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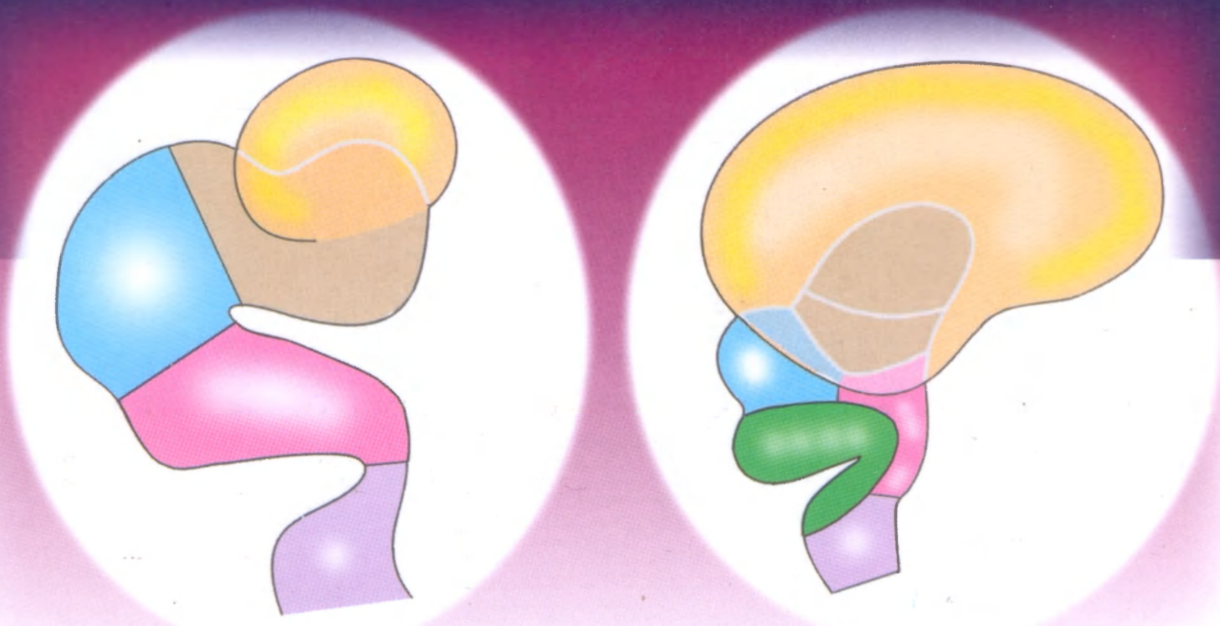
HUMAN EMBRYOLOGY

TENTH EDITION



Inderbir Singh

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TENTH EDITION

INDERBIR SINGH

JAYPEE

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Preface to the Tenth Edition

The publication of the tenth edition of this book takes place at a historic juncture.

The book, first published in 1976, went through nine editions under the patronage of "MACMILLAN" (under different names). For reasons best known to them this publisher decided to stop publication of the book in 2013. I am grateful to them for giving this book the status of a classic of medical publishing in India.

Through an agreement between Macmillan Publishers India Ltd and Jaypee Brothers, Medical Publishers Pvt. Ltd, the book has been taken over by the latter. That is how it happens that the tenth edition of the book appears under the banner of JAYPEE BROTHERS, Medical Publishers Pvt. Ltd.

The change of publisher does not mean any dilution of the standards either of content or of production values. I am sure that the enthusiasm and drive of the new publisher will carry the book to much greater heights than before, and that the book will remain a household word for generations to come.

Because of my long association with Mr. J.P. Vij (Group Chairman), I have full confidence in him. Mr. Ankit Vij (Managing Director) brings fresh ideas and a great deal of vigour and enthusiasm to the venture. I am grateful to them for all their help and support. I am much obliged to Dr Sakshi Arora (Chief Development Editor) for highly meticulous editing of the text and for improving the book in various other ways.

Dr. G.P. Pal has been associated with the book for a few editions till the ninth. He has made useful contributions and brought new vigour to the book and I thank him.

I am grateful to the very large body of teachers and students who have given me invaluable moral support and encouragement. This book could not have been what it is without their blessings.

I must end this preface on a personal note. I will soon enter my eighty fifth year and I certainly do not hope to produce another edition of any book. My overall experience of many years of book writing has been one of great satisfaction and happiness. The happiness has come from the respect, bordering on devotion, that students have showered on me. I look on them as a very big family of children and grand children. My blessings to each one of them.

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Inderbir Singh

Preface to the First Edition

This book on human embryology has been written keeping in mind the requirements of undergraduate medical students. The subject of embryology has traditionally been studied from imported textbooks of anatomy or of embryology. Experience has shown that the treatment of the subject in most of these books is way above the head of the average medical student in India. The difficulty has increased from year to year as there has been, and continues to be, progressive deterioration in the standards of the teaching of English in our schools and colleges. The combination of unfamiliar sophistications of language and of an involved technical subject, has very often left the student bewildered.

In this book care has been taken to ensure that the text provides all the information necessary for an intelligent understanding of the essential features of the development of various organs and tissues of the human body. At the same time, several innovations have been used to make the subject easy to understand.

Firstly, the language has been kept simple. Care has been taken not to compress too many facts into an involved sentence. New words are clearly explained.

Secondly, simultaneous references to the development of more than one structure have been avoided as far as possible. While this has necessitated some repetition, it is hoped that this has removed one of the greatest factors leading to confusion in the study of this subject.

Thirdly, almost every step in development has been shown in a simple, easy to understand, illustration. To avoid confusion, only structures relevant to the discussion are shown. As far as possible, the drawings have been oriented as in adult anatomy to facilitate comprehension.

Fourthly, the chapters have been arranged so that all structures referred to at a particular stage have already been adequately introduced.

In an effort of this kind it is inevitable that some errors of omission, and of commission, are liable to creep in. To obviate as many of these as possible a number of eminent anatomists were requested to read through the text. Their suggestions have greatly added to the accuracy and usefulness of this book. Nevertheless, scope for further improvement remains, and the author would welcome suggestions to this end both from teachers and from students.

Rohtak
January 1976

INDERBIR SINGH

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Chapter 1

Some Preliminary Considerations

HIGHLIGHTS

- Embryology is the study of the development of an individual before birth.
- During the first two months we call the developing individual an ***embryo***. After that we call it a ***fetus***.
- The ***testis*** is the male sex organ or male gonad. The ***ovary*** is the female sex organ or gonad. They produce ***gametes***.
- Male gametes produced by the testis are called ***spermatozoa***. The process is called ***spermatogenesis***.
- Female gametes produced by the ovary are called ***ova***. The process is called ***oogenesis***. Spermatogenesis and oogenesis are together called ***gametogenesis***.
- ***Fertilization*** takes place when one spermatozoon enters an ovum. The fused ovum and sperm form the ***zygote***.
- Characters of parents are transmitted to offspring through codes borne on strands of DNA. ***Genes*** are made of such strands of DNA. They are located on ***chromosomes***.
- A typical cell contains 46 chromosomes (= ***diploid number***).
- A gamete contains 23 chromosomes (= ***haploid number***).
- The diploid number of chromosomes is restored as a result of fertilization.
- Multiplication of cells takes place by cell division. The usual method of cell division, seen in most tissues, is called ***mitosis.*** Daughter cells resulting from a mitotic division are similar to the parent cell, and have the same number of chromosomes (46).
- A special kind of cell division takes place in the testis and ovary for formation of gametes. It is called ***meiosis***. The gametes resulting from meiosis have the haploid number of chromosomes (23). The various gametes formed do not have the same genetic content.

Chapter 2

Spermatogenesis and Oogenesis

HIGHLIGHTS

- A ***spermatozoon*** has a head, a neck, a middle piece and a principal piece or tail (Fig. 2.1).
- ***Stages of spermatogenesis*** are summarized in Fig. 2.5.
- Spermatozoa are derived from rounded ***spermatids***. The process of conversion of a spermatid to a spermatozoon is called ***spermiogenesis*** (Fig. 2.6).
- ***Stages of oogenesis*** are summarized in Fig. 2.8.
- An ***ovarian follicle*** is a rounded structure that contains a developing ovum surrounded by follicular cells. The follicle has a cavity filled with fluid (Fig. 2.12).
- Ovarian follicles have a cellular covering called the ***theca interna.*** The cells of the theca interna produce oestrogens (Fig. 2.13).
- The follicle gradually increases in size and finally bursts and expels the ovum. This process of shedding of the ovum is called ***ovulation***.
- The ***corpus luteum*** is formed by enlargement and transformation of follicular cells, after-shedding of the ovum (Fig. 2.16). The corpus luteum secretes progesterone, which is essential for maintenance of pregnancy.

Chapter 3

The Menstrual Cycle

HIGHLIGHTS

- The term ***menstrual cycle*** is applied to cyclical changes that occur in the endometrium every month. The most obvious feature is a monthly flow of blood (***menstruation***).
- The menstrual cycle is divided into the following phases: ***postmenstrual***, ***proliferative***, ***secretory***, ***menstrual*** (Fig. 3.3).
- The menstrual cycle is also divided into the ***follicular phase*** (in which changes are produced mainly by oestrogens), and the ***luteal phase*** (in which effects of progesterone predominate). Both phases are of roughly equal duration.
- The main changes in the endometrium are (a) increase in thickness, (b) growth of uterine glands, (c) changes in epithelial cells lining the glands and (d) increase in thickness and fluid content of the endometrial stroma (Figs. 3.4, 3.5).
- Just before onset of menstruation, the blood supply to superficial parts of the endometrium is cut off (Fig. 3.6). This part is shed off and there is bleeding.
- The menstrual cycle is influenced by oestrogens, by progesterone, by the follicle stimulating hormone (FSH) and by the Luteinizing hormone (LH).

Chapter 4

Formation of Germ Layers

Highlights

- Fertilization of the ovum takes place in the ampulla of the uterine. The fertilized ovum is a large cell. It undergoes a series of divisions (clevage).
- When there are 16 cells the ovum is called a morula. It has an inner cell mass covered by an outer layer of cells, the trophoblast.
- Fluid partially separates the inner cell mass from trophoblast. The morula now becomes a blastocyst.
- The cells of the inner cell mass multipy, and are rearranged to form an ***embryonic disc*** having two layers. These layers are the ***epiblast*** and the ***hypoblast***. Later, the epiblast differentiates into three germ layers, the ***ectoderm*** (outer), the ***endoderm*** (inner), the ***mesoderm*** (middle). Cells of the hypoblast become flattened and line the yolk sac.
- A cavity appears on the ectodermal side of the disc. This is the ***amniotic cavity***. Another cavity appears on the endodermal side. This is the ***yolk sac***.
- At first the walls of the amniotic cavity and yolk sac are in contact with trophoblast. They are soon separated from the latter by ***extraembryonic mesoderm***.
- A cavity, the ***extraembryonic coelom*** appears and splits the extraembryonic mesoderm into a ***somatopleuric*** layer (in contact with trophoblast) and a ***splanchnopleuric*** layer (in contact with yolk sac).
- The trophoblast and underlying somatopleuric mesoderm form a membrane called the ***choroin***.
- The cells forming the wall of the amniotic cavity form the ***amnion***.
- The amniotic cavity is now attached to trophoblast by some mesoderm into which the extraembryonic coelom has not extended. This mesoderm forms the ***connecting stalk***.
- If we view the embryonic disc from the ectodermal side we see that near one edge it has a rounded area called the ***prochordal plate***. Here ectoderm and endoderm are not separated by mesoderm.
- An elevation, the ***primitive streak***, is also seen on the embryonic disc. A line drawn through the prochordal plate and the primitive streak divides the embryonic disc into right and left halves.
- Cells multiplying in the primitive streak move into the interval between ectoderm and endoderm and form the ***mesoderm*** (third germ layer).
- Caudal to the primitive disc we see a round area called the ***cloacal membrane***. It is made up only of ectoderm and endoderm.

Chapter 5

Further Development of Embryonic Disc

HIGHLIGHTS

- The cranial end of the primitive streak enlarges to form the ***primitive knot*** (Fig. 5.1).
- Cells of the primitive knot multiply and pass cranially to form a rod-like structure reaching up to the prochordal plate. This is the ***notochordal process***.
- The notochordal process undergoes changes that convert it first into a canal and then into a plate, and finally back into a rod-like structure. This is the ***notochord***.
- Most of the notochord disappears. Remnants remain as the ***nucleus pulposus*** of each intervertebral disc.
- A wide strip of ectoderm overlying the notochord becomes thickened and forms the ***neural plate*** (Fig. 5.4C) from which the brain and spinal cord develop.
- ***Intra-embryonic mesoderm*** shows three subdivisions (Fig. 5.4D). The mesoderm next to the middle line is called the ***paraxial mesoderm***. It undergoes segmentation to form ***somites***. The mesoderm in the lateral part of the embryonic disc is called the ***lateral plate mesoderm***. A cavity called the ***intra-embryonic coelom*** appears in it and splits the mesoderm into a ***somatopleuric*** layer (in contact with ectoderm) and a ***splanchnopleuric*** layer (in contact with endoderm) (Fig. 5.5D). A strip of mesoderm between the lateral plate mesoderm and the paraxial mesoderm is called the ***intermediate mesoderm***.
- The intra-embryonic coelom later forms the pericardial, pleural and peritoneal cavities.
- The embryonic disc, which is at first flat, undergoes folding at the cranial and caudal ends. These are the ***head and tail folds*** (Fig. 5.7). Lateral folds also appear. As a result of these folds, the endoderm is converted into a tube, the gut. It is divisible into ***foregut***, ***midgut*** and ***hindgut***.
- After formation of the head fold the gut is closed cranially by the prochordal plate, which is now called the ***buccopharyngeal membrane***. Caudally, the gut is closed by the ***cloacal membrane***. The ***umbilical cord*** develops from the connecting stalk. It contains the right and left umbilical arteries, the left umbilical vein, and remnants of the vitello-intestinal duct and yolk sac. The ground substance of the umbilical cord is made up of Wharton's jelly derived from mesoderm. The cord is covered by amnion.
- The ***allantoic diverticulum*** arises from the yolk sac before formation of the gut (Fig. 5.10). After formation of the tail fold, it is seen as a diverticulum of the hindgut.
- The ***pericardial cavity*** is derived from part of the intra-embryonic coelom that lies cranial to the prochordal plate (Fig. 5.11). The developing heart lies ventral to the cavity (Fig. 5.12). After formation of the head fold the pericardial cavity lies ventral to the foregut; and the developing heart is dorsal to the pericardial cavity (Fig. 5.13).
- The ***septum transversum*** is made of intra-embryonic mesoderm that lies cranial to the pericardial cavity (Figs 5.11, 5.12). After formation of the head fold, it lies caudal to the pericardium and heart (Fig. 5.13). The liver and the diaphragm develop in relation to the septum transversum.

Chapter **6**

The Placenta Fetal Membranes Twinning

HIGHLIGHTS

- A developing embryo gets attached to the uterine endometrium. This is called ***implantation***.
- In human beings the embryo gets buried in the substance of the endometrium. This type of implantation is called ***interstitial*** implantation.
- After implantation the endometrium is called the ***decidua***.
- The ***placenta*** is formed partly from embryonic structures and partly from the decidua. It is responsible for transport of nutrients and oxygen to the fetus, and for removal of waste products.
- The essential elements of the placenta are ***chorionic villi***. The villi are surrounded by maternal blood. Fetal blood circulates through capillaries in villi.
- The maternal blood and the fetal blood are separated by a very thin ***placental membrane*** (or barrier). All substances passing from mother to fetus (and vice versa) traverse this membrane.
- The fetal tissue that takes part in forming the placenta is ***chorion***. It consists of trophoblast (one layer of cells) resting on extra-embryonic mesoderm.
- Proliferation of cells of the trophoblast leads to formation of two layers: ***cytotrophoblast***, which is cellular and ***syncytiotrophoblast***, which is a syncytium (cytoplasm with nuclei, but no cell boundaries).
- The first-formed villi are called ***primary villi***. They consist of a central core of cytotrophoblast covered by syncytiotrophoblast.
- ***Secondary villi*** have three layers. From inside out these are extra-embryonic mesoderm, cytotrophoblast and syncytiotrophoblast.
- In ***tertiary villi***, blood capillaries are formed in the extra-embryonic mesoderm.
- Villi are surrounded by an intervillous space that contains maternal blood. As the placenta enlarges, septa grow into the intervillous space dividing the placenta into lobes. The fully formed placenta is about six inches in diameter and about 500 g in weight.
- The placenta is normally attached to the upper part of the body of the uterus. A placenta attached lower down is called ***placenta praevia***. It can cause problems during child birth.
- The embryo is surrounded by three large cavities. These are the amniotic cavity, the extra-embryonic coelom, and the uterine cavity. Enlargement of the amniotic cavity obliterates the extra-embryonic coelom, leading to fusion of amnion and chorion. Further enlargement of amniotic cavity obliterates the uterine cavity. Fused amnion and chorion (called ***membranes***) bulge into the cervical canal (during child birth) and help to dilate it.

Chapter 7

Formation of Tissues of the Body

HIGHLIGHTS

- ***Epithelia*** may originate from ectoderm, endoderm or mesoderm.
- Epithelia lining ***external surfaces*** of the body, and terminal parts of passages opening to the outside are derived from ectoderm.
- Epithelium lining the ***gut***, and of organs that develop as diverticula of the gut, is endodermal in origin.
- Epithelium lining most of the ***urogenital tract*** is derived from mesoderm. In some parts, it is endodermal in origin.
- ***Mesenchyme*** is made up of cells that can give rise to cartilage, bone, muscle, blood and connective tissues.
- ***Blood cells*** are derived from mesenchyme in bone marrow, liver, and spleen. Lymphocytes are formed mainly in lymphoid tissues.
- Most ***bones*** are formed by ***endochondral ossification***, in which a cartilaginous model is first formed and is later replaced by bone. Some bones are formed by direct ossification of membrane (***intramembranous ossification***).
- An area where ossification starts is called a ***centre of ossification***. In the case of long bones the shaft (or diaphysis) is formed by extension of ossification from the ***primary centre of ossification***. Secondary centres (of variable number) appear for bone ends. The part of bone ossified from a secondary centre is called an ***epiphysis***.
- In growing bone the diaphysis and epiphysis are separated by the ***epiphyseal plate*** (which is made up of cartilage). Growth in length of a bone takes place mainly at the epiphyseal plate.
- The portion of diaphysis adjoining the epiphyseal plate is called the ***metaphysis***.
- ***Somites*** undergo division into three parts. These are: (a) the ***dermatome*** which forms the dermis of the skin; (b) ***myotome*** which forms skeletal muscle; and (c) ***sclerotome*** which helps to form the vertebral column and ribs.
- ***Skeletal muscle*** is derived partly from somites and partly from mesenchyme of the region.
- Most ***smooth muscle*** is formed from mesenchyme related to viscera, and blood vessels.
- ***Cardiac muscle*** is formed from mesoderm related to the developing heart.
- ***Neurons*** and many ***neuroglial cells*** are formed in the neural tube. The myelin sheaths of peripheral nerves are derived from ***Schwann cells,*** while in the central nervous system they are derived from ***oligodendrocytes.***

Chapter 8

The Skin and Its Appendages

HIGHLIGHTS

- The ***epidermis*** is derived from surface ectoderm.
- The ***dermis*** is formed by mesenchyme derived from dermatomes of somites.
- ***Nails*** develop from ectoderm at the tip of each digit. Later, this ectoderm migrates to the dorsal aspect.
- ***Hair*** are derived from surface ectoderm which is modified to form hair follicles.
- ***Sebaceous glands*** (ectoderm) arise as diverticula from hair follicles.
- ***Sweat glands*** develop as downgrowths from the epidermis that are later canalised.
- ***Mammary glands*** arise from surface ectoderm. They are formed along a milk line extending from axilla to the inguinal region.

Chapter 9

The Pharyngeal Arches

HIGHLIGHTS

- Pharyngeal arches are rod-like thickenings of mesoderm present in the wall of the foregut.
- At first there are six arches. The fifth arch disappears and only five remain.
- The ventral ends of the arches of the right and left sides meet in the middle line in the floor of the pharynx.
- In the interval between any two arches, the endoderm (lining the pharynx) is pushed outwards to form a series of pouches. These are called endodermal, or pharyngeal, pouches.
- Opposite each pouch the surface ectoderm dips inwards as an ectodermal cleft.
- Each pharyngeal arch contains a skeletal element (cartilage that may later form bone), striated muscle supplied by the nerve of the arch, and an arterial arch.
- The cartilage of the first arch (Meckel's cartilage) gives origin to the incus and malleus (of middle ear).
- The cartilage of the second arch forms the stapes, the styloid process and part of the hyoid bone.
- The cartilage of the third arch forms the greater part of the hyoid bone.
- The cartilages of the fourth and sixth arches give rise to the cartilages of the larynx.
- The nerves of the pharyngeal arches are as follows: First arch = mandibular; second arch = facial; third arch = glossopharyngeal; fourth arch = superior laryngeal; fifth arch = recurrent laryngeal. The muscles supplied by these nerves are derived from the mesoderm of the arch concerned.
- The external acoustic meatus develops from the first ectodermal cleft.
- The first endodermal pouch (and part of second) give off a diverticulum called the tubotympanic recess. The middle ear and the auditory tube develop from the tubotympanic recess.
- The palatine tonsil arises from the second pouch.
- The inferior parathyroid gland and the thymus are derived from the third pouch.
- The superior parathyroid gland is derived from the fourth pouch.
- The thyroid gland develops mainly from the thyroglossal duct. This duct is formed as a median diverticulum arising from the floor of the pharynx (at the foramen caecum).

Chapter 10

The Skeleton

HIGHLIGHTS

- The vertebral column is derived from the sclerotomes of somites. Each sclerotome divides into three parts: cranial, middle and caudal.
- A vertebra is formed by fusion of the caudal part of one sclerotome and the cranial part of the next sclerotome. It is, therefore, intersegmental in position.
- The middle part of the sclerotome forms an intervertebral disc, which is therefore segmental in position.
- The sternum is formed by fusion of right and left sternal bars.
- The skull develops from mesenchyme around the developing brain. Some skull bones are formed in membrane (e.g. parietal); some partly in membrane and partly in cartilage (e.g. sphenoid); and a few entirely in cartilage (e.g. ethmoid).
- The mandible is formed in membrane from the mesenchyme of the mandibular process.
- Limbs are first seen as outgrowths (limb buds) from the side wall of the embryo. Each bud grows and gets subdivided to form parts of the limb.
- Limb bones develop from mesenchyme of the limb buds. Joints are formed in intervals between bone ends.

Chapter 11

Face, Nose and Palate

HIGHLIGHTS

- The ***stomatodaeum*** (future mouth) is a depression bounded cranially by a bulging produced by the brain, and caudally by a bulging produced by the pericardial cavity.
- Three prominences appear around the stomatodaeum. These are the ***frontonasal process*** (above), and the right and left ***mandibular arches*** (first pharyngeal arches) (Fig. 11.3A).
- The mandibular arch divides into a ***maxillary process*** and a ***mandibular process*** (Fig. 11.3B).
- The right and left mandibular processes meet in the midline and fuse (Fig. 11.4A). They form the ***lower lip*** and ***lower jaw***.
- The ***upper lip*** is formed by fusion of the frontonasal process with the right and left maxillary processes. Failure to fuse completely leads to various forms of ***harelip***.
- The ***cheeks*** are formed by fusion of (the posterior parts of) the maxillary and mandibular processes.
- The ***nose*** is derived from the frontonasal process.
- The ***nasal cavity*** is formed as follows. An ectodermal thickening, the nasal placode, appears over the frontonasal process (Fig. 11.4A). The placode gets depressed below the surface to form the nasal pit (Fig. 11.4B). The nasal pits enlarge to form the nasal cavity.
- ***Paranasal sinuses*** appear as outgrowths from the nasal cavity.
- The ***palate*** is formed by fusion of three components. These are the right and left palatal processes (arising from the maxillary process); and the primitive palate (derived from the frontonasal process) (Fig. 11.19). Deficiency in fusion leads to various forms of ***cleft palate*** (Fig. 11.20).

Chapter 12

Alimentary System—I: Mouth, Pharynx and Related Structures

HIGHLIGHTS

- The ***oral cavity*** is derived partly from the stomatodaeum (ectoderm), and partly from the foregut (endoderm). These two are separated by the buccopharyngeal membrane which later disappears (Fig. 12.1).
- ***Teeth*** are formed in relation to the dental lamina (Fig. 12.2). An enlargement of the lamina is formed for each tooth. It is called the ***enamel organ*** (Fig. 12.6).
- ***Ameloblasts*** (derived from ectoderm) form the ***enamel***. ***Odontoblasts*** (derived from mesoderm) form ***dentine***. The ***pulp*** is formed by mesenchyme that invaginates into the enamel organ (Fig. 12.6E).
- Three swellings appear in the floor of the pharynx, in relation to the first pharyngeal arch. These are the right and left ***lingual swellings***, and a median swelling the ***tuberculum impar*** (Fig. 12.11). Another median swelling is formed in relation to the third and fourth arches. This is the ***hypobranchial eminence***.
- The ***anterior two-third of the tongue*** is formed from the lingual swellings and the tuberculum impar.
- The ***posterior one-third of the tongue*** is formed by the cranial part of the hypobranchial eminence.
- ***Salivary glands*** develop as outgrowths of buccal epithelium.
- The ***palatine tonsil*** develops in relation to the second pharyngeal pouch.
- The ***pharynx*** is derived from the foregut.

Chapter 13

Alimentary System—II: Gastrointestinal Tract

HIGHLIGHTS

- ***Endoderm***, which is at first in the form of a flat sheet, is converted into a tube by formation of head, tail and lateral folds of the embryonic disc. This tube is the ***gut***.
- The gut consists of ***foregut***, ***midgut*** and ***hindgut***. The midgut is at first in wide communication with the yolk sac (Fig. 13.1). Later it becomes tubular. Part of it forms a loop that is divisible into ***prearterial*** and ***postarterial*** segments (Fig. 13.2).
- The most caudal part of the hindgut is the cloaca. It is partitioned to form the ***primitive rectum*** (dorsal) and the ***primitive urogenital sinus*** (Fig. 13.4).
- The ***oesophagus*** is derived from the foregut.
- The ***stomach*** is derived from the foregut (Fig. 13.12).
- ***Duodenum***: The superior part and the upper half of the descending part, is derived from the foregut. The rest of the duodenum develops from the midgut.
- The ***jejunum*** and ***ileum*** are derived from the prearterial segment of the midgut loop.
- The postarterial segment of the midgut loop gives off a caecal bud. The ***caecum*** and ***appendix*** are formed by enlargement of this bud.
- The ***ascending colon*** develops from the postarterial segment of the midgut loop.
- After its formation the gut undergoes ***rotation***. As a result the caecum and ascending colon come to lie on the right side; and the jejunum and ileum lie mainly in the left half of the abdominal cavity.

Chapter 14

The Liver and Biliary Apparatus, The Pancreas and Spleen; The Respiratory System; The Body Cavities and Diaphragm

HIGHLIGHTS

- The ***liver and biliary passages*** (endoderm) are derived from the ***hepatic bud***. This bud arises from the gut at the junction of foregut and midgut.
- The ***pancreas*** (endoderm) develops from two buds, dorsal and ventral, that arise from the gut near the junction of foregut and midgut. Most of the pancreas is formed from the dorsal bud. The ventral bud forms part of the head of the pancreas.
- The ***spleen*** (mesoderm) develops in the dorsal mesogastrium.
- The ***respiratory system*** develops from a median diverticulum of the foregut (endoderm). At its caudal end the diverticulum divides into right and left ***lung buds***.
- The ***larynx*** and ***trachea*** develop from the part of the respiratory diverticulum cranial to its division.
- The lung buds undergo repeated division to establish the bronchial tree and alveoli of the ***lungs***.
- The peritoneal, pericardial and pleural cavities develop from the intra-embryonic coelom. This coelom at first consists of right and left halves that are connected, across the middle line, cranial to the prochordal plate.
- The ***pericardial cavity*** is derived from the median midline part of the intra-embryonic coelom. After formation of the head fold this cavity comes to lie ventral to the foregut.
- The ***peritoneal cavity*** is derived from the right and left limbs of the intra-embryonic coelom. The two limbs unite to form a single cavity after formation of lateral folds of the embryonic disc.
- The ***pleural cavities*** are formed from right and left pericardio-peritoneal canals that connect the pericardial and peritoneal cavities. Each canal is invaginated by the corresponding lung bud. Enlargement of the bud leads to great enlargement of the canal, and formation of the pleural cavity.
- The ***diaphragm*** develops in relation to the septum transversum. It receives contributions from the pleuro-peritoneal membranes, the body wall and the mesenteries of the oesophagus.

Chapter 15

Cardiovascular System

HIGHLIGHTS

- The ***heart*** develops from splanchnopleuric mesoderm related to that part of the intra-embryonic coelom that forms the pericardial cavity. This mesoderm is the ***cardiogenic area***.
- Two ***endothelial heart tubes*** (right and left) appear and fuse to form one tube. This tube has a venous end, and an arterial end (Fig. 15.1, 15.2).
- A series of dilatations appear on this tube (Fig. 15.3). These are (1) ***bulbus cordis***, (2) ***ventricle***, (3) ***atrium***, and (4) ***sinus venosus***.
- Further subdivisions are named as follows (Fig. 15.3). The bulbus cordis consists of a proximal one-third (which is dilated), a middle one-third called the ***conus***, and a distal one-third called the ***truncus arteriosus***. The narrow part connecting atrium and ventricle is the ***atrioventricular canal***. The sinus venosus has right and left horns.
- The right and left atria of the heart are formed by partition of the primitive atrium. This partition is formed by the ***septum primum*** and the ***septum secundum (Fig. 15.6)***. A valvular passage, the ***foramen ovale***, is present between these two septa. It allows flow of blood from right atrium to left atrium.
- The dilated proximal one-third of the bulbus cordis, the conus, and the primitive ventricle unite to form one chamber. This is partitioned to form right and left ventricles. This partition is made up of the following. (1) ***Interventricular septum*** that grows upwards from the floor of the primitive ventricle. (2) a ***bulbar septum*** that divides the conus into two parts. (3) The gap left between these two is filled by proliferation of atrioventricular cushions that are formed in the atrioventricular canal (Fig. 15.11).
- The truncus arteriosus is continuous with the ***aortic sac*** (Fig. 15.27). This sac has right and left horns. Each horn is continuous with six ***pharyngeal (or aortic) arch arteries***. These arteries join the dorsal aorta (right or left). The first, second and fifth arch arteries disappear. The caudal parts of the right and left dorsal aortae fuse to form one median vessel (Fig. 15.28).
- The ***ascending aorta*** and ***pulmonary trunk*** are formed from the truncus arteriosus (Fig. 15.28B).
- The ***arch of the aorta*** is formed by the aortic sac, its left horn, and the left fourth arch artery (Fig. 15.29A).
- The ***descending aorta*** is formed partly from the left dorsal aorta, and partly from the fused median vessel (Fig. 15.29B).
- The ***brachiocephalic artery*** is formed from the right horn of the aortic sac (Fig. 15.29C)
- The ***common carotid artery*** is derived from part of the third arch artery (Fig. 15.30B).
- The ***pulmonary artery*** is derived from the sixth arch artery (Fig. 15.31B).
- The ***arteries to the gut*** are formed from ventral splanchnic branches of the dorsal aorta (Fig. 15.36).

Chapter 16

Urogenital System

Highlights

- The ***urogenital system*** is derived from the ***intermediate mesoderm***, and the ***primitive urogenital sinus*** (UGS) which is a part of the cloaca.
- The primitive UGS divides into the ***vesicourethral canal*** and the ***definitive UGS*** (Fig. 16.3).
- The vesicourethral canal divides into the ***urinary bladder*** and the ***primitive urethra***.
- The definitive UGS has a ***pelvic part*** and a ***phallic part***.
- The ***kidneys*** develop from two sources. The excretory tubules (nephrons) are derived from the ***metanephros*** (= lowest part of nephrogenic cord which is derived from intermediate mesoderm). The collecting part is formed by ramification of the ***ureteric bud*** (which arises from the mesonephric duct).
- The ***ureter*** arises from the ureteric bud.
- The ***urinary bladder*** is derived from the cranial part of the vesicourethral canal (endoderm). The epithelium of the trigone is derived from absorbed mesonephric ducts.
- The ***female urethra*** is derived from the primitive urethra and the pelvic part of the UGS.
- In the male, the ***prostatic urethra*** corresponds to the female urethra. The ***membranous urethra*** is derived from the pelvic part of UGS and the ***penile urethra*** from the phallic part of the UGS. The terminal part is ectodermal.
- The ***prostate*** is formed by buds arising from the caudal part of the vesicourethral canal and the pelvic part of the UGS.
- The ***uterine tubes*** are derived from ***paramesonephric ducts*** (mesoderm).
- The ***uterus*** is formed from the uterovaginal canal (fused right and left paramesonephric ducts).
- ***External genitalia*** are formed from swellings that appear around the urogenital membrane.
- ***Gonads*** (testis and ovary) are derived from coelomic epithelium covering the nephrogenic cord. Ova and spermatozoa arise from ***primordial germ cells*** that arise in the region of the yolk sac. The testis is formed in the lumbar region, and later descend to the scrotum.
- The ***duct system of the testis*** is derived from mesonephric tubules and from the mesonephric duct.

Chapter 17

The Nervous System

HIGHLIGHTS

- Ectoderm overlying the notochord becomes thickened to form the ***neural plate***.
- Neural plate is converted to ***neural groove***, and then to ***neural tube***.
- Neural tube has an enlarged cranial part that forms the ***brain***, and a narrow caudal part that becomes the ***spinal cord***.
- The cranial part of neural tube shows three dilatations: ***prosencephalon***, ***mesencephalon***, and ***rhombencephalon***. The prosencephalon divides into ***diencephalon*** and ***telencephalon***. The rhombencephalon divides into ***metencephalon*** and ***myelencephalon***.
- The telencephalon forms most of the ***cerebral hemisphere*** including the corpus striatum. The ***lateral ventricle*** is the cavity of the telencephalon.
- The diencephalon forms the ***thalamus***, ***hypothalamus*** and related structures. Its cavity is the ***third ventricle***.
- The mesencephalon forms the ***midbrain***. Its cavity forms the ***cerebral aqueduct***.
- The metencephalon forms the ***pons***. It also forms the ***cerebellum***.
- The myelencephalon forms the ***medulla oblongata***. The ***fourth ventricle*** is the cavity of the rhombencephalon.
- The ***neural crest*** is made up of cells that lie along the lateral edges of the neural plate. Its most important derivatives are cells of ***sensory ganglia***, ***parasympathetic ganglia*** and of ***sympathetic ganglia***. It also forms the cells of the ***adrenal medulla*** and ***Schwann cells*** that form sheaths for peripheral nerve fibres.
- The wall of the neural tube at first has a single layer of cells. They multiply and form three layers, ***ependymal mantle*** and ***marginal***. Neurons develop in the mantle layer.
- The mantle layer divides into a ventral part, the ***basal lamina***, and a dorsal part, the ***alar lamina***. These are separated by a groove, the ***sulcus limitans***.
- In the spinal cord the alar lamina forms the ***posterior grey column***, and the basal lamina forms the ***ventral grey column***. The marginal layer becomes white matter.
- In the medulla, pons and midbrain, ***efferent cranial nerve nuclei*** develop in the basal lamina and ***afferent nuclei*** in the alar lamina.
- The alar lamina of the mylencephalon also forms the ***olivary nuclei*** (which migrate ventrally), and the ***pontine nuclei*** which migrate into the pons. The ***cerebellum*** is derived from the alar lamina of the metencephalon.
- The alar lamina of the mesencephalon forms the ***colliculi***, the ***red nucleus*** and the ***substantia nigra***.

Chapter 18

Hypophysis Cerebri, Pineal, Adrenal

HIGHLIGHTS

- The pars anterior and intermedia of the ***hypophysis cerebri*** develop from Rathke's pouch. The pars nervosa develops from a downgrowth arising from the floor of the third ventricle.
- The ***pineal gland*** develops as a diverticulum from the roof of the third ventricle (diencephalon).
- The ***adrenal cortex*** is derived from coelomic epithelium. The cells of the ***adrenal medulla*** are derived from the neural crest.

Chapter 19

The Eye and Ear

HIGHLIGHTS

- The ***retina*** is formed from the ***optic vesicle***, an outgrowth of the prosencephalon. The optic vesicle is converted into the ***optic cup***.
- The ***lens*** of the eye is derived from a thickened area of surface ectoderm, the lens placode. The placode is converted into the lens vesicle which comes to lie in the optic cup.
- Other coats of the eyeball are derived from mesoderm surrounding the optic vesicle. The epithelium covering the superficial surface of the ***cornea*** is derived from surface ectoderm.
- The ***eyelids*** are formed by reduplication of surface ectoderm above and below the cornea.
- The ***lacrimal sac*** and ***nasolacrimal duct*** are derived from ectoderm buried in the naso-optic furrow.
- The ***membranous labyrinth*** (internal ear) is derived from a thickening of surface ectoderm called the ***otic placode***. The placode is converted into the ***otic vesicle*** and then to different parts of the labyrinth.
- The ***bony labyrinth*** is formed from mesenchyme surrounding the membranous labyrinth.
- The ***middle ear*** and ***auditory tube*** develop from the tubo-tympanic recess (from first and second pharyngeal pouches).
- The ***malleus*** and ***incus*** are derived from Meckel's cartilage. The ***stapes*** is derived from the cartilage of the second pharyngeal arch.
- The ***external acoustic meatus*** is derived from the first ectodermal cleft. The ***auricle*** is formed from swellings that appear around the cleft.

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HUMAN EMBRYOLOGY

This is the tenth edition of the best-selling title Human Embryology, first published in 1976. It is not only the leading textbook, but has now become an authority on the subject. It's long-standing popularity is on account of it's readability, concise and clear text, and a large number of simple but informative illustrations.

The book presents essential concepts in human development for medical students. Each chapter opens with highlights, followed by various descriptions of the normal development of particular systems in a systematic manner. All the chapters have been completely revised and edited with great care. Clinical correlations have been added and highlighted in separate boxes to enhance the clinical concepts of the students and grounding their understanding of the subject. Chapters conclude with a time-table of development events.

To avoid unnecessary details that could interrupt the flow for undergraduate students, some aspects of the subject relevant only for postgraduates are available in the accompanying CD.

Professor Inderbir Singh MBBS MS PhD FAMS has over 50 years of teaching experience. He taught Anatomy and Embryology at various medical colleges from 1952 to 1989 and retired as Professor of Anatomy, Government Medical College, Rohtak. Professor Singh has been conferred the title of Professor Emeritus by Maharishi Dayanand University, Rohtak. To his credit are a large number of research papers and books on Gross Anatomy, Histology and Neuroanatomy. He has recently been awarded with Emeritus Teacher Award by National Board of Examination for making invaluable contribution for teaching of Anatomy.

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