup becomes increased and occupied by a mass of mesenchyme which contains blood vessels and nerves called **dental papilla**. The **tooth germ** thus formed by the enamel organ and the dental papilla together looks like a cap and therefore this stage is called **cap stage**.

The cells at the concave inner surface of the enamel organ become elongated and differentiate into **Ameloblasts**. The cells deposit the organic matrix and mineral crystals of the enamel. The peripheral (mesodermal) cells of the dental papilla which remain adjacent to ameloblasts become differentiated into **Odontoblast cells**. These cells produce dentin. It is also believed that odontoblast cells are derived from neural crest cells. Now the whole primitive tooth looks like a bell and therefore called **Bell stage**. In the meantime the dental

buds become disconnected from the dental lamina. The ameloblastic layer and the odontoblastic layer remain separated by a basement membrane. Both layers of cells deposit their products (enamel by ameloblasts and dentin by odontoblasts) towards the basement membrane. With their continuous deposition, both the cell layers move away from each other.

The enamel is deposited at the tip of the tooth at first and then spread over the crown.

On full formation of enamel the ameloblasts disappear leaving a membranous dentinal cuticle which again disappears during the time of eruption.

The odontoblast cells first deposit pre-dentin collagen fibers which subsequently calcified to form definitive dentinal tubules. This process continues throughout the life of the tooth. During this process the odontoblast cells retreat towards the pulp cavity which is now filled with blood vessels, nerves and other mesenchymal tissue.

Eventually maxilla and mandible are formed by the process of ossification and surround the roots of the developing teeth. The roots of the teeth are developed by in growth of the ectodermal root sheath. Here the ameloblasts do not grow but the Odontoblasts appear and lay down dentin. With the deposition of layers of dentin, the pulp cavity at the root become narrow and convert this part of the cavity into root canal.

The mesenchymal layer which covers the dentin of the root area differentiates into a layer of cells called **cementoblasts**. These cells produce a layer of dense bone called cementum.

Permanent teeth

At a latter stage the permanent teeth develop as solid buds from the dental lamina at the lingual aspect of the deciduous teeth. The process of development is just identical to those of milk teeth. The appearance of permanent teeth induces osteoclastic activity which causes absorption of alveolar sockets and roots of milk teeth. Subsequently at maturity all deciduous teeth are replaced by permanent teeth.

POST LARYNGEAL PART OF FORE GUT

Development of esophagus

It is developed from the fore gut extending from the caudal aspect of laryngeal diverticulum to the fusiform rudimentary stomach. The musculature is derived from the splanchnic mesoderm around the tube. Generally the muscles in the cranial part is striated and the caudal part is smooth. The tunica externa which is fibrous at the cervical part and serous in the

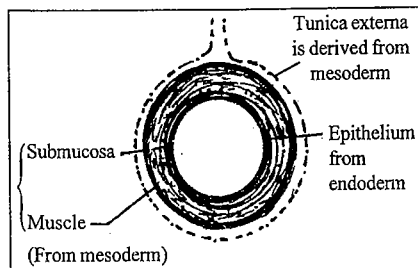


Fig. 3.33

thoracic part are also derived from splanchnopleuric mesoderm. At first the esophagus is short but it elongates with the formation of neck, enlargement of pleural cavities and migration of septum transversum. At the beginning, the mucous membrane is composed of ciliated columnar epithelium but latter the epithelium becomes simple columnar and at the end it is changed to stratified squamous epithelium.

Development of stomach

SIMPLE STOMCH

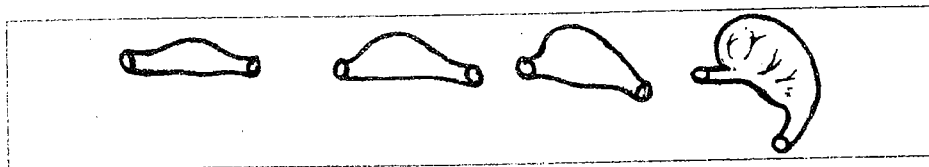


Fig. 3.34

It appears as a fusiform dilatation of the fore gut just caudal to the esophagus at about 4 to 5 weeks of gestation. At the beginning it is placed in the median plane. The dorsal border grows at a faster rate than the ventral border and therefore the fundus and greater curvature are developed. The pyloric part is pushed more ventrally and the ventral border becomes more concave. The dorsal border is attached to the dorsal wall of the body cavity by dorsal mesogastrium and the ventral border of the primitive stomach is attached to the ventral wall of septum transversum by ventral mesogastrium. Latter on the hepatic bud develops into ventral mesogastrium and divides it into lesser omentum and falciform ligament. Similarly the spleen develops within dorsal mesogastrium and divides it to form gastrosplenic ligament and lienorenal ligament.

The stomach undergoes about 90° rotation along the longitudinal axis to the

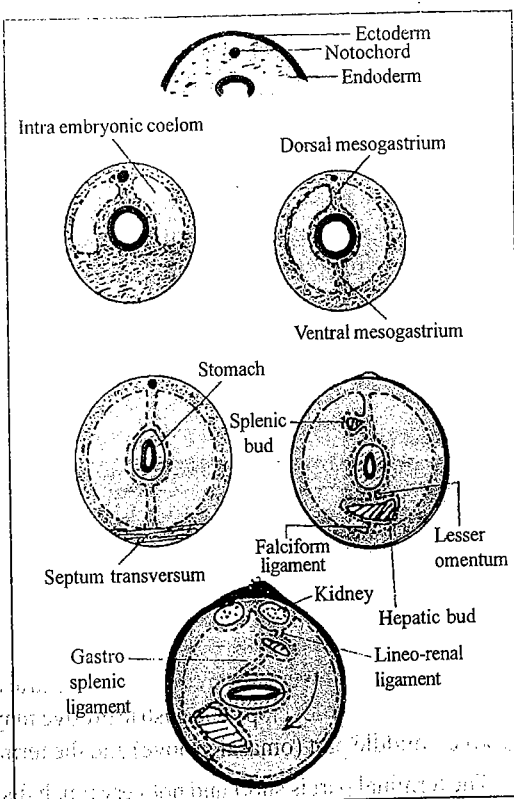


Fig. 3.35

right and therefore the left surface becomes ventral and the right surface becomes dorsal in position. Subsequently differential growth those occur in the stomach results in considerable change in its shape and orientation.

Development of Ruminant Stomach

At first the dilatation of the foregut takes place in the similar manner that occurs in case of simple stomach. Then it becomes more flattened laterally and the lesser curvature becomes convex. The dilated sac now rotates to the left and therefore right side become dorsal and left side becomes ventral. Ridges project into the lumen and separate the gastric groove from the cavity of the fundus and lesser curvature. After the rotation the rumen develops as an outgrowth on the dorsal aspect of the primordium. The ruminal outgrowth extends dorsally and cranially and to the left. Very soon caudo-dorsal and caudo-ventral blind sacs appear by divisions at the free end. At this stage the ruminal sac appears as a tubular structure and

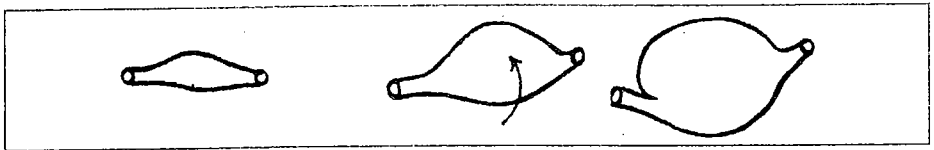


Fig. 3.36

grows caudally and dorsally over the main fundus. **Reticulum** is formed by another outgrowth from the cranio-ventral aspect of the ruminal primordium at the left side. The **omasum** develops as a small bulging from the lesser curvature between the developing reticulum and abomasum. The remaining ventral part of the primordium reconstitute the fundic and pyloric part of **abomasum**.

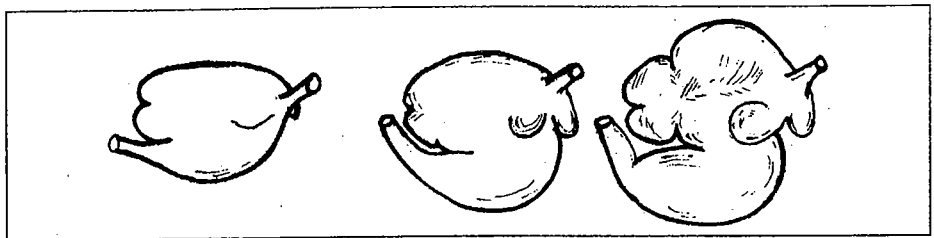


Fig. 3.37

The **gastric groove** is the area along the central axis from which all the compartments of ruminant stomach develop. The gastric groove may be divided into a cranial part (reticular groove), middle part (omasal groove) and the terminal part (abomasal groove).

The terminal part is short and not very much distinct.

All the four pouches can be identified on 48-50 days of gestation.

At 45 mm stage – All the four compartments possess equal size

At 80 mm stage – Rumen and abomasum grow faster and become larger.

At 85 mm stage – Most of the morphological features are detected.

Up to 170 mm stage – Growth rate of rumen is fastest.

Considerable changes take place after birth of the full term foetus and an account for the relative capacity of various compartments is presented below.

In new born calf – $(\text{Rumen} + \text{Reticulum}) \times 2 = \text{Abomasum}$

At 8th week of age – $\text{Rumen} + \text{Reticulum} = \text{Abomasum}$

At 12th week of age – $(\text{Rumen} + \text{Reticulum}) / 2 = \text{Abomasum}$

In adult stage – Rumen = 80%, reticulum = 5%, Omasum = 7% and Abomasum = 8%

Development of Intestine

The proximal part of **duodenum** is developed from foregut and the remaining part of it is derived from mid gut. The junction of foregut and mid gut corresponds to the hepatopancreatic ampulla in horse and termination of bile duct in other domestic animals. The primitive duodenum presents a loop with caudal convexity.

Jejunum and ileum are developed from the pre-cecal part of mid-gut. The **cecum** is formed by the enlargement of the cecal bud which appear as a diverticulum from the midgut. The cecal bud first appear caudally. But it takes cranial position when the intestinal loop rotates 180°. It again gains caudal position when the intestine completes its 360° rotation. In some animals a part of vitello-intestinal duct (duct of yolk sac) may persist in the form of a diverticulum at the terminal part of jejunum or ileum. This is called **Meckel's diverticulum**.

Ascending colon and transverse colon are developed from mid gut where as the **descending colon** is developed from the hind gut. The **rectum** is developed from the dorsal

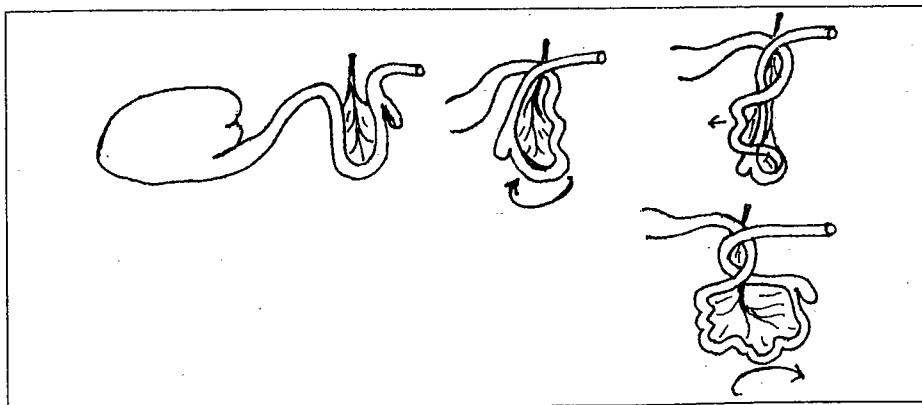


Fig. 3.38

subdivision of the Cloaca – the caudal part of hind gut. A partition appears and divide the cloaca into a dorsal and a ventral part. The dorsal part is narrow and gives rise to rectum. The ventral wide part forms urogenital sinus.

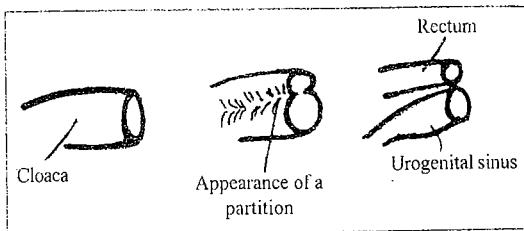


Fig. 3.39

The epithelium of **anal canal** is formed jointly by endoderm and ectoderm. The endoderm forms the primitive rectum and the ectoderm forms the proctodaeum. The anal columns are formed at the junction between the two. The musculature is developed from mesoderm.

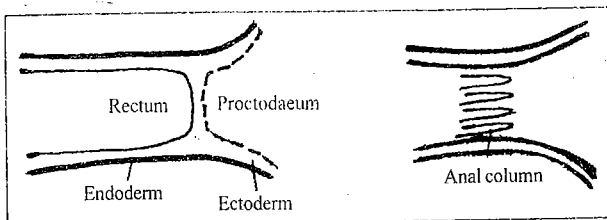


Fig. 3.40

Developmental anomalies of gut

1. Atresia – continuity of the lumen is obliterated in this condition.
2. Stenosis – Lumen become very narrow.
3. Thickened muscular wall may occur.
4. *Imperforate anus* – This occurs due to stenosis or atresia at the caudal most part of rectum or anal canal.

It is very common in new born calves and the condition is popularly known as **Atresia ani**. In this condition generally a considerable amount of fibrous tissue appear in between the cloacal membrane and proctodaeum.

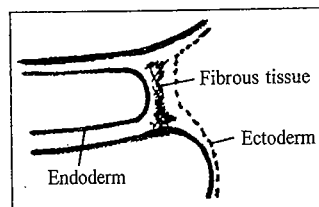


Fig. 3.41 Atresia ani.

5. The rectum may abnormally communicate with bladder, urethra or vagina. Generally such abnormalities appear in association with imperforate anus.

DEVELOPMENT OF LIVER

At the ventral aspect of the gut on the junction between the foregut and mid gut an endodermal diverticulum – the **hepatic bud** develops to form the liver and its duct system. This hepatic bud grows ventrally and cranially within ventral mesogastrium and passes into the septum transversum. It divides into a large part called **pars hepatica** and a small part

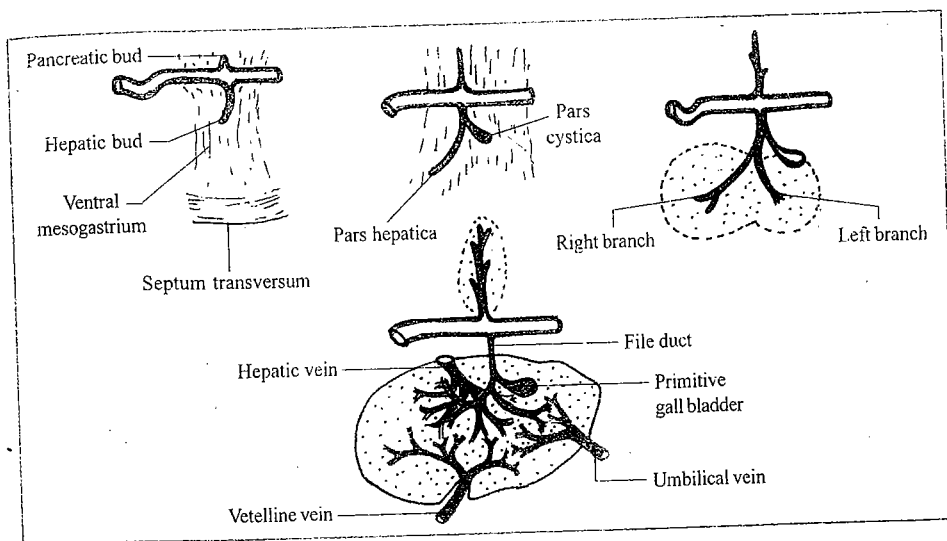


Fig. 3.42

called **pars cystica**. The pars hepatica divides into a right and a left branch. Each of these branches contributes in the formation of one lobe of liver. The pars cystica forms the gall bladder.

Cluster of cells are derived from these branches and at the primary stage form solid masses. They differentiate into plates of liver cells. These plates branch and join with each other to form the parenchyma of the liver. Therefore the endoderm of hepatic bud gives rise to the parenchyma of the liver as well as bile capillaries. The original stalk of the hepatic bud forms the bile duct and its main branches form hepatic ducts. The number of these ducts is variable from species to species and corresponds to the number of lobes in the liver. However, in horse pars cystica does not develop.

The capsule as well as the fibro-areolar stroma of the liver are derived from the mesoderm of the septum transversum.

The course of the umbilical and vitelline veins which lie in the septum transversum are disrupted with the growth and development of hepatic plates. These vessels break up into capillary network within the liver parenchyma and become connected with hepatic sinusoids.

In cow, bile formation begins at about 3-4 months of the age of fetus. The greenish black colour of first stool (meconium) of the new born calf is due to the bile.

DEVELOPMENT OF PANCREAS

One dorsal and one ventral pancreatic buds arise from the endoderm at the terminal portion of the post laryngeal part of the foregut close to the origin of hepatic bud. The dorsal

bud arises from the dorsal wall of the gut and grow in dorsal mesogastrium. It extends dorsally and cranially and most of the parenchyma is developed from this bud. The ductules and ascini of the pancreas are derived by the repeated sprouting of the ducts of the bud.

The ventral bud arises in close relation to the hepatic bud at the junction between foregut and mid gut. The ductules also give rise to acini and smaller ductules in the similar manner. This bud forms the lower part of the head of pancreas.

With the development of these buds the duodenum undergoes axial rotation. As a result of differential growth of the wall of the duodenum and increased speed of rotation of ventral duct in comparison to that of dorsal duct, the ventral duct along with the primitive bile duct winds round the dorsal aspect of duodenum and reach to the left side, close to the dorsal duct. Due to further rotation with increased speed, the ventral duct along with the hepatic duct crosses the dorsal duct and becomes again ventral in position.

Now the axial rotation stops and both the primordial lobes fuse together to form a single mass of pancreas. **Islets of Langerhans** are developed from the acinar cells i.e. from the primitive duct system which are ultimately separated from the alveoli and form independent cluster of cells.

The duct systems of pancreas is developed by the establishment of a cross communication between the dorsal and ventral ducts at the time of fusion of both the pancreatic masses. The part of the duct of dorsal bud which remain between the junction area and the duodenum becomes narrow. This narrow tube forms the accessory pancreatic duct. The ventral duct, the distal part of dorsal duct and their communication - these three components together form the main pancreatic duct.

In cow the accessory pancreatic duct develops only from the dorsal pancreatic primordium and the ventral duct disappears. It therefore opens to the duodenum about 30 cm caudal to the opening of bile duct. Occasionally the left part of the gland is drained by a small duct which represents the ventral duct.

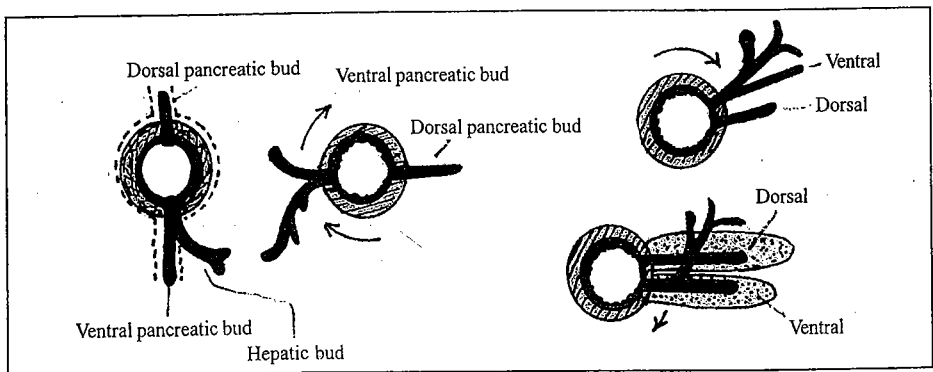


Fig. 3.43

Dog and horse possess the main as well as accessory pancreatic ducts. In small ruminants only one pancreatic duct is present and it joins with the common bile duct.

Anomalies

1. Lobes of liver may be rudimentary.
2. Gall bladder may be absent. There may be anomalies in terms of shape and position. The GB may be partially or completely duplicated.
3. There may be duplication of duct system.
4. The pancreatic tissue may be divided.
5. Accessory pancreatic tissue may be found in different places in the abdomen.

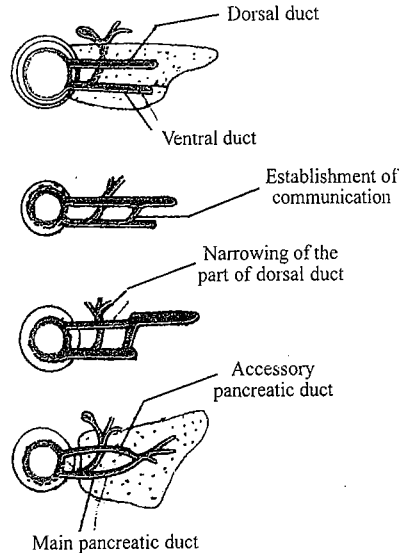
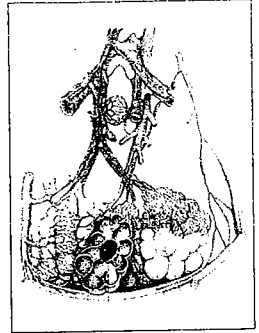


Fig. 3.44

4

RESPIRATORY SYSTEM



Components :

1. Nasal cavity
2. Pharynx
3. Larynx
4. Trachea
5. Lung

Nasal cavity

The nasal cavities (left & right) which are separated by osseo-cartilaginous partition extends from nostrils to choanae. These cavities are formed by cartilages and bones and are lined by mucous membrane. There are three parts in this structure- a) Vestibular part, b) Respiratory part and c) Olfactory part.

Vestibular part

The outer portion is similar to epidermis. This portion has long thick hairs. Sebaceous and sweat glands are present. The next portion is called transitional zone, which is lined by stratified squamous epithelium. Occasionally serous and seromucous glands are present in the propria submucosa. Plenty of superficial capillary network are found to be connected to larger vessels at the depth of propria submucosa.

Respiratory part

This is lined by pseudo-stratified columnar epithelium with goblet cells. Plenty of blood vessels, serous and mucous glands are present in the sub-epithelial tissue. The paranasal sinuses are lined by simple (squamous/ cuboidal) or transitional epithelium or sometimes by pseudo-stratified columnar ciliated epithelium with few goblet cells. The sub-epithelial connective tissue contains collagen and elastic fibers.

Olfactory part

This is the region of ethmoturbinate, part of the dorsal turbinate and nasal septum. It forms posterior $\frac{1}{4}$ th part of nasal cavity. It is lined by neuro-epithelium which contains olfactory, supporting and basal cells. The olfactory cells are modified neurons, bipolar and their axons form the bundles of olfactory nerves. Dendrites are distributed on the epithelium and serve as receptors. The supporting cells are columnar type and the basal cells are small cuboidal cells. Tubulo alveolar olfactory glands are present in the lamina propria.

Pharynx

See digestive system.

Larynx

The components are –

- a) Cartilages (Thyroid, cricoids, arytenoids and epiglottis).
- b) Muscles
- c) Mucous membrane

Cartilages – The epiglottis is a leaf like structure and composed of a central core of elastic cartilage and covered by mucous membrane on both surfaces. Other cartilages – cricoid, thyroid and basal part of arytenoids are composed of hyaline cartilaginous tissue. The apex of arytenoids and corniculate are made up of elastic cartilage.

Muscles – The muscles are extrinsic and intrinsic. The intrinsic muscles are responsible for movement and skeletal in nature.

Mucous membrane – The larynx is mostly lined by pseudo-stratified columnar ciliated epithelium. However, the epiglottis, vocal folds and aryepiglottic folds are lined by stratified squamous non-keratinised epithelium. The lamina propria accommodates mucous and mixed sero-mucous glands and blood vessels.

Trachea

This flexible tube is composed of fibro elastic connective tissue and cartilages.

A variable number (40 to 50) of incomplete cartilaginous rings unite one after another to make this tubular air passage. The ends of cartilages are interconnected by elastic fibers and bundles of smooth muscle fibers called Tractialis muscles. The rings are made up of hyaline cartilage.

Externally the wind pipe is covered by a outer fibrous coat which is composed mainly of elastic fibers.

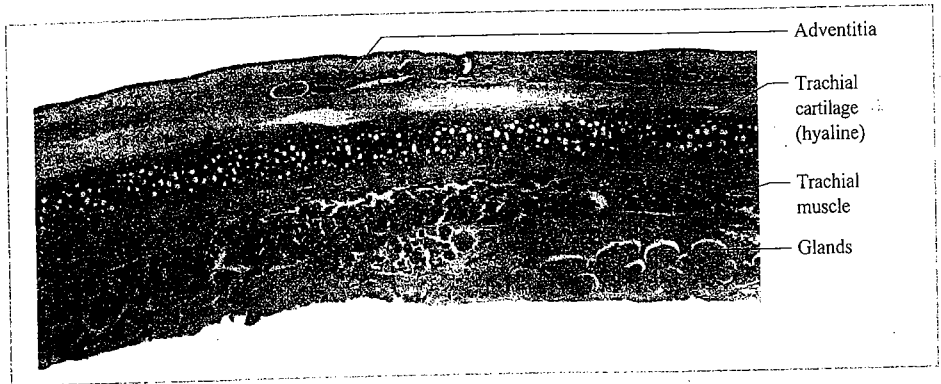


Fig. 4.1 Trachea.

The inner mucous coat is composed of a lining epithelium and lamina propria. The lining membrane is made up of Pseudo-stratified columnar ciliated epithelium with numerous goblet cells. The lamina propria contains plenty of elastic fibers, glands (mucous, serous and mixed) and vessels.

The structure of Principal bronchi are similar to that of trachea. However they are smaller in size but the lumen is almost circular. The cartilaginous rings are complete near bifurcation of trachea. With the subsequent branchings of the air passage the cartilaginous rings are transformed to plates. The passages supported by cartilage are called **bronchi**. Such passages which are not supported by cartilages are called **bronchioles**. In the bronchi the mucous membrane is thrown into longitudinal folds during expiration. Discontinuous layer of smooth muscle is present in the mucosa.

The bronchial tree

In the branching arrangement, two principal bronchi although variable from animal to animal but presents a definite pattern in each species. The sequence of the branching is as follows in most of the mammals :

1. Principal bronchus (Primary)
2. Lobar bronchus (secondary)
3. Segmental bronchus (Tertiary) – several order of branches lead to terminal branchings.
4. Terminal bronchus
5. Bronchioles – several order of branches lead to terminal bronchioles.
6. Terminal bronchiole – subdivides into one to three generations to form respiratory bronchioles.
7. Respiratory bronchiole
8. Alveolar ducts

9. Atria
10. Alveolar sacs
11. Alveolus

Broncho pulmonary segment

Each segmental bronchus ramifies within a self contained functionally independent units of lung tissue. Therefore a segmental bronchus along with its associated lung parenchyma is called broncho pulmonary segment.

Lungs

The lobes of the lungs are enclosed by a serous coat – the pulmonary pleura. Beneath the serous coat a subserous coat is present which is composed mainly of elastic fibers. The lung parenchyma is composed of finer branches of bronchial tree which end into a number of alveoli, blood vessels, lymphatics and nerves.

Under microscope the lung tissue shows numerous alveoli in the form of empty spaces surrounded by thin walls, various branches of air passage and blood vessels.

Structure of bronchi (Primary, secondary and Tertiary)

- a) The lumen is almost circular.
- b) It is lined by pseudo-stratified columnar ciliated epithelium with goblet cells.
- c) The lamina propria contains smooth muscles arranged in spiral manner along the length.

The mucosa is thrown into longitudinal folds due to muscular contraction. Spasmodic contraction of bronchial muscles constrict the bronchi which leads to difficulty in breathing during asthma. The lamina propria contain mucous and seromucous glands.

- d) Cartilagenous plates (hyaline) are arranged in series but in an irregular and overlapping manner.

Structure of bronchioles/terminal bronchioles/Respiratory bronchioles

- a) Diameter of these air passages is about 1 mm.
- b) They are lined by simple columnar ciliated epithelium. Goblet cells are very few in number.
- c) Cartilages, glands and lymphoid tissue are absent.
- d) Walls are mainly made up of smooth muscles and elastic fibers.

A small portion of lung tissue ventilated by one bronchiole is called lobule.

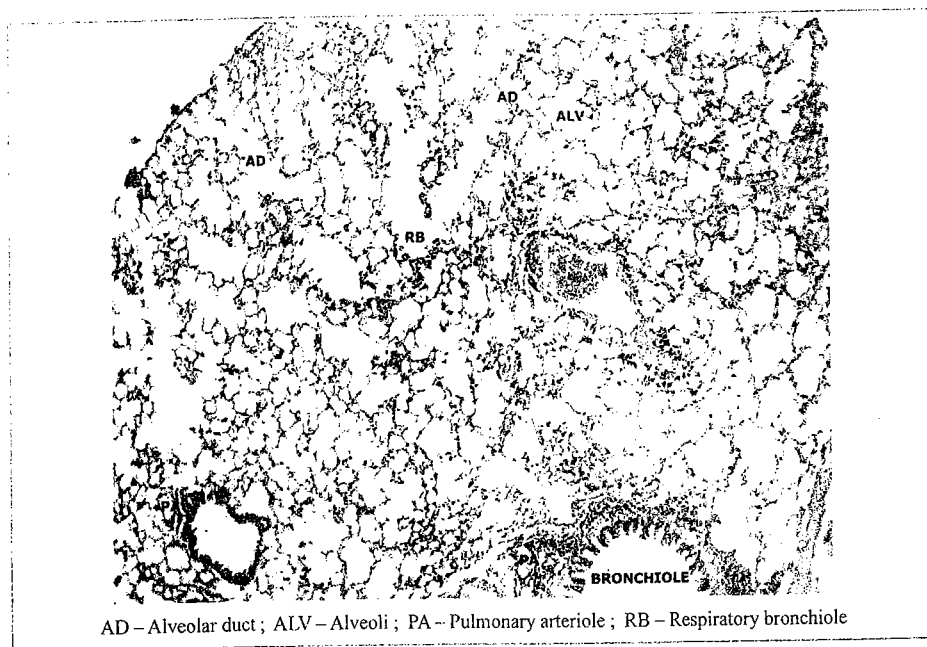


Fig. 4.2 Lung.

- e) The respiratory bronchioles are generally 0.5 mm in diameter. Their lining epithelium changes to simple cuboidal nonciliated type. Goblet cells are absent. A number of single alveoli protrude out from their walls.

Structure of alveolar duct/atria/alveolar sacs

The alveolar ducts arise from the respiratory bronchioles. They are thin walled and studded with alveolar sacs as well as alveoli. The wall is composed of smooth muscle fibers and elastic fibers and lined by simple squamous epithelium. The alveolar ducts lead to the formation of alveolar sacs from a common space known as atrium. The alveolar sacs give rise to a number of alveoli. The wall of the atrium and sacs are not supported by smooth muscle and therefore composed of elastic fibers and lined by simple squamous epithelium.

Structure of alveoli

These are closely packed tiny spaces and are the ultimate subdivisions of the bronchial tree. Alveoli are lined by a layer of simple squamous epithelium. Since they are tightly packed with the adjacent alveoli, no separate wall of an individual alveolus is formed. Therefore an interalveolar septa is available which contains — a) alveolar epithelium (*Pneumocyte-I*), (b) reticular and elastic fibers, (c) Blood capillaries, (d) septal cells (*Pneumocyte-II*) and (e) *Alveolar phagocytes*. However the adjacent alveoli are connected by some minute

alveolar pores. So the blood air barrier is formed by the alveolar epithelium along with its basal lamina and capillary endothelium.

The Pneumocyte-II cells are large cuboidal cells with micro villi at their free surfaces. These cells secrete a fluid known as *surfactant*. This fluid contains phospholipids, reduces surface tension within the alveoli and helps in keeping the alveoli open and prevent them from collapsing. The alveolar phagocytes remain within the septa or in free form inside the alveoli. They are responsible for removing dust and carbon particles which enter the lung during inspiration.

Other components of lung parenchyma are nerve fibers (sympathetic and parasympathetic), pulmonary and bronchial vessels and lymphatics. However lymphatics are absent in atria, alveolar sac and alveoli.

DEVELOPMENT OF FACE, NOSE, PALATE AND RESPIRATORY ORGANS

Stomatodaeum or stomodaeum is a depression which develops between the developing brain and pericardium. The buccopharyngeal membrane separates the stomatodaeum and the foregut. A **frontonasal process** develops by proliferation of mesoderm in front of the developing cranium and above the stomatodaeum. The first pharyngeal arch (mandibular) which appears at the ventrolateral aspect of the stomatodeal pouch along with the frontonasal process gives rise to the face.

The mandibular arch gives rise to a dorsal bud known as **maxillary process** and extends ventro-medially to form **mandibular process**. **Nasal placodes** appear bilaterally as localized thickening on the ectoderm above the stomatodaeum, at the frontonasal process. The placodes deepen to form **nasal pits**. These pits extend forward and communicate with the stomatodaeum and thereby **medial nasal process** and **lateral nasal processes** are developed.

Now the **lower lip** and **lower jaw** is formed by the fusion of extended mandibular processes. The upper lip and upper jaw are formed by the growth of

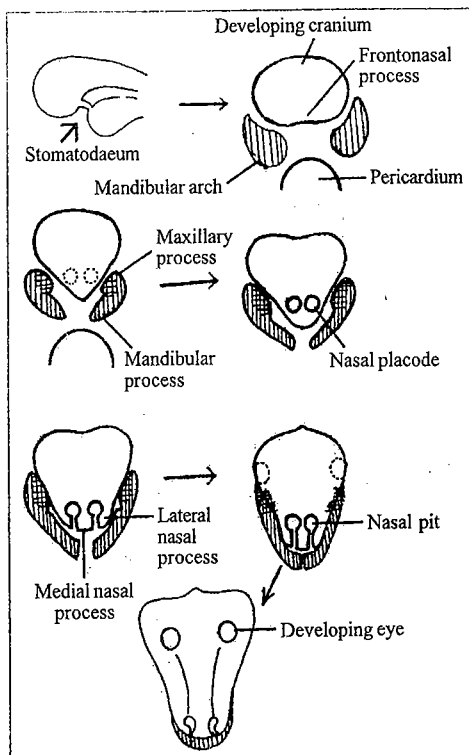


Fig. 4.3

maxillary processes and with their fusion to the corresponding lateral nasal process and medial nasal process. By this development the nasal pits become separated from the stomatodaeum and from **external nares**. The nasal septum is developed by the proliferation of mesodermal cells at the midline of the frontonasal process. The nasal pits which are now separated from the stomatodaeum become extended to form **nasal cavities** on either side of the nasal septum. The **cheeks** are formed by the fusion of maxillary process and mandibular process. The **lense placodes** appear as ectodermal thickening at the ventrolateral aspect of the developing brain. The **external ears** develop from a series of mesodermal thickenings around the dorsal part of first ectodermal clefts. These thickenings fuse to form auriculum on either side.

Anomalies (face development)

1. Hare lip – The upper lip of rabbit (hare) normally has a cleft and therefore similar disposition of the upper lip which occur due to non-fusion of various parts of upper lip (Lateral and medial nasal processes, frontonasal process etc) is known as hare-lip. The hare lips may be of different types depending upon the non-fusion of particular components.
2. Congenital fistula – It may occur due to formation of abnormal nasal pits.
3. Middle mandibular defect may appear due to non-fusion of mandibular processes. However in cattle the rami of the mandible do not fuse completely even in adult life in normal condition and form mandibular symphysis.

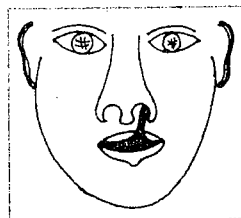


Fig. 4.4

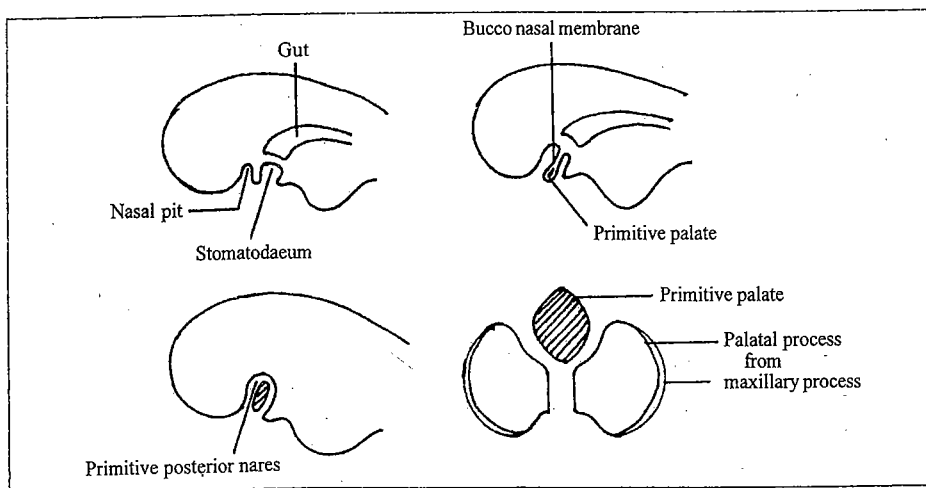


Fig. 4.5

Development of nasal cavities

The nasal pits extend to form nasal cavities. A partition develops between the nasal pits and stomatodaeum by the appearance of primitive palate and by the fusion of medial and lateral nasal processes. Nasal sacs are formed by further deepening of nasal pits and become separated from the stomatodaeum by bucconasal membrane. The bucconasal membrane breaks and opens into the stomatodaeum. Thus the primitive posterior nasal aperture is formed. This large opening of the nasal cavity with the mouth gradually becomes narrow by the development of palates.

The palate develops from three sources – Primitive palate is formed by the frontonasal process and two lateral plates (palatal process). These lateral plates grow in the form of shelf like projections from the maxillary processes. Fusion of these three components form the palate and separates the nasal cavity from the mouth. The lateral nasal process gives rise to lateral wall of the nose. The nasal conchae are developed from the lateral wall.

Further development of respiratory passage

About at the 4th week of development in cow a median groove appears at the ventral wall of the pharyngeal part of the fore gut. This is called **laryngo-trachial** or **tracheo-bronchial** groove.

The groove deepens and its distal part becomes separated from the primitive esophagus. The cranial part, however, maintains its continuity with the developing pharynx.

The laryngotrachial groove which now transformed into a blunt tube, grows caudally in the mesenchyme between the developing heart and esophagus. The caudal blunt end bifurcates to form right and left lung buds.

The cranial most part of the diverticulum forms the larynx and the next part forms the trachea. The lung buds give rise to bronchial tree and lung parenchyma with the help of splanchnopleuric mesoderm as follows :

Components	Derived from
Mucous membrane of respiratory passage	} Gut endoderm
Lung alveoli	
Muscle fibers	} Splanchnopleuric mesoderm
Cartilage	
Fibroareolar stroma	

Development of Larynx

It develops from the cranial part of laryngo-trachial tube. The epiglottis is formed by the caudal part of hypobranchial eminence (see development of tongue). The fourth branchial

arch forms thyroid cartilage. Cricoid and arytenoids cartilages are derived from 5th and 6th pharyngeal arches. Branchial mesoderm forms the laryngeal muscles. The communication between the gut and the tube persists as aditus laryngis.

Development of Trachea

The part of the laryngo-tracheal tube which extends from the developing larynx to the point of bifurcation gives rise to trachea. Its mucons lining is derived from the gut endoderm. The cartilage and connective tissue components are derived from mesoderm and probably from 6th arch. However, in case of cow an additional lung bud appears at the right side which gives rise to the apical lobe of the right lung.

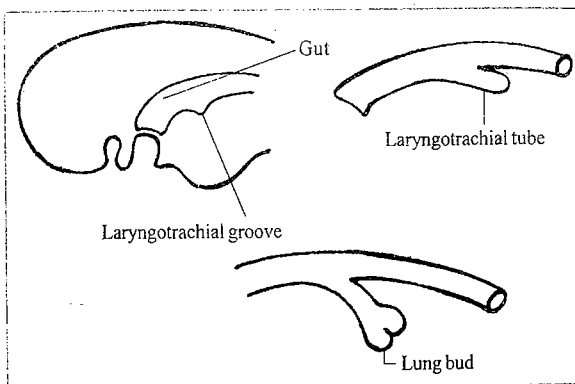


Fig. 4.6

Development of Lungs

Each of the two divisions of the laryngo-tracheal tube and the additional lung bud in bovines form the principal bronchi. Each bronchus subdivides within the lung bud. Subsequent divisions of bronchi establish the bronchial tree. Alveoli are formed by the expansion of the terminal bronchioles. In the meantime the splanchnopleuric mesoderm invests each of the buds and persists as pulmonary pleura. This mesoderm also forms the connective tissue of the lung parenchyma. The fissures are developed due to the investment of the pleura to each of the lobe separately.

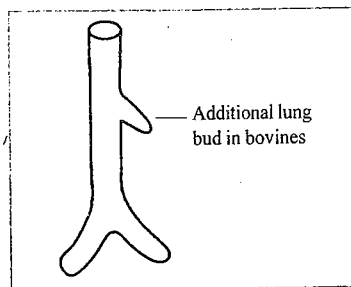


Fig. 4.7

During the proliferation of the bronchial tree, it encounters three phases of development. These are ***glandular phase***, ***canalicular phase*** and ***alveolar phase***.

At the early stage (4th to 5th week of gestation) the divisions of bronchi remain surrounded by cluster of cells. This is called ***glandular phase***. In the ***canalicular phase*** the subdivision of bronchial tree are canalized and become lined by cuboidal epithelium. Ramification of blood vessels occurs around the primitive alveoli.

At about 7th to 8th month of gestation period, the alveolar bulgings come in close contact with the blood capillaries. The lining epithelium of alveolar sacs are transformed from cuboidal to thin flat cells. This phase of development is called ***alveolar phase***. These cells in developed lung remain as pneumocyte-I.

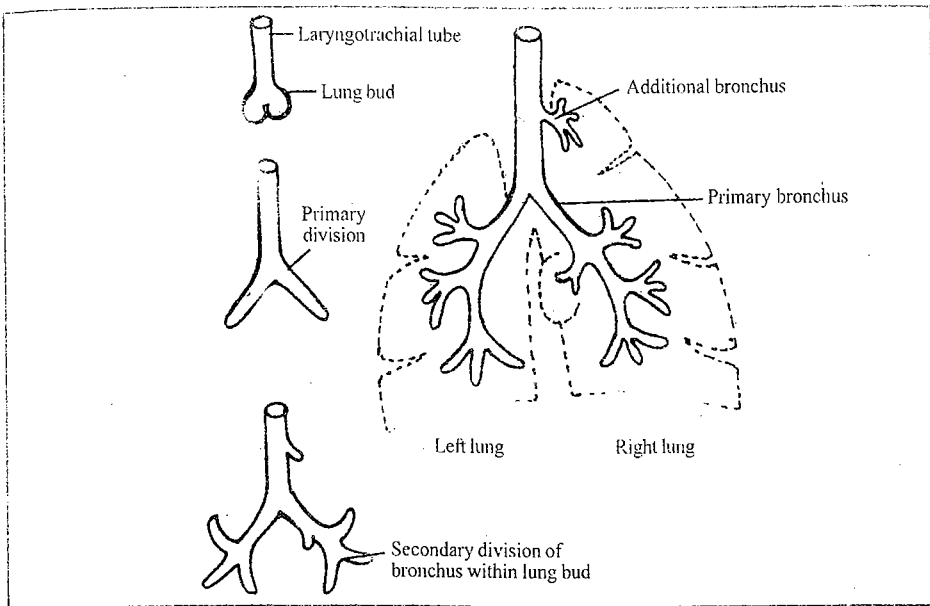


Fig. 4.8

Some alveolar cells become specialized and produce surfactant fluid which contains phospholipids. The surfactant forms a thin layer over the alveolar cells and thereby reduces surface tension and prevents collapse of the alveoli. These are developed to form pneumocyte-II cells.

In case of premature birth (before 7th month) the calf cannot survive if the surfactant fluid is not sufficiently available. 7th months onwards the fetus, if delivered, may survive independently in the external environment with the on set of pulmonary respiration.

Within a very short period most of the alveoli are inflated with air and the surfactant is reabsorbed.

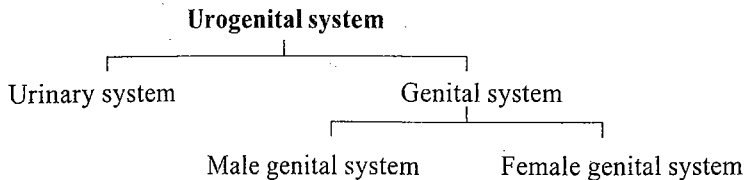
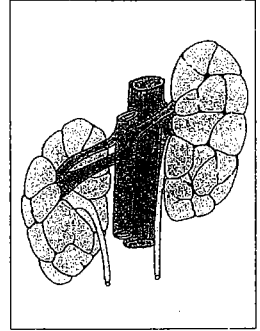
At birth about 16 to 18 generations of bronchi are formed. During post-natal development few more generations are developed.

Anomalies

1. Laryngocoele – The cavity of larynx becomes abnormally large.
2. Agenesis and Hypoplasia – Whole or part of lung fails to develop.
3. Lung hernia – It may develop due to defect in thoracic wall.
4. Formation of abnormal fissures or accessory lobe.

5

UROGENITAL SYSTEM



STRUCTURE OF URINARY SYSTEM

Components :

- 2 Kidneys
- 2 Ureters
- Urinary bladder
- Urethra

KIDNEYS

These are a pair of reddish-brown roughly bean shaped organs situated on either side of the vertebral column at the caudal part of the abdomen. They are retroperitoneal in position, invested by a thin capsule and remain surrounded by adipose tissue.

When cut longitudinally, this organ exhibits two distinct zones – a dark peripheral portion, the **cortex** and lighter zone with parallel streaks, the **medulla**. The medulla forms conical structures with the apices directed inwards and base attached to cortex known as **Pyramids**.

In warm-blooded animals the kidney is composed of several individual lobes which may remain independently or may fuse partially or completely, depending upon species.

In birds and dolphins the lobes are numerous mostly separated. In cattle and in human new born, fusion at the cortex is partial but medulla remain unfused.

In pig and human the cortical portion fuses completely and the surface appears almost smooth but the medullary portions remain separated. In horse, dog, cat and rodents both

cortex and medulla are so fused that the organ appears to be smooth surfaced and unipyramidal.

The apex of a pyramid projects into a small funnel shaped structure known as calyx minor. Several calyces minors unite to form major calyces which are generally two in number. These major calyces join together to form the **pelvis** of the kidney. From the pelvis ureter begins. At the medial border of the kidney there is a depression known as **renal sinus** which accommodates the renal pelvis, renal artery, renal vein, nerves and lymphatics. Spaces in between the structures remains filled with fat.

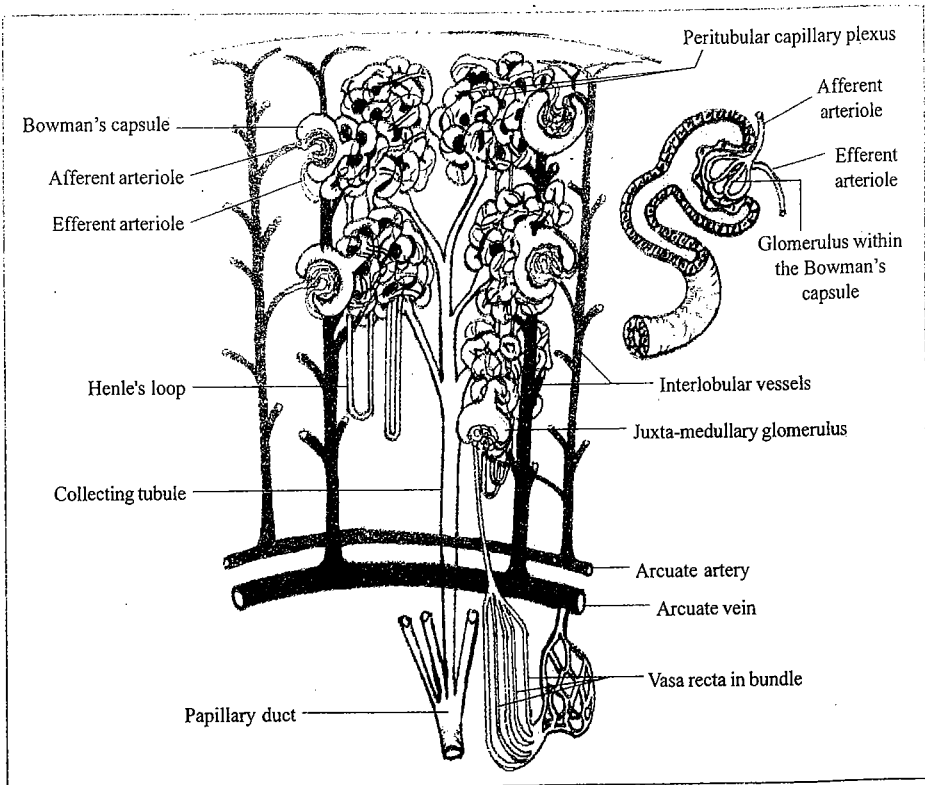


Fig. 5.1 Renal tubules and vessels (Diagramatic).

Structure

Capsule

The whole of the organ remains covered by a capsule which is composed of collagen, elastic and smooth muscle fibers. The capsule is surrounded by perirenal fat which is continuous with the fat of renal sinus.

Lobes

Each lobe of the kidney exhibits 1) a peripheral dark part- the cortex and 2) a inner lighter zone – the medulla. The cortex is composed mainly of renal corpuscles, proximal convoluted tubules and distal convoluted tubules and that is why darker is colour. The medulla contains bundles of straight collecting tubules which converge towards the apex called ***medullary rays***.

Uriniferous tubules

These are the main components of a kidney. Each of the uriniferous tubule is composed of two parts- a) Nephron and b) collecting tubule. These tubules are responsible for excretion and collection of urine. The whole length of a uriniferous tubule is lined by a single layer of epithelial cells placed on a basement membrane.

Nephron

It is the structural and functioned unit of the kidney and comprises of a convoluted tubular system with a blind distal end which is invested by capillaries. Each nephron has following parts :

- Renal corpuscle
- Proximal convoluted tubule
- Loop of Henle
- Distal convoluted tubule

Renal corpuscles

These are dark granules (about 0.2 mm in diameter) situated in the cortex and serves as the main filtration apparatus. These are also called Malpighian corpuscles. Each corpuscle is composed of two parts – (a) Bowman's capsule and (b) Glomerulus.

Bowman's capsule

The expanded blind end of the nephron is invaginated by a tuft of fine blood vessels to form a double layered cup shaped structure is called Bowman's capsule. Its parietal layer is lined by simple squamous epithelium and the visceral layer is formed by a some modified cells having feet like processes called **podocytes**. Between the foot processes (pedicles) there are tiny spaces called filtration sites. The dialyzing membrane between the blood and glomerular filtrate is formed by the basal lamina of podocytes and endothelial lining of glomerular capillaries. Around the capillaries some phagocytic cells are found called

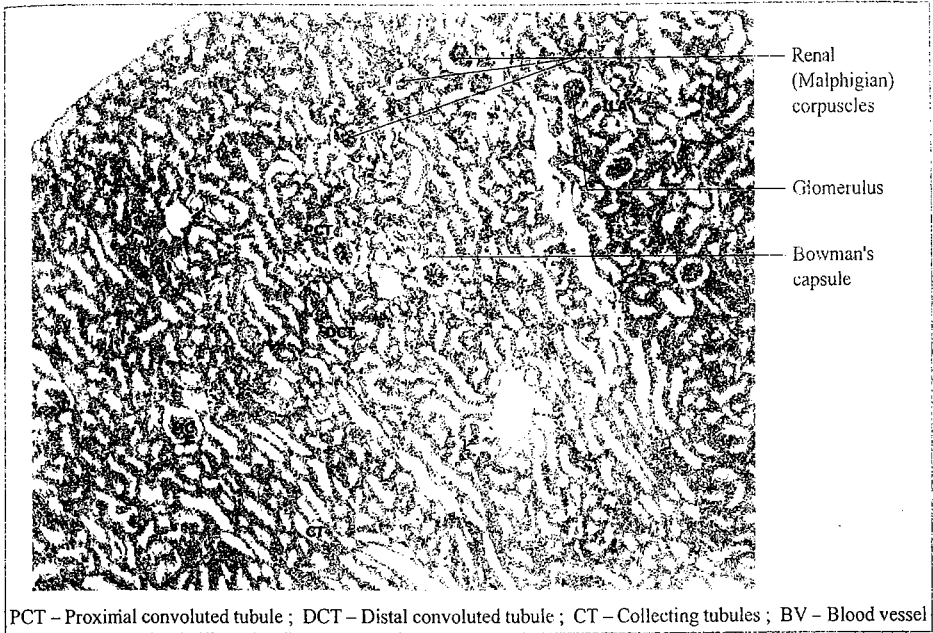


Fig. 5.2a Kidney (cortex).

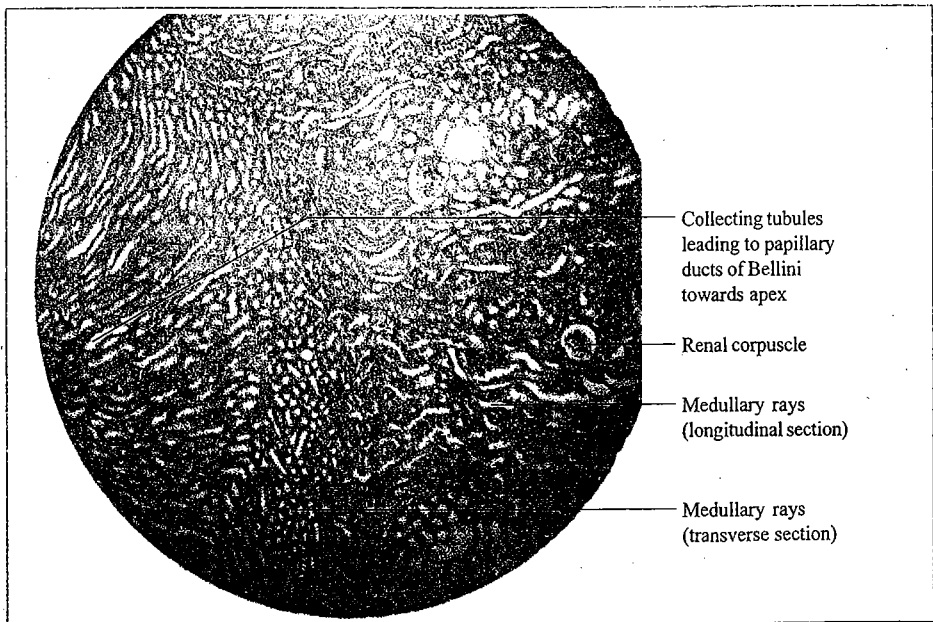


Fig. 5.2b Kidney (cortico-medullary junction).

mesengial cells. The space between the parietal and visceral layers of Bowman's capsule which is continuous with proximal convoluted tubule is known as capsular space.

Glomerulus

The afferent arteriole while invaginating the Bowman's capsule breaks down into numerous capillaries which club together to form a lobulated tuft called glomerulus. The lining endothelial cells of these capillaries are perforated by numerous pores of about 0.1 micron diameter. About 30 to 40 capillaries arise from an afferent arteriole to form a glomerular tuft which again re-unite to form efferent arteriole. The efferent arteriole which arises from the glomerular tuft leaves the renal corpuscle at a place close to the entry of afferent arteriole called vascular pole.

Proximal convoluted tubule (PCT)

This is the next part of the nephron after the Bowman's capsule in the form of a convoluted tubule situated in the cortex. The average length of this part is about 14 mm and diameter is about 60 micron. This part of the tubule is lined by a single layer of large cuboidal or truncated pyramidal cells having microvilli at their free surfaces (luminal) and therefore brush border in appearance. The lumen of these tubules are smaller than those of distal convoluted tubules. The basal portion of these cells show infoldings.

The main function of proximal convoluted tubule is to re-absorb about 90% of the filtrate which contains water, electrolytes, glucose, amino acids and small proteins. The microvilli and interdigitations are probably responsible for such functions. The terminal part of PCT becomes straight and continuous with the descending limb of Loop of Henle.

Loop of Henle

This is an U shaped loop formed between the proximal and distal convoluted tubules and has a descending limb and an ascending limb. These loops are mostly located in the medulla and partly in the cortex.

Descending limb is continuous with the PCT. Its upper part is lined by simple cuboidal epithelium and lower part by simple squamous epithelium.

Ascending limb is continuous with the thin segment of descending limb after the loop and lined by the same simple squamous epithelium at the lower part and simple cuboid epithelium at its upper part.

The loops of cortical nephrons which constitute 80-85% of the total number, are short but those situated at the deep layer near the medulla (juxta medullary nephrons) have long loops and located in the medulla.

Distal convoluted Tubules (DCT)

The ascending limb is continuous with the next part of the nephron which is convoluted again between the afferent and efferent arterioles of the glomerulus. It is located in the cortex of the kidney. The lumen is larger than that of PCT. A single layer of small cuboidal cells line the DCT. Instead of brush border, a few micro villi are present on the free surface of these epithelial cells. Infoldings are also seen at the basal plasma of this part of tubule. With the influence of Aldosterone (from posterior pituitary) permeability of DCT to water is increased.

The terminal part of the DCT joins with the collecting tubules. However a small junctional or connecting tubule connects the nephron with the straight collecting tubule which are situated at the medullary rays of the cortex. The collecting tubules while entering the medullary ray join with similar tubules several times.

The junctional tubule and collecting tubules are lined by cuboidal to columnar cells having clear cytoplasm. Microvilli are absent.

Types of nephrons – They are two types.

a) ***Cortical nephrons*** – They are numerous (about 85% of total)

Efferent arterioles are narrower than afferent.

Loop of Henle is shorter and ascending limb is thicker

Situated mostly in the cortex.

b) ***Juxtamedullary nephrons*** – They are less in number (15% of total)

Efferent and afferent arterioles are of similar thickness.

Henle's loop is long.

Ascending limb is thin at the beginning and then becomes thick.

Situated adjacent to medulla.

Juxtaglomerular apparatus (JGA)

This is a complex formed by the part of Distal convoluted tubule, Afferent arteriole and some extraglomerular mesangial cells. The main components are – Macula densa, Juxtaglomerular cells and Lacis cells.

Macula densa is a row of tightly packed cells lining the part of DCT which is in contact of afferent and efferent arterioles.

Juxtaglomerular cells are modified smooth muscle cells of the tunica media of afferent arteriole. These cells have granules which contain rennin and act as baroreceptor.

Lacis cells – These are agranular mesangial cells found in the triangular space formed by afferent arteriole, efferent arteriole and macula densa and therefore extra glomerular in position.

The JGA by its tubuloglomerular feedback mechanism regulates flow of blood through glomerular vessels and thereby controls glomerular filtration rate. The macula densa helps secretion of rennin from the JG cells. Renin helps in the local production of Angiotensin II which constricts efferent arteriole and thereby control flow of blood through glomerular capillaries and in turn regulates filtration.

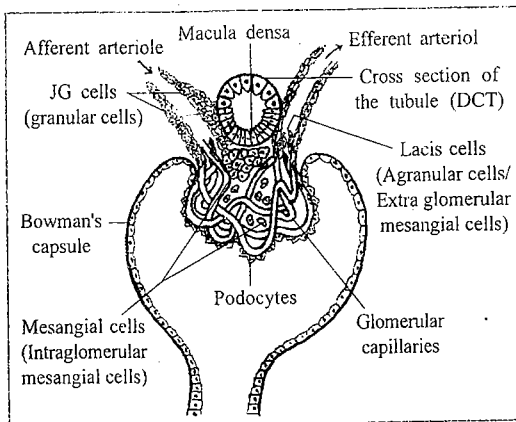


Fig. 5.2c Juxtaglomerular apparatus.

(By Courtesy : Dr. A.B.S. Mahapatra)

Collecting tubules – The collecting tubules, as has been mentioned earlier proceed towards the medulla collectively after joining with similar adjacent tubes several times and form the medullary ray. Finally such 20-25 tubules open at the apex of the pyramid (renal papilla) as the ducts of Bellini.

Renal Papillae

These are the apexes of renal pyramid which project into minor calyces in the renal sinus. The papillae are composed of the terminal parts of the collecting tubules, loops of Henle of juxtamedullary glomeruli and vasa recta. The renal papilla is covered by transitional epithelium which also enters for a short distance into the papillary ducts (ducts of Bellini). The papillary ducts empty into minor calyces.

The calyces minor as well as calyces major are lined by transitional epithelium having 2 to 3 layers of cells.

Blood vessels

Since the function of this organ is directly related to blood vessels, a brief description of their distribution is important.

Just a little before or at the point of entry into the kidney the renal artery divides into few segmental arteries. Each of them again divides into few interlobar arteries in the sinus. Each interlobar artery passes between renal pyramids and at the cortico-medullary junction breaks up into arch-shaped arcuate arteries without anastomosing with adjacent arcuate arterioles. From arcuate arteries numerous parallel arteries arise almost in right angles and proceed towards the cortex. These are interlobular arteries. These vessels give off a number of side branches called afferent arterioles which form glomerular tufts in the Bowman's capsule and

finally form efferent arterioles. In case of cortical glomeruli the efferent arterioles are of less in caliber and divide to form peritubular capillary plexus around PCT, DCT and loops of Henle and join the interlobular vein. Juxta medullary glomeruli receive afferent arterioles from the beginning of the interlobular arteries. The efferent arterioles of these glomeruli are of same caliber to those of afferent which break into numerous parallel vessels and proceed towards the medulla between the loops of Henle and collecting tubules. These bundles of parallel vessels are called *vasa recta*. They form hairpin loops, re-return to the cortico-medullary junction, re-unite to form venule and enter the arcuate vein directly.

Ureter

This slender long tube extends from the kidney to the bladder. The wall is composed of a) Outer fibrous layer, b) Middle muscular layer and c) Inner mucous layer.

- a) The outer fibrous layer consists of Collagen and reticular fibers.
- b) The middle muscular layer is made up of an inner longitudinal and outer circular layer at the cranial two third part. In caudal one third part there is an additional outer longitudinal layer. Intervening connective tissue is present between these layers.



Fig. 5.3 Urinary bladder (mucosa).

- c) The inner mucous layer is formed by transitional epithelium which consists of 4 to 5 layers of cells. The lumen appears to be star shaped in transverse section due to foldings of the mucous membrane in non distended condition.

Urinary bladder

This oval elongated sac is the store house of urine. The composition of the wall is similar to that of ureter but is more thick at the neck due to its muscular layer. The outer fibrous layer is covered by a serous coat at its cranial end. The fibrous layer attaches the bladder with surrounding organs. The muscular layer is thick and

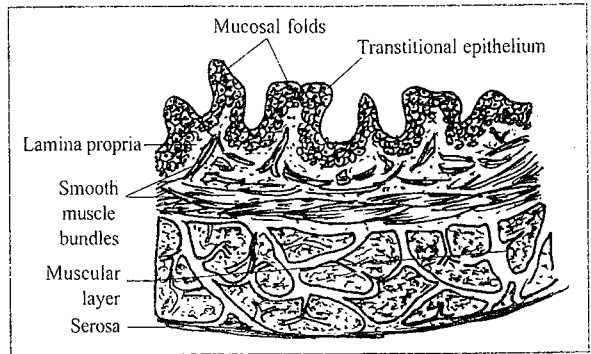


Fig. 5.4 Urinary bladder.

consists of an inner longitudinal middle circular and outer longitudinal layer. However, in some places these bundles are mixed up due to interlacing between muscular bundles of different layers. The in between connective tissue contains numerous ganglia. Circular layer is more thick at the neck to form internal sphincter of the internal urethral orifice. The mucous layer is thrown into many folds and composed of transitional epithelium with 6 to 8 layers of cells. Mucous glands are almost absent. Lamina propria (stroma) is composed of loose connective tissue which accommodates many lymphoid cells.

Urethra (female)

The structure of male urethra has been discussed in the male reproductive system.

The female urethra is composed of a) an outer adventitial layer, b) Middle muscular layer, c) Sub mucous layer and d) Inner mucous layer.

The mucosa is folded and therefore the lumen presents stellate appearance. The lining epithelium is transitional near the bladder and gradually changes to stratified squamous epithelium at the external urethral orifice. In between them a small part lined by pseudostratified cuboidal or columnar epithelium.

The sub mucous layer is compact at the adjacent area of the epithelium. It is composed of fibro elastic tissue, diffuse lymphatic tissue and cavernous spaces. These spaces give the appearance of erectile tissue. The muscular layer consists of thick inner circular and thin outer longitudinal muscles.

DEVELOPMENT OF UROGENITAL SYSTEM

The intra embryonic mesoderm is divided into three parts. a) **Paraxial mesoderm**, which become segmented to form somites. b) **Lateral plate mesoderm**, within which intra embryonic coelom appears and gives rise to somatopleur and splanchnopleur with the overlying ectoderm and with the underlying endoderm respectively. The mesoderm of

somatopleuric layer forms the parietal peritoneum, pleura, pericardium, skeletal muscles, subcutaneous tissue and dermis. The splanchnopleuric layer gives rise to visceral layer of peritoneum, pericardium, pleura and muscles of gut and heart. c) The **intermediate mesoderm** is placed between paraxial mesoderm and lateral plate mesoderm. The **urogenital system develops from this intermediate mesoderm**.

At first a pair of bulgings develop on the dorsal abdominal wall at the lateral aspect of the dorsal mesentery of the gut which extends from the cervical region to sacral region of the embryo. These inner bulgings on either side are called **nephrogenic cords**. The primitive kidneys develop from these cords and the gonads (testis or ovary) develop from the coelomic epithelium covering the medial aspect of the nephrogenic cord. Therefore the nephrogenic ridge is placed laterally and the genital ridge is placed medially.

URINARY SYSTEM

Development of kidneys

In the vertebrates the chronology of the development of kidneys pass through three stages of evolution. At first the **pronephros** is formed in relation to the cervical region of the nephrogenic cord during the end of 1st month of gestation. The pronephros comprises of 7 to 8 horizontally and segmentally arranged tubules. The down turned ends of the tubules join one after another and form **pronephric duct**. These tubules open medially into the **coelomic cavity**. In higher vertebrates the pronephros is nonfunctional and disappears soon. However

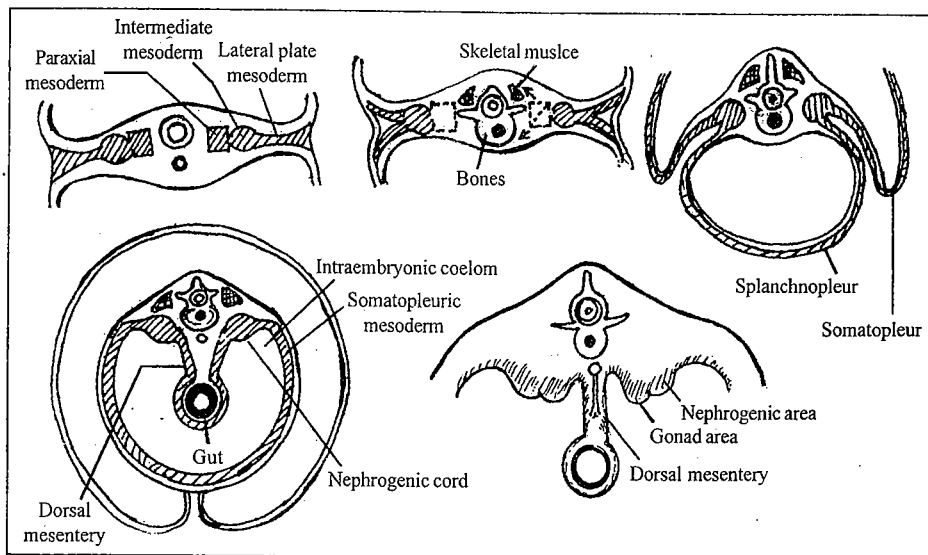


Fig. 5.5

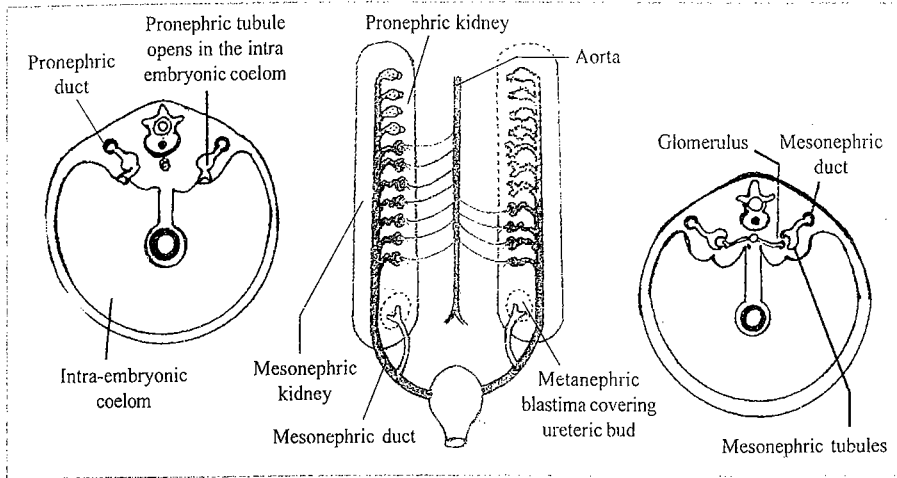


Fig. 5.6

the pronephric ducts which joined the cloaca, persists. The pronephric kidneys remain as functional kidneys in some cyclostomes and fishes.

The pronephric kidney is replaced by **mesonephric kidney** which utilizes the pronephric duct as its own and therefore now termed **mesonephric duct**. The mesonephros is formed within the intermediate cell mass in the caudal thoracic and lumbar region. It comprises of about 60 to 80 mesonephric tubules arranged in series and communicate laterally with mesonephric duct or **Wolffian duct**. The medial end of each mesonephric tubule becomes dilated and receives an internal glomerulus from a branch of the aorta without being opened into the celomic cavity. All the mesonephric tubules do not appear at a time. Few proximal

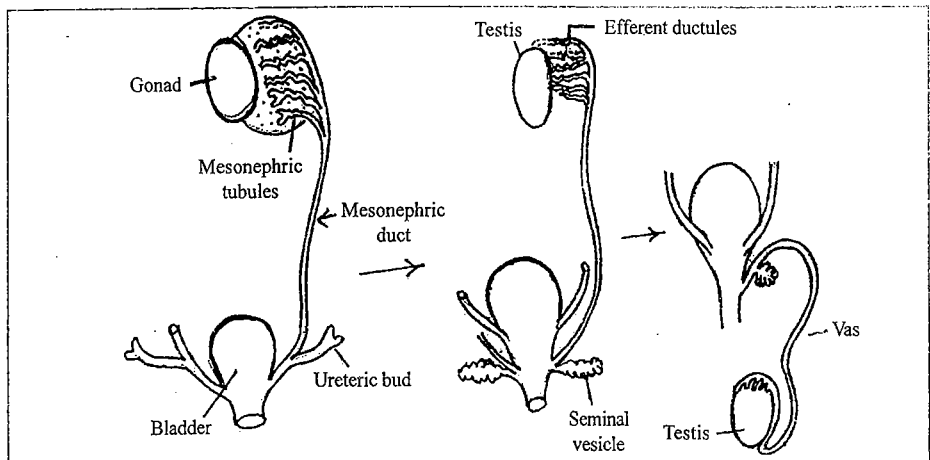


Fig. 5.7

tubules disappear and some distal tubules appear and join with mesonephric duct. The process continues.

In higher vertebrates most of the mesonephric tubules disappear but in the male embryo some of them are modified and become associated with the formation of the duct system of the testis. The mesonephric tubules are converted to efferent ductules of the testis and the mesonephric duct forms the duct of epididymis, vas deferens, seminal vesicle and ejaculatory duct.

The mesonephric kidney is replaced by **metanephric kidney**. This probably occur due to the failure of the mesonephric kidney to perform the function of selective absorption. However, mesonephric kidney remains as functional kidney in most of the anamniots. The formation of permanent or metanephric kidney appears in higher vertebrates in lumbosacral region. The metanephric kidney may be divided into two portions – a) collecting part and b) excretory part.

Collecting part

First an ureteric bud appears and grow from the medial aspect of the caudal part of the mesonephric duct and subsequently shift from medial aspect to lateral aspect. The dilated end of the ureteric bud invade the caudal part of the nephrogenic chord. At the time of shifting the nephrogenic tissue forms a cuplike investment around the dilated end of the ureteric bud, called **metanephric blastima**. The dilated end or the ampulla divides repeatedly.

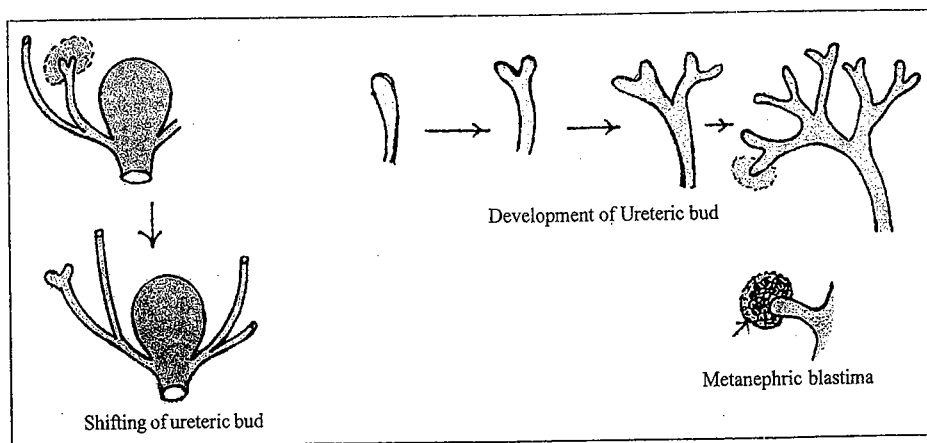


Fig. 5.8

First few generations of these divisions fuse to form pelvis of the kidney. The subsequent divisions form calyces majors, calyces minors and collecting tubules. Depending upon the size of the kidney the number of collecting tubules may be two to three million.

The stalk of the ureteric bud forms the ureter. The part of the mesonephric duct between the cloaca and ureteric bud is called common excretory duct. The common excretory duct blends with the mucous membrane of the trigonium vesicae and therefore the ureteric bud directly opens into the bladder. In males the mesonephric duct proceeds more caudally and opens in the urogenital sinus and thus forms the vas.

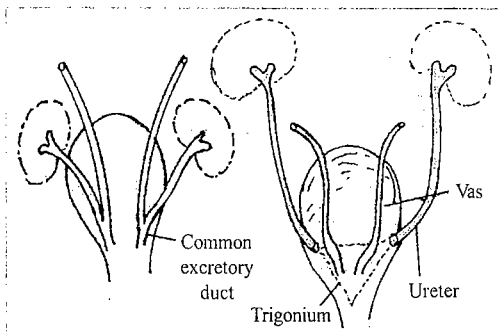


Fig. 5.9

Excretory part

Being induced by the insertion of ureteric bud into the caudal part of the nephrogenic cord, the mesodermic cells of that region are differentiated to form metanephric blastima. The nephrons are formed by the cells of the metanephric blastima which remain in contact of the **ampullae**. The ampullae are developed from the growing tips of each of the numerous branches of ureteric bud.

A solid lump of cells close to an ampulla become hollow and form a **vesicle**. The vesicle become elongated and open into the ampulla.

The elongated pear shaped vesicle having communication with the ampulla now extend to form '**S**' shaped tubules. At this stage the closed ends become little dilated and subsequently becomes invaginated by tufts of capillaries to form glomeruli and renal corpuscles. Various parts of nephron are derived from the primitive '**S**' shaped tubule.

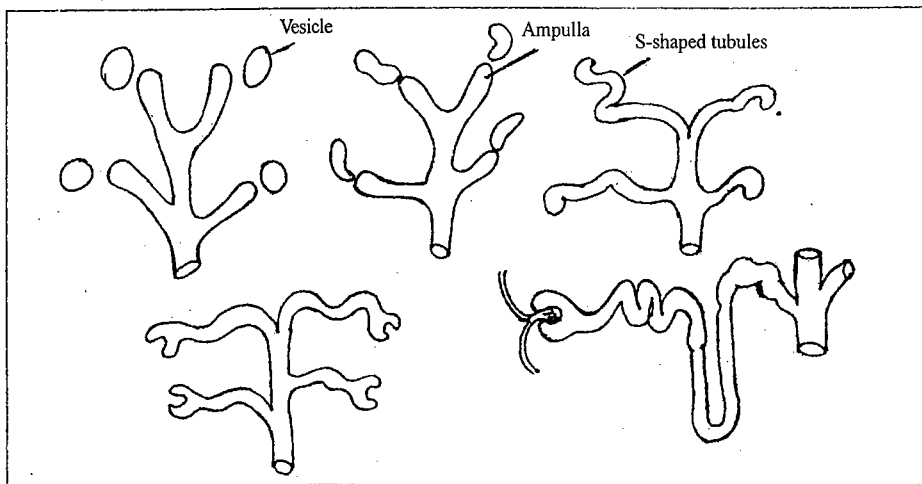


Fig. 5.10

Urogenital sinus

Cloaca – This is the caudal part of the hind gut situated behind the allantoic diverticulum. In this cloaca two grooves appear bilaterally. These grooves deepens and form a urorectal septum. This septum subdivides the cloaca into a broad ventral part and narrow dorsal part. The ventral part forms the urogenital sinus and the dorsal part forms the rectum.

Development of Urinary bladder

From the ventral aspect of hind gut the allantoic diverticulum develops. The tip of this diverticulum extends through the umbilical cord to form allantoic vesicle. The post allantoic part of the hind gut is called endodermal cloaca. Caudally this is closed by cloacal membrane which is made up of endoderm and ectoderm. The mesonephric ducts open into the urogenital sinus. The cranial vesicourethral part of the urogenital sinus along with part of allantoic diverticulum develop into urinary bladder. The

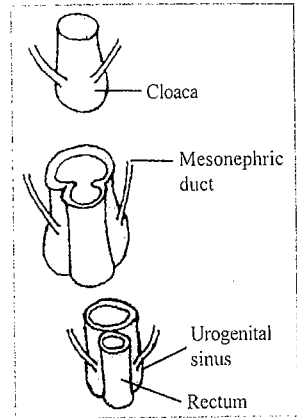


Fig. 5.11

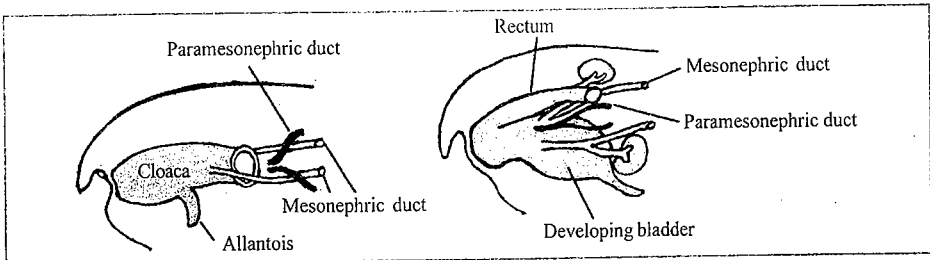


Fig. 5.12

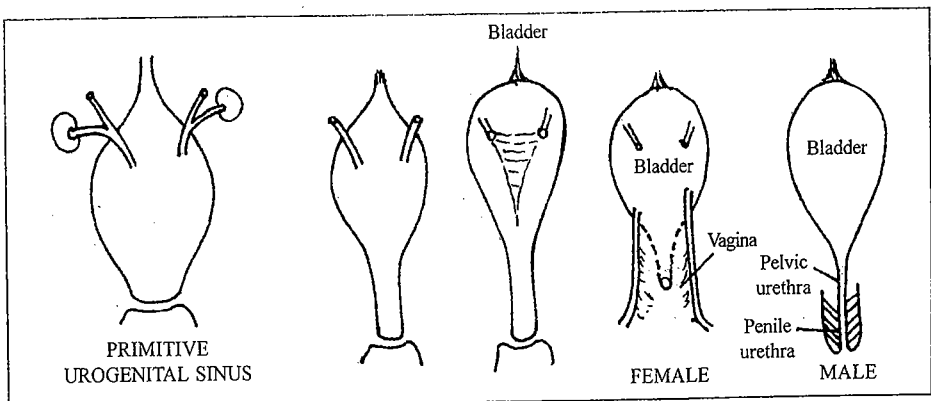


Fig. 5.13 Development of bladder.

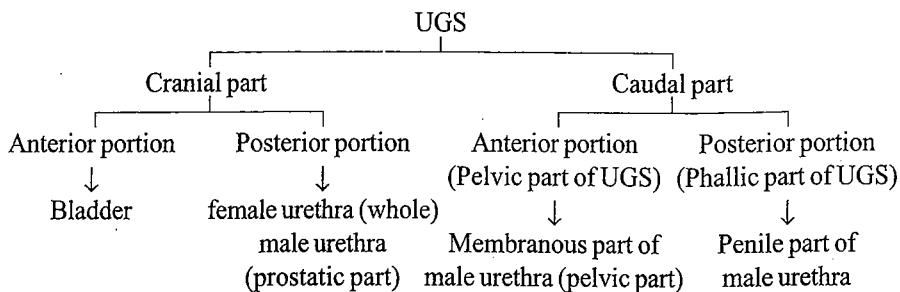
caudal part is known as definitive urogenital sinus and receives the terminations of mesonephric ducts. The mesonephric ducts persist in males as sex ducts (duct of epididymis and vas). In the female they regress but in some animals e.g. cow they remain in the form of small canals at the floor of vagina and known as **canals of Gartner**. These canals open on either side of the opening of urethra.

Initially the ureteric bud and the mesonephros has a common opening into the sinus but due to absorption of the caudal part of the mesonephric duct by the sinus the bud canals get their separate openings and thus ureters are formed. The openings of the mesonephric ducts in males are drawn further caudally and reach to the dorsal wall of the beginning primitive urethra.

The mucous membrane of the bladder is developed from the cranial part of the urogenital sinus (endoderm). The epithelium of the trigone of the bladder is drawn and derived from absorbed mesoderm of the mesonephric duct. The apex of the primitive bladder is cranially continuous with allantois. This continuation is obliterated before birth and persists as a fibrous band in post-natal life called **urachus**. Therefore the urachus extends from apex of the bladder to the umbilicus. The musculature and serous covering of the bladder is derived from splanchnopleuric mesoderm.

Development of Urethra

The urogenital sinus (UGS) appears in the form of a enclosed sac. Its cranial part is known as vesicourethral canal and the caudal part is called definitive UGS.



Close to the junction of these two parts the mesonephric ducts open into the UGS. The anterior part of the vesicogenital canal expands to form Urinary bladder. The posterior part forms the whole urethra in female and prostatic part of urethra in male. The membranous part of the male urethra is derived form the pelvic part of U.G.S. The penile part of the urethra is derived form the phallic part of UGS.

Anomalies of kidneys

Agenesis – One or both the kidneys may be absent.

Hypoplasia – Underdevelopment of the kidney.

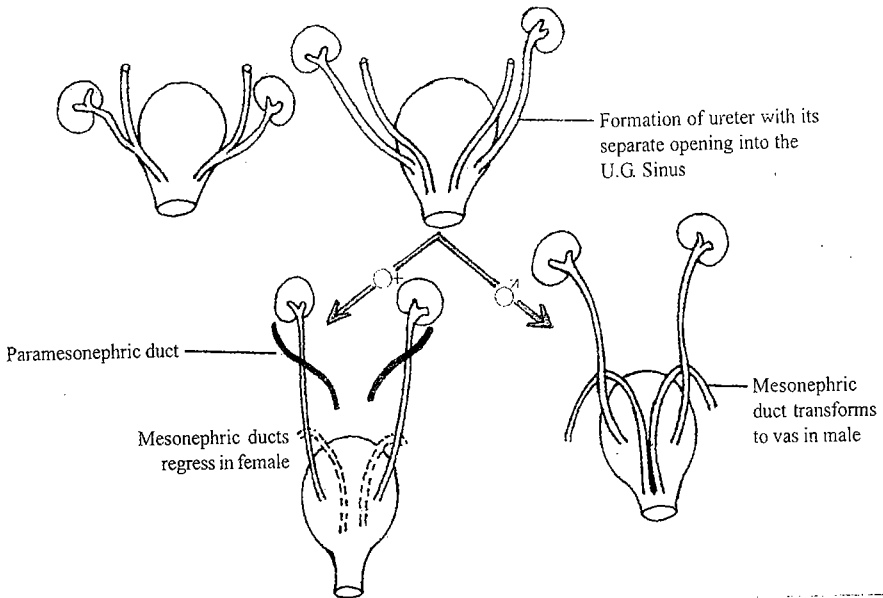


Fig. 5.14

Hyperplasia – Overdevelopment of the kidney.

Duplication – Formation of one extra kidney.

Abnormal Shape – Shapes may be abnormal depending upon the species.

Anomalies of ureter

Duplication – Ureter may be partially or completely duplicated.

Abnormal formation of ureter – The ureter may terminate in urethra instead of bladder.

Anomalies of bladder

Agenesis – The bladder may be absent

Duplication – There may be formation of more than one bladder.

Abnormal opening – Bladder may communicate with rectum

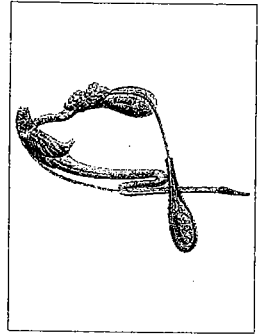
Anomalies of urethra

Obstruction at the beginning of urethra may occur.

Diverticulum formation.

Duplication

REPRODUCTIVE SYSTEM (MALE)



Male reproductive system

Components :

Testis – one pair

Ducts – a) Vasa efferentia
b) Epididymis
c) Vas deferens
d) Ejaculatory duct

Penis

Glands – a) Seminal vesicles
b) Prostate
c) Bulbo urethral gland

Testis

This ovoid male sex gland is placed within the scrotal sac and responsible for production of male germ cells i.e. Spermatozoa and male sex hormone i.e. testosterone.

The whole of the gland is covered by tunica albugenia, a thick fibrous capsule. Outside tunica albugenia the gland is covered by tunica vaginalis propria, which is derived from processus vaginalis of peritoneum. The parital layer of tunica vaginalis i.e. tunica vaginalis reflexa remains attached to the inner wall of scrotum.

The outer layer of testis, **tunica albugenia** is thick and composed of collagen and elastic fibers. Sometimes smooth muscle fibers are present in case of stallions. The deep layer of tunica albugenia contains numerous blood vessels and hence termed **tunica vasculosa**. From the tunica albugenia a number of septa/trabeculae extend towards the center. The septa appear as partition walls radiating from the **mediastinum testis** situated along the central axis of the gland. The trabeculae or septa are composed of collagen fibers, vessels and nerves. These partitions are complete in dog and boar and thin in ruminants. The connective tissue elements of the septa are continuous with the intralobular connective tissue.

Each of the lobules accommodates several highly convoluted seminiferous tubules and interstitial tissue between them. The convoluted tubules become straight at the apex of the lobule and enter the **mediastinum testis**. Here the tubules coming from adjacent lobules join each other and form a network, the **rete testis**. The convoluted part is called tubuli contorti, straight part directed towards center known as tubuli recti and the network portion within mediastinum is called rete testis. The upper end of rete testis is connected to a number (10–15) small ductules called **vasa efferentia** which come out of the proximal end of testis and enter into the head of epididymis. These tubules are lined by pseudo-stratified columnar epithelium. They unite together to form the single duct of epididymis.

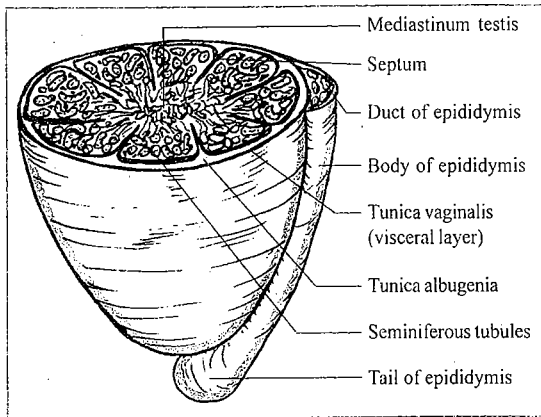


Fig. 5.15 Transverse section of testis.

Seminiferous tubules

Sectoins of this convoluted tubules appear as a collection of round or oval or elongated structures under light microscope. The wall of each tubule is composed of a) An outer capsule consists of fibroelastic connective tissue along with a thin homogenous basement membrane and b) Lining of cuboidal epithelium arranged in several layers and consists of two types of cells-i)Spermatogenic cells and ii) Supporting Sertoli cells.

Spermatogenic cells

From the basement membrane and towards the lumen, these cells are arranged in 4 to 8 layers in sexually matured animals. These cells are formed by the differentiation of the basal cuboidal cells. Four successive stages of differentiation can be recognized. These are spermatogonia, primary spermatocytes, secondary spermatocytes and spermatids.

Spermatogonia

These cells rest on a basal lamina between Sertoli cells and form a outer layer of cuboidal cells with small nuclei. These are derived from primordial germ cells. They divide mitotically and form three types of daughter cells – a) **Pale A type**, b) **Dark A type** and c) **B type**. The B type spermatogonia differentiate to form primary spermatocytes.

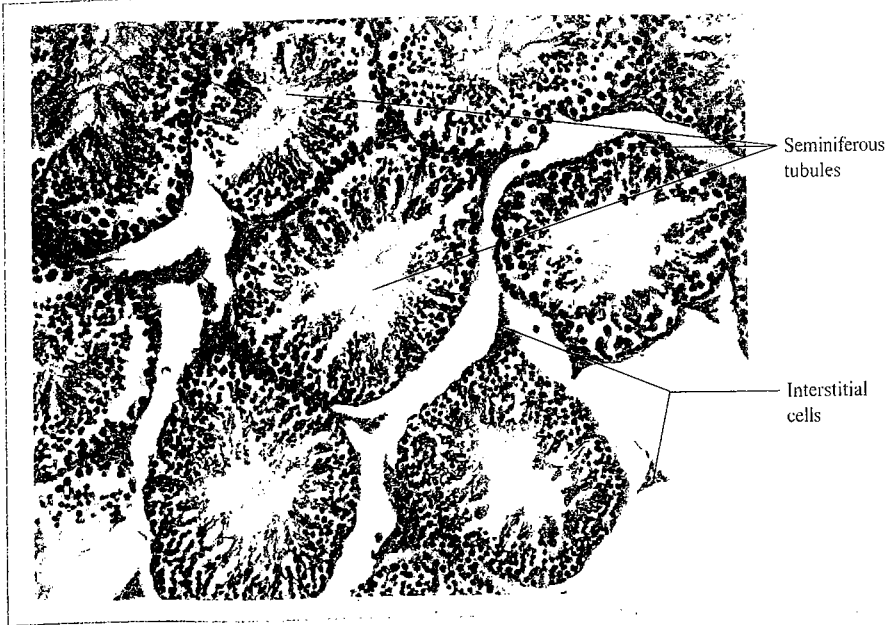


Fig. 5.16 Testis (low magnification).



Fig. 5.17 Testis (higher magnification).

Primary spermatocytes

They are larger in size and contain large spherical nuclei. These cells undergo meiotic (reduction) division and form secondary spermatocytes with haploid number of chromosomes.

Secondary spermatocytes

These are smaller in size with small nuclei and half number of chromosomes. Generally half of these cells contain X type and other half of cells contain Y type sex chromosomes.

Spermatids

Each secondary spermatocyte undergo second meiotic (non-reduction) division and give rise to spermatids. The spermatids are small rounded or elongated cells and form several layers around the lumen of the tubule. The spermatids are transformed into spermatozoa and for some time remain attached to the apices of Sertoli cells.

Spermatozoon

This is a motile structure and composed of head, body and tail. The head is oval in shape and contains a condensed nucleus. The anterior two-third is covered by a bilaminar head cap called *acrosome*. It is derived from Golgi body. The body in the middle part contains axial filaments surrounded by the mitochondrial sheath. The constricted part between the head and body is the neck. It contains proximal centriole and a basal body. The tail is an extended long structure accommodates axial filaments and helps in movement. Each spermatozoon contains either X (female) and Y (male) sex-chromosome.

Sertoli cells

These are elongated fairly large cells situated between the spermatogenic cells. The bases of these cells are attached to the basement membrane and contain large vesicular oval nucleus. The free ends are extended towards the lumen and give attachment to many developing spermatozoa. Sertoli cells provide mechanical support and nutrition to the developing spermatozoa.

Interstitial tissue

Clusters of cells situated in between the seminiferous tubules are called interstitial cells or cells of Leydig. These cells contain large spherical nuclei, acidophilic cytoplasm and remain surrounded by loose vascular connective tissue. This is the endocrine part of testis and secretes testosterone and small amount of estrogen.

Duct of Epididymis

The wall of this duct comprises of a) an outer coat and b) lining epithelium. The lumen in large and contains bunches of spermatozoa. The outer wall is composed of smooth muscle and elastic fibers. The lumen is lined by pseudostratified columnar epithelium containing mainly tall columnar cells and some small basal cells. The free surface of these tall cells possess stereocilia. This highly convoluted tube provides accommodation and nutrition to the spermatozoa.



Fig. 5.18 Epididymis.

Vas Deferens

This long tube extends from the tail of epididymis and terminates in a little dilated form called ampulla. The wall of this tube is thick and the lumen is narrow. It is composed of an outer fibrous coat, middle muscular coat and an inner mucous coat. A) Outer fibrous coat – It is composed of fibroelastic tissue containing numerous

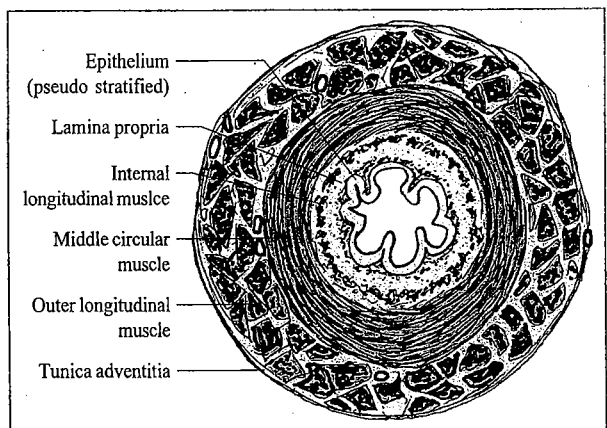


Fig. 5.19 Vas deferens.

blood vessels, nerves and scattered bundles of smooth muscle fibers. B) Middle muscular coat – This is very thick and composed of outer longitudinal, middle circular and inner longitudinal muscle fibers. C) Inner mucous coat – Some longitudinal folds are present in this layer. It is lined by pseudo-stratified epithelium comprises mainly of columnar cells and few basal cells. Some of these cells contain stereocilia. The lumen of the ampulla portion is large and has more longitudinal folds. Submucosa is highly vascularised and composed of loose connective tissue.

Urethra

The whole of the urethral mucosa is thrown into longitudinal folds which disappear during time of erection and micturation. The prostatic part (bladder to caudal edge of prostate) is generally lined by transitional epithelium in most of the domestic animals. But in dog, cat and buck it is stratified columnar epithelium. A slightly raised dorsomedian fold of the mucosa of this part form the colliculus seminalis. The said lining of the other two portions – membranous part (from the level of prostate gland to the ischial arch) and penile part (from root to external urethral orifice) is made up of stratified columnar or cuboidal epithelium. The lamina submucosa of urethra is composed of dense irregular connective tissue, smooth muscle fibers and diffuse lymphatic tissue. The tunica muscularis of prostatic part is composed of inner and outer longitudinal and middle circular layer of smooth muscle fibers. The prostatic and pelvic urethra is encircled by urethral muscles in stallion, dog and buck but do not do so in domestic ruminants. The said muscle surrounds only the ventral and lateral aspect. The dorsal portion is formed by connective tissue sheet containing elastic fibers. Bulbo cavernous muscle replaces the urethral muscle at the level of bulbo urethral gland. The tunica muscularis is covered by the tunica adventitia which is formed by irregular connective tissue.

Penis

The body of the penis is formed by a bulky muscle – the *corpus cavernosum penis* and another muscle which surround the urethra – the *corpus cavernosum urethrae* (corpus spongiosum penis). The corpus cavernosum penis presents a ventral groove along the length called urethral groove which gives accommodation of urethra surrounded by corpus cavernosum urethrae. The tunica albuginea surrounds the corpus cavernosum penis and send tabeculae or septa inside the muscle. These septa are composed of fibroelastic and smooth muscle fibers and form boundaries of cavernous space for erectile tissue. The septal arteries give rise to capillaries which open into cavernous spaces. The corpus cavernosum urethrae possesses similar structures to that of corpus cavernosum penis but the septa are of finer variety and cavernous spaces are less in number. The erectile tissue is less in bulls, buck and dog in comparison to that of stallion. In the dog the caudal half of corpus cavernosum penis is divided in to two portions along the length which are separated by a layer of connective tissue. The cranial half accommodates the os penis.

Mechanism of erection

The trabecular/septal arteries of the corpus cavernosum give rise to *helicine arteries* which run spirally and open directly into blood sinuses (cavernous spaces). Normally these vessels remain contracted and the spaces remain almost empty. During erection these arteries are relaxed and the spaces become filled with blood. At this stage the venous return is minimized by compression and the penis remains tensed. After ejaculation the helicine arteries contract and reverse action takes place.

Seminal Vesicle

These are a pair of glands and each of them is composed of a single tube coiled on itself and thereby lobulated in appearance in bull. The seminal fluid secreted by the lining cells contributes a large part of the semen. The mucous coat is made up of pseudostratified columnar epithelium with tall columnar and small spherical cells. The submucosa is composed of vascularised loose connective tissue. It is continuous with connective tissue trabeculae which appear to subdivide the organ into lobules. A thin tunica muscularis and tunica adventitia surrounds the organ. In stallion this gland is sacular and has wide central lumina where short branched tubuloalveolar glands open. The secretory epithelium is folded. These glands are **absent in dog**.

Prostate

This structure surrounds the prostatic urethra and is composed of numerous tubuloalveolar glands embedded in the framework of fibromuscular tissue. In bull two portions of the gland are recognized – an external part is called *corpus prostaticae* and an internal portion called *pars disseminata*. The gland is encapsulated with a layer of collagen, elastic and smooth muscle fibers. In the external portion the glands and their ducts are surrounded by fibromuscular connective tissue. Trabeculae which are mostly muscular in the external part originate from the capsule. The external portion of the gland is well developed in carnivores. Two bilateral lobes are recognized in these animals. In stallion two lobes are prominent but the pars disseminata is absent. The tubules and alveoli are lined by simple cuboidal or columnar epithelium. These branched tubules have dilated ends and in section they appear as follicles of different shapes and sizes. The ducts are sometimes lined by two layers of cells. The secretion is thin milky, slightly alkaline and forms a considerable part of seminal fluid.

Bulbourethral gland

These glands are tubuloalveolar in bull and stallion and compound tubular in buck and cat. The gland is **absent in dog**. The tubules are lined by simple cuboidal or columnar epithelium. The secretion is mucoid in nature and rich in protein.

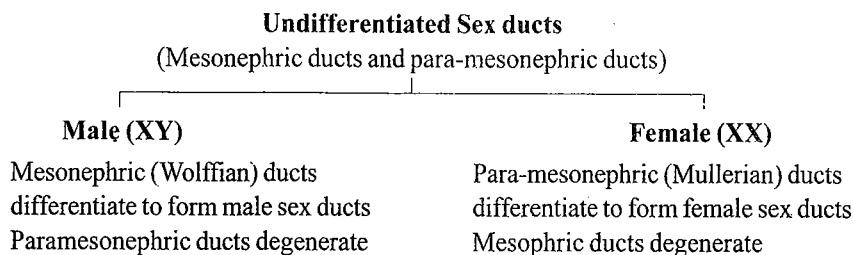
DEVELOPMENT OF GENITAL SYSTEM

Gonads include testes in male and ovaries in female. They contain reproductive primordial germ cells or primitive sex cells i.e. Spermatogonia in testis and oogonia in ovary. The gonads develop in the undifferentiated genital ridge.

Sex ducts – Male sex ducts are (a) efferent ductules, (b) Canal of epididymis, (c) vas, (d) seminal vesicle and (e) ejaculatory duct. The female sex ducts are (a) Uterine tubes, (b) Uterus (c) Vagina.

The primitive sex ducts are (a) A pair of **Mesonephric (Wolffian)** duct and (b) a pair of **Paramesonephric (Mullerian)** duct. In male the mesonephric ducts form the duct system and the paramesonephric ducts degenerate.

In female the paramesonephric ducts differentiate to form female sex ducts and the mesonephric ducts regress.



Sex differentiation

The sex is determined at the time of fertilization. When a Y bearing sperm fertilizes the ovum and form a XY combination, the zygote leads to the formation of male fetus. On the other hand absence of Y chromosome results in the formation of female Fetus. Primitive gonads develop on the 5th or 6th week of development. They appear as elongated swellings called genital ridges by the proliferation of coelomic epithelium which covers the medial surface of the mesonephric ridge.

The cells of the indifferent gonads are believed to originate from the endoderm of the dorsal wall of the hind gut, close to the allantois and migrate along the dorsal mesentery of the gut and reach to the gonadal ridge. These primordial germ cells give rise to spermatozoa or ova throughout the life. The gonads do not develop until the migration of these primitive sex cells occurs. These primary sex cells after their migration from the dorsal wall of hind gut to the genital ridge through dorsal mesentery, if reach to the cortex, the medulla regresses and ovaries develop. When these sex cells reach to the medulla, the cortex regresses and testes develop.

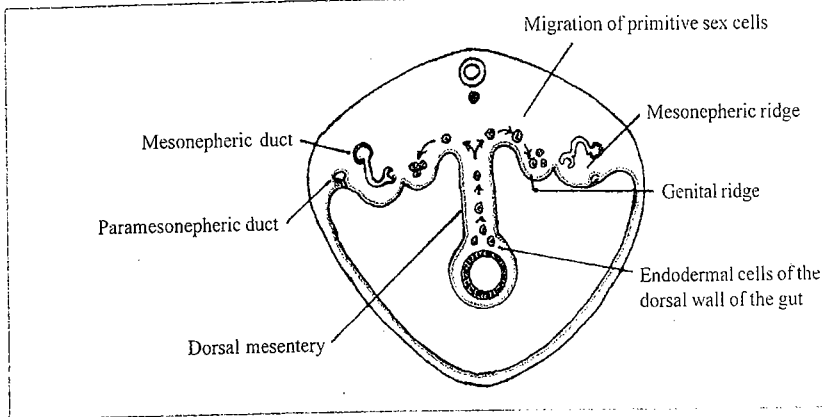


Fig. 5.20

DEVELOPMENT OF MALE GENITAL ORGANS

Each testis develops within the genital ridge which is formed by thickening of coelomic epithelium. A number of solid sex-cords grow from the surface epithelium and project deep into the gonad. They become closely associated with the mesonephric tubules. Now these solid cords become canalized to form seminiferous tubules. At the same time primary sex cells which migrated from the gut and reached to the developing testis, get incorporated in the seminiferous tubules.

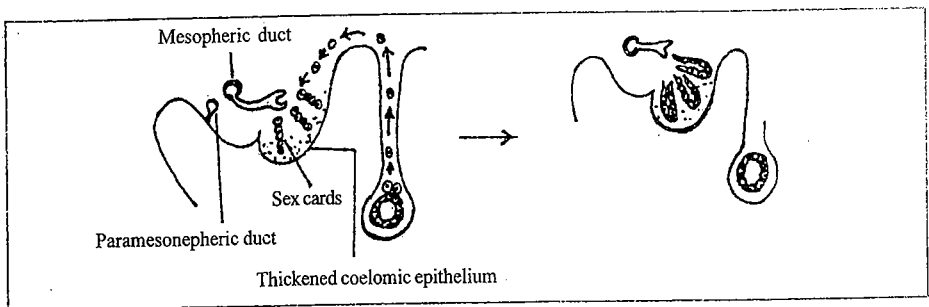


Fig. 5.21

The surrounding mesenchymal cells form tunica albuginea, mediastinum testis, septa and interstitial cells. However, some authors have stated that the interstitial cells of the testis are derived from the sex cords which failed to canalize. The presence of interstitial cells in fetal life occur due to the influence of chorionic gonadotrophin. These cells degenerate at birth and again reappear after puberty. At this stage the testis cords are detached from the surface of the genital ridge and the migrated sex cells persist as spermatogonia. Sertoli cells are derived from the surface epithelium.

Development of the duct system of testis

The development of testis takes place in close association with the mesonephros and thereby the mesonephric tubules and the mesonephric duct. The terminal parts of Seminiferous tubules, join together to form rete testis. Most of the mesonephric tubules degenerate but some of these (10-15) persist and establish connection with the rete-testis and are transformed into vasa efferentia. The cranial part of the mesonephric duct becomes coiled and form the duct of epididymis. The caudal part becomes vas deferens.

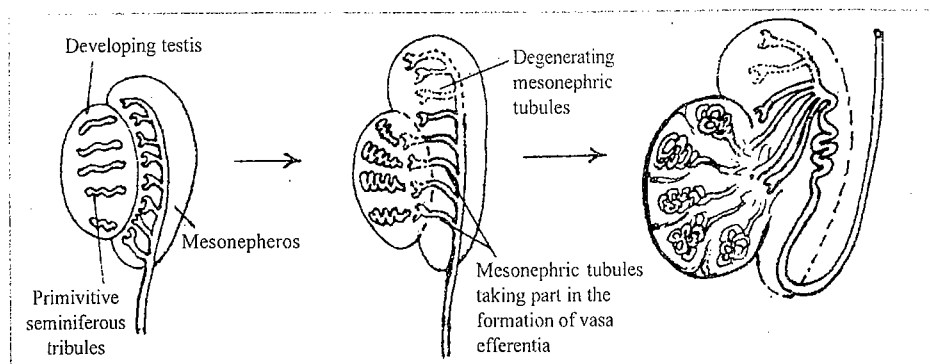


Fig. 5.22

Descent of testis

Each testis develops retroperitoneally at the dorsal abdominal wall (genital ridge) in relation to the lumbar region. It reaches the deep inguinal ring at about 7th month of intrauterine life and descends in the scrotum before birth.

Factors responsible for the descent of testis are as follows :

1. Guidance of **Gubernaculum testis** – Gubernaculum is a fibro-muscular band which extends from the caudal pole of testis to the scrotum. Shortening of this structure widens the passage and helps in the descent of testis.
2. Increased **intra-abdominal pressure** leads to the out pouching of abdominal wall and development of scrotum.
3. Active growth of **processus vaginalis** – From the ventral abdominal wall a diverticulum from the peritoneum extends actively into the scrotal sac (as shown in figure). This extended part of the developing peritoneum is known as processus vaginalis. During the descent, the testis invaginates partially in the processus vaginalis from the caudal aspect. When the descent is complete, the processus vaginalis becomes the tunica vaginalis.
4. Action of **hormones** – Mainly the testicular hormones take active part.

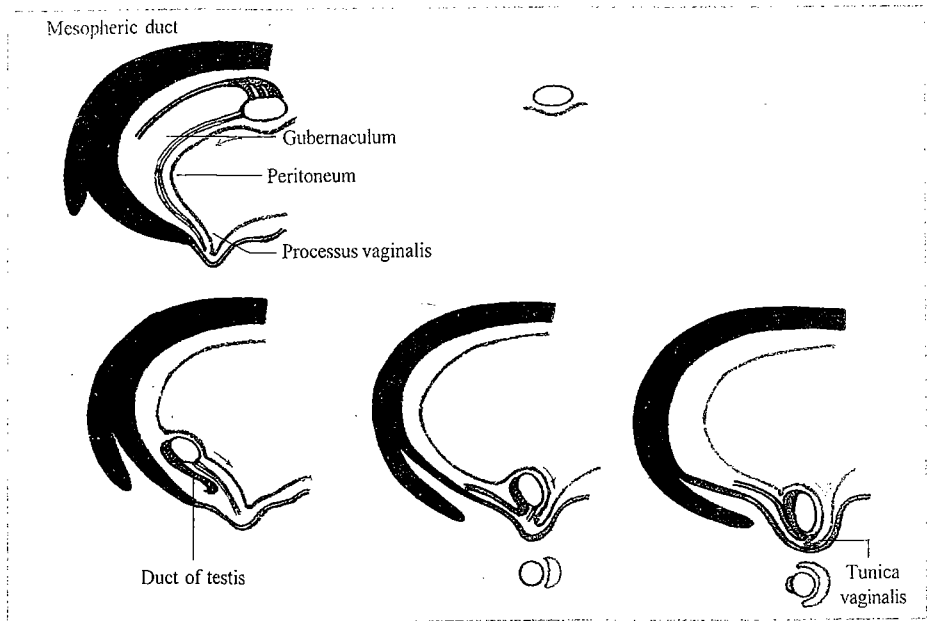


Fig. 5.23 Descent of testis and formation of tunica vaginalis.

Anomalies

Agenesis of testis.

Duplication or fusion of testes.

Cryptorchidism – The descent of testis do not occur at all or the descent is incomplete.

Abnormal position.

Hermaphroditism – Development of testis in one side and ovary on other side.

Abnormal or ill development of seminiferous tubules and vas.

Formation of male external genitalia

- (i) The genital swellings or genital folds enlarge on either side and form the scrotal sacs. The sacs become ready to receive the testes at the later period.
- (ii) The genital tubercle elongates forward between the primitive scrotal sacs. At this stage it is called phallus. It enlarges further to form penis.

Due to the growth of genital folds on either side, a groove develops at the middle of the urogenital membrane which is externally covered by ectoderm. This groove also extends along the ventral surface of the growing phallus. The urogenital sinus ruptures and become open to exterior. The ectodermal covering of the ventral groove degenerates and is replaced by the growing endoderm of the ruptured urogenital sinus.

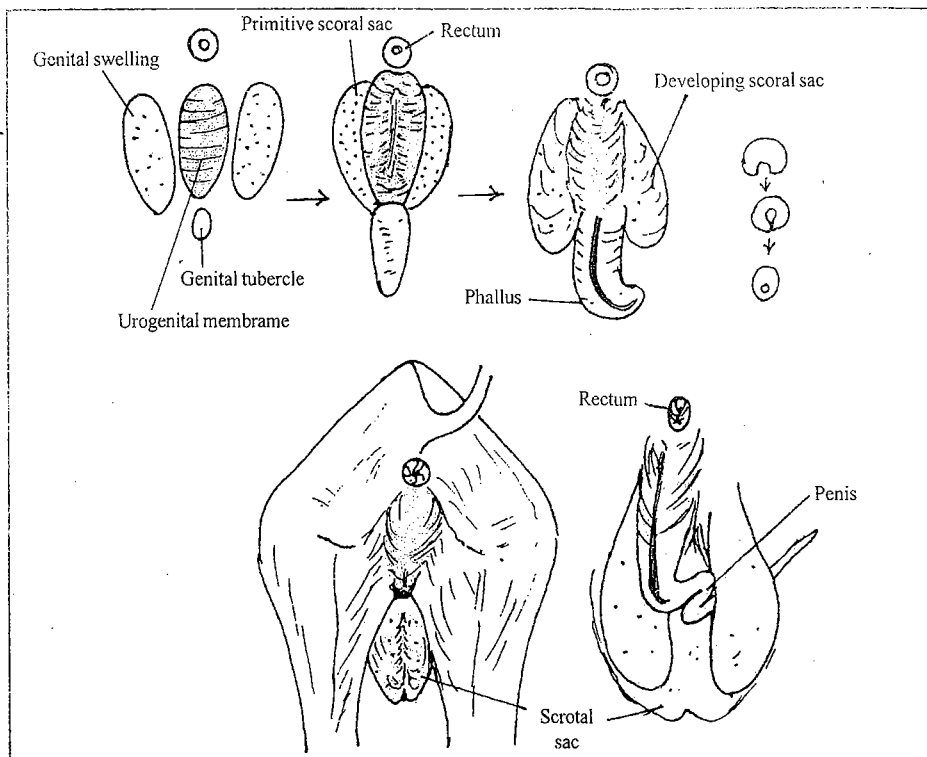


Fig. 5.24

The margins of the groove approach each other and ultimately fuse to form **penile urethra**.

The terminal part of penile urethra is formed by canalization of the solid mass at the tip of the penis. The open urogenital sinus is also closed by same procedure.

Anomalies

Penis may be absent.

Urethra may open at the dorsal or ventral aspect of penis.

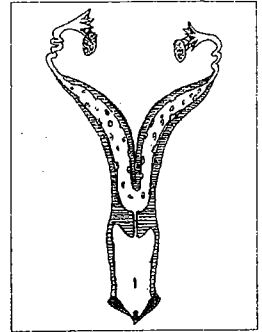
Penis may be bifid.

In rare occasions penis may lie posterior to scrotal sac.

Hermaphroditism

This condition occurs due to abnormal development of gonads and genitalia. In a true hermaphrodite both testes and ovaries are present, either in pairs or single. Pseudohermaphrodites have gonads and internal genitalia of one sex while external genitalia of opposite sex.

REPRODUCTIVE SYSTEM (FEMALE)



Female Reproductive System

Components :

- a) Ovaries – two
- b) Uterine tubes – two
- c) Uterus – one
- d) Vagina
- e) Vulva

Accessory sex gland – Mammary glands

OVARIES

These are two oval bodies, one on each side, situated a little above the middle of the pelvic inlet and are attached to the broad ligament by a fold of peritoneum. The size is highly variable from animal to animal. In cow the average length is 2-3 cm; width is 2 cm and thickness is 1 cm. The organ is richly supplied with blood vessels. The attached mesovarial border is considered as the hilus of the ovary.

Structure

This organ exhibits maximum histological variations in various phases of life. A normal mature ovary has the following structures.

Germinal epithelium

It is the external covering of the ovary formed by a single layer of cuboidal cells on a basement membrane. This is actually a modified peritoneum.

Tunica albuginea

This is a thin capsule of collagen fibers encloses the ovary and situated deep to the germinal epithelium.

Ovarian Stroma

It consists of reticular fibers and spindle shaped stromal cells (connective tissue) looks like smooth muscle but have no fibrils in their cytoplasm and are not contractile. The interstitial

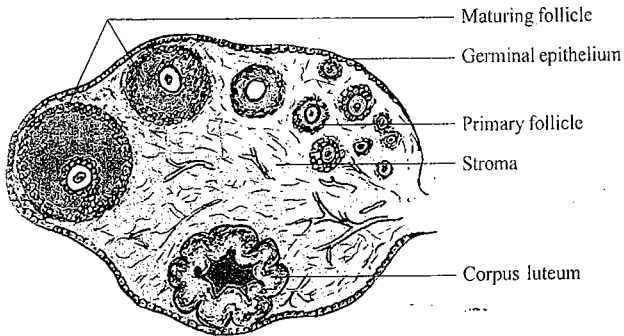


Fig. 5.25a Ovary.

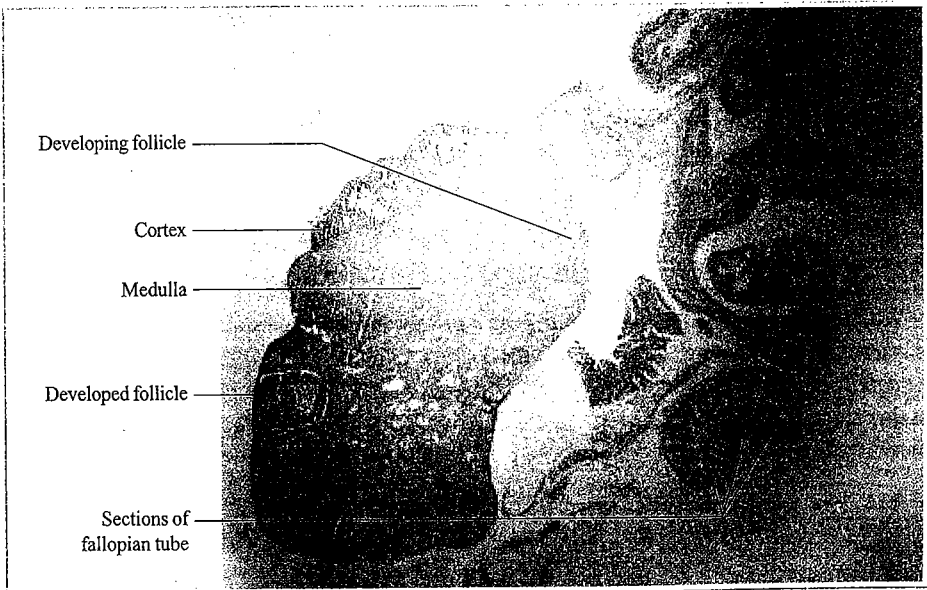


Fig. 5.25b Ovary.

cells are derived from stromal cells. The ovarian tissue is composed of an outer cortex and an inner medulla. The cortex is the outer thicker part situated between tunica albugenia and medulla. It is dense, less vascular and contains a) Stromal cells, b) Ovarian follicles in different stages of development and regression and c) Corpus luteum. However, the cortical tissue is absent at the hilus where medulla is continuous with the tissue of mesovarium. Medulla is placed centrally and at the hilus and composed of loose fibroelastic tissue, plenty of tortuous blood vessels and some scattered smooth muscle fibers.

In mare, the disposition of cortex and medulla is reverse. The medullary tissue is placed out side and cortical components are situated inside. The free surface contains ovulation fossa which is only covered by cuboidal surface epithelium. ***In bitch and she cats,*** the cortical stroma of ovaries contains interstitial gland cells. ***In hens*** numerous follicles of various sizes are attached to a central mass in a loose manner with the help of stalks.

Ovarian Follicles

These are spherical vesicle like structures which are formed and matured in the ovary during the fertile period (puberty to menopause) of females.

Primordial Follicle

The primordial germ cells are differentiated to form oogonia when they reach to the developing ovary by migrating from gut. The oogonia divide mitotically to form primary oocytes which become surrounded by a single layer of epithelial cells, known as primordial follicle. These epithelial cells are flat in shape and are derived from the epithelium which covers the ovary. The epithelial covering may be complete or incomplete. The number of primordial follicles is few lakhs in new born out of which near about one hundred actually reach maturity and others degenerate in cow. Degeneration of primordial follicles mostly occurs in the early part of life.

Primary Follicle

With the beginning of puberty a number of primordial follicles starts developing in each estrous cycle. The surrounding flatten cells become cuboidal and called follicular cells. The ***zona pellucida***, a homogenous transparent membrane is formed around the primary oocyte. At this stage the follicle is called Primary follicle which has a diameter of about 30 to 40 microns.

Secondary Follicle

The follicular cells become multi layered. At the peripheral layer the follicular cells become enveloped by a layer called theca folliculi. Its outer dense fibrous and flat cellular layer is

called *theca externa* and the inner cellular and vascular layer is called *theca interna*. A cavity appears between the follicular cells called antrum. The oocyte is pushed eccentrically. The antrum accommodates a fluid called liquor folliculi.

Graafian Follicle

The secondary follicle undergoes further maturation along with the ovum in it. The diameter of the follicle may be 10 – 15 mm and that of ovum becomes 100 – 150 microns. The

antrum increases with the enhancement of liquor folliculi and thereby the follicular cells are divided into a peripheral part known as

membrana granulosa and an inner layer surrounding ovum called **cumulus oophorus**. Adjacent to the zona pellucida some cells of the cumulus oophorus are arranged in a radiating

manner and called **corona radiata**. The oocyte becomes more eccentric and in one area the membrana granulosa and cumulus oophorus cells are in contact with each other. This area along with the cells is called **discus proligerus**. At this stage first meiotic reduction division takes place with the formation of a large Secondary oocyte and the first polar body. Both the structures remain within the zona pellucida and contain half number of Chromosomes. The cell membrane of this Secondary oocytes is now called **Vitelline membrane**.

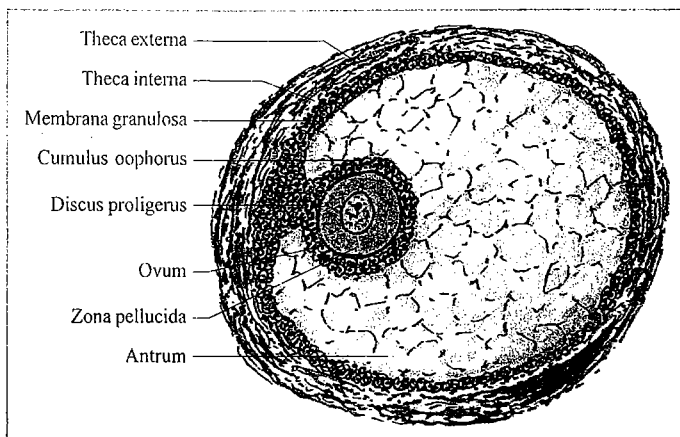


Fig. 5.26 Graafian follicle.

Ovulation

Rupture of mature Graafian follicle and release of ovum in the peritoneal cavity is known as ovulation. The ovum surrounded by cumulus oophorus comes out of the follicle as well as of the ovary at the time of ovulation. Generally ovum is released at a time from alternate ovary which is swallowed by the funnel shaped fimbriated end of the fallopian tube.

Corpus Luteum (C.L.)

After ovulation, the follicular cells re-organize to form a structure with blood known as **Corpora hemorrhagicum**, which in turn develops into a yellow coloured endocrine gland

– the corpus luteum. The membrana granulosa and theca interna becomes folded and theca externa sends connective tissue inwards. The granulosa cells are arranged as a thick in-folded stratified layer around the left-over central cavity. These cells with abundant cytoplasm which contain lipid droplets and yellowish pigments are called **granulosa-lutin cells**. These cells secrete Progesterone. The cells of theca interna are converted to **theca-lutin cells** and secrete Estrogen. This development occurs due to the influence of LH. The theca externa encapsulate the gland. The C.L. will regress if pregnancy does not occur. The lutin cells degenerate and become replaced by fibrous tissue to form corpus albicans. If pregnancy occurs, the C.L. becomes enlarged (2-3 cm in cow) and continues secretion of progesterone during the first half of the pregnancy. It starts degenerating after wards with the production of progesterone by placenta and finally replaced by corpus albicans.

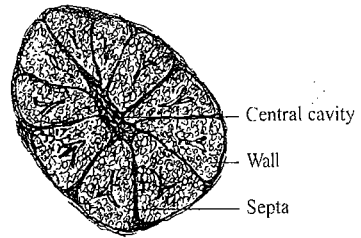


Fig. 5.27 Corpus luteum.

Atretic Follicles

Many of the primordial follicles or growing follicles degenerate and disappear without being matured. This process is known as atresia. At first the ovum degenerates and then the follicular cells follows. The space become replaced by stroma. Atresia mostly occurs in the early part of life and before puberty. Some cells of theca interna of atretic follicles form groups of epitheloid cells in the ovarian stroma, called Interstitial cells which secrete estrogen.

Fallopian tube

All the different parts of the tube – Infundibulum, Ampula, Isthmus and Intramural have a common histological structure.

- a) Outer serous coat – It is loose, thick and continuous with peritoneum and broad ligament.
- b) The muscular coat consists of inner circular and outer longitudinal layers. The inner circular layer is thicker than the longitudinal layer. The muscular coat is thickest at the Isthmus and become gradually thin towards fundibulum.
- c) Inner mucous coat – It is highly variable in structure at different level as well as in different stages of estrus cycle. The lumen of infundibulum and ampulla accommodate large number of folds with primary, secondary and tertiary branching. These folds decrease in height towards isthmus. The lining epithelium is simple columnar type containing both secretory and ciliated cells. In the first half of the cycle cells are taller than those of second half. The number of nonciliated peg-shaped cells increases in

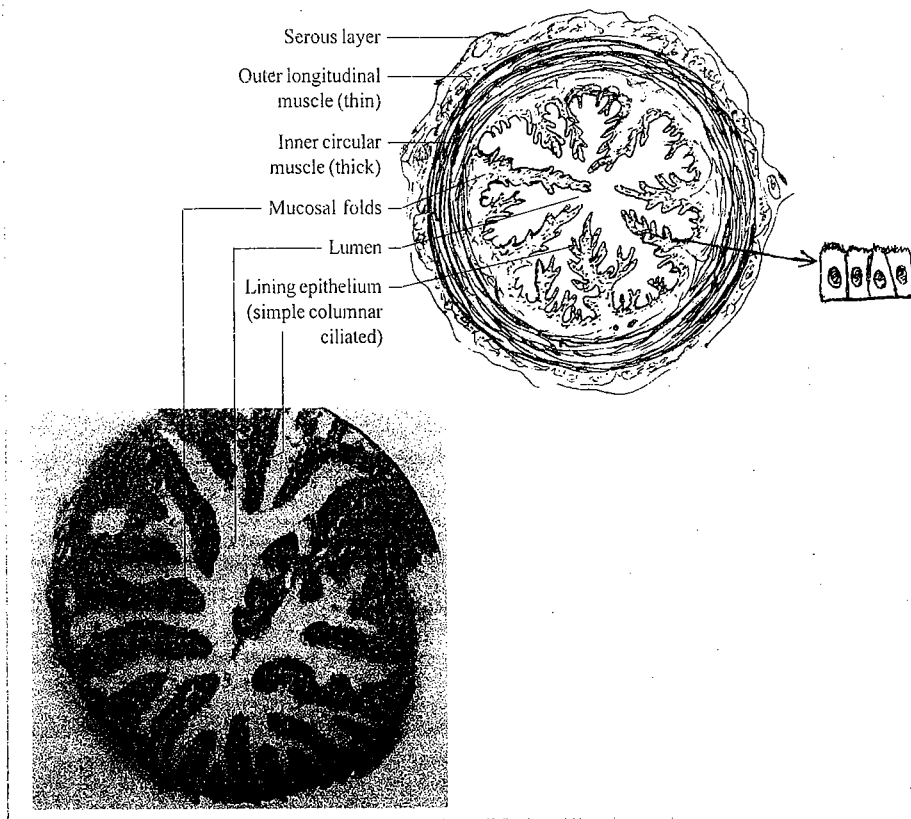


Fig. 5.28 Fallopian tube (transverse section).

the luteal phase of the cycle as well as during pregnancy. The transport of the ovum is facilitated by the beats of the cilia and waves of muscular contraction.

UTERUS

In most of the domestic mammals the body of the uterus is small which is connected bilaterally with capacious horns. One of the two horns accommodates the foetus during pregnancy. The wall of the horn or uterus is composed of three layers – Endometrium, Myometrium and Perimetrium.

Endometrium

The inner mucous coat is lined by simple columnar epithelium in most of the animals. In sow and ruminants it may be pseudostratified columnar epithelium. The superficial layer of



Fig. 5.29 Uterus.

submusoca is composed of loose connective tissue, fibroblasts, macrophages, mast cells along with plenty of blood vessels. The deep layer of submucosa is composed of loose connective tissue and less cellular. Endometrial oedema is found in young ruminants during the time of estrus. The oedema is observed in the form of large irregular tissue spaces which contain intercellular fluid. In between caruncles the endometrium of ruminants contains plenty of simple coiled branched tubular glands. These glands are lined by ciliated and non ciliated simple columnar epithelium.

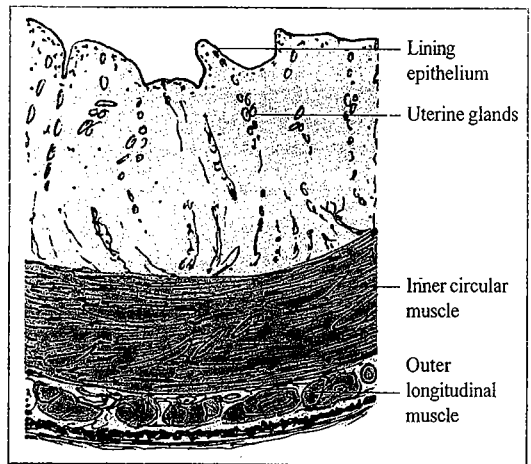


Fig. 5.30 Wall of uterus (transverse section).

The glands are less branched in carnivores and more extensive in mare. In primates the endometrium is composed of three layers. The superficial layer (stratum compactum) and the middle layer (stratum spongiosum) are the functional layers and play active role in menstruation. The deep layer (stratum basale) undergoes little change during cycle. From basal layer the superficial and middle layers regenerate.

Caruncle

These are numerous (about 80) circumscribed thickening of submucous layer of the endometrium in ruminants. The caruncles contains plenty of fibroblast and blood vessel along with other types of cellular components of submucosal layer. The maternal part of placentomes are formed by these caruncles. During pregnancy the bovine placentome become elongated and convex. The stalk contains maternal blood vessels. The surface is occupied by numerous crypts which receive the corresponding chorionic villi.

Myometrium

This middle muscular coat is very thick and composed of bundles of smooth muscles, arranged in a thick inner circular and an outer longitudinal layers. In some places particularly in the body of the uterus, the inner layer contains few oblique fibers. Large arteries, veins and lymph vessels are present within the deep (circular) muscular layer of the body and horns. During pregnancy, these muscle fibers increase in number and size under the influence of oestrogen. In the caruncular areas the vessels are more prominent.

Perimetrium

This thin layer consists of loose connective tissue and continuous with the peritoneum of broad ligament. The broad ligament is composed of (a) the perimetrium, (b) Some longitudinal muscle fibers and blood vessels of myometrium and (c) connective tissue fibers.

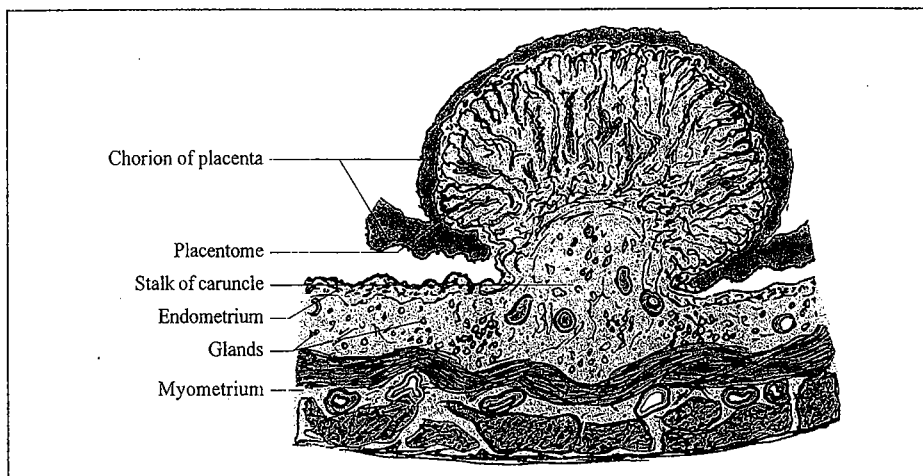


Fig. 5.31 A placentome.

Structural changes those occur during different phages of estrus cycle in cow are given in the table.

	Pro-estrus (2-3 days)	Estrus (One day)	Metestrus (2-3 days)	Diestrus (15 days)	Anestrus
	Period of follicular growth and maturation and development of endometrium	Period of ovulation	Period of C.L. development	Period of luteal phase can be prolonged in pregnancy or pseudo pregnancy	Period of prolonged sexual inactivity
OVARY	Growth of follicles	Maturation of follicles <i>i.e.</i> presence of large follicle (G.F.) or ruptured follicle	Presence of C.L. and immature or atretic follicles	Presence of large C.L. at mid-diestrus	Presence of regressing C.L. and less matured follicles
Endo- metrium	Proliferation of endometrium leads to its thickening	Endometrium become edematous and hyperemia occurs. Mast cells appear in caruncular areas	Uterine glands develop to the greatest extent. Glands become coiled and longer, epithelium is higher	Endometrial stroma and gland regress at the later part. During pregnancy endometrium (deciduas) remain in secretory phase. Epithelial cells become large with granular cytoplasm. Glands elongate. The gravid horn increase enormously along with blood vessels. After parturition all elements return to their normal structure.	

Cervix

It is covered by adventitia for most of the length. Dorsal aspect is covered by serosa. The tunica muscularis, particularly the circular layer is very thick and contains elastic fibers.

The mucosa and sub mucosa form few large circular folds and numerous longitudinal folds, These longitudinal folds are associated with secondary and tertiary folds. Near the junction with the vagina, the epithelium is stratified squamous type. Cranially the cervical canal is lined by simple columnar epithelium. The glands of the cervical wall are mucigenous. These glands are branched, alveolar and lined by simple columnar mucous epithelium and open in the depression between ridges.

Vagina and vestibule

The outer fibrous coat is merged with surrounding connective tissue. The muscular coat is composed of a thick outer longitudinal layer and a inner thin circular layer. At the caudal part of vagina there is a sphincter, made up of skeletal muscle which is not recognisable in most of the domestic mammals. The mucous coat possesses longitudinal folds and lined by stratified squamous epithelium. Glands are mostly absent. However at the cranial part of the vagina in cow the tunica mucosa bears a surface layer of columnar cells and goblet cells. The height of these cells changes during different stages of estrus cycle.

The wall of the vestibule is almost similar to that of vagina. However, some sub-epithelial lymph nodules are present particularly in the wall close to clitoris. The wall also contains bilaterally placed compound tubuloacinar major vestibular mucous glands and some small branched tubular glands. The secretions of these glands provides lubrication to the vestibule. The major glands are homologue to the male bulbourethral gland and somthimes called ***Bartholine's glands***.

Vulva

The labia is covered by skin and possess fine hairs. Plenty of sebaceous glands are present. The hypodermis contains striated muscle the constrictor vulvae, blood and lymph vessels.

The mucous coat possess longitudinal folds and lined by stratified squamous epithelium. Glands are mostly absent.

MAMMARY GLAND

This is a compound tubulo-alveolar gland of ectodermal origin. This gland is a modified sweat gland and of apocrine type. Below the skin the gland is covered by two layers of fascia. The gland substance is covered by a fibro-elastic tissue which also contains smooth muscle fibers. Numerous septa extend from this layer and form interlobular stroma. Plenty of lobules so formed by the branches of septa is composed of a number of alveoli. The alveolar cells vary in their form and contents according to the stages of the activity of the gland. In lactating stage the distended alveoli are lined by single layer of cuboidal to columnar

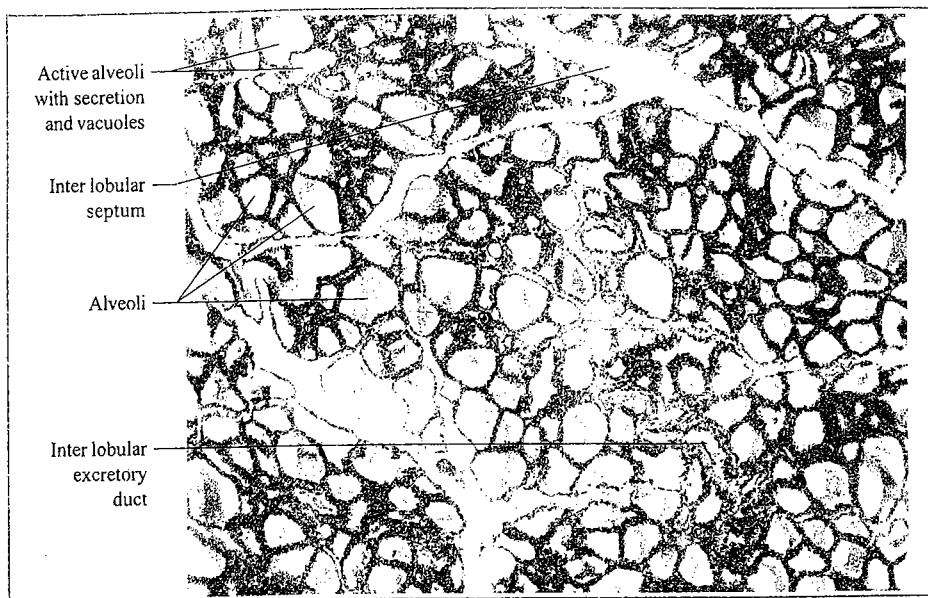


Fig. 5.32 Mammary gland.

cells. The alveoli are large in outline and have an average diameter of 100-200 microns. Myoepithelial cells located between the lining cells and basal lamina help in ejection of milk. The structure of the alveolar ducts is similar to alveoli but the remaining duct system is lined by two layers of cuboidal cells.

The wall of a teat is composed of skin, outer fibrous layer, intermediate muscular layer, inner fibrous layer and mucosa of teat canal. The muosal lining is formed by stratified squamous epithelium. It possesses many longitudinal folds and appear in the form of radiating projections from the lumen in transverse section called **rosette of Furstenberg**. The muscular layer is mostly composed of circular fibers with a thin layer of longitudinal muscle. Surrounding the base of teat there are a number of modified sebaceous glands, which are developed during pregnancy, known as **tubercles of Montgomery**.

DEVELOPMENT OF FEMALE GENITAL ORGANS

OVARY

If the primitive sex cells appear at the cortex of the genital ridge, the medulla regresses. The cortex is converted to ovary and the sex cells, form oogonia. Up to the development of sex-cords the procedure is similar to that of testis. In this case the

sex-cords are broken into small masses. These cells of each such mass surround one primordial germ cell that migrated from the gut to form a primary follicle. The migrated cells become the oocytes of the follicles. The follicular cells and Interstitial gland cells are formed from the mesenchyme.

At birth each ovary contains about 250000 primary follicles. Most of them degenerate before onset of puberty. Only a small number of noncapsulated sex cells remain beneath the germinal epithelium. They undergo maturation successively in each oestrus cycle of reproductive life. The follicular cells are derived from the germinal epithelium. Since this epithelium does not produce any germ cell, the term germinal epithelium is a misnomer.

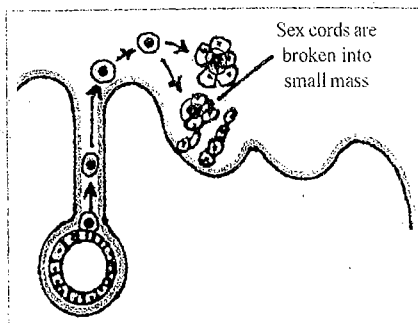


Fig. 5.33

Development of Uterus and uterine tubes

As already described, a pair of Mesonephric (Wolffian) ducts and a pair of paramesonephric (Mullerian) ducts appear as primitive sex ducts. The paramesonephric ducts are formed by the invagination of coelomic epithelium.

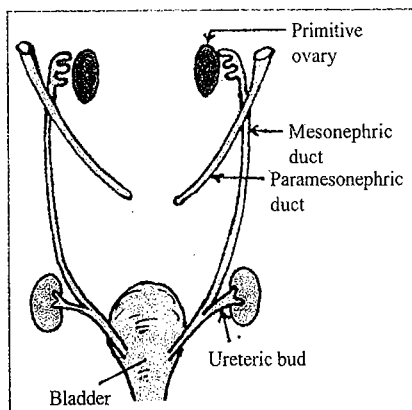


Fig. 5.34

In female the paramesonephric ducts differentiate to form the female sex ducts and the mesonephric ducts degenerate.

At the beginning the paramesonephric ducts are placed lateral to the mesonephric ducts. But later the caudal parts cross the mesonephric duct and come to the medial side. The ducts from either side pass further caudally and come in close contact. Eventually they fuse to form a single duct at the midline. This is called uterovaginal canal. So the cephalic portion of each duct lie lateral to mesonephric duct, the intermediate portion cross

to the medial side and a caudal straight portion runs parallel to the opposite duct and finally fuse with each other. The caudal part comes close to the Urogenital Sinus. The **Oviduct** or the uterine tubes are developed from the cephalic part of the paramesonephric duct. The beginning (original invaginating point) of the tube persists as abdominal ostium of the tube through which it communicates with the coelomic cavity. Therefore the peritoneal cavity in female is an open sac.

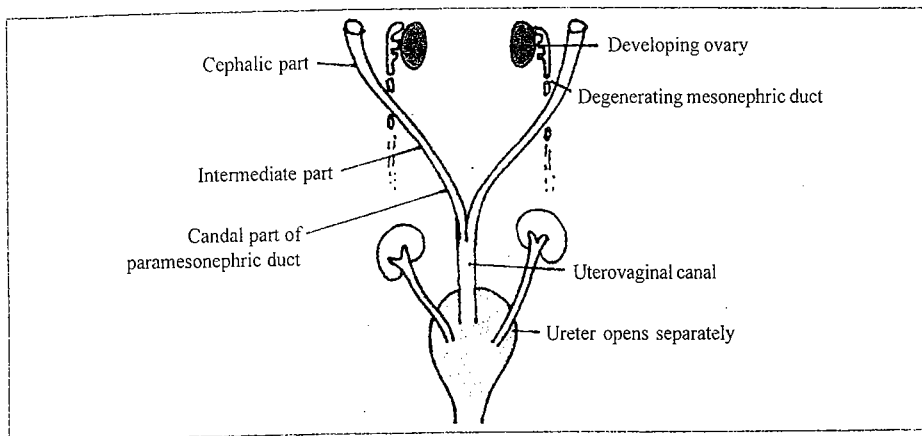


Fig. 5.35

Each **Horn of uterus** is formed from the intermediate part of the paramesonephric duct. The myometrium is developed from the surrounding mesoderm, which gradually increases in thickness. The **Body of the Uterus** is developed from the cranial part of the uterovaginal canal. The **Cervix** is also developed from its middle part.

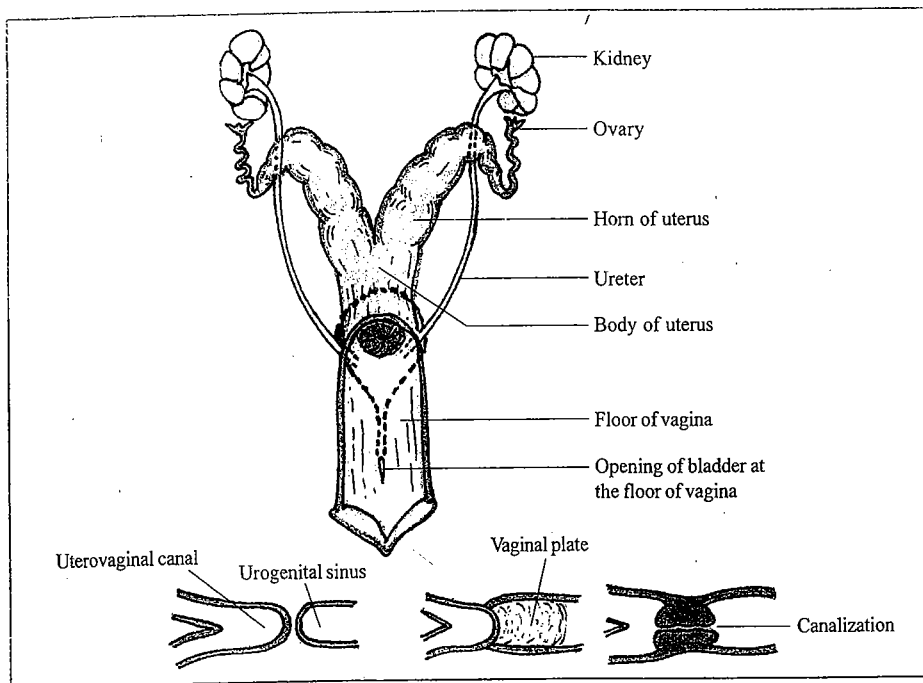


Fig. 5.36

The most part of the **vagina** is developed from the caudal part of the utero-vaginal canal. The caudal part of vagina, and **vestibule** and **vulva** are developed from the uro-genital sinus. The caudal end of the utero-vaginal canal come in close contact with the cranial end of urogenital sinus but are separated by a thick solid plate called vaginal plate. The **vaginal plate** becomes canalized and the lumen is formed. Therefore the vaginal mucosa is derived from endoderm of uro-genital sinus and that of uterus is derived from mesoderm of paramesonephric duct.

Anomalies

Agenesis of ovary.

Duplication of ovaries.

Abnormal descent of ovary.

Imperforate hymen.

Duplication – Failure of fusion of paramesonephric ducts leads to formation double uterus, double cervix and double vaginal canal.

Development of External Genitalia

The uro-rectal septum subdivides the cloaca into a dorsal part – the rectum and a ventral part – the uro-genital sinus. The UGS remains externally covered by the Uro-genital membrane.

The primitive streak remains dorsal to the cloaca. A pair of Genital folds or primitive urethral folds are formed by the accumulation of mesodermal cells which migrated from the primitive streak to both sides of cloacal membrane. These folds are arranged in a longitudinal manner and three other elevations also appear at the same time. They are **right and left genital swellings and a genital tubercle**. The genital swellings appear on either side of the caudal end of UGS and the genital tubercle arises on the midline just below the UGS.

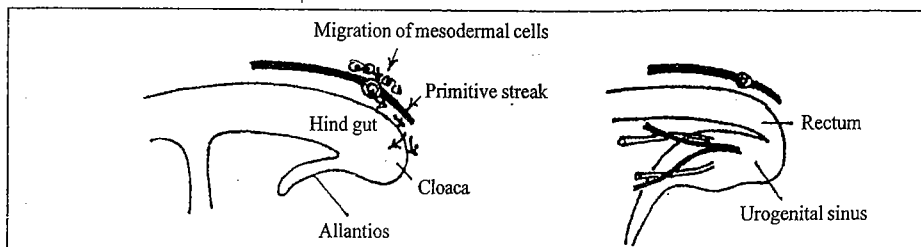


Fig. 5.37

Formation of female external genitalia

- (i) The uro-genital membrane ruptures, and the uro-genital sinus establishes continuity with the exterior to form the **vestibule**. The primitive urethral folds give rise to labia minora. However the labia minora are not developed in cattle.
- (ii) The paired genital swellings elongate on either side to form labia majora. Their dorsal ends fuse to form dorsal commissure and ventral ends fuse to form ventral commissure.
- (iii) The genital tubercle forms the clitoris.

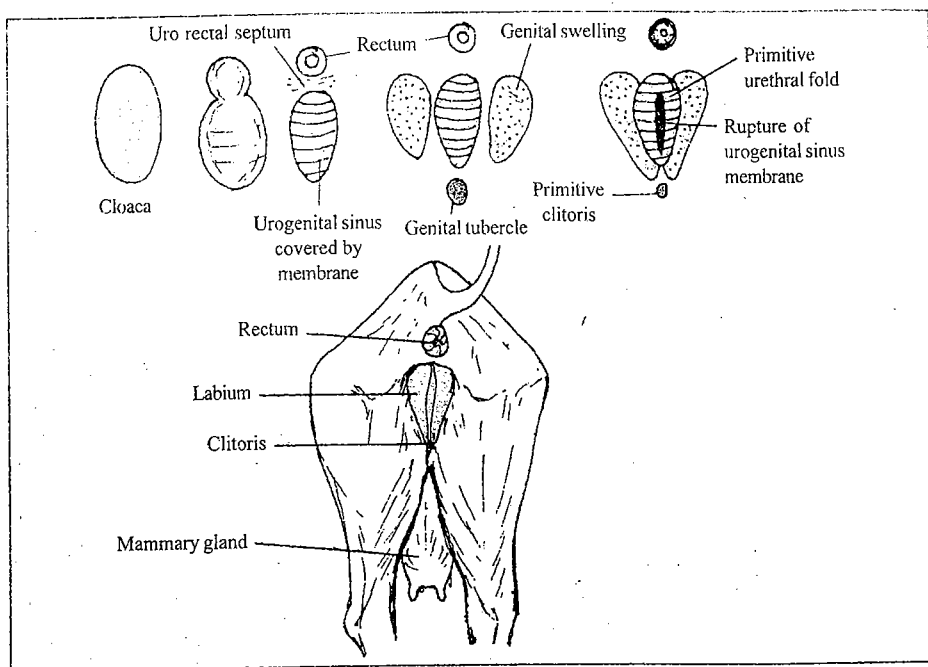


Fig. 5.38 Development of external genitalia of cow.

Mammary gland

They are the modified sweat glands and are ectodermal in origin.

Bilateral mammary ridges appear on each side of the ventral surface of the trunk and extend from pectoral to inguinal region. In some animals (bitch, pig) series of glands develop on these lines. In cow cranial two third of the mammary lines disappear. Ultimately four mammary glands in the inguinal region are developed in cow. Each gland develops separately but get attached at their bases with each other during post-natal development.

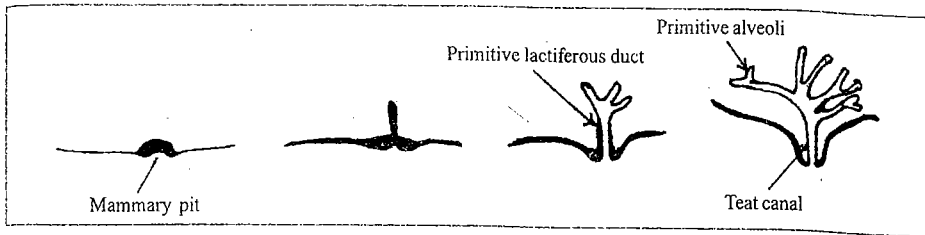
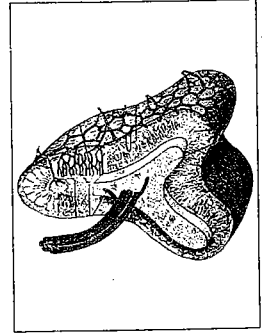


Fig. 5.39

A small area on the inguinal region develops a depression called **mammary pit**. At the mid gestation period an epithelial cord grows inward into the dermis. This solid cord becomes canalized and form primitive **lactiferous duct**. In case of bitch these cords are 10 to 12 in number. The cord goes deep, sub divides further in several orders and the terminal ends become little dilated to form alveoli and ductules. Therefore the alveoli and ductules are **ectodermal** in origin. The branches of this solid cord becomes canalized at the time of birth. At the same time the mammary pit becomes evaginated to form teat. The surrounding area of the teat becomes little prominent due to cell proliferation. In males this condition persists throughout life. In females the glands grow in puberty under the influence of sex hormones. They grow further during pregnancy and lactation. The fibrofatty stroma, septa, capsule, vessels, nerves, lymphatics etc. are developed from the underlying **mesoderm**.

6

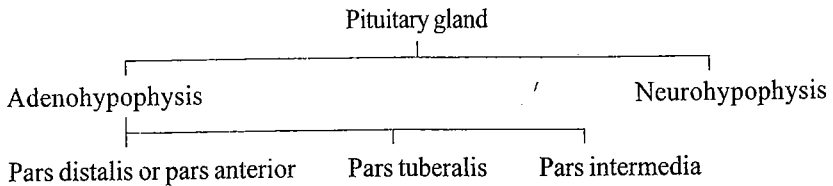
ENDOCRINE GLANDS



PITUITARY GLAND (*Hypophysis cerebri*)

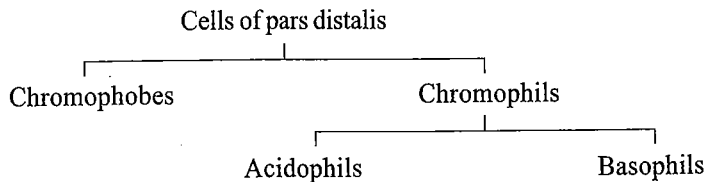
This reddish grey colored pea sized gland is situated in the sella turcica of sphenoid bone and connected to the 3rd ventricle at the base of the brain with a stalk called infundibulum.

It has following parts :



Pars distalis

It is a bulky part and consists of cells arranged in cords or clumps around sinusoids and supported by reticular framework.



Chromophobes are smallest cells. The cytoplasm is agranular and takes light stain. They constitute about 50% of the cell population in pars anterior.

Acidophils are round or ovoid cells with centrally placed nucleus and contain eosinophilic granules in their cytoplasm. They take acid stain and appear pink in H & E preparations. These cells produce (a) growth hormone- STH (Somato trophic hormone) and (b) LTH (Prolactin or Lactogenic hormone).

Basophils are the largest cells in pars distalis. The granules are smaller than those of acidophils and take basic stains. They stain darker with H&E. Basophil cells produce (a) ACTH (Adrenocorticotrophic hormone), TSH (Thyrotrophic hormone), FSH (Follicle stimulating hormone) and LH (Luteinising hormone)/ ICSH (Interstitial cell stimulating hormone)

Pars tuberalis

The parenchyma of pars anterior extended upward around the infundibulum to form pars tuberalis. The cells are cuboidal in shape and arranged in clusters along the columns with elongated capillaries. Function of this part is not known.

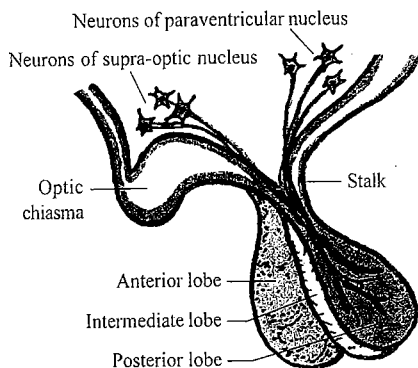


Fig. 6.1 Hypophysis (Pituitary gland).



Fig. 6.2 Pituitary gland (pars anterior) showing different types of pituicytes.

Pars intermedia

This is a small strip of tissue separated from pars anterior by a cleft, the remnant of Rathke's pouch and remains in intimate contact with part nervosa. It contains small basophilic cells of polyhedral shape. They secrete MSH (Melanocyte stimulating hormone).

Pars nervosa

This is the main component of posterior pituitary. The parenchyma of pars nervosa contains pituicytes and non-myelinated nerve fibers. The axons of the cells of supra-optic and paraventricular nuclei of hypothalamus, pass along the pituitary stalk and terminate at the pars nervosa as bulbar expansions. ADH (Anti-diuretic hormone or vasopressin) and oxytocin produced in the cells of those nuclei pass through the axons in the form of secretory granules and stored in the bulbar expansions. These are called **Herring bodies**.

SUPRARENAL (ADRENAL) GLAND

These are paired glands situated close to the cranial ends of the corresponding kidneys. Each gland comprises of an outer cortical part and an inner medullary part. Externally the gland is enclosed by a thick fibro-elastic capsule containing few smooth muscle cells. The reticular connective tissue of the gland is formed from the septa which extend from the capsule.

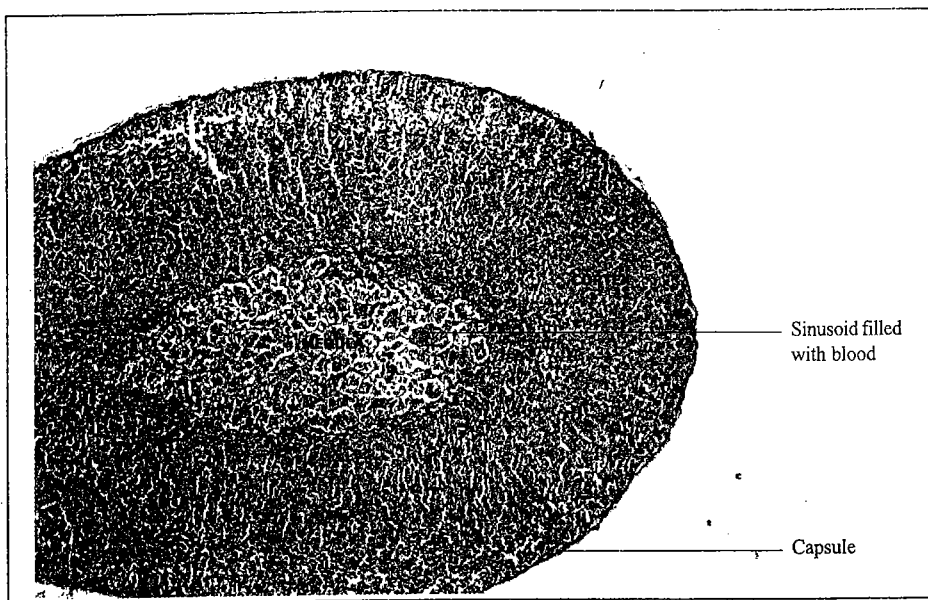


Fig. 6.3 Adrenal gland.

Cortex

It is derived from the mesoderm and comprises of three histological zones –zona glomerulosa, zona fasciculata and zona reticularis.

Zona glomerulosa is the thin outer zone situated below the capsule consists of short columnar cells grouped around capillaries. Each cell contains deeply stained nucleus and basophilic cytoplasm. This zone secretes mineralocorticoid hormones (Aldosterone and deoxycorticosterone). These hormones are responsible for maintaining water and electrolyte balance.

Zona fasciculata is the thick middle zone and composed of one or two cell thick straight type cords of polyhedral cells arranged in parallel rows. Straight blood vessels and connective tissue elements are present in between these columns. This zone secretes glucocorticoids (Cortisone and cortisol) for maintaining protein, fat and carbohydrate metabolism.

Zona reticularis is the inner most zone composed of anastomosing network of cords of polyhedral cells situated around the sinusoids. Both dark staining and light staining cells are present. These cells secrete sex hormones.

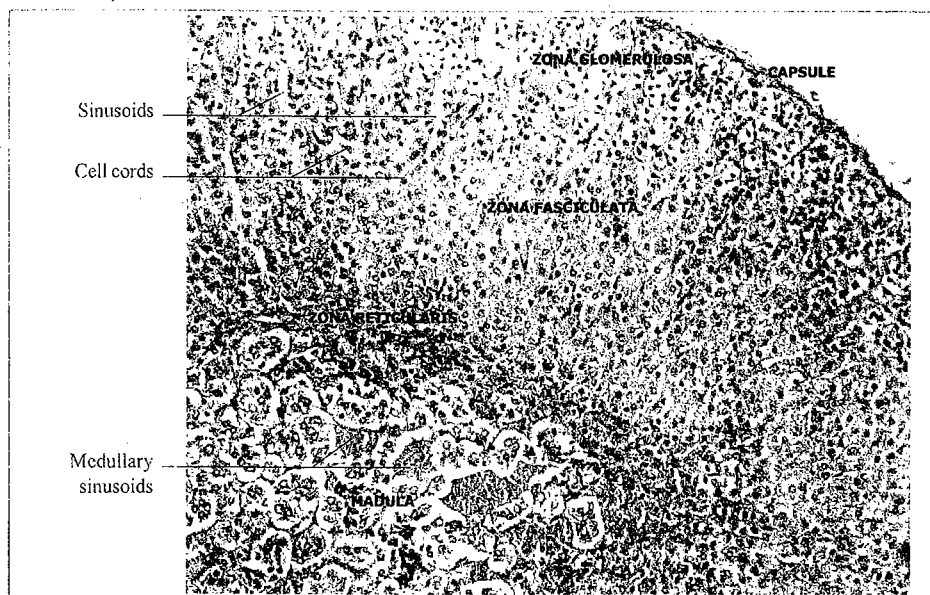


Fig. 6.4 Adrenal gland (higher magnification).

Medulla

Except at the hilum the medulla is surrounded by cortex. It is composed of ovoid cells arranged in groups or in anastomosing cords around wide sinusoids. These cells contain variable amount of secretory granules in their cytoplasm. These cells are also called Chromaffin cells because the granules take yellow brown colour when stained with potassium bi-chromate. This chromaffin reaction is due to oxidation of catecholamine (adrenalin and noradrenalin) present in the granules.

The gland is richly supplied with blood vessels. Numerous fine arterioles originate from the subcapsular capillary plexus and enter the gland through septa. These vessels pass between columns of cells and empty in the sinusoids of zona reticularis or in those of medulla. The prominent suprarenal vein situated close to the center contains muscle fibers in the adventitia along the length. Adrenalin and small amount of noradrenalin is produced by the medulla.

THYROID GLAND

These are two roughly triangular dark brown glands situated at the ventrolateral aspect of the junction of larynx and trachea. Both the lobes are connected ventrally by isthmus which traverses the ventral aspect of the trachea at the level of 2nd ring.

The connective tissue framework is composed of the capsule, septa and interfollicular reticular connective tissue containing numerous blood vessels, nerves and lymphatics. The septa which extend from the capsule divide each gland into a number of lobules each of which contains a large number of follicles.

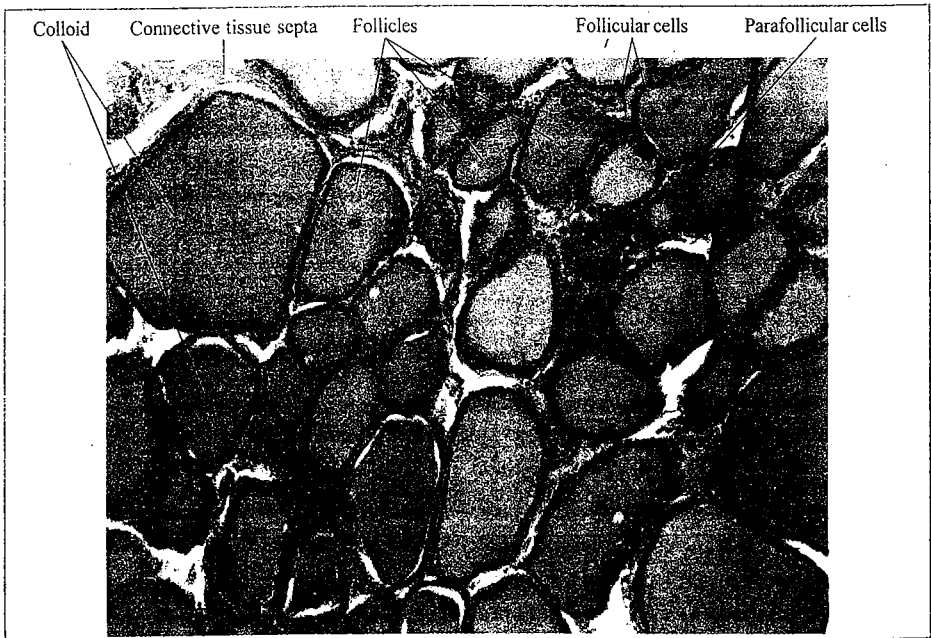


Fig. 6.5 Thyroid gland.

Follicles

There are irregularly spherical or oval structures of varying sizes situated within the thyroid gland and are the structural unit of the gland. Each follicle is composed of a wall formed by simple cuboidal epithelium and the enclosed cavity generally remains filled with gel like substance called **Colloid**. In active stage the epithelial cells become columnar and colloid decrease in quantity. Microvilli and pinocytotic vesicles are present on the luminal ends of these cells. The colloid containing Thyroglobulin rich in iodine. Golgi bodies, mitochondria, lysosomes and fagosomes are well visible under EM.

The gland secretes **thyroid hormone** which is responsible for normal growth and development of the body.

Para-follicular cells or 'C' cells are a second variety of cells remain in scattered form either in single or in clusters. The cells are polyhedral or oval in shape and with acidophilic cytoplasm containing secretory granules. These cells secrete thyrocalcitonin, which maintain blood calcium level of the body.

PARATHYROID GLAND

These are a pair of small glandular mass of yellow brown colour and situated close to the posterior border of each thyroid.

The connective tissue framework is similar to that of thyroid but the lobules do not contain any follicle. The parenchyma is formed by the epithelial cells in the form of cords or clusters, placed around sinusoids. Two types of cells are found in these glands (a) **Chief or principal cells** and (b) **Oxyphil cells**.

The chief cells are more in number. They contain clear cytoplasm and vesicular nucleus. Active cells contain ER and Golgi complex. The inactive cells are rich in glycogen. The chief cells secrete **parathormone** which is responsible for calcium and phosphate metabolism of the body.

The oxyphil cells are large and their cytoplasm contains acidophilic granules. Function of these cells are not known.

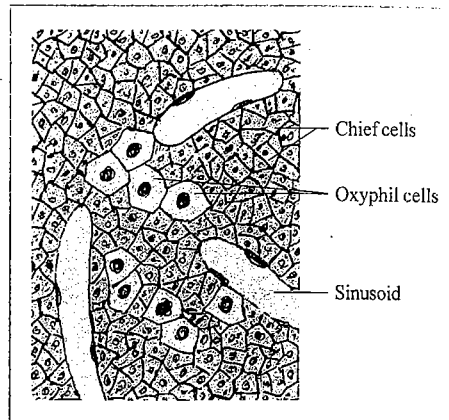
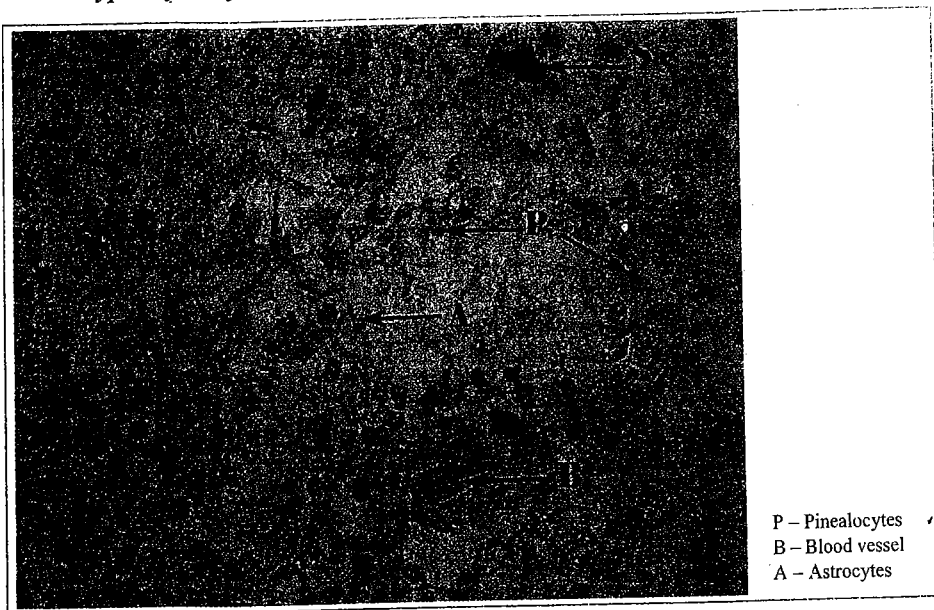


Fig. 6.6 Parathyroid.

PINEAL GLAND (Epiphysis)

This cone or nodule like small body attached to the roof of third ventricle with a stalk. The connective tissue frame work is made up of fibrous capsule derived from

piamater which send septa inside the gland. This invagination leads to the folding of the wall of the diverticulum and appears lobulated in histological sections. This lobular pattern is well marked in birds than that of mammals. The septa are richly vascularised. The main cells are the *pinealocytes* which have large nucleated body and long processes with club shaped ends in contact with blood vessels. Some supporting *neuroglial cells* are also present. A third variety of tall cells which generally lines the lumen of the lobules particularly in birds are called *Ependymocytes*. Sometimes a fourth variety of cells structurally somewhat different from the pinealocytes and ependymocytes are called *Hypendymocytes*.



P – Pinealocytes
B – Blood vessel
A – Astrocytes

Fig. 6.7 Pineal gland.

The brain sand (*corpora arenacea*) are irregular lumps of mineral salts (phosphates and carbonates of calcium and magnesium) are seen within the parenchyma in human. Such brain sands are generally not found in domestic animals and birds. Pineal gland secretes melatonin and serotonin.

DEVELOPMENT OF ENDOCRINE GLANDS

Pituitary gland (*hypophysis cerebri*)

This gland has two origins. (a) the anterior and intermediate part is developed from an upward diverticulum of the stomatodaeum called **Rathke's pouch** which subsequently becomes cut off from stomatodaeum. (b) the posterior part and the stalk of the gland is

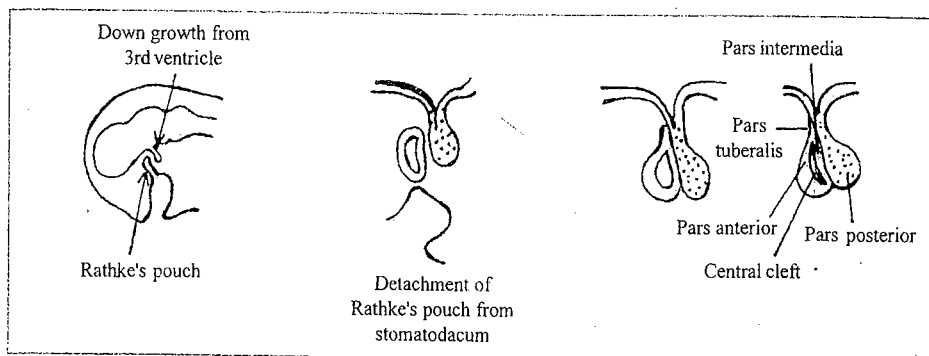


Fig. 6.8

developed from a down growth of the floor of the 3rd ventricle and therefore called **pars Nervosa**.

Pars anterior is formed by the proliferation of the cells of the anterior wall of Rathke's pouch.

Pars intermedia is formed by the posterior wall of the Rathke's pouch without much proliferation. The pouch becomes narrow and remains as a very thin cleft between these two parts.

Pars tuberalis is formed by the upward growth and multiplication of some cells of anterior part.

Pars nervosa, which is developed from the down growth of the 3rd ventricle becomes fused with the (pars intermedia) *i.e.* posterior wall of Rathke's pouch.

The gland is formed within second month of gestation.

Anomalies

1. There may be development of an accessory lobe.
2. Hypoplasia (under development) may occur.

Adrenal gland

The **adrenal medulla** is developed from the cells of neural crest. The cells of the neural crest migrate to the site of the formation of the gland like neurons of sympathetic ganglia. There they become surrounded by the developing cortical cells.

The **adrenal cortex** is formed from the cells of coelomic epithelium at the junction between the developing gonad and its attachment with the primitive mesentery. These proliferative coelomic epithelial cells surround the medulla layer by layer and form the adrenal cortex.

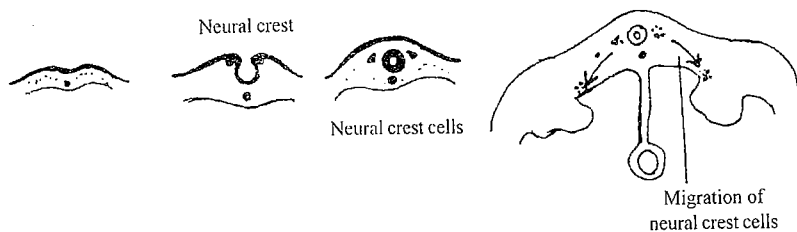


Fig. 6.9

The gland starts developing at about 35th day of intra-uterine life.

Anomalies

1. The whole or part of the gland may be ectopic in development.
2. The gland may be fused with the kidney.
3. Congenital hyperplasia (over development) of cortex may occur. It would lead to early development of sexual characters in male or over development of clitoris in female.

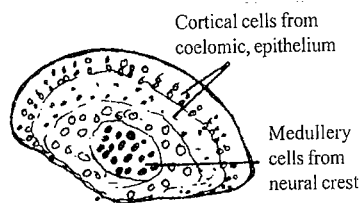


Fig. 6.10

Thyroid gland

Just behind the tuberculum impar a thickening appears in the epithelium of the floor of the pharynx. Soon a depression is formed on the middle of the thickening. This event occurs before fusion of tongue rudiments. Now this depression deepens and forms a diverticulum, which again goes downward and backward to form **thyroglossal duct**. The beginning of the thyroglossal duct which is situated behind the tuberculum impar is now called **foramen caecum**. The duct goes further caudally along the midline, crosses the laryngeal cartilage, reaches ventral to the cranial part of the trachea and bifurcates at its tip. The two lobes of the thyroid gland and the isthmus are developed by the proliferation of this bifid ends.

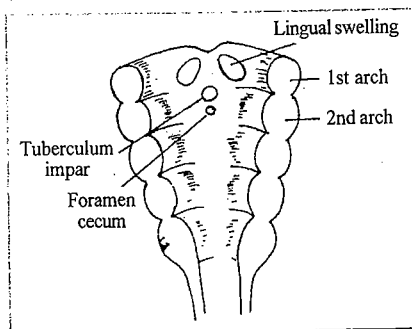


Fig. 6.11

The thyroglossal duct disappears but the beginning of the depression persists as foramen caecum. Before regression this duct proliferates inside the lobes and forms primary follicles. The secondary or definitive follicles are developed by the buddings from the primary follicle.

The para-follicular cells are derived from the caudal part of 4th pouch (**ultimobranchial body**) of the Branchial apparatus.

Anomalies

1. Agensis of thyroid – It may occur due to presence of anti-thyroid antibody in mother. It leads to cretinism.
2. Thyroglossal cyst or fistula – A cyst may occur due to persistence of a part of the thyroglossal duct and its subsequent cystic dilataion. When the cyst breaks through skin, fistula occurs.
3. Lingual thyroid – It develops due to failure of the thyroglossal duct to grow downward and the thyroid gland develops within the tongue.
4. Ectopic thyroid – Small masses of thyroid tissue have been found to be grown in Larynx, trachea, Esophagus, pleara etc.

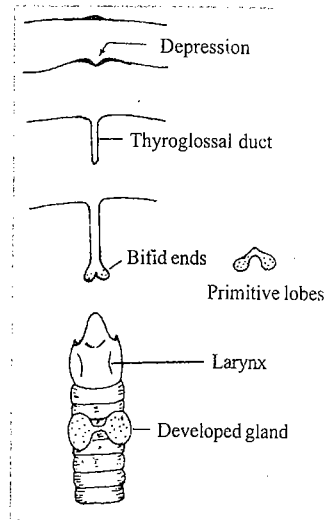
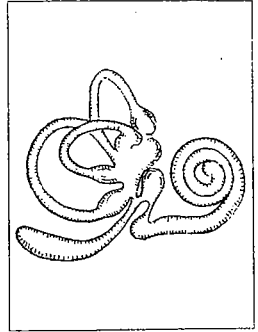


Fig. 6.12

7

ORGANS OF SPECIAL SENSE



EYE

Cornea

This transparent membrane is composed of five layers of cellular elements.

- Corneal epithelium is composed of a thin stratified squamous epithelium which is continuous with bulbar conjunctiva at the periphery.
- Anterior elastic lamina is a thin transparent membrane beneath the epithelium.
- Substantia propria comprises of transparent bundles of collagen fibers and forms the bulk of the structure. Few cells with branched processes are present in this layer.
- Posterior elastic lamina is similar to that of anterior lamina. At the sclerocorneal junction this lamina breaks up into bundles to form pectinate ligament which connects the sclera with the root of iris.
- The mesothelium of anterior chamber is made up of single layer of fat cells attached to the posterior lamina.

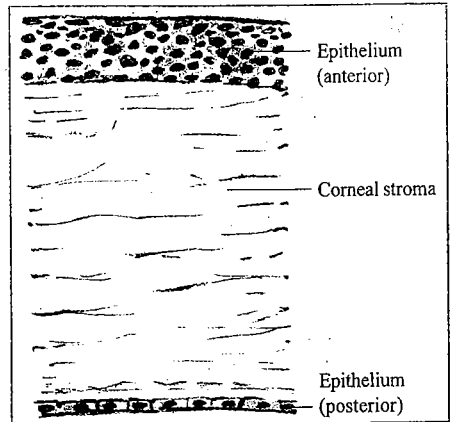


Fig. 7.1 Cornea.

Retina

It is composed of 10 layers of tissue elements out of which 3 layers are of neurons. These layers from outside inwards are as follows :

- Pigment cell layer** – This is the outermost layer and remains in contact with the choroid. It comprises of a single layer of cuboidal cells and each cell is

attached to about 10 rods and cones. This layer reduces scattering of light within the eye ball.

2. **Layer of rods and cones** – The dendrites of the cells of outer nuclear layer have been modified to form the rods and cones. The rods are thin, long and contain rhodopsin. The cones are conical, thick and contain iodopsin. The rods are more in number than cones. The posterior part of the retina contains relatively more cones. In the fovea centralis, the depressed central point on the macula lutea (yellow spot) contains only cones. Optic disc (blind spot) which is situated 3 to 5 mm towards the nasal side does not contain any rod or cone.
3. **External limiting membrane** – It is formed by the processes of the **Muller (glial) cells**.

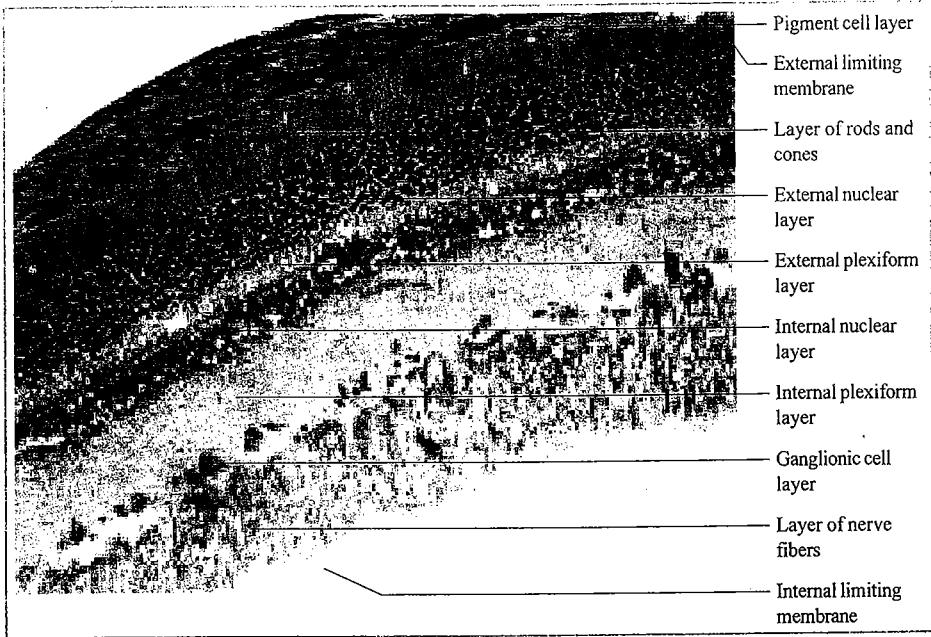


Fig. 7.2 Retina.

4. **External nuclear layer** – It is composed of the cell bodies of rods and cones.
5. **External plexiform layer** – This layer is formed by the synapses between the central processes of the cells of rods and cones and the dendrites of inner nuclear layer.
6. **Internal nuclear layer** – It is composed of cell bodies of bipolar neurons and of modified neuroglial cells.
7. **Internal plexiform layer** – It is also a layer formed by the synapses between the axons of bipolar cells and dendrites of ganglionic neurons.

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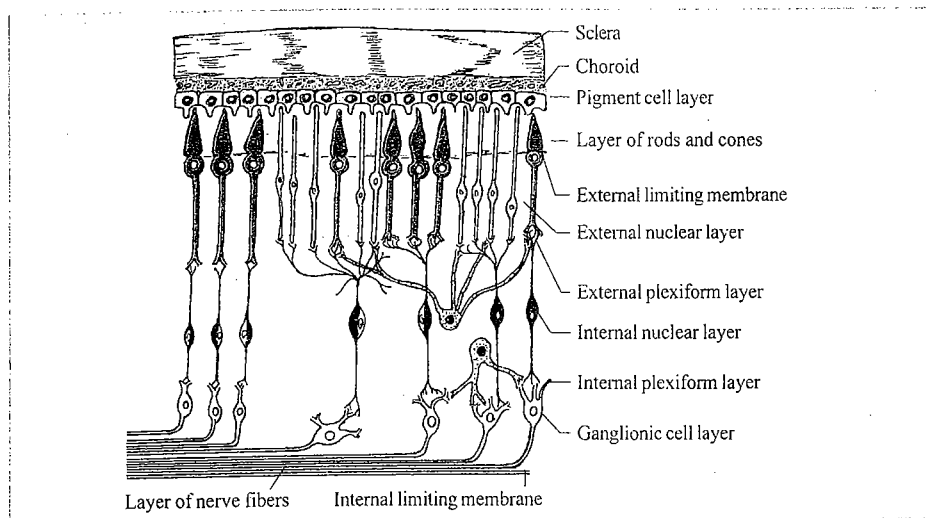


Fig. 7.3 Layers of retina (diagramatic).

(Retina is magnified many times in comparison to sclera and choroid).

8. **Ganglionic cell layer** – It is formed by a single layer of large multipolar neurons. However, at the macula lutea these cells form several layers.
9. **Layers of nerve fibers** – It contains the axons of ganglionic cells which ultimately form optic nerve.
10. **Internal limiting membrane** – This is a homogenous layer formed by the ends of supporting cells.

EAR

Organ of corti

It is composed of : 1) Hair cells, 2) Rods of corti, 3) Supporting cells and 4) Basilar membrane.

Hair cells

These are columnar cells and bear number of hairs (microvilli) on their free surfaces. They are

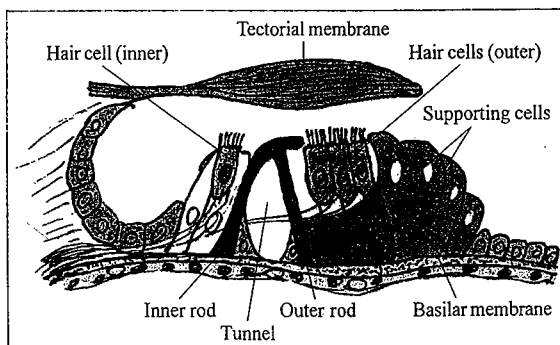


Fig. 7.4 Organ of corti (diagramatic).

arranged in a single row at the inner aspect of the inner rod and in multiple rows of 3 to 4 at the outer aspect of the outer rod. Their bases are attached to the supporting phalangeal cells which in turn are attached to the basilar membrane. The hair cells are innervated by cochlear nerve.

Rods of corti

There is an inner rod and an outer rod. They are widely separated at their bases but meet at their heads in a slanting manner. The bases are attached to the basilar membrane and thereby form the tunnel of corti.

Supporting cells

They are also called **phalangeal cells**. They are attached to the basement membrane and give support to the hair cells. The inner phalangeal cells are situated between the inner pillar and hair cells. Outer phalangeal cells are maintained in position by outer hair cells. **Cells of Hensen** are situated outside the outer phalangeal cells. These Hensen cells gradually become shorter and continuous with the **cells of Claudius** and thereby with epithelial cells which cover remainder of basilar membrane.

Basilar membrane

This membrane extends from the tympanic lip of osseous spiral lamina to the crista basilaris. Its innermost part, zona arcuata is thin and composed of small collagen like filaments. The outer part, called zona pectinata is thick and composed of an upper zone of homogenous layer of compact fibers, lower zone of compact bundles of longitudinal fibers and an intermediate structure containing few cells. The undersurface of the basilar membrane is covered by connective tissue containing blood vessels and some elongated cells.

Tectorial membrane

It extends from the outer border of spiral lamina and overhangs the hair cells. It is composed of delicate fibers embedded in a jelly like substance.

DEVELOPMENT OF EYE AND EAR

EYE

At the early stage and before closure of anterior neuropore two swellings develop bilaterally from the wall of the diencephalon. These swellings are further dilated to form rounded **optic**

vesicles and tubular **optic stalks**. Due to the lateral expansion, the optic vesicles come close to the ectoderm. The nearest ectoderm becomes thickened to form the **lense placode**. At the same time the rounded optic vesicle develops a depression at the lateral wall close to the lense placode. It deepens further to form **optic cup**. The optic cup is therefore has an outer wall and an inner wall. The lense placode invaginates inside the optic cup and forms a vesicle known as **lense vesicle**. Subsequently the lense vesicle

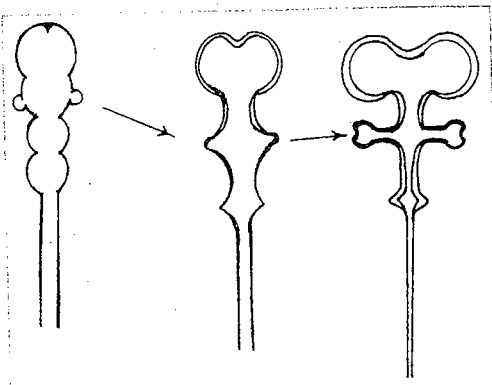


Fig. 7.5 Formation of optic vesicle.

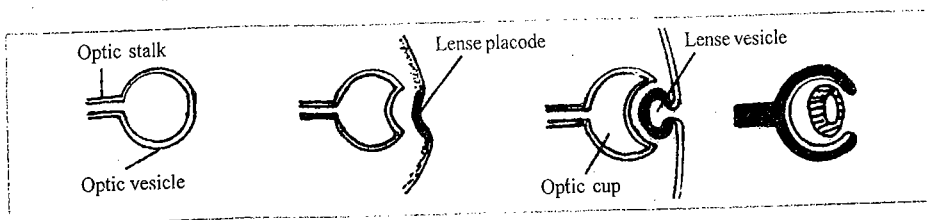


Fig. 7.6

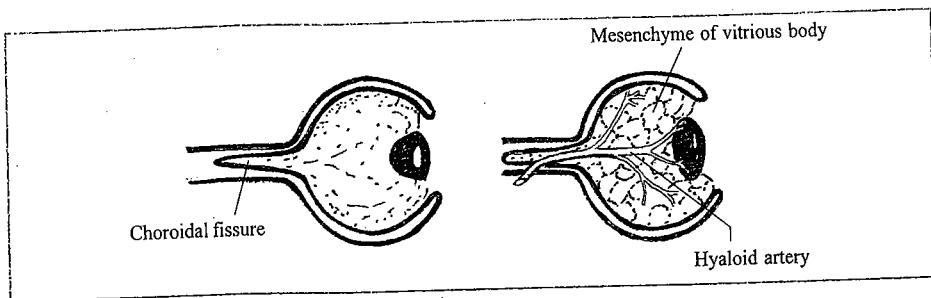


Fig. 7.7

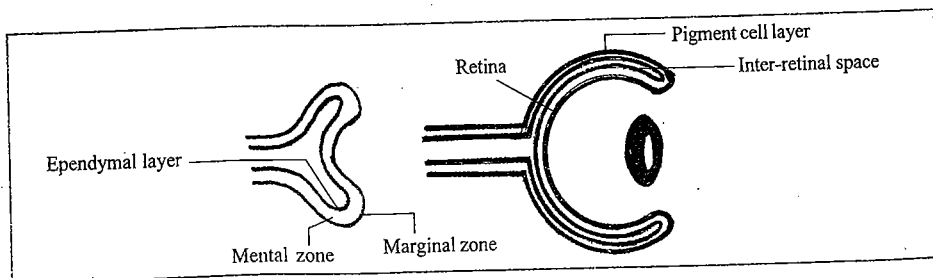


Fig. 7.8

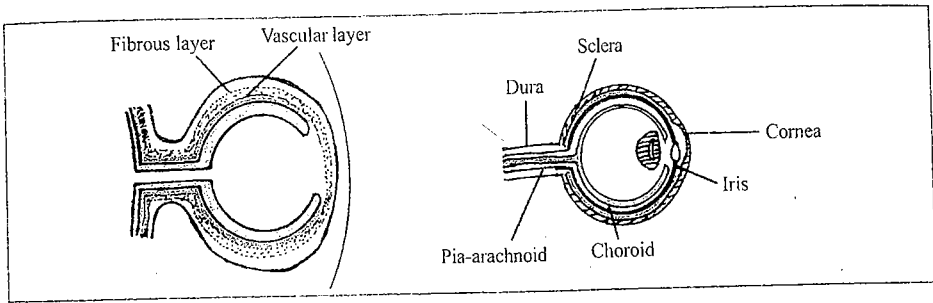


Fig. 7.9

is pinched off and becomes separated from the ectoderm as it goes inside the optic cup. Incidentally the inner wall of the optic cup extends inside further through optic stalk and is called **choroidal/fetal fissure**. Through this choroidal fissure hyaloid artery and mesenchyme of the vitreous body enter into the lumen of the cup, behind the lens. The outer wall of the optic cup gives rise to pigment cell layer of retina. The ependymal layer forms **rods and cones** cells, the mantle layer forms the **neurons and neuroglial cells** and the marginal layer forms **nerve fiber** layer of retina. The space between the outer and inner layer of optic cup i.e. between pigment cell layer and nervous layer is known as **inter-retinal space**. The space is obliterated soon. The surrounding mesenchyme of the developing eye condense to form a fibrous layer outside and a vascular layer inside. The vascular layer forms the **choroids** and correspond to pia-arachnoid matter. This layer extends in front to form **caliary body** and **iris**. However the musculature of the iris is ectodermal (optic cup) in origin. The outer fibrous layer forms the **sclera** and **cornea** and corresponds to duramater.

Formation of lense

The lense vesicle gives rise to lense. This vesicle is lined by a layer of cuboidal epithelium at the beginning. The cells of the posterior wall become elongated gradually and lose their nuclei to form fibers of lense. The cavity of the lense also becomes obliterated by the elongation of posterior layer cells. The cuboidal cells of anterior wall remain unchanged and make an epithelial covering.

The **eye lids** and **conjunctiva** are derived from the ectoderm. The lids are formed by the reduplication of surface ectoderm. The mesenchymal tissue entrapped between this double fold forms the **tarsal plate**. The upper as well as lower lids grow further and fuse with each

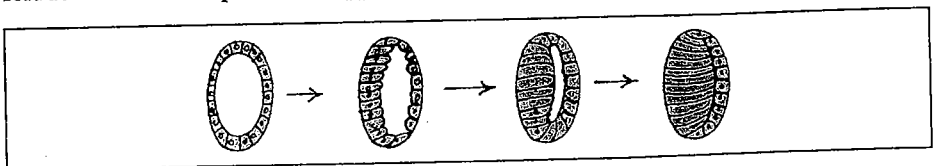


Fig. 7.10 Formation of lense.

other. This fusion continues up to the last part of intra-uterine life and then open again. However in dogs and cats the pups born with fused eyelids. They open in subsequent weeks.

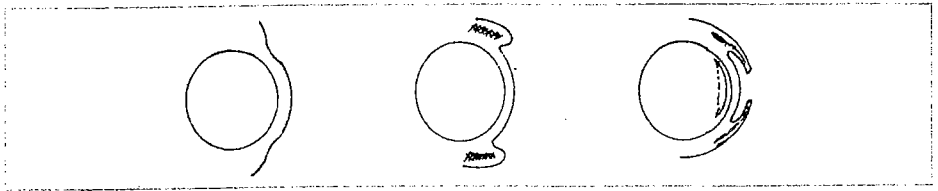


Fig. 7.11 Formation of eye lids.

The **lacrimal gland** develops as an outgrowth in the form of numerous buds from the upper fornix conjunctiva and therefore ectodermal in origin.

Anomalies

- (a) Congenital cataract.
- (b) Congenital cyst formation in any part of lacrimal apparatus.
- (c) Anophthalmos – Entire eyeball fail to develop.
- (d) Cyclopia – Formation of single eye due to fusion of the two.

EAR

The components of the ear are developed as follows :

Internal ear – Develops from ectodermal vesicle.

Middle ear – Develops from endoderm of tubo-tympanic recess of first pharyngeal (branchial) pouch.

External ear – Develops from ectoderm of first branchial cleft.

Internal ear

Two **Otic placode** appears on the surface ectoderm in the form of thickenings on either side of the rhombencephalon. Each placode is transformed to **otic pit** when it is depressed at the middle. The pit deepens further into underlying mesenchyme, form vesicle and gets detached from the surface ectoderm. This vesicle is called **otic vesicle** or **otocyst**.

Formation of membranous labyrinth

It is developed from the otic vesicle. The otic vesicle is oval in shape at the first stage. **Ductus endolymphaticus** develops as an outgrowth from the medial wall of the otic vesicle.

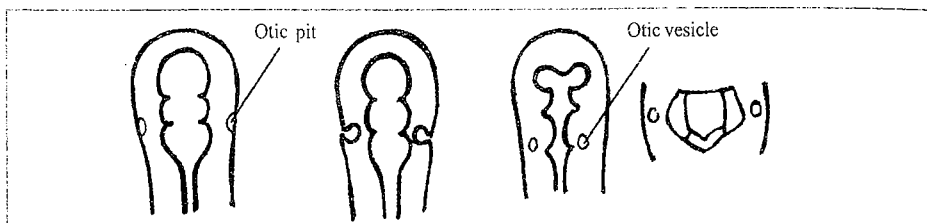


Fig. 7.12

At this stage it divides into an upper part and a lower part which form **utricle** and **Sacculle**. **Semicircular canals** are developed by the outgrowths from the dorsal aspect of utricle. The **cochlear duct** arises from the ventral part of saccule and extends spirally (2.5 turn)

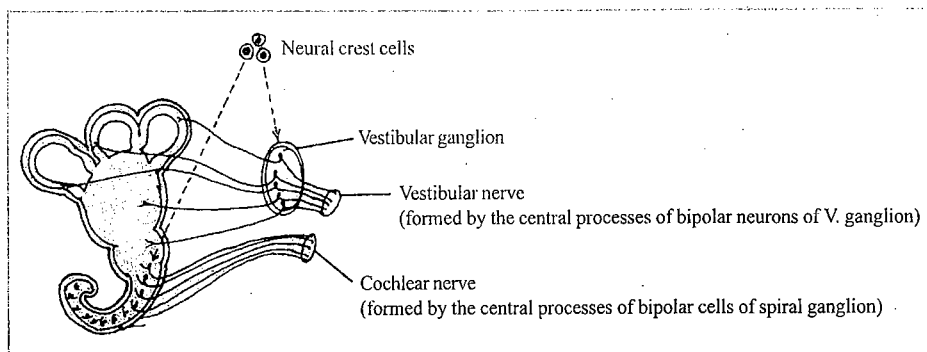


Fig. 7.13

around an ossified mesenchyme – the primitive **modulus**. Some specialized areas of membranous labyrinth undergo differentiation to form **organ of Corti**.

The cells of the neural crest along with some neuroepithelial cells of otic vesicle form the bipolar neurons of vestibular ganglion and spiral ganglion.

Formation of bony Labyrinth

The surrounding mesenchyme of otic vesicle at first condenses to form an **otic capsule**. The capsular tissue is converted to cartilage. It takes the shape of the developing membranous labyrinth. The mesenchyme between membranous labyrinth and cartilaginous capsule disappears to form **semicircular canals** and **vestibule**. In the cochlear duct area two perilymphatic spaces are developed along the length of the cochlear duct, one on either side – the **scala tympani** and **scala vestibule**. The scala tympani extends towards the tympanic cavity and the scala vestibule communicates with the vestibular cavity. The cartilaginous labyrinth subsequently becomes ossified to form **bony labyrinth**.

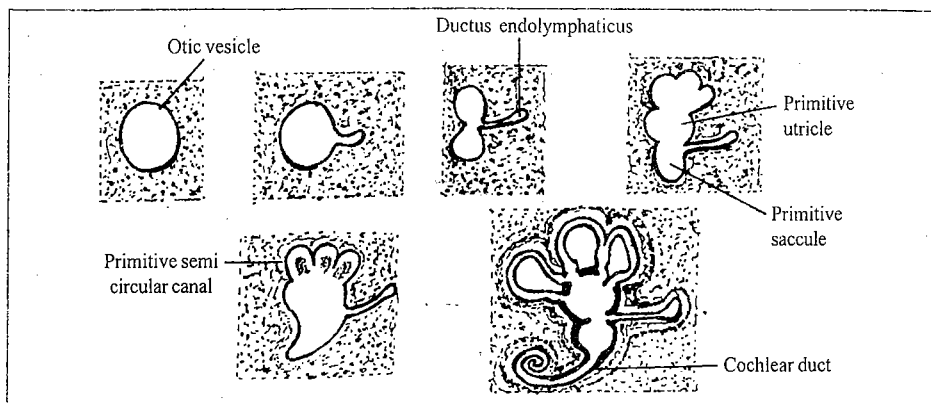


Fig. 7.14

Middle ear

The tubotympanic recess is developed by the outward extension of the first and part of second pharyngeal pouches. The first part of the recess forms the **auditory tube** and the second part dilates to form **tympanic (middle ear) cavity**. The **malleus** and **incus** are derived from the cartilage (Meckel's cartilage) of first pharyngeal arch and the **stapes** is formed by the cartilage of second pharyngeal arch. These bones invaginate the mucous membrane and remain covered by it. The muscles – **Tensor tympani** and **stapedius** are derived from mesoderm of first and second pharyngeal arches respectively.

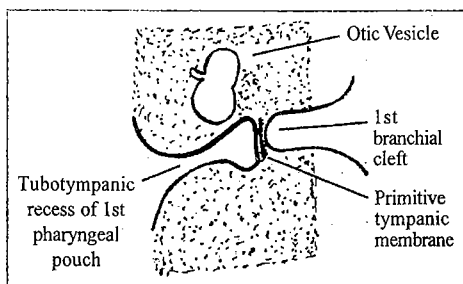


Fig. 7.15

External ear

The first branchial cleft gives rise to external acoustic meatus. At first the deep part of the cleft gets plugged by proliferation of ectodermal cells. This plug is known as **meatal plate**. At the latter part of intrauterine life these cells degenerate and become canalized to establish external acoustic meatus.

The **tympanic membrane** is formed at the bottom of the first branchial cleft apposed with tympanic cavity and with the adjoining mesodermal tissue. So the outer cuticular layer is derived from the ectoderm of the branchial cleft, Inner mucous layer is formed from the endoderm of tympanic cavity and the middle fibrous layer is formed from the surrounding mesoderm. The **auricle** (pinna) is developed from few mesodermal thickenings known as

tubercles or hillocks. They appear on the first and second pharyngeal arch around the opening of external acoustic meatus.

Anomalies

1. Malformation of auriculum may occur due to incomplete fusion of hillocks.
2. Congenital fistula of the external ear.
3. Stenosis of external auditory meatus.
4. Malformation of ossicles.
5. Malformation of internal ear, leading to congenital deafness.

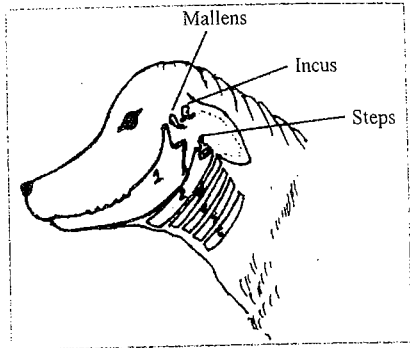
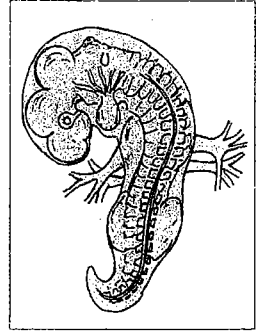


Fig. 7.16

8

EARLY DEVELOPMENT IN THE CHICK EMBRYO



In the birds the whole of the pre-natal development takes place within the egg shell and outside the body of the mother. Therefore instead of gestation period, this period is called incubation period. Since the fundamental process of the development and differentiation of organ systems are same and they occur in quick succession due to very short period of development (incubation), the various sequences of embryological changes occur in different schedule. A brief synopsis of the said schedule which occurs in chick embryo is presented below.

Hours of incubation	Development observed
12 hours	Primitive streak appears.
18 hours	Formation of notochord and neural plate is marked.
22 hours	Neural groove is formed and somites start their appearance.
24 hours	Demarcation of head become prominent. 3 pairs of somites appear.
28 hours	Closure of neural tube starts from cephalic end. 3 primary brain vesicles are distinguished. 8 pair of somites appear.
30 hours	Extra embryonic vascular area (area vasculosa) could be detected. Gut is recognized and foregut lengthens. Primitive heart tube appears.
33 hours	Optic vesicles appear. 12 pairs of somites are formed.
35 hours	Auditory placodes are seen.
38 hours	Five characteristic regions of brain can be distinguished. Extra-embryonic blood vessels are observed. Formation of fundamental regions of heart occurs.
40 to 50 hours	Flexion and torsion of the longitudinal axis of the body takes place. Circulation of blood starts. Pronephric tubules appear.

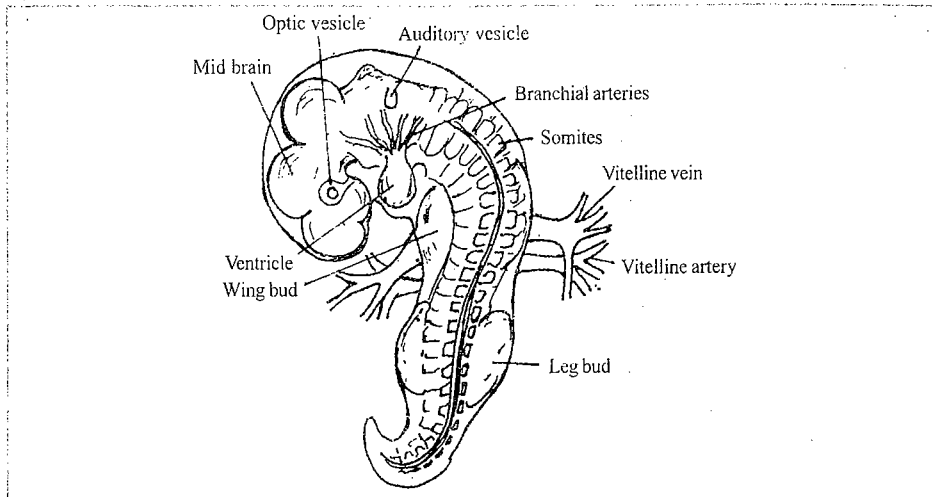


Fig. 8.1 Chick embryo. 70 hours of incubation (34 somite stage).

Hours of incubation	Development observed
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55 hours	Folding of head is marked. Cranial flexure is well visible. Growth in the telencephalic region takes place. Epiphysis, diencephalic diverticulum, Rethke's pouch appear. Fore gut became extended. Stomatodaum is seen. Branchial apparatus is formed. U shaped heart tube form a loop. Differentiation of somites starts. Hepatic primordium is recognized.
72 hours	Development of cranial and cervical flexure takes place. Appendage buds appear. Brain develops further. Ganglia of cranial nerves are formed from the cells of neural crest. Most of the structures of the eye are recognized. Auditory vesicles appear. Olfactory organs appear in the form of two depressions. Oral opening is established. Pharyngeal derivites start formation. Laryngo-trachial groove deepens and lung buds appear. Liver gets a considerable form. Pancreatic buds become prominent. Embryonic circulation begins. Aortic archs, sinus venosus, atria, ventricles are recognized.

Alimentary system

The tongue primordium appears on 4th day of incubations. Branchial apparatus appears on the 3rd to 4th day. Primordia of esophagus, stomach (glandular and muscular), mid gut and hind gut appear within 4th day of incubation. Primordia of liver and pancreas appear on 2nd to 3rd day. Allantoic diverticulum arises on 3rd day from the hind gut.

Respiratory system

Laryngotracheal groove appears on 3rd day of incubation. Lung buds arise on 4th day. Extension and branching of these buds occur during the first week of incubation. Air sacs are formed during the second week.

Uro-genital system

Pronephric tubules appear on second day of incubation and start degenerating on 4th day. Mesonephros appears subsequently and starts degeneration on 11 th day. Ureteric buds appear on 14th day and the Metanephric kidney starts developing soon. With the degeneration of mesonephros the metanephros starts functioning.

No urinary bladder is formed and the cloaca divides into three regions and the urodeum receives the urogenital ducts.

The gonads develop after 7th day of incubation.

In male Wolffian ducts from the vas deferens and the Mullerian ducts degenerate.

In female right Mullerian duct degenerates and the left duct form the oviduct.
The right ovary degenerates after formation and the left ovary grow larger.

Extra embryonic membranes in birds

The extra embryonic membranes in birds are as follows :

1. Yolk
2. Amnion
3. Serosa
4. Allantois

Yolk sac

In the chick the gut first appears between the cellular roof of the yolk sac and the yolk itself. The splanchnopleur extends and makes an investment over the yolk. As the development progresses the gut is formed by the wall of yolk sac. The neck of the yolk sac becomes

constricted, vitelline (omphalo mesenteric) arteries and veins are developed. With the formation of stalk of the yolk sac this stored food materials of the embryo becomes suspended from the mid-gut. But at the terminal part of incubation period (19th, 20th day) the yolk sac becomes enclosed within body wall of the embryo and finally the yolk is absorbed and the remains of the yolk sac is pinched off after hatching.

Amnion

The ectoderm and the extra embryonic somatopleur make folding from either sides of the embryo. Subsequently these folds develop further and fuse together. Thus the amniotic cavity is formed and filled with amniotic fluid.

Serosa

Actually the inner layer of the amniotic folds fuse to form the amniotic cavity and the outer layer forms the serosa. The extra embryonic coelom is developed between the serosa and amnion.

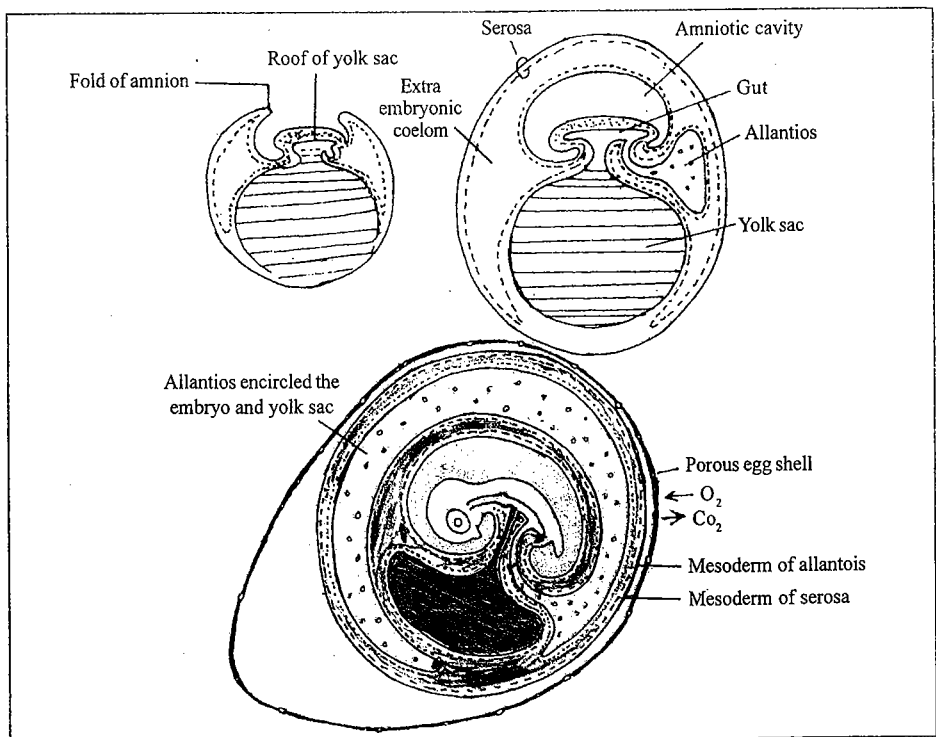


Fig. 8.2 Extra embryonic membranes in chick.

Allantois

It appears on 3rd day as a diverticulum. It comes out and grow fast up to 10 day of incubation and becomes extended within the sero amniotic cavity (extra embryonic coelom) and thereby surrounds the embryo as well as yolk sac. The mesoderm of allantois comes in contact with the mesoderm of serosa. Blood vessels appear in this junction and the allantois now serves the purpose of exchanging oxygen and carbon dioxide between the embryo and the exterior due to its close contact with the porous shell of the egg.

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