ELEMENTS OF EMBRYOLOGY

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PREFACE

In view of the absence of a more suitable text-book answering the purpose I had strictly to keep in view, no apology may perhaps be necessary for the appearance of this small treatise on embryology.

The importance of embryology has of late been so fully recognised, that a course of anatomy is now considered incomplete without it. But, in spite of the emphasis laid in recent years on the study of embryology, a serious want has been felt for some time of a treatise dealing in a concise manner with the more important facts of the subject. The syllabus of medical studies has become so complicated and over-loaded that a student, however keen and ambitious he may be, finds it difficult to follow a complete text-book. He cannot really afford the time even to wade through, much less master, the elaborate details and theories incidental to the exhaustive treatment of the subject in a general text-book.

The present volume has no pretensions to being an original contribution to the subject of embryology, but it may lay a modest claim to its having been especially designed to meet the requirements of the ordinary student, who is not debarred, however, in view of the limited compass natural to this work, from having access to other books which are devoted to a fuller study of the subject.

No pains have been spared to make the work fully illustrated by incorporating, in addition to some original illustrations, those drawn from models by Friedrich Ziegler and others taken from different sources with suitable modifications. To all these my acknowledgments are due.

It is eminently desirable that the use of the book should go hand in hand with well-arranged lecture and laboratory work, and the student would be well advised, in his own interest and with a view to making his study thoroughly practical, to prepare his own diagrams and plasticine models while studying the subject.

My special thanks are due to Mr. S. S. Choudhry for his valuable suggestions, to Mr. S. M. Moinul Haque and Mr. S. M. Azam for kindly going over the MSS., to the Departments of Biology and Physiology of the Prince of Wales Medical College for their cooperation and to many friends and colleagues who have helped me in various ways.

PATNA

H. HYDERALI KHAN

May 1931

CONTENTS

CORRIGENDA

Page 12	*line* 21	*for*	outer cell mass	*read*	outer cell layer.
„ 39	„ 2	„	ilium	„	ileum.
„ 57	„ 15	„	vellum	„	velum.
„ 63	„ 12	„	right venous	„	7, right venous.
„ 71	„ 14	„	duck	„	duct.
„ 81	„ 3	„	vasculosi	„	vesiculosœ.
„ 90	„ 14	„	Chorioidial	„	Chorioidal.
„ 93	„ 16	„	sympathetic chromaffin	„	sympathochromaffin.
„ 94	„ 13	„	medial	„	middle.

Introduction

EMBRYOLOGY or developmental anatomy treats of the structural history of an individual. The fertilisation of a female germ cell or an ovum by a male germ cell or spermatozoon is followed by a series of changes, and for a pre-embryonic period of fourteen days in which the different portions are not differentiated the fertilised ovum is called a *zygote*. After this period, the embryonic tissue separates from the others but it is not till the end of the second month that the various parts are clearly defined. This is known as the embryonic period and the differentiated portion is called an *embryo*. From the end of the second month till the birth of the child after nine months the structure is called a *fœtus*, and the period is known as the fœtal period. These three periods are included in the prenatal period. The period following it is called the postnatal period.

Embryology, strictly speaking, is the science of the development of the embryo, but in its wider sense includes the prenatal period and even the postnatal period up to the adult stage. The subject is important as it not only deals with the development of the various organs but explains the intricacies and variations in them. Although the development of every animal is interesting, human embryology is of far greater importance to us human beings. We cannot, however, help having recourse to animal embryology or comparative anatomy to fill in the gaps of what we cannot study in the human embryo due partly to want of knowledge as to the exact age of the embryo and partly to scarcity of material to experiment upon.

Human embryology is a modern science and has enhanced and added considerably to our knowledge of anatomy. As a matter of fact knowledge of anatomy is now considered incomplete without an insight into embryology.

Aristotle, at about 350 B.C., knew something of anatomy and had followed the development of a chick ; Galen (130 – 200 A.D.) improved upon this knowledge by means of dissections of apes. Vesalius, however, was the founder of human anatomy but his embryology was concerned only with animals. To Balfour (1874) and the modern pioneers like His, Keibel and Streeter belongs the credit of bringing human embryology to the present state.

The Animal Cell

TISSUES are made up of cells which have originated from a single cell. In a simple animal like the amœba only one cell constitutes the whole animal, and this solitary cell performs all the functions of a living animal. In the higher animals, however, there are a number of cells which form groups, each group having a special function, and the cells are so altered as to adapt themselves to their particular function.

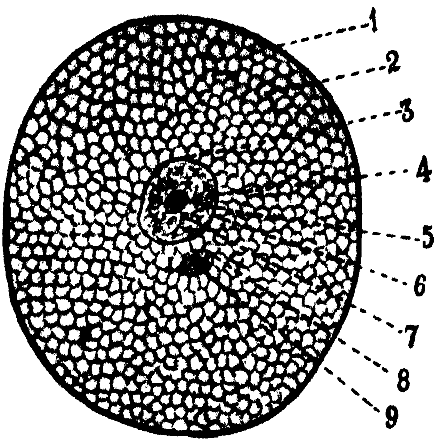

FIG. 1.—AN ANIMAL CELL.

1. Cell membrane, 2. Cytoplasm, 3. Nucleus, 4. Linin, 5. Chromatin, 6. Nuclear membrane, 7. Nucleolus, 8. Centrosome, 9. Centriole.

The cell consists of a mass of protoplasm which can usually be differentiated into a covering called the cell membrane, the greater part of the cell contents or cytoplasm, and a nucleus which is embedded in the cytoplasm; on one side of the nucleus a clear spherical spot is found known as the *centrosome* which contains one or two deeply stained bodies called the *centrioles.* Minute rod-shaped particles called *mitochondria* are scattered about in the cell. The mitochondria are dissolved by acetic acid but take some of the basic stains. A system of canaliculi called *Golgi apparatus* is spread out in the cell and is filled with a watery fluid.

The nucleus is surrounded by a nuclear membrane delimiting the denser protoplasm of the nucleus called the *karyoplasm*, from the general cytoplasm of the cell. The karyoplasm is seen to consist of a reticulum filled with the nuclear juice and in it there is a small spherical body known as the *nucleolus.* The reticulum consists of a part which does not take basic stains called *achromatin fibres* or *linin*, and a basic staining part called *chromatin.* When the cell is in a state of rest, the chromatin is diffused and mixed up as small particles with the linin. But when the cell begins to divide, the chromatin granules come together and form small segments called chromosomes. The number of chromosomes is constant in the same species of animal. In man, the number is usually forty-eight. Each chromosome represents certain hereditary qualities and one of the chromosomes represents the sex.

Ordinarily a cell, soon after its appearance, grows, performs its functions for a certain period and then either divides into two daughter cells or breaks up into fragments and dies. The division of a cell takes place either directly by simple fission or amitosis, or indirectly by *mitosis* or *karyokinesis*, by means of a complicated process. Amitotic division takes place by a constriction of the cell initiated in the nucleus and extending into the cell by means of which it is divided into two daughter cells. Each daughter cell contains a portion of the nucleus and a centrosome which has also most probably divided.

Of the two cell divisions the mitotic is the more important; of this two varieties are known, viz., the *heterotype* and the *homotype mitosis.* The heterotype mitosis takes place in the formation of sperms and mature ova as well as in the cell divisions of cancerous and malignant growths. In this case only half the characteristic number of chromosomes is present in the resulting daughter cells.

Mitosis is said to consist of four stages known as *prophase*, *metaphase*, *anaphase* and *telophase*.

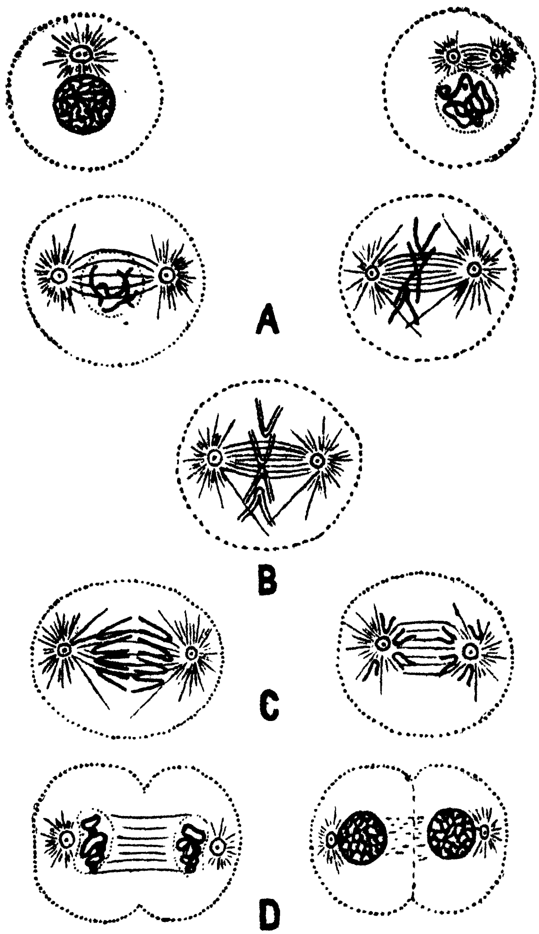

FIG. 2.—HOMOTYPE MITOSIS. (AFTER SCHAFFER.)

A. Prophase, B. Metaphase, C. Anaphase, D. Telophase.

HOMOTYPE MITOSIS

Prophase.—In this stage the chromatin gets arranged into a spirem or tangled thread. Each centrosome divides into two and each daughter centrosome passes towards the opposite poles of the nucleus. The linin arranges itself in the form of a spindle, the two ends of the spindle correspond to the two daughter centrosomes. The nuclear membrane and the nucleolus disappear. The chromatin thread further breaks up into a number of V, O or U shaped segments which are arranged near the equator and each becomes associated with the fibrils of the spindle.

Metaphase.—Each chromosome splits up into two equal parts.

Anaphase.—Half the number of the split chromosomes move towards one centrosome and the other half towards the other.

Telophase.—A constriction appears round the cell and causes it to divide into two. The linin and the chromatin become aggregated in each daughter cell thus produced; a nucleus is formed by the appearance of a nuclear membrane, a nucleolus appears as well and each daughter cell grows and performs all its functions independently.

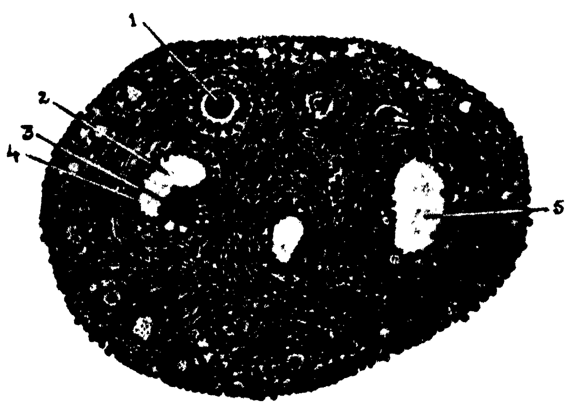

FIG. 3.—OVARY OF A RABBIT. T. S.

1. Primordial ovum, 2. Ovarian follicle, 3. Cumulus oophori, 4. Stratum granulosum, 5. Corpus luteum.

THE OVUM

The female germ cells or ova are developed from the primitive germ-cells situated on the surface of the ovary. As growth proceeds the primitive germ-cells or primordial ova sink into the substance of the ovary and are surrounded by the other cells of the ovary. A cavity which is soon filled with a fluid called *liquor folliculi* appears between these cells and splits the group of cells into a group immediately surrounding the primordial ovum and the other on the outside. The cells surrounding the ovum are called the *cumulus oophori* and the latter *stratum granulosum.* The cells of the cumulus, however, are continuous at one spot with the cells of the stratum granulosum.* The whole constitutes the *ovarian follicle*. As the fluid increases in the cavity the follicle once more comes to the surface and ruptures owing to the activities of the cells. The ovum is thus set free in the abdominal cavity surrounded by the cells of the cumulus called the *zona radiata*. As soon as the ovum is set free it is picked up by one of the processes of the uterine tube and is carried inside the tube where it either gets fertilised or is discharged after passing through the uterus.

The site of rupture of the Graafian follicle undergoes a series of changes; yellow cells called luteal cells appear and form what is called the corpus luteum. These changes, however, terminate by the end of the first month and the corpus luteum shrinks; but if the ovum is fertilised, the corpus luteum keeps on growing, attains its maximum development in the fifth month, becomes very vascular and is called *corpus hæmorrhagicum*. The corpus luteum is supposed to produce a hormone which materially aids in embedding the ovum in the uterine decidua.

An ovum measures about 100 microns and has all the component parts of the cell, but the various parts are called by different names. The cell membrane is called *oolemma*, the cytoplasm is called *ooplasm*, and the nucleus is known as the *germinal vesicle*.

In order that the ovum may be capable of being fertilised it undergoes maturation division. To begin with the ovum increases in size and is called the *oocyte of the first order*. This divides by heterotype mitosis into the *oocyte of the second order* and a small body called the *first polar body* which sometime divides by homotype mitosis later on.

HETEROTYPE MITOSIS

The process resembles the homotype mitosis but differs in the following:—

Prophase.—The spirem is formed of the chromosomes attached by their ends. The chromosomes next arrange themselves in pairs forming twin chromosomes near the equator of the spindle. The chromosomes are thus apparently reduced to half their original numbers, i.e., 24. One of the poles of the spindle containing the centrosome protrudes from the cell forming an elevation.

Metaphase.—The twin chromosomes separate, their number is now equal to the original number in the cell (in homotype mitosis the number in the cell at this stage is double).

Anaphase.—The separated chromosomes travel to the opposite poles of the spindle.

Telophase.—The elevation on the cell separates from the main cell and forms the first polar body and contains half the number of chromosomes while the other half remains in the main cell, which is now called the *oocyte of the second order.* The second maturation division takes place by homotype mitosis, both in the oocyte of the second order and in many cases in the first polar body. The oocyte of the second order divides into a mature ovum and a small body called the second polar body. The first polar body, if it divides, splits up into two polar bodies. It will thus be seen that a primordial ovum divides into a mature ovum, which is capable of being fertilised, and three polar bodies, which are not. A nucleus appears in the mature ovum and is called the female pronucleus. It should be noted, however, that the mature ovum does not contain any centrosome. The ovum now enters into a resting stage and does not divide any further unless it is fertilised.

THE SPERMATOZOON

Maturation of the male gamete.—The spermatozoa are formed from the germinal cells in the tubules of the testes. These also possess other cells called the supporting cells. The germinal cells called *spermatogonia* first develop into what are called the *spermatocytes of the first order.* These undergo heterotypical mitotic division. Each divides into two, and each portion contains half the number of chromosomes and is called the *spermatocyte of the second order.* The second maturation division, which is homotypical, divides the spermatocytes of the second order into two *spermatids* each. The spermatid undergoes further development and becomes a *spermatozoon.*

The transformation of a spermatid into a spermatozoon is interesting. The spermatid is more or less globular; the nucleus emerges from the cell and constitutes the head of the spermatozoon, the centrosomes follow next and form the connecting piece, and lastly the cytoplasm gives rise to the body and tail.

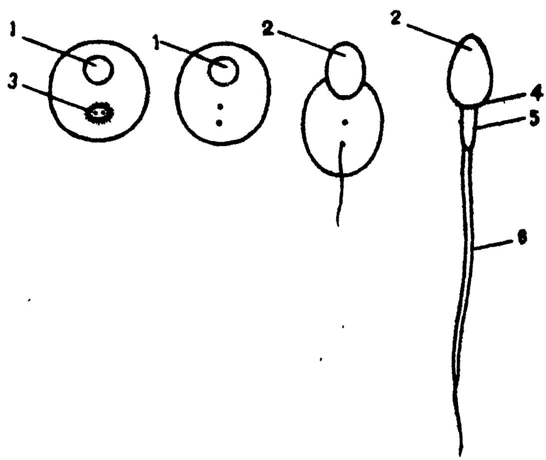

FIG. 4.—TRANSFORMATION OF A SPERMATID INTO A SPERMATOZOON.

1. Nucleus, 2. Head, 3. Centrosome, 4. Neck, 5. Connecting piece or body, 6. Tail.

It will thus be seen that each spermatogonium divides into four mature and functional spermatozoa, each of which has half the number of chromosomes contained in the original spermatogonium. These mature gametes, whether male or female, have no power of further subdivision unless the male and the female gametes unite and bring the number of chromosomes to normal.

The reduction of half the number of chromosomes in the gametes is essential for the betterment of the race as the chromosomes contain the hereditary characteristics, and the union of the chromosomes of the mother and the father produces an individual endowed with the characteristics of the race both of the mother and the father. For example, if the father descends from a race renowned for physical fitness and the mother from a highly intellectual family then the result will probably be an individual either endowed with both the qualities, or with one, while the other is dormant. If the family of the mother or father intermarry amongst themselves the offspring will not have any profitable addition of characteristics.

The chromosomes, as has already been said, bear various characteristics. One of the chromosomes is known as the X chromosome and the other the Y chromosome. These are supposed to determine the sex. The X chromosome is present in all the ova, and the Y chromosome is present in half the number of spermatozoa while the other half possesses X chromosomes. As the Y chromosome is very difficult to detect, it was considered that some of the spermatozoa were one chromosome short and if this variety of spermatozoa came in contact with an ovum the result was a male. It has now been recognised that if an ovum comes into contact with a spermatozoon with the X chromosome the result is a female; on the other hand, if an ovum comes into contact with a spermatozoon with the Y chromosome, the offspring will be a male. This may be expressed thus:—

X+X=female

X+Y=male

The difference of sex is initiated by the chromosome but the sexual features are obtained by chemicals in the chromosomes.

A spermatozoon consists of a head, a neck or connecting piece, a body and a tail. The total length is approximately 52 microns, the size of the germinal vesicle. The head, 5 microns in length, is ovoid in shape, compressed laterally appearing like a pear when seen in profile, and is covered over by a head-cap. The neck is slightly constricted and connects the head with the body and bears the anterior and the posterior centrosomes. The body is 6 microns in length and consists of an axial sheath containing mitochondria. The tail is 41 microns long and ends in a thin end piece.

Fertilisation

AS soon as the ovum is set free by the rupture of the Graafian follicle, the ovum is caught by the fimbria of the uterine tube and conveyed inside the tube. Here it may be fertilised; otherwise it passes through the tube aided by the cilia of the tube to the uterus and thrown out. During coitus semen is discharged into the vagina the secretion of which is acid and injurious to the spermatozoa, they are naturally drawn into the uterus the secretion of which is alkaline, where the spermatozoa can live for long periods and retain their power of fertilisation for over a week; thence they usually pass on into the uterine tube and if any spermatozoon comes into contact with an ovum it is fertilised. The fertilised ovum normally passes through the tube into the uterus where it attaches itself to the fundus and grows.

When a spermatozoon approaches the ovum, the latter shows signs of excitement and the contents of the ovum flow out at one point towards the approaching spermatozoon producing a knob on the surface of the ovum which is called the *cone of attraction.* The spermatozoon enters through this cone as the oolemma at this point has become thin on account of increased tension in this region. During its passage into the ovum the spermatozoon loses its tail, becomes rounded, and is known as the *male pronucleus.* It possesses half the number of chromosomes and the centrosome which is wanting in the ovum. The male pronucleus, shortly afterwards, approaches the female pronucleus and fuses with it. The ovum, thus fertilised, starts mitotic divisions.

Ectopic Gestation.—It sometimes happens that on account of some abnormality or disease such as stenosis or inflammation the ovum is fertilised in the tube, in the abdominal cavity or on the surface of the ovary, sticks there and grows; such a condition is known as *ectopic gestation;* this may be tubal pregnancy, abdominal pregnancy or ovarian pregnancy according to whether the fertilised ovum is implanted in the uterine tube, in the abdominal cavity or in the ovary respectively. Any of these abnormal pregnancies is a source of danger to the mother on account of rupture and the subsequent hæmorrhage that takes place.

Segmentation

As soon as the male and the female pronuclei fuse together, mitotic division begins and the cell divides and redivides till a mass of cells, called *morula*, is formed. Some observers have noticed at this stage a differentiation of a group of cells called *generative cells*; these ultimately form sex glands, form ova and spermatozoa of the future embryo and bear the hereditary characteristics of the individual and the race. The remaining cells which take part in the formation of the body are called *somatic cells.* The cells of the morula are differentiated into an *outer cell layer* and an *inner cell mass.* The outer cell layer, which covers the inner cell mass entirely, becomes the *trophoblast* and serves for the protection and nutrition of the embryo. The most important functions of the individual, i.e., reproduction, nutrition and protection are thus provided for at the very beginning of development. The cells of the inner cell mass soon differentiate themselves into a group of cells called the *ectoderm* and another group known as the *entoderm.* In some mammals a cavity called the segmentation cavity appears between the outer cell layer

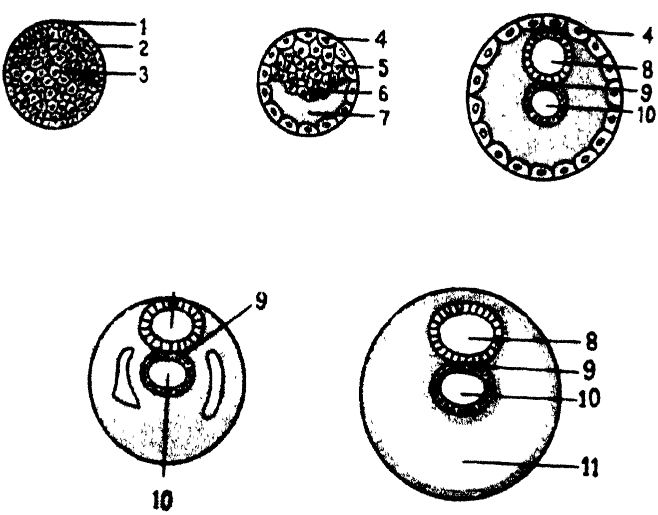

FIG. 5.—DIFFERENTIATION OF THE CELLS OF THE ZYGOTE. (DIAGRAMMATIC.)

1. Oolemma, 2. Outer cell mass, 3. Inner cell mass, 4. Trophoblast, 5. Ectoderm, 6. Entoderm, 7. Primary mesoderm, 8. Amniotic cavity, 9. Embryonic area, 10. Archenteron, 11. Extra-embryonic cœlom.

and the inner cell mass and the whole structure is known as the *gastrula*. In man a third group of cells called the *primary mesoderm* is also differentiated.

Cavities appear in these groups of cells. A big cavity is formed surrounded by the ectoderm and is called the *amnion*, another cavity surrounded by the entoderm is called the *archenteron*. Clefts appear in the primary mesoderm and join together to form a single cavity known as the *extra-embryonic cœlom*. The primary mesoderm thus splits and spreads out, a part of it covering the amnion and archenteron and another lining the trophoblast. A portion of the primary mesoderm, however, insinuates itself in between the amnion and the archenteron.

The outer cells of the trophoblast divide rapidly and form a multinucleated mass of protoplasm or syncytium called *syncytio-trophoblast*. The internal cells of the trophoblast are quite distinct and are called *cytotrophoblast* or *layer of Langhans*. These become lined by the primary mesoderm and form the *chorion*.

The amnion is in contact with the trophoblast at one end and with the archenteron at the other. The point where the amnion and the trophoblast meet is the site of the future placenta. The area of contact of the amnion with the archenteron is called the embryonic area and is the site of the formation of the embryo.

The earliest fertilised ovum that has been described is the *Miller's ovum* of about ten days. In this ovum the embryonic area is defined but the chorionic villi are not present.

FIG. 6.—MILLER'S OVUM. (AFTER STREETER.)

1. Uterine glands, 2. Primary mesoderm, 3. Trophoblast, 4. Embryonic area.

The embryonic area consists of the ectoderm, the primary mesoderm and the entoderm. The area is circular to begin with but owing to the elongation of the amniotic cavity and the archenteron it becomes ovoid in shape.

A furrow called the primitive streak appears in the posterior end of the embryonic area. A groove appears in the primitive streak and is called the primitive groove; this becomes deep in its anterior end, perforates the cells of the amnion and the archenteron and opens into the archenteron. The opening is known as the *neurenteric* canal and is a temporary opening.

The anterior end of the embryonic area becomes thickened and is known as the neural plate; a groove appears on this plate called the neural groove. The sides of the groove become elevated into the neural folds; these folds unite in the dorsal region and form the commencement of the neural tube, from which the greater portion of the nervous system and the essential parts of the sense-organs develop.

The cells underneath the primitive streak proliferate and give rise to a rod-shaped structure called the *notochord* anteriorly and a group of cells known as mesoderm cells posteriorly. These cells which may be called secondary mesoderm displace the primary mesoderm which has insinuated itself between the ectoderm and the entoderm. It is doubtful as to whether the primary mesoderm takes any part in the formation of the tissues of the embryo. The greater parts of the tissues, however, are formed from the secondary mesoderm which will henceforth be called the mesoderm.

It will thus be seen that the embryonic area which was bilaminar to begin with consisting of the ectoderm and entoderm becomes trilaminar with three layers, i.e., ectoderm, mesoderm and entoderm. From these three layers the various tissues of the body are formed. The cells change their shapes and get modified according to the functions they have to perform. The ectoderm cells columnar at first become flattened and form a covering for the body, or assume various shapes when some of them become nerve cells. The mesoderm cells are rounded and branched but later assume the shapes peculiar to the red blood corpuscles or the connective tissue cells. The entoderm cells at first flattened become columnar and secrete the various digestive juices.

From the ectoderm are derived the epidermis and its appendages such as the hair, nails, the enamel of the teeth, epithelium of the cornea, mouth and its glands, the hypophysis, the anus, nervous tissue and chromaffin tissue, muscles of the iris and sweat glands, and the crystalline lens.

The mesoderm gives rise to the skeletal, muscular, vascular and excretory systems, the lining membranes, i.e., the pericardium, pleura and peritoneum, lymphoid organs, and cortex of the suprarenal.

The entoderm forms the epithelial lining of the greater part of the digestive tube and its associated glands including the liver and the pancreas, the auditory tube, the tympanic cavity, the trachea, the bronchi, the air cells of the lungs, the greater portion of the urinary bladder, a portion of the urethra, the prostate, the follicles of the thyroid, the parathyroid, the thymus and the tonsils.

The notochord though intimately blended with the entoderm is most probably derived from the mesoderm. The mesoderm spreads out laterally and anteriorly. It falls short just in front of the head where the ectoderm and the entoderm come in contact forming the buccopharyngeal membrane; further forward the mesoderm is carried along the sides to the front of the head as a cross bar and forms the pericardial area. In the caudal region the ectoderm and entoderm again come in contact and form the cloacal membrane. The buccopharyngeal and the cloacal membrane disappear by the third and the fourth week respectively. Communication is thus established between the interior of the primitive gut and the exterior.

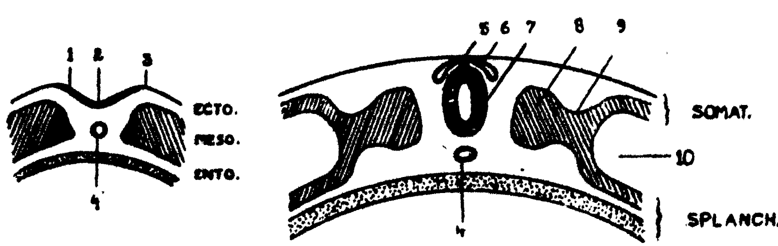

FIG. 7.—DIAGRAM SHOWING THE DIFFERENTIATION OF THE MESODERM.

1. Neural plate, 2. Neural groove, 3. Neural fold, 4. Notochord, 5. Neural crest, 6. Sympathetico-chromaffin cells, 7. Neural tube, 8. Paraxial mesoderm, 9. Intermediate cell mass, 10. Cœlom, ECTO. ectoderm, MESO. mesoderm, ENTO. entoderm., SPLANCH. splanchnopleure, SOMAT. somatopleure.

The mesoderm spreads out laterally but is separated in the middle line by the neural tube and the notochord. On each side the mesoderm becomes constricted longitudinally separating a medial portion of the mesoderm which is called the *paraxial mesoderm*, and lateral portion called the *lateral mesoderm*. The constriction which is called the *intermediate cell mass* gives rise to the kidney and the sex glands. The paraxial mesoderm spreads medially and surrounds the neural tube and the notochord. Transverse slits appear in the paraxial mesoderm which is thus divided into segments, the slits appear in the region of the hindbrain and proceed downwards. A cavity appears in each segment called *myocœl* which disappears very soon.

Small cavities appear in the lateral mesoderm. These run together into a single cavity and result in the splitting up of the lateral mesoderm into an external or *somatic* and internal or *splanchnic* portion. The external layer fuses with the ectoderm and forms the *somatopleure* while the internal layer from which the involuntary muscles are developed fuses with the entoderm and forms the *splanchnopleure*. The cavity which is called the *cœlom* becomes continuous with the extra-embryonic cœlom, which, however, becomes obliterated. The cœlom forms the pericardial, the pleural and the peritoneal cavities.

The archenteron is constricted into a portion which is included into the embryo and called the *primitive gut* and a portion outside called the *yolk sac*. The constriction itself gets considerably elongated and is known as the *vitelline duct*. Vessels appear on the sac and the veins carry blood to a tubular heart which is formed by the fusion of two primitive aortæ. The embryo thus gets its nutrition at an early stage from the yolk sac. The embryo as it gets elongated is bent upon itself and forms a cephalic and a caudal fold into both of which the primitive gut extends. As the cephalic end is bent downwards it carries with it the pericardium and the buccopharyngeal membrane, so that the pericardium gets reversed, and the fore-gut lies behind the pericardium and the buccopharyngeal membrane. The membrane disappears in the third week and the fore-gut opens externally. The hind-gut is at first closed by the cloacal membrane but opens externally at about the fourth week on account of the disappearance of the membrane.

A diverticulum called the *allantois* arises from the posterior aspect of the archenteron; it is of no importance in man and soon shrinks up. The vitelline duct also disappears but in rare instances may persist as a blind pouch called *Meckel's diverticulum* about a meter above the ileo-cæcal junction. Sometimes a constriction is found in the fully developed ileum in this situation.

The amnion has been described as a cavity formed in the ectoderm cells and being in contact at one end with the trophoblast. The cavity, however, soon gets filled up by a fluid called liquor amnii which increases to such an extent that it distends the amniotic cavity so that it fills up the whole of the extra-embryonic cœlom. The point of contact of the amnion with the trophoblast becomes elongated and is known as the bodystalk. The umbilical vessels run through it and the umbilical cord is thus formed. During the bending of the embryo the surfaces of the embryo are reversed and the bodystalk which is situated dorsally becomes ventral. The mesoderm of the amnion fuses with the mesoderm of the vitelline duct and the bodystalk and forms the umbilical cord which forms a connection between the embryo and a specialised

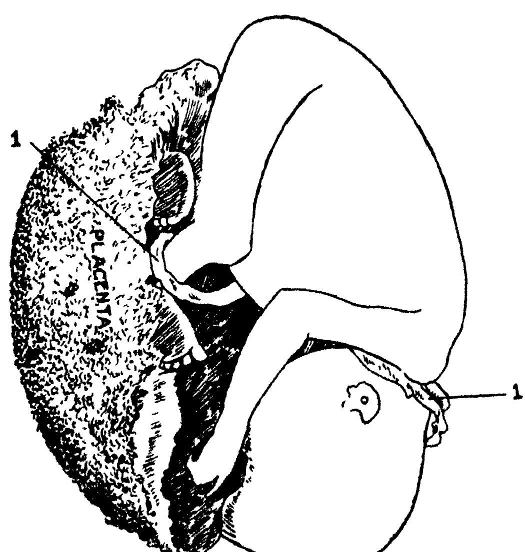

FIG. 8.—A FŒTUS OF ABOUT THE FOURTH MONTH IN ITS NATURAL POSITION.

1. Umbilical cord.

portion of the chorion called the placenta. The umbilical cord thus consists of the umbilical vessels, the allantois, the vitelline duct and vessels packed in a jelly-like tissue called Wharton's jelly and enclosed in the amniotic ectoderm. Of these the allantois and the vitelline ducts and vessels get obliterated. The umbilical cord gets considerably elongated attaining a length of about twenty inches and gets twisted upon itself.

EMBEDDING OF THE OVUM

After fertilisation which takes place in the ampulla of the uterine tube, the ovum travels into the uterus in three or four days. By this time it has developed the trophoblast which adheres and eats into the uterine mucous membrane and gets embedded there. By this process some of the blood

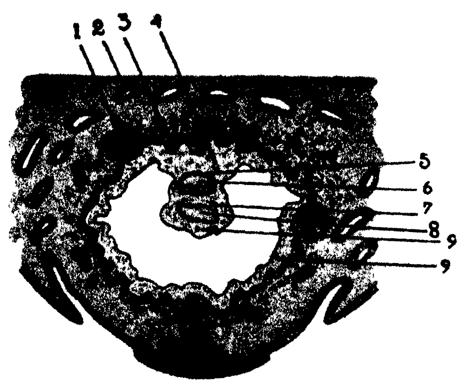

FIG. 9.—DIAGRAM OF A HUMAN OVUM 19 MM., EMBEDDED IN UTERINE MUCOSA. (AFTER PETER.)

1. Maternal vessels, 2. Uterine glands, 3. Trophoblast, 4. Bodystalk, 5. Ectoderm, 6. Amniotic cavity, 7. Entoderm, 8. Archenteron, 9. Primary mesoderm.

sinuses of the uterus are laid bare. The trophoblast develops finger-like processes called *primary chorionic villi* into which extension of mesoderm takes place to form umbilical vessels. The processes with the vessels are called the *secondary chorionic villi*.

As soon as fertilisation takes place the mucous membrane of the uterus shows signs of reaction and becomes more vascular, The cells of the mucous membrane of the uterus proliferate and are known as *decidual cells.* These form the *decidua.*

The embedding of the fertilised ovum takes place usually at the fundus of the uterus, and the spot where it is embedded and which is going to form the placenta is called *decidua basalis* or *decidua placentalis.* A portion of the decidua covers the ovum and is called *decidua capsularis.* The rest of the decidua which lines the remaining surface of the uterus, and which together with the developing embryo occupies the interior of the uterus is called *decidua vera* or *decidua parietalis.*

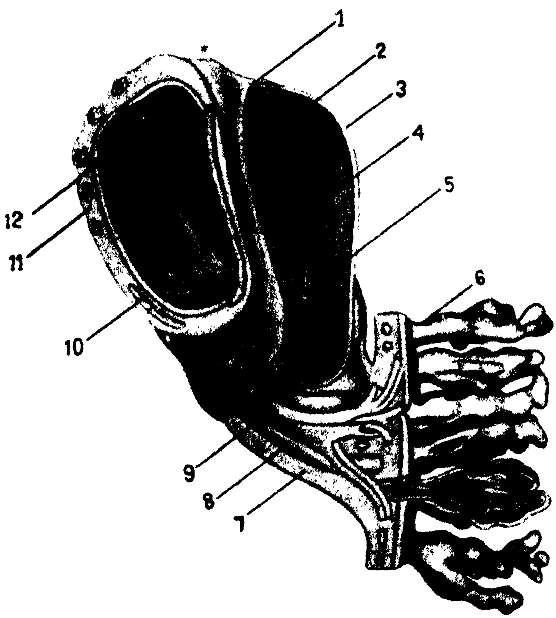

FIG. 10.—HUMAN EMBRYO, 1·3 MM. LONG. (FROM A MODEL BY ZIEGLER AFTER ETERNOD.)

1. Somatic mesoderm, 2. Amniotic cavity, 3. Amnion, 4. Neural groove, 5. Neurenteric canal, 6. Chorionic villi, 7. Bodystalk, 8. Umbilical vessels, 9. Allantois, 10. Vitelline vein, 11. Splanchnic mesoderm, 12. Entoderm.

The finger-like processes which are developed all round the chorion get pressed against the decidua vera, and atrophy and are called *chorion læve.* At the spot where the zygote gets embedded, however, the processes become well developed and

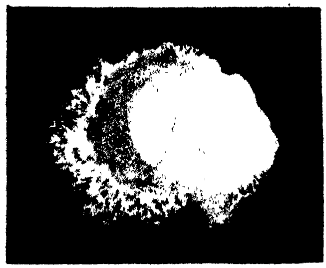

FIG. 11.—AN EARLY CHORIONIC VESICLE.
Chorion læve and chorion frondosum are clearly seen.

form the *secondary villi.* This portion of the chorion is called *chorion frondosum.* A section of one of these villi shows a core of mesoderm with afferent and efferent vessels surrounded by a layer of cells of the cytotrophoblast round which is a layer of the syncytiotrophoblast.

THE PLACENTA

The respiration, nutrition and excretion of the embryo are carried on by the placenta which is normally attached to the fundus of the uterus. Rarely the zygote is fixed near the internal os and the placenta is developed there, constituting what is called *placenta prævia*, a condition which causes great difficulty in delivery and danger to both the mother and the child. The placenta consists of two portions, the maternal constituting the decidua basalis, and the fœtal consisting of chorion frondosum. The villi of the placenta are bathed in the sinuses of blood in the uterus laid open by the destructive action of the trophoblast. Blood is brought to the uterus and taken away from it by the uterine vessels, and is conveyed to the embryo by the umbilical veins and is returned to the placenta by the umbilical artery.

The fœtus floats in the amniotic fluid contained in the amniotic cavity which is surrounded by the amnion, the chorion, and the decidua; all these become fused together and are continuous with the placenta. At birth the amniotic sac ruptures, the fluid escapes and the fœtus is expelled by the contractions of the uterus.

The Skeleton

THE skeleton is derived from the mesoderm and consists of the axial skeleton comprising the skull, the vertebræ, the ribs and the sternum, and appendicular skeleton which includes the pectoral and the pelvic girdles together with the bones of the limbs. Bones of man are developed from a membranous structure which undergoes chondrification except for the flat bones of the face and the bones of the cranial vault which ossify directly in the membrane.

The first skeletal axis to appear is the notochord which lies ventral to the neural tube. The bodies of the vertebræ are formed from the paraxial mesoderm which surrounds the notochord.

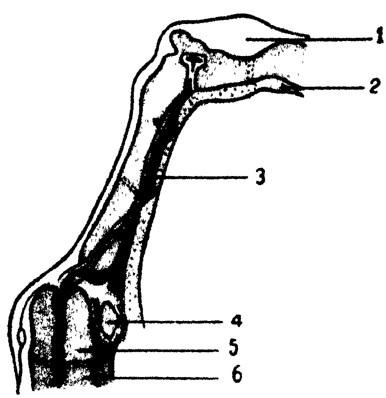

FIG. 12.—NOTOCHORD. (AFTER KEIBEL.)

1. Fossa hypophyseos, 2. Mesoderm of skull, 3. Notochord, 4. Anterior arch of the atlas, 5. Dens of the epistropheus, 6. Third cervical vertebra.

The notochord extends from the mid-brain to the tail-end of the embryo through the bodies of the vertebræ and the intervertebral disc of fibrocartilage, the dens of the epistropheus, the axial ligament of the dens, the basiocciput and the basisphenoid. A portion of the notochord sometimes passes below the basiocciput and occasionally gives rise to pharyngeal tumours. The notochord persists as the axial skeleton in the amphioxus but in the human being it disappears except for a trace in the centre of the intervertebral fibrocartilage known as the *nucleus pulposus.*

FIG. 13.—DIAGRAM SHOWING THE PORTION OF ADULT VERTEBRÆ DERIVED FROM THE BODY (STIPPLED), VERTEBRAL ARCHES (TINTED), AND COSTAL PROCESSES (WHITE), RESPECTIVELY.

The paraxial mesoderm on each side of the notochord divides transversely into a series of segments, each of which is supplied by a spinal nerve. A cavity called *myocœl* is formed in each segment but soon disappears. The outer portion of the segment becomes the myotome or muscle plate from which the muscles of the trunk develop; the inner portion forms the sclerotome from which the vertebræ are formed. The sclerotomes surround the notochord and fuse in the middle line. Dorsal extensions from the sclerotomes enclose the neural tube. The notochord and the neural tube are thus surrounded by a continuous membranous sheet called the membranous vertebral column. This column is still segmental and each segment divides transversely into two, an articular fibrocartilage appears later on in between the divisions of the segment and forms the vertebral joint of the body. The tissue round the mesoderm which surrounds the notochord is called the *hypochordal bow*, and that surrounding the neural tube is called the *vertebral bow*. Centres of chondrification appear on each side of the notochord and develop into a cartilagenous vertebral body. The hypochordal bow disappears except in the first vertebra where it persists as the arch of the atlas, while the body of the atlas is fused with the second vertebra constituting the dens of the epistropheus. A centre of chondrification appears in each lamina which later fuses with the body and at the point of fusion the spinous process develops. Failure of fusion of the two laminæ causes what is called *spina bifida* in which condition the bony wall of the vertebral canal is deficient behind.

The costal process in the cervical region forms the anterior boundary of the foramen in the transverse process. In the thoracic region the costal processes extend ventrally in the muscle plate and become the ribs. These arise in front of the transverse processes, and a joint is formed later on. In the lumbar region the costal process fuses with the transverse process and forms the transverse process of the lumbar vertebra. In the sacrum the costal processes of the upper three vertebræ fuse, while the lower two pieces and the coccyx have no costal process. The transverse processes grow behind the costal processes. In the cervical region the transverse process forms the posterior boundary of the intertransverse foramen, in the thoracic region it forms the transverse process and articulates with the rib, in the lumbar region it fuses with the costal process and forms the costal process of the lumbar vertebra, and in the upper pieces of the sacrum the transverse processes fuse with the costal processes. One or two costal processes sometimes develop into extra ribs in the cervical or in the lumbar region.

Ossification takes place by the appearance of centres of ossifications in the chondrified vertebræ.

THE STERNUM

The ventral ends of the upper seven ribs get connected together on each side by means of a longitudinal rod. The rods come together and fuse in the middle line forming the manubrium and the body of the sternum. The xiphoid process is the caudal extension of the fused rods. This rod consists of mesenchymal tissue which chondrifies and lastly ossifies.

THE SKULL

The skull forms a protective covering for the brain and the organs of special senses and is blended with the bones of the face helping to form the apparatus for mastication.

The forebrain falls over the rigid notochord producing the flexure in the mid-brain. The mesoderm extends upwards and envelops the brain. The basal part of this envelope becomes cartilagenous previous to its ossification but the upper part remains membranous and ossification takes place in membrane. Two regions can be distinguished in the base, one round the notochord called the chordal region and the other in front of this constituting the prechordal region. Segmentation can be detected in the chordal region, and four segments take part in its formation. There is no indication of segmentation in the prechordal region. Chondrification begins in the second month; a cartilagenous nucleus appears on each side of the notochord, extends forwards to the hypophysis and joins with each other forming a cartilagenous base called the *occipital plate*; this extends laterally to enclose the hypoglossal nerve forming the hypoglossal canal. The hinder region of the occipital plate does not join so early and occasionally remains separate giving rise to the condition known as *meningocele*. A pair of centres next appear in front of this and develops into the basisphenoid; these unite behind and later in front leaving an opening, the *craniopharyngeal canal*, which usually closes after a diverticulum called the *hypophysis* is given off from the base of the brain.

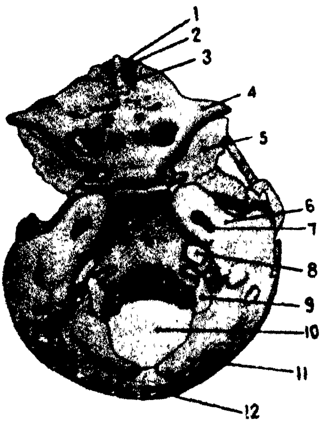

FIG. 14.—CRANIUM OF A HUMAN FŒTUS 80 MM. LONG. INSIDE VIEW. (FROM A MODEL BY ZIEGLER AFTER HERTWIG.)

1. Nasal capsule, 2. Crista galli, 3. Lamina cribrosa, 4. Orbito-sphenoid, 5. Alisphenoid, 6. Auditory capsule, 7. Internal auditory meatus, 8. Jugular foramen, 9. Condyle. 10. Foramen magnum, 11. Posterior tectum, 12. Supra-occipital.

A cartilagenous centre appears on each side which develops and becomes the alisphenoids; this constitutes the great wing of the sphenoid and fuses later with the basisphenoid. A cartilagenous centre appears for the small wing and forms the orbitosphenoid; this grows backwards and encloses the optic nerve forming the optic foramen. The small wing joins the body of the sphenoid later. The space between the great wing and the small wing becomes the superior orbital fissures. The small wing is at first bigger in size than the great wing but owing to absorption of the cartilage it becomes very small. Further chondrification in front of the basisphenoid forms the presphenoid and the nasal septum. All these fuse together to form a cartilagenous basis. The auditory capsule chondrifies next and joins the sphenoid cartilage and the occipital cartilage. The space between the capsule and the occipital becomes the jugular foramen. The nasal capsule consisting of a septum and two lateral wings chondrify in front of the presphenoid by the end of the third month; these ossify and form the ethmoid bone; the inferior nasal concha and the remaining portion persist as the nasal cartilages. It will be seen that the foramina for the transmission of vessels and nerves to and from the cranium are formed either by the junction of two portions of cartilages or by the bridging across of one part of the cartilage to the other.

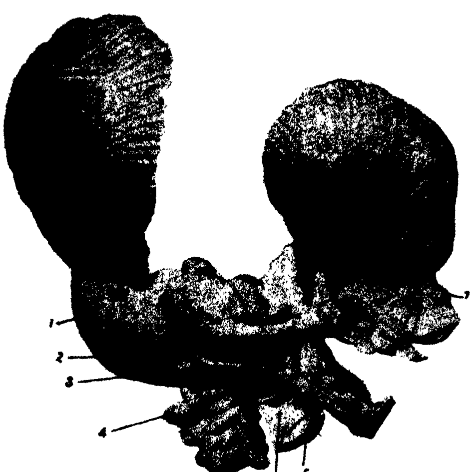

FIG. 15.—CRANIUM OF A HUMAN FŒTUS 80 MM. LONG. LATERAL VIEW (FROM A MODEL BY ZIEGLER AFTER HERTWIG.)

1. Supraparietal. 2. Tympanic, 3. Styloid, 4. Cervical vertebræ, 5. Thyroid, 6. Cricoid, 7. Nasal.

The roof of the cranium is probably developed from three *tecta* called the posterior tectum, the intermediate tectum and the anterior tectum respectively; of these the posterior tectum is the more important and persists to ossify as the supraoccipital portion of the occipital bone. The vault of the skull consists of the frontal, the parietal, the interparietal, the squama and the tympanic portion of the temporal bone, all of which ossify in membrane and are called membrane or dermal bones. Some of these fuse with the cartilage bone, such as the interparietal of the occipital, the tympanic, and the squama of the temporal while others remain free.

Development of bones takes place by the appearance of a centre of ossification called the primary centre in the cartilage (except in membrane bones in which case the centre appears in the membrane). Ossification takes place round this centre and thus a bony structure is produced which in the case of long bones is called diaphysis. A secondary centre called the epiphysial centre usually makes its appearance and ossifies. The epiphysis is separated from the diaphysis by a cartilage known as the epiphysial cartilage which ossifies later and bony continuity is established.

The Muscles

IT will be remembered that the mesoderm breaks up into somites, a portion of which becomes the myotome or muscle plate. The muscle plate is supplied by the segmental nerve, and even when the muscles deviate or migrate from their segmental arrangement, the distribution of the nerves remains unaltered.

In the region of the head which is supposed to consist of nine segments, the upper three segments give rise to the musculature of the eye, and the lower three to the musculature of the tongue. The musculature of the face and neck is derived from the branchial arches, the muscles of mastication are derived from the first or mandibular arch, and the facial muscles from the second or the hyoid arch In the thoracic region the segmental arrangement persists as the intercostal muscles; laterally portions of the myotomes unite, extend ventrally and become the rectus, the external oblique, the internal oblique, and the transversus muscles of the abdomen. The rectus muscle at first lies laterally but ultimately extends medially in apposition to its fellow of the opposite side, carrying with it the segmental nerves. The muscular segments undoubtedly extend into the limbs, but it is not definitely known as to whether they extend throughout the whole length of the limb or the peripheral muscles grow locally. The muscles, however, do not only extend forwards as in the case of intercostal and the abdominal muscles, but migrate above and below their origin, as in the case of the face muscles which originate from the second or hyoid arch and migrate above to the face, the diaphragm originating from the fourth cervical segment and migrating to the lower aspect of the thorax, and the serratus anterior muscle belonging to the fifth, sixth and the seventh cervical segments migrating down to the eighth rib.

The Skin

THE skin is derived from the ectoderm and the mesoderm. The superficial layer or epidermis, and the appendages such as hairs and nails, glands such as the sebaceous, the sudoriferous and the mammary glands are developed from the ectoderm. The mesoderm underlying the epidermis splits into two to form the corium and the connective tissue. The ectoderm which develops into the epidermis consists at first of a single layer of cells. The layer soon becomes divided into a superficial layer of flat cells called the epitrichium and a deeper layer of cubical cells called the stratum germinativum which produces the different layers of the epidermis. The superficial cells during the later period of intrauterine life are shed freely and these cells mixed with the sebaceous secretion of the embryo form a coating over it called *vernix caseosa.*

THE NAILS

The nails appear on the dorsal surface and tips of the terminal phalanges from nail folds which are developed by the invagination of the epidermis. Growth takes place at the nail folds and the nails grow until they reach the summit of the phalanges in a full term fœtus.

THE HAIR

The hair grow as solid downgrowths from the epidermis into the corium, the deeper portion becomes dilated and forms the hair bulb which fits on the mesodermic corium which forms the papilla underneath. Proliferation of cells at the bulb results in the growth of the hair outwards till it protrudes from the surface.

THE SEBACEOUS GLAND

The sebaceous glands are solid outgrowths from the sides of the hair follicles. The outgrowth becomes lobulated and hollowed out, resulting in the sebaceous gland and its duct.

SUDORIFEROUS GLAND

The sudoriferous gland develops as a flask-shaped downgrowth from the ectoderm. The flask-shaped process becomes hollow and forms the gland and its duct.

THE MAMMARY GLAND

The mammary gland is now considered to be a circumscribed collection of modified sweat glands. At about the fifth week a ridge called the *primitive mammary ridge* extending from the axilla to the inguinal region appears in the ectoderm on each side. In the lower animal such as the cat, localised swellings appear in this ridge which eventually develop into mammary glands. The number of mammary glands usually corresponds to the number of the offspring. In the human being only one mammary gland develops in the pectoral region on each side. Occasional rudiments of mammary glands or nipples sometimes persist along this ridge. Thickening appears in the ridge in the pectoral region. The thickening becomes depressed and from the depression fifteen to twenty flask-like processes grow into the underlying mesoderm. By rapid proliferation of the cells the depression is elevated to the level of the skin and later on it is raised above it to form the nipple. The flask-shaped processes multiply and become hollow to form the glands and their ducts which open at the summit of the nipple. The connective tissue round the gland is developed from the underlying mesoderm.

In the female the breast undergoes considerable hypertrophy at puberty, attains its maximum development after the termination of pregnancy when it secretes milk and atrophies in the old age. In the male the mammary gland retains its infantile condition throughout life.

The Limbs

AT about the third week a ridge appears on each side of the body of the embryo from the ends of which limb buds appear. The buds of the superior extremity appear earlier.

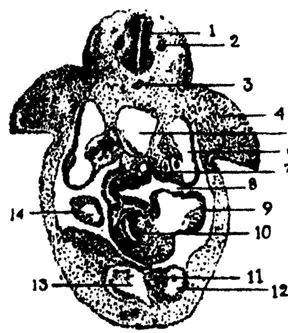

FIG. 16.—TRANSVERSE SECTION OF A 9 MM. PIG EMBRYO THROUGH THE FORE-LIMB.

1. Medulla spinalis, 2. Spinal ganglion, 3. Notochord, 4. Fore-limb, 5. Dorsal aorta, 6. Postcardinal vein, 7. Œsophagus, 8. Pleural cavity, 9. Left atrium, 10. Trachea, 11. Interventricular septum, 12. Left ventricle, 13. Right ventricle, 14. Right auricle.

The buds of both the extremities at first grow parallel to the body and are directed towards the tail, by the sixth week they turn at right angles to the body. Each limb now has a flexor surface directed ventrally and an extensor surface directed dorsally, separated by the preaxial border which is cephalic and postaxial border which is caudal. Several segments of the body extend into the limbs as indicated by the distribution of nerves. The segments accompanied by the anterior divisions of the corresponding nerves extend into the limbs in a regular order, the highest segments entering the preaxial border and the lowest entering the postaxial border. This arrangement of nerve distribution is retained even after torsion of the limb which takes place later on. Seven segments, *i. e.*, the fourth cervical to the second thoracic take part in the formation of the superior extremity and ten segments, *i. e.*, the twelfth thoracic to the fourth sacral go to form the inferior extremity. Grooves appear in the limb buds and mark out the various parts of the extremity. The fingers and toes grow as small buds from the distal portion of the differentiated hand and foot respectively. Condensation of the mesoblastic tissue takes place in the limb resulting in the formation of a single solid rod of cartilage, the tissue surrounding this rod becomes fibrous and is known as the perichondrium. The rod of cartilage is later replaced by bones and joints and the perichondrium becomes the periosteum and the ligaments respectively. The limb further undergoes a torsion to a right angle to occupy the normal position in which it is found.

The superior extremity is supplied by the anterior divisions of the fourth, fifth, sixth, seventh, eighth cervical and the first and second thoracic nerves. The limb is differentiated by the grooves into the arm, the forearm and the hand. The lateral condyle of the humerus, the radius and the thumb lie in the preaxial border which is cephalic. Torsion of about a right angle in a forward and outward direction takes place resulting in the preaxial border being directed laterally and the postaxial border medially. The flexor surface therefore becomes ventral and the extensor surface dorsal.

The lower limb is supplied by the anterior divisions of the twelfth thoracic, the first, second, third, fourth and fifth lumbar, the first, second, third and fourth sacral nerves. The grooves separate the thigh from the leg and the leg from the foot. The preaxial border, which is formed of the medial condyle of the femur, the tibia and the great toe, becomes medial on account of torsion of about a right angle which takes place in an inward and backward direction. The flexor surface thus becomes dorsal and the extensor surface becomes ventral.

The Joints

JOINTS are formed in the interval which is produced between the two developing bones. The joints are classified as immovable joints called synarthrosis, partly movable joints known as amphiarthrosis and joints with complete movements called diarthrosis.

In synarthrosis the embryonic connective tissue in the interval between the two adjacent bones becomes modified and connects the two bones together, such as in the articulation of the skull bones.

In amphiarthrosis the embryonic connective tissue found in the interval may develop into a thick pad of fibrocartilage, the intervertebral disc is an example.

In diarthrosis the embryonic connective tissue is either completely absorbed with the formation of a joint cavity or is developed into a fibrocartilagenous disc which divides the joint partially or completely such as in the kneejoint and the sternoclavicular joint respectively.

The membrane which runs from one bone to the other and forms the periosteum over the bones is modified over the interval (the joint) and forms the capsule of the joint. The cells of the deep surface of the capsule are modified to form the synovial membrane which secretes synovial fluid. Special bands are formed on the sides of the capsule and are called ligaments. These may either simply be the thickened capsule, modified tendons or aponeuroses of muscles. Some joints are further reinforced by tendons and aponeuroses of muscles.

The Face

THE stomodæum is bounded above by the frontonasal process, below by the mandibular process and on each side by the maxillary process which is given off from the dorsal extremities of the mandibular process. Two thickenings called the *olfactory plates* appear in the frontonasal process on each side. The olfactory plates sink and the depressions are called

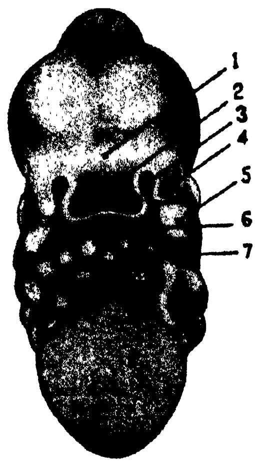

FIG. 17.—HEAD OF A HUMAN EMBRYO ABOUT THIRTY DAYS OLD. (AFTER PETER.)

1. Future apex of the nose, 2. Medial nasal process, 3. Olfactory pit, 4. Lateral nasal process, 5. Maxillary process, 6. Stomodæum, 7. Mandibular arch.

the *olfactory pits.* These divide the frontonasal process into a medial portion called the *medial nasal process* and two lateral portions called the *lateral nasal processes.* The medial nasal process develops a swelling on each side called the *globular process* which grows medially and develops into the premaxilla and the middle portion of the upper lip. The central portion of the medial nasal process gets depressed and forms the inferior part of the nasal septum or *columella.* The upper part of the process gives rise to the apex and bridge of the nose. The upper part of the nasal septum is formed of two plates called the *nasal laminæ* which grow backwards from the medial nasal process and fuse later. The ala of the nose is formed from the lateral nasal process which also gives rise to a part of the ethmoid bone, inferior nasal concha, the alar cartilages, the lacrimal, the nasal and the frontal processes of the maxillary bone. The maxillary process grows on each side and fuses with the lateral nasal process above and the globular process medially. The lacrimal sac and the nasolacrimal duct develop in the line of fusion between the maxillary process and the lateral nasal process. The lateral part of the upper lip and the posterior part of the nares as well as the primitive palate result from the fusion of the maxillary process with the globular and lateral nasal processes. The maxillary process gives rise to the lower eyelid, the cheek, the lateral part of the upper lip, the zygomatic bone and the greater portion of the maxilla. The mandibular arch gives rise to part of the mandible and the lower lip.

The olfactory pits grow backwards over the primitive palate. They are at first separated from the stomodæum by a partition called the bucconasal membrane which disappears at about the fifth week and the stomodæum communicates with openings of the olfactory pits which have now become the primitive choanæ. At about the ninth week a projection called the palatine process grows medialwards from each maxillary process and fuses with each other and the nasal septum, forming the greater part of the hard palate ; the anterior part of the hard palate, however, is formed of the premaxillæ. A secondary growth from each palatine process grows backwards into which the palatine muscles extend, fuse in the middle line and become the soft palate and the uvula. The permanent choanæ are formed at about the eleventh week. The cartilagenous septum remains as the septal cartilage anteriorly and develops into the vomer and the perpendicular plate of the ethmoid posteriorly. An entodermal diverticulum extends backwards and upwards into the lower and anterior part of the nasal septum on each side and forms the rudiment of the *vomeronasal organ of Jacobson.*

Occasionally these processes fail to unite resulting in harelip and cleft palate. Harelip is the result of want of union of the maxillary process with the globular process and sometimes the lateral nasal process as well. Cleft palate is caused for want of union of the palatine processes, or the palatine process and the nasal process. Harelip is often associated with cleft palate.

The Pharynx

THE cephalic portion of the foregut dilates to form the primitive pharynx. The buccopharyngeal membrane disappears soon after and continuation with the stomodæum is established. Thirteen depressions appear in the interior of the pharynx, of these five on each side develop into what are called pharyngeal pouches. Of the three medial depressions one grows dorsally and develops into a vesicle called the Seessel's pouch which is a temporary structure; another grows ventrally and forward and develops subsequently into the thyroid gland ; the third grows ventrally and caudally and forms the respiratory system. Depressions appear outside the pharynx corresponding to the pharyngeal pouches and are known as branchial clefts or grooves. Each of these grooves is separated from the corresponding pouch by a structure which consists of the ectoderm and entoderm only, called the covering membrane. This membrane is perforated in gill-bearing animals to form gill clefts. The portion between the two pouches and the two clefts is condensed and is called branchial arch. Five of these arches are present, of which the last is invisible from the outside.

Each of these arches has a cartilagenous element, a muscular element, an artery known as the aortic arch and a nerve. These develop into the bone, the muscles, the artery and the nerve of the arch respectively. The first arch is known as the mandibular arch, the second as the hyoid arch, the third, the fourth and the fifth arches have not received special names but are sometimes called the first, the second, and the third arches proper respectively. The mandibular and hyoid arches grow rapidly and overlap the lower three arches. A depression called the cervical sinus is formed at the point of overlapping. This sinus becomes a vesicle which usually disappears by the eighth week.

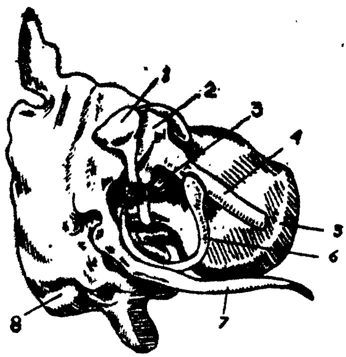

FIG. 18.—VISCERAL SKELETON OF THE AUDITORY REGION IN A HUMAN FŒTUS 80 MM. LONG. (FROM A MODEL BY ZIEGLER AFTER HERTWIG.)

1. Incus, 2. Malleus, 3. Stapes, 4. Meckel's cartilage, 5. Auditory capsule, 6. Tympanic ring, 7. Styloid, 8. Mastoid.

The mandibular arch is situated between the stomodæum and the first cleft. The cartilagenous element of this arch is called the Meckel's cartilage, its ventral part gives rise to a portion of the mandible, the intermediate part is degenerated and forms the sphenomandibular ligament, and the dorsal part gives rise to the two ossicles of the ear known as the malleus and the incus. The muscular element of this arch gives rise to the muscles of mastication, the mylohyoid, the anterior belly of the digastric and the tensor tympani muscles. The anterior two-thirds of the tongue is developed from the sides of the arch. The maxillary process which arises from the dorsal end of the arch gives rise to the zygomatic bone and the greater part of the maxilla. The nerve of the arch becomes the mandibular nerve and the artery becomes the internal maxillary artery.

The hyoid arch lies between the first and the second cleft. The cartilagenous element of the arch is called the hyoid bar and gives rise dorsally to the third ossicle of the ear called the stapes and the styloid process (*tympanohyal* and the intermediate portion degenerates into the stylohoid ment (*epihyal*) and forms the lesser cornu of the hyoid bone (*ceratohyal*), the ventral portion fuses with the ventral portion of the third arch and forms the body of the hyoid bone (*basihyal*). The muscles form the muscles of expression (facial), the stylohyoid, the posterior belly of the digastric and the stapedius. The nerve of this arch becomes the facial nerve, and the artery becomes the external maxillary artery.

The third branchial arch (the first arch proper) has its cartilagenous element fused with the hyoid arch to form the body of the hyoid bone. The posterior third of the tongue is also derived from the fused second and third arches. The muscles form the pharyngeal muscles, the nerve of the third arch becomes the glossopharyngeal nerve, and the artery becomes the lingual artery.

The fourth and fifth arches give rise to the thyroid and cricoid cartilages through their cartilagenous element, the muscles form the pharyngeal and laryngeal muscles, the nerve of the arches becomes the vagus nerve, and the artery becomes the superior thyroid artery.

The first branchial groove develops into the concha and the external acoustic meatus; the auricle is formed from several swellings which appear on the mandible and hyoid arches. The remaining branchial grooves disappear and no trace is left of them.

The upper portion of the first and second pharyngeal pouches develop into the tympanic cavity and the auditory tube; the covering membrane between the mandibular and hyoid arches is again invaded by mesoderm and develops into the tympanic membrane. The dorsal extremity of the second pharyngeal pouch gives rise to the tonsil and the supratonsillar fossa. The third pharyngeal pouch gives rise to the thymus and the inferior parathyroid; the position of the third pouch is indicated in the adult by the piriform fossa. The superior parathyroid is developed from the fourth pouch. The fifth pouch gives rise to the ultimobranchial body which blends with the thyroid rudiment but does not take any part in its formation.

The Digestive System

THE primitive digestive tube consists of the foregut, the midgut, and the hindgut.

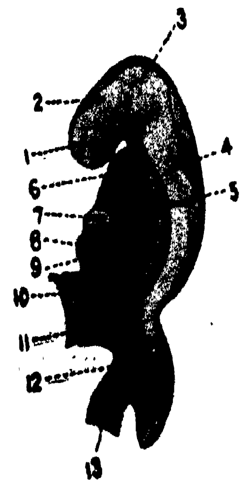

FIG. 19.—MEDIAN SECTION OF A HUMAN EMBRYO OF THE THIRD WEEK. (FROM A MODEL BY ZIEGLER AFTER HIS.)

1. Optic vesicle, 2. Mesencephalon, 3. Isthmus, 4. Myelencephalon, 5. Notochord, 6. Primitive pharynx, 7. Heart, 8. Liver, 9. Foregut, 10. Midgut, 11. Yolk sac, 12. Hindgut, 13. Bodystalk.

The *Foregut* is situated in the cephalic region of the embryo dorsal to the pericardium and gives rise to the pharynx, the œsophagus, the stomach, the greater part of the duodenum, together with the thyroid, the parathyroid, the thymus, the liver and the pancreas.

The *Midgut* which gives rise to the greater part of the small intestine is the intermediate portion of the primitive gut and is connected with the yolk sac by the vitelline duct.

The *Hindgut* is situated in the tail end of the embryo and gives rise to the terminal portion of the ilium, the large intestine with the exception of a small portion of the anal canal, the urachus, the urinary bladder, the female urethra and the greater portion of the male urethra.

On account of the bending of the embryo the pericardial area is brought down from the cephalic to the ventral position and the forebrain follows it. A depression is formed between the forebrain and the pericardium called the stomodæum; this is separated from the foregut by a partition called the bucco-pharyngeal membrane which does not contain mesoderm but is formed of the ectoderm and the entoderm. The membrane disappears at about the third week and the foregut communicates with the stomodæum. The cephalic portion of the foregut keeps pace with the elongation of the neck and trunk, and forms the pharynx and the œsophagus.

The growth of visceral arches on each side from the dorsal wall between the forebrain and the pericardium further aids in the formation of the face and neck. The first arch, called the mandibular arch, forms the lower (caudal) boundary of the stomodæum. A process, called the maxillary process, is given off from each side of the mandibular arch and limits the stomodæum laterally. The upper boundary is formed of the projecting portion of the forebrain called the frontonasal process A depression called the labial groove appears in the boundaries of the stomodæum and separates the internal alveolar portion which forms the alveolar process from the lips and cheeks. Meanwhile processes from the lateral walls called the palatine processes approach each other and meet medially separating a lower buccal cavity from an upper nasal cavity.

THE TONGUE

The tongue is developed from two distinct sources: one from the mouth called the buccal part concerned with mastication and the other known as the pharyngeal part from the pharynx concerned chiefly with deglutition. An elevation in the region of the mandibular arch called the tuberculum impar was according to His supposed to form the anterior two-thirds of the tongue, but later investigations by Kallius and others show that at least the greater part of the anterior portion of the tongue is formed of two lingual buds each arising from the sides of the mandibular arch, and uniting in the middle line. It is doubtful as to whether the tuberculum impar takes any part in the formation of the tongue. The bifid condition of the anterior part of the tongue in the very early embryo or occasionally in the adult points to its bilateral origin. The posterior or pharyngeal portion of the tongue is developed from an elevation called the copula formed of the fused ventral ends of the second and third visceral arches. A V-shaped furrow called the sulcus terminalis marks the junction of the two portions of the tongue. From the apex of the furrow the thyroid takes its origin as a median diverticulum and is represented by a shallow pit called the foramen cæcum.

THE THYROID GLAND

The thyroid gland develops at about the fourth week as a bud behind the tuberculum impar. The bud descends into the neck and gives off two lateral lobes. The part which joins the two lobes forms the Isthmus. The stalk by which the bud descends is called the thyroglossal duct. It disappears by the second month with the exception of the foramen cæcum in the tongue above and the pyramidal lobe below. The thyroglossal duct sometimes persists and passes in front of the cricoid and thyroid cartilages and may pass behind, in front or through the hyoid bone. Occasionally glandular tissue may develop in the course of the duct. Cysts in the course of thyroglossal duct are also met with. The ultimobranchial body which is developed from the fifth pouch is associated with the thyroid gland but does not take any part in its formation being a transitory structure in the human being.

The *Parathyroid Glands* develop from the third and the fourth pouches. The pair arising from the third pouch is associated with the thymus and descends with it and becomes the inferior parathyroid. The pair arising from the fourth pouch retains its position and becomes the superior parathyroid.

THE SALIVARY GLANDS

The salivary gland develops from a groove which becomes tubular; the terminal portion of which gives off numerous solid buds. These become hollow and form the acini of the gland. The tube becomes the main duct. The cells of the epithelium of the buds develop into the secreting cells of the gland while those of the tube become the lining cells of the duct.

The *Parotid Gland* develops at about the fourth week as a groove between the mandibular arch and the maxillary process. The submaxillary and sublingual glands are developed similarly from their respective positions at a later period.

THE TEETH

The principal part of a tooth consists of the enamel, the dentine and the tooth pulp. The milk tooth is enclosed in a sac which is absorbed in time and eruption of the tooth takes place. The tooth sac and the enamel are derived from the ectoderm covering the primitive alveolar process. The dentine and the tooth pulp are derived from the mesoderm.

At about the sixth week a uniform thickening called the *dental lamina* appears in the ectoderm of the primitive alveolar process. From the dental lamina ten processes corresponding to the teeth grow deep into each jaw and form a cup-shaped structure which gives rise to the enamel of the tooth. The underlying mesoderm gets into the hollow of the cup and forms the *dental papilla* which gives rise to the dentine superficially and the tooth pulp in its deeper aspect. Blood vessels, lymphatics and nerves grow in the pulp. The enamel and dentine become very hard by calcification and form the tooth substance. The ectoderm overlying the cup becomes the tooth sac. A permanent set of teeth next develop deep to, and to the lingual side of the temporary set above described. Some of the permanent teeth replace the temporary ones and are called the *successional permanent teeth*. Those that develop in addition to the *successional* ones are called the *superadded permanent teeth.*

THE PALATINE TONSIL

The dorsal end of the second pharyngeal pouch forms the sinus tonsillaris the upper end of which forms the supratonsillar fossa and the lower end gives rise to solid buds which form the crypts of the tonsil. Lymphoid tissue grows in between the crypts and forms lymphoid follicles.

THE THYMUS

A diverticulum from the entoderm of the third pouch grows caudalwards and joins a similar diverticulum of the opposite side to form the thymus gland. The stalk of the thymus is at first hollow but later degenerates into a fibrous cord. Cells multiply in the diverticulum which is invaded by lymphoid tissue and the thymus thus develops till about the age of two years when it reaches its maximum development and later atrophies by puberty. Rarely the thymus persists in the condition known as *status lymphaticus* in which the lymphoid tissue in general, is enlarged. A portion of the thymus is sometimes formed from the fourth pouch as well.

THE HYPOPHYSIS

The hypophysis or the pituitary body consists of an anterior lobe formed of a pars anterior and a pars intermedia, and a posterior lobe. It is developed from the nervous tissue of the brain and the epithelium of the stomodæum, both of which are derived from the ectoderm. The anterior lobe is developed from the stomodæum in front of the buccopharyngeal membrane in the form of a diverticulum which passes forwards (cephalic) ventral to the notochord to the base of the forebrain and forms a vesicle called Rathke's pouch ; there it meets another diverticulum which forms the posterior lobe from the base of the third ventricle. The two meet, fuse and become compressed. The anterior wall of Rathke's pouch becomes the pars anterior, and the posterior wall becomes the pars intermedia. The anterior lobe is connected for a short while with the stomodæum. The cavity of the anterior lobe disappears but occasionally persists as a slit between the pars anterior and the pars intermedia. The posterior lobe has a cavity which is connected to the cavity of the third ventricle. The cavity however disappears but the lobe remains connected to the forebrain by means of the infundibulum, Behind Rathke's pouch an evagination from

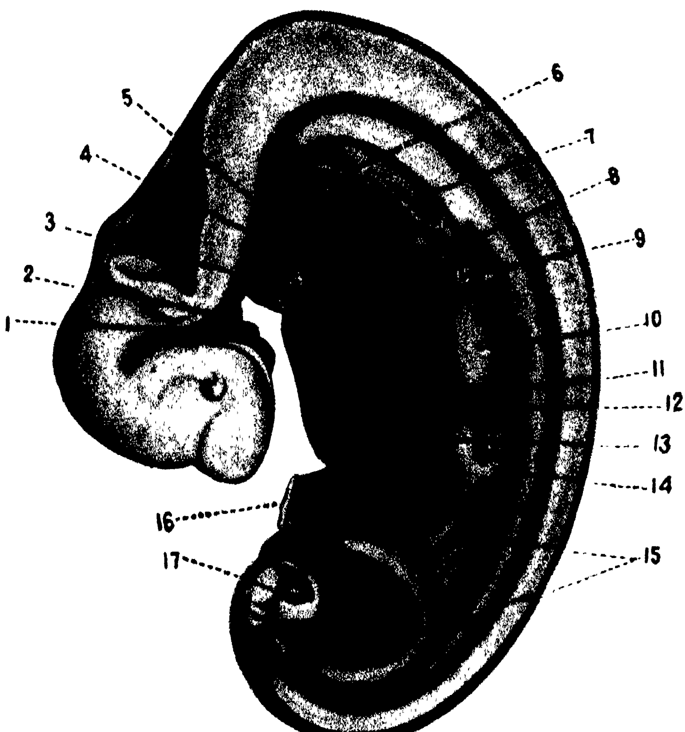

FIG. 20.—MEDIAN SECTION OF A HUMAN EMBRYO OF THE FIFTH WEEK, SHOWING GENERAL RELATIONS OF THE ALIMENTARY CANAL. (FROM A MODEL BY ZIEGLER AFTER HIS.)

1 Rathke's pouch, 2. Maxillary process, 3. Mandibular process, 4 Tongue, 5. Thyroid, 6 Laryngotracheal groove, 7. Œsophagus, 8. Bronchus, 9. Lung bud, 10. Stomach, 11. Spleen, 12 Liver, 13. Bile duct, 14. Dorsal pancreas, 15. Intestine, 16. Umbilical cord, 17. Cloacal membrane

the foregut develops into another vesicle called the Seessel's pouch which disappears in man, but persists in some mammals.

THE STOMACH

At about the fourth week a dilatation in the caudal portion of the foregut forms the primitive stomach. The portion between the pharynx and the primitive stomach elongates and forms the œsophagus. The dilatation becomes fusiform in shape, its dorsal portion develops very rapidly and becomes the greater curvature of the stomach, the ventral portion, however, does not develop to such an extent and becomes the lesser curvature. According to Lewis a canal called the gastric canal running along the lesser curvature of the stomach is found in a 16 mm. embryo and attains its maximum development in a 43 mm. embryo. The canal has been found to exist even in the adult stomach by some observers. The development of the septum transversum and the liver causes the stomach to descend. The above factors bring about the rotation of the stomach to the right so that the right surface becomes dorsal and the left ventral. The right and the left vagi nerves which were situated one on each side of the stomach become dorsal and ventral respectively.

The gut is suspended from the dorsal wall by means of a mesentery which in the case of the stomach is called the dorsal mesogastrium. A ventral mesentery derived from the septum transversum is also present at the lesser curvature of the stomach and is called the ventral mesogastrium.

THE DUODENUM

The portion of the gut immediately succeeding the stomach is bent and becomes the duodenum; on account of the rotation of the stomach the duodenum is applied to the dorsal abdominal wall, the mesentery and the peritoneum of the dorsal wall of the duodenum gets absorbed resulting in its fixation there.

The remaining portion of the gut forms a loop with its convexity forwards where the vitelline duct is attached. The superior mesenteric artery runs in the loop through the mesentery.

The appearance of the primitive cæcum in the shape of a dilatation in the convex margin of the gut below the vitelline duct determines the division of the gut into the small and the large intestine. The portion of the gut cephalic to the cæcum becomes the jejunum and ileum and that caudal to the cæcum becomes the colon, the rectum and a part of the anal canal.

The cæcum develops in an irregular manner, the caudal portion becomes elongated resulting in a cone, a condition known as the *infantile cæcum* if it persists. Further elongation and narrowing of the caudal portion results in the vermiform process (appendix). The lateral portion of the cæcum is free and therefore grows and gives the characteristic appearance to the cæcum.

Considerable elongation of the gut takes place resulting in the coiling of the small intestine and rotation of the large. The cæcum, on account of the rotation, is carried at first below the stomach, then across and below the liver and finally descends into the right iliac fossa to its normal position. Rarely complete rotation does not take place with the result that the cæcum may remain below the liver.

THE RECTUM

The hindgut forms a dilatation in its caudal extremity called the entodermal cloaca into which the allantois the Mullerian ducts and the Wolffian ducts open ventrally. A depression is produced into the corresponding region externally called the ectodermal cloaca which is separated from the entodermal cloaca by the cloacal membrane. A coronal partition called the *urorectal septum* extends downwards to the cloacal membrane and divides the entodermal cloaca into a ventral portion which forms the urogenital sinus and bladder, and a dorsal portion which forms the rectum. The cloacal membrane which is also divided into an anterior and a posterior portion disappears by the end of the fourth week and the urogenital sinus, the bladder and the rectum open externally. A portion of the hindgut termed the post-anal gut extends into the tail end of the cloaca but soon disappears.

Incomplete development of these processes result in various abnormalities. The *rectovesical fistula* is the result of incomplete division of the entodermal cloaca by the urorectal septum. Persistent cloacal membrane results in *imperforate anus.*

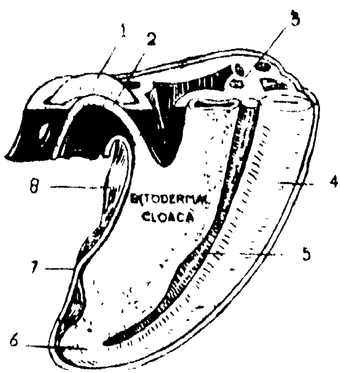

FIG. 21.—THE TAIL END OF A HUMAN EMBRYO ABOUT FOUR WEEKS OLD, SHOWING URORECTAL SEPTUM. (FROM A MODEL BY ZIEGLER AFTER KEIBEL.)

1. Umbilical artery, 2. Allantois, 3. Aorta, 4. Spinal medulla, 5. Notochord, 6. Postanal gut, 7. Cloacal membrane, 8. Ectodermal cloaca

The Cœlomic Cavity which appears between the somatopleur and the splanchnopleur is divided into an upper pleural, and a lower peritoneal cavity by the development of the diaphragm.

The Diaphragm.—In the early embryo a thick mesodermal partition called the septum transversum appears and extends ventrally from the level of the second cervical segment between the pericardium and the vitelline duct to the body wall. Laterally it is deficient and the pleural and pericardial cavities communicate through the deficiency. The caudal portion of the septum transversum gives rise to the ventral mesogastrium which develops into the falciform and coronary ligaments, a portion of the liver and the lesser omentum. The cephalic portion of the septum gives rise to the central tendinous part of the diaphragm. The muscular part of the diaphragm is derived from two sources: the sternocostal portion from the ventral longitudinal muscles of the neck and the dorsal portion from the prevertebral muscles. These fuse with the septum transversum and form the diaphragm.

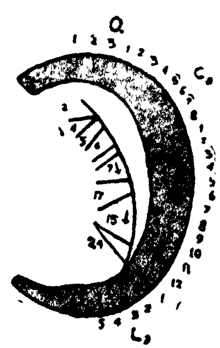

FIG. 22.—DIAGRAM TO SHOW THE POSITION OF THE SEPTUM TRANSVERSUM IN A GROWING EMBRYO FROM 2 MM. TO 24 MM. (AFTER MALL.)

O. Occipital, C. Cervical, T. Thoracic, L. Lumbar.

The septum transversum which originates from the third and fourth cervical segments and hence innervated by the third and fourth cervical nerves through the phrenic, descends with the heart and the pericardium, as the latter develop and descend caudally. The union of the central tendinous with the lateral muscular portions is sometimes wanting with the result that a pleuro-peritoneal opening persists, as a rule on the left side and abdominal viscera may herniate into the thoracic cavity. Such a condition is known as *diaphragmatic hernia.*

THE PERITONEAL CAVITY

The abdominal cavity is lined by peritoneum which is reflected from the dorsal wall of the abdomen to enclose the primitive gut forming the dorsal mesentery. On account of the development and rotation of the stomach, the dorsal border of the stomach and its mesentery which is called the dorsal mesogastrium are turned forward to the left. Two organs make their appearance in the dorsal mesogastrium: the spleen is developed above and to the left, and the pancreas is developed below. The spleen applies itself to the posterior and superior aspect of the left dome of the diaphragm, and the pancreas to the dorsal wall of the abdomen by its right surface. The mesogastrium between the pancreas and the stomach becomes immensely elongated and forms the great omentum.

The right surface of the stomach which becomes dorsal covers a cavity called the omental bursa which extends between the layers of the great omentum. The cavity communicates with the greater sac on the right side by a wide opening called the epiploic foramen (Winslow). As the stomach increases in size the omental bursa as well as the epiploic foramen grow proportionately in size; the growing liver. however, obliterates a greater portion of the foramen epiploicum and fusion of the layers of the great omentum causes a diminution in the size of the omental bursa. The great omentum comes in contact with the transverse mesocolon and fuses with it.

THE LIVER

The liver (see Figures 19 and 20) is developed from that portion of the foregut which ultimately forms the duodenum. A bud is given off from the ventral aspect of the foregut, and grows into the ventral mesogastrium. The bud is soon differentiated into two portions which form the right and left lobes of the liver. Columns of cells soon grow and enclose the vitelline and the umbilical veins, which break up into capillaries which pervade the cells and form a vascular network called sinusoids. The cells next arrange themselves into groups, each surrounding a minute channel which becomes the bile capillary. These meet to form small ducts which join together and become the hepatic ducts. The original stalk which arises from the duodenum becomes the bile duct. A solid bud is given off from the bile duct, becomes hollow and forms the cystic duct and the gall bladder. The position of the opening of the bile duct which was ventral to begin with changes to the left and finally occupies the dorsal position. The ventral mesogastrium which is the caudal portion of the septum transversum is divided by the growing liver into a cephalic portion forming the falciform and the coronary ligaments and a caudal portion which forms the lesser omentum. The size of the liver is relatively very large and at the third month occupies almost the whole of the abdominal cavity. The development is retarded later on, specially on the left side, resulting in a larger right lobe and a smaller left lobe. The liver, however, remains relatively larger than in the adult even at birth.

THE PANCREAS

In a 4 mm. embryo the pancreas may be observed to develop in the dorsal mesogastrium by two buds from the dorsal and ventral aspect of that portion of the alimentary canal which forms the duodenum. The dorsal bud appears earlier and arises from the dorsal wall of the duodenum and gives rise to the upper part of the head, the body and the tail. The ventral bud arises from the root of the hepatic bud and gives rise to the lower part of the head. On account of the rotation of the stomach and the duodenum the two buds come together and fuse at about the sixth week. The duct of the ventral bud becomes the main duct and that of the dorsal bud becomes the accessory duct. During the process of fusion of the two buds, the ducts also join and open into the bile duct. The continuation of the accessory duct into the duodenum usually disappears, and even if the duct persists it does not convey any secretion to the duodenum. The pancreas is at first situated with its head ventral but owing to the rotation of the stomach and the duodenum the head occupies the right side in the bend of the duodenum, the tail points to the left in contact with the spleen, its right side becomes dorsal and its left side becomes ventral. The pancreas possesses for a short time a mesentery which is eventually absorbed as the dorsal surface of the pancreas becomes fixed to the posterior abdominal wall.

THE SPLEEN

The spleen develops in the dorsal part of the mesoderm of the dorsal mesogastrium at about the fourth week. A thickening appears in that region and becomes vascular. Lymphoid tissue appears next and forms the spleen pulp. The fibrous capsule and the trabeculæ are derived from the mesoderm. Due to the rotation of the stomach the spleen moves to the left behind the stomach and comes in contact with the left kidney. The tail of the pancreas next to which the spleen bud originated remains in contact with it.

The Respiratory System

AT about the fourth week a groove called the laryngotracheal groove appears in the ventral wall of the pharynx and by the approximation of its margins is converted into a tube called the *laryngotracheal tube.* The lining of the tube is continuous with the entodermal lining of the pharynx. The proximal portion of the tube opens into the pharynx and forms the larynx. The distal portion develops into the trachea which bifurcates into the two bronchi. The extremities of the bronchi dilate, become saccular, and form the lung buds.

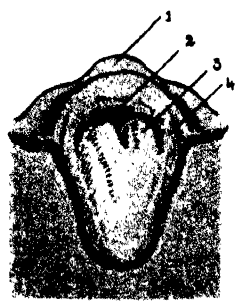

FIG. 23.—THE DEVELOPING LARYNX. (FROM A MODEL BY ZIEGLER AFTER PETER.)

1. Base of the tongue, 2. Epiglottis, 3. Arytenoid cartilage, 4. Aryepiglottic fold.

At the beginning of the third month lateral swellings appear on each side of the proximal opening of the trachea to form the arytenoid cartilages and the aryepiglottic folds. A little later another swelling appears in the middle line and develops into the epiglottis.

The lung buds on each side divide into three lobules on the right and two on the left. These lobules develop into the lobes of the lungs. Further subdivision of the lobules takes place and form the infundibula. Blood vessels and capillaries next make their appearance. The artery which goes to the lungs is derived from the right sixth arch and forms the pulmonary artery. As development of the neck and thorax proceeds the lungs descend caudally into the pleural cavity. The mesoderm surrounding the lungs becomes the pleuræ.

The Nervous System

THE nervous system is derived from the ectoderm in the mid-dorsal region of the embryo. The ectoderm becomes thickened and forms the neural plate, the sides of which become elevated and are called the neural folds. The depression between these folds is called the neural groove. The neural folds grow and fuse dorsally and convert the neural groove into a neural tube.

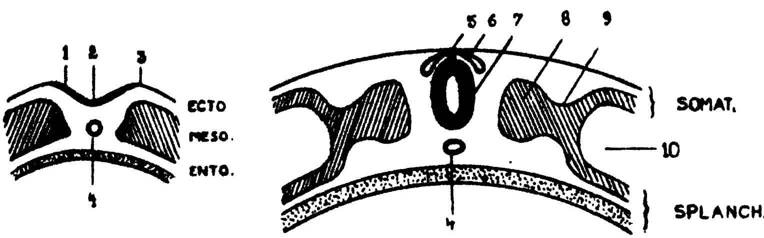

FIG. 24.—DIAGRAM OF THE DEVELOPMENT OF THE NEURAL TUBE.

1. Neural plate, 2. Neural groove, 3. Neural fold, 4. Notochord, 5. Neural crest, 6. Sympathetico-chromaffin cells, 7. Neural tube, 8. Paraxial mesoderm, 9. Intermediate cell mass, 10. Cœlom, ECTO. ectoderm, MESO. mesoderm, ENTO. entoderm, SPLANCH. splanchnopleure, SOMAT. somatopleure.

The neural tube is open at both ends to begin with. These openings which are called neuropores close by the third week. The cephalic end of the tube is dilated and is differentiated by means of constrictions into three vesicles called the fore-brain, the mid-brain and the hind-brain. The cavity of the neural tube in this region is modified to form the ventricles and the aqueduct of the brain. The remaining caudal part of the neural tube becomes the spinal medulla, and the cavity becomes the central canal of the medulla spinalis.

As the neural folds are raised to fuse in the middle line they carry with them the adjacent ectoderm, which closes dorsally. The cells between the dorsum of the neural tube and the joined ectoderm develop into what is called the neural crest which is the rudiment of the cerebral, spinal, and the sympathetic ganglia, the chromaffin system, and the primitive nerve sheath.

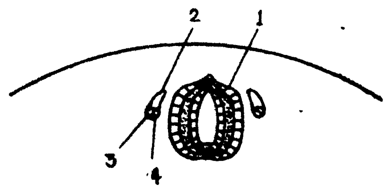

FIG. 25.—DIAGRAM OF THE DIFFERENTIATION OF THE SYMPATHETICO-CHROMAFFIN CELLS.

1. Neural tube, 2. Spinal ganglion, 3. Chromaffin cells, 4. Sympathetic ganglion.

Outgrowth of cells takes place from each side of the neural crest. These cells which are called the primitive ganglia are arranged in pairs in each segment; each loses its connection with the neural crest and migrates laterally. The neural crest after giving rise to the primitive ganglia disappears. The primitive ganglia at this stage lie by the side of neural tube quite free and increase in size owing to proliferation of the cells and are differentiated into ventral and dorsal portions. The ventral portion develops into the sympatho-chromaffin cells, migrates forward and differentiates into the rudiments of chromaffin tissue and of the sympathetic ganglia. The dorsal portions form the rudiments of the cerebral and the spinal ganglia. The rudiments of the chromaffin tissue get separated from the main mass and form the carotid body, the medulla of the suprarenal and other chromaffin bodies. The separated rudiments of the sympathetic ganglia form the various sympathetic ganglia. Fibres proceed from the rudiments of the spinal and the cerebral ganglia in opposite direction to form the spinal and the cerebral nerves respectively. In the case of the spinal nerve some of the fibres rejoin the dorsal region of the medulla spinalis, while the others pass forwards, become associated with fibres proceeding from the ventral portion of the medulla spinalis, and form the spinal nerve trunk. The cells of the spinal ganglia as mentioned above are bipolar, with two sets of fibres or processes passing in the opposite directions. These processes gradually approach each other and fuse to form a T-shaped process. The bipolar arrangement, however, persists in the ganglia of the acoustic nerve and the cells of the retina.

The nerve tube to begin with consists of a single layer of ectoderm cells enclosing the neural canal. The lateral walls become thickened while the ventral and dorsal portions remain undeveloped and thin and are called the *roof plate* and the *floor*

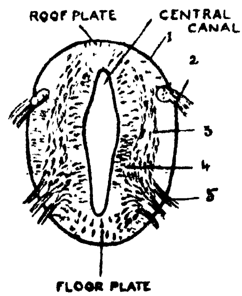

FIG. 26.—A TRANSVERSE SECTION OF THE MEDULLA SPINALIS OF A HUMAN EMBRYO FOUR WEEKS OLD. (AFTER HIS.)

1. Marginal layer, 2. Posterior nerve root, 3. Mantle layer, 4. Ependymal layer, 5. Anterior nerve roots.

plate respectively. The cells of the lateral wall proliferate so rapidly as to produce a syncytium which becomes defined into three layers, the external called the marginal, the intermediate called the mantle, and the internal called the ependymal layer The marginal layer forms the framework for the white funiculi of the medulla spinalis; the mantle layer becomes the grey matter of the medulla spinalis and is differentiated into two series of cells, the spongioblasts which form the neuroglia cells or the connective tissue of the nervous system and the neuroblasts which form regular nerve cells; the ependymal layer becomes the ependyma of the central canal. At an early stage the cavity of the neural tube is represented by a longitudinal slit, which later becomes dilated and its widest part separates the interior of the lateral wall into a ventral portion called the *basal lamina* and a dorsal portion called the *alar lamina*. The roof plate, the floor plate, the alar and the basal laminæ get modified to form the various structures of the brain and the medulla spinalis.

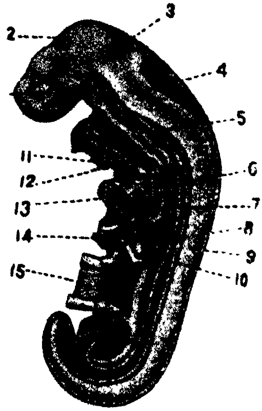

FIG 27. —MEDIAN SECTION OF A HUMAN EMBRYO THREE WEEKS OLD. (FROM A MODEL BY ZIEGLER AFTER HIS.)

1. Optic vesicle, 2. Mesencephalon, 3. Isthmus, 4. Myelencephalon, 5. Notochord, 6. Trachea, 7. Œsophagus, 8. Stomach, 9. Medulla spinalis, 10. Dorsal aorta, 11. Ventral aorta, 12. Primitive pharynx, 13. Heart, 14. Liver, 15. Yolk sac.

THE BRAIN

The thickened cephalic portion of the neural tube differentiates itself into the three portions, *i.e.*, prosencephalon or fore-brain, mesencephalon or mid-brain and rhombencephalon or hind-brain.

Three flexures appear in the region of the brain. The first flexure with its concavity forwards appears in the mid-brain over the notochord and is called the ventral cephalic flexure. The second one known as the cervical flexure appearing at the junction of the hind-brain and the medulla spinalis is concave forwards. The third flexure, which is known as the pontine flexure, differs in being convex forwards and appears in the region of the pons.

The Prosencephalon or the fore-brain presents at an early period a thin roof and floor plate connecting two thick lateral walls. Each lateral wall is divided by a furrow called the *sulcus of Munro* into an alar and a basal lamina.

A diverticulum called the optic vesicle appears on each side of the anterior aspect of the fore-brain and expands ventrally to form the retina. The dorsal portion of diverticulum elongates and forms the optic nerve. The fore-brain grows forwards and develops a pouch on each side. These pouches expand, overlap the fore-brain, the mid-brain and the hind-brain and become the cerebral hemispheres. The cavities within these pouches become the lateral ventricles and communicate freely by means of a wide passage with the third ventricle which is the original cavity of the fore-brain. The passage between the lateral and the third ventricle becomes narrow and is known as the interventricular foramen (Monro). The hemispheres are connected together by means of a portion of brain matter called the lamina terminalis. The corpus callosum, the fornix and the anterior commissure develop later and form further connections. The fore-brain is thus subdivided into an anterior portion called the *telencephalon* and a posterior portion called the *diencephalon*.

The telencephalon consists of the cerebral hemispheres and the anterior part of the third ventricle. This develops from the alar lamina; the roof plate remains thin; the basal lamina and the floor plate give rise to the anterior part of the tuber cinerium, the infundibulum, the posterior lobe of the hypophysis, and the optica chiasma, which together constitute the *pars optica hypothalami.* The infundibulum and the posterior lobe of the hypophysis develop by a diverticulum from the floor. The posterior lobe of the hypophysis meets the anterior lobe derived from the stomodæum to form the hypophysis.

The two optic nerves meet at the optic chiasma where a partial decussation of the nerve fibres takes place. An elongation backwards from each side of the chiasma proceeds to the diencephalon and mesencephalon and forms the optic tract.

The cerebral hemispheres are well developed in the mammals specially in man. Three divisions of cerebral hemispheres have been described. They are *the rhinencephalon*, *the corpus striatum*, and *the neopallium.*

The Rhinencephalon is well developed in fishes and reptiles but not in man. It consists of the olfactory bulb, the olfactory tract, the olfactory trigone, the anterior perforated substance, the septum pellucidum, the subcallosal, supracallosal and denatate gyri, the fornix, the hypocampus, and the uncus.

The Corpus Striatum is developed in the fourth week as a thickening in the floor of the telencephalon and forms an elevation in the floor of the fourth ventricle. When the cerebral hemisphere encircles the rest of the brain to form the temporal lobe, the posterior part of the corpus striatum is carried into the inferior horn as the tail of the caudate nucleus. By the fifth month the corpus striatum is partly cut up by the internal capsule into an inner portion called the caudate nucleus and an outer part known as the lentiform nucleus.

The Neopallium forms the greater part of the cerebral hemisphere and encloses the lateral ventricle. The lamina terminalis which lies between the two hemispheres does not keep pace with the growth of the hemisphere and consequently a longitudinal fissure results between the two hemispheres. A process of mesoderm is lodged in the fissure and eventually develops into the falx cerebri. As the hemisphere grows backwards and downwards its cavity is also prolonged and forms the inferior horn. A backward extension of the cavity forms the posterior horn of the lateral ventricle. The roof plate remains thin and

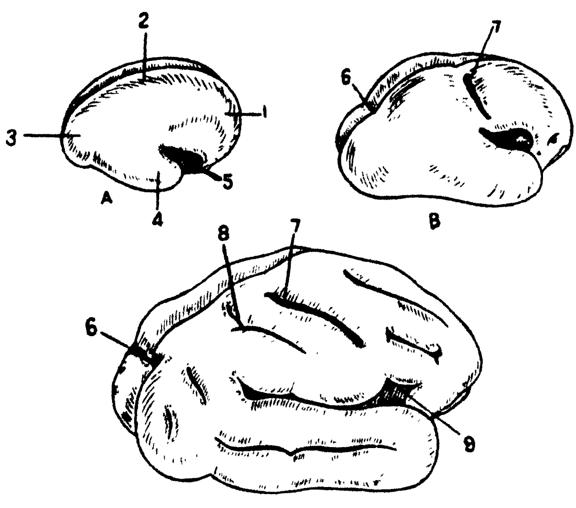

Fig. 28.—Lateral View of the Cerebral Hemispheres. (From Models by Ziegler after Ecker.)

A. Fifth month, B. Six months, C. Seven months.

1. Frontal lobe, 2. Parietal lobe, 3. Occipital lobe, 4. Temporal lobe, 5. Insula, 6. Parieto-occipital fissure, 7. Central sulcus, 8. Postcentral sulcus. 9. Lateral fissure.

is invaginated into the lateral ventricle constituting the choroid fissure which extends into the inferior horn. The choroid fissure is invaded by blood vessels which form the choroid plexus.

Each hemisphere, to begin with, has a smooth surface but as the surface increases in extent it becomes puckered; portions of brain are raised up as convolutions or gyri. Furrows produced by these are called fissures of sulci. The principal sulci and gyri are developed by the seventh month. *The lateral sulcus*, however, develops by the depression of a portion of brain which forms the insula; the brain substance surrounding the insula undergoes rapid development, overlaps the insula and gives rise to the temporal, the parietal, the frontal and the orbital opercula separated by the constituent parts of the lateral sulcus.

The Diencephalon forms the remaining part of the third ventricle. From the alar lamina the thalamus, the metathalamus and the epithalamus develop. *The thalamus* is the thickening of the anterior two-thirds of the alar lamina; at first visible, is submerged later under the cerebral hemispheres. The thalamus grows on each side and is connected to each other by the intermediate mass, the cavity of the third ventricle is thus reduced in size and becomes narrow. The metathalamus consists of the medial and the lateral geniculate bodies which arise as eminences; the medial geniculate body under cover of the posterior part (pulvinar) of the thalamus, and the lateral on the lateral and posterior part of the thalamus. *The epithalamus* consists of the pineal body, the posterior commissure and the trigonum habenulæ. The pineal body is developed on the roof plate immediately in front of the mid-brain as a bilateral evagination. The right one eventually atrophies. In the lower vertebrates the evagination becomes solid distally and represents a rudimentary third eye, while proximally it develops into a glandular structure. In man only the pineal body is represented, the proximal part being the recessus pinealis. The posterior commissure is formed of fibres developing below the pineal body. The trigonum habenulæ is developed in front of the pineal recess.

The Mesencephalon is not so extensive in its development as the prosencephalon. The cavity of the mesencephalon is reduced in size and becomes the cerebral aqueduct which connects the third with the fourth ventricle. The basal lamina becomes thickened and the nerve cells gather round the aqueduct to form the nuclei of the oculomotor, the trochlear, and one of the roots of the trigeminal nerve. Some of the cells aggregate to form the red nucleus. The alar lamina becomes thickened to form the quadrigeminal lamina, in which a vertical groove and later a horizontal groove make their appearance dividing the lamina into the four colliculi.

The Rhombencephalon.—The primitive hind-brain bends on itself so as to produce a curve with its concavity backwards. This results in an opening out of the central canal so that it expands, becomes diamond-shaped, and forms the fourth ventricle. The rhombencephalon is constricted in the cephalic region to form the isthmus from which the brachia conjunctiva of the cerebellum and the anterior medullary vellum develop. The remaining portion of the rhombencephalon is differentiated into an upper portion called the metencephalon and a lower portion known as the myelencephalon.

The Metencephalon undergoes further development; the roof thickens to become the cerebellum and the floor develops into the pons.

The myelencephalon becomes the medulla oblongata. Its roof becomes the ependyma over the choroid plexus of the fourth ventricle. The cavity of the rhombencephalon as mentioned above becomes the fourth ventricle and is continuous above with the cerebral aqueduct and below with the central canal of the

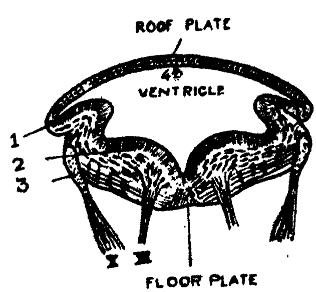

FIG. 29.—A TRANSVERSE SECTION THROUGH THE MEDULLA OBLONGATA OF A HUMAN EMBRYO. (AFTER HIS.)

1. Alar lamina, 2. Basal lamina, 3. Tractus solitarius, X. Vagus nerve, XII. Hypoglossal nerve.

medulla spinalis. Cells in the alar or the basal lamina aggregate to form nerve centres, *e.g.*, the centre for the hypoglossal. Rudiments of ganglia may become associated with the substance of the medulla and fuse as in the case of nucleus solitarius of the vagus.

THE MEDULLA SPINALIS

The basal lamina in the region of the medulla spinalis develops into the anterior horn of the grey matter; the cells give rise to nerve fibres which become the anterior roots of the spinal nerves. In the thoracic and the upper lumbar region a lateral expansion forms the lateral horn from which the fibres of the splanchnic nerves are given off; these fibres come out in the anterior roots to the sympathetic ganglia through the white rami communicantes. The alar lamina which is sensory in function develops into the posterior column of the grey matter.

The anterior median fissure is formed by the outgrowth of the anterior funiculi; the groove separating these funiculi is called the anterior median fissure. The posterior median septum is probably developed by the fusion of the dorsal part of the central canal and by the extension of a septum from the ependymal cells.

Various changes take place in the medulla spinalis as it grows. The cervical and the lumbar thickenings appear concurrently with the limb buds. The rapid growth of the vertebral column causes the medulla spinalis to be pulled up together with the spinal nerves; the spinal nerves of the lower series therefore become oblique. The medulla spinalis at first occupies the whole length of the vertebral column, reaches the level of the third lumbar vertebra by the sixth month of intra-uterine life and reaches the adult level of the first lumbar vertebra by the third year. The lower portion of the medulla spinalis, however, is attached to the coccyx and stretched out into a thin filament called the filum terminale.

The mesoderm surrounding the neural tube differentiates itself into three membranes which form the covering of the brain and the medulla spinalis. The outermost which is strong and tough is called dura mater, the intermediate is termed the arachnoid, and the innermost is known as the pia mater.

These are soon separated by cavities. The subdural space is situated between the dura mater and the arachnoid and the subarachnoid space is situated underneath the arachnoid. The dorsal wall of the fourth ventricle and the pia mater covering it are pierced by a median and two lateral foramina by which the fourth ventricle communicates with the subarachnoid space.

The Vascular System

THE vascular system most probably develops from the mesoderm in the form of solid strands of cells called *angioblasts* which become tubular. The surrounding cells of the angioblastic tubules become the endothelium of the blood vessels and the cells inside become the blood islands; from these the cells separate as nucleated blood corpuscles. The nuclei of some of the cells disappear either by disintegration or extrusion, and the cells, after acquiring colouring matter, become red blood corpuscles.

The vessels of the yolk sac appear very early in the form of a network of capillaries from which two definite blood channels called the vitelline veins are formed and enter the body of the embryo. As the human yolk sac does not contain any appreciable quantity of nutrition another series of blood vessels called the umbilical vessels develop which connect the placental portion of the chorion with the embryo. The umbilical veins unite in a single trunk called the *vena umbilicalis impar.* It enters the body along with the body stalk and divides into a right and a left umbilical vein. Each umbilical vein passes through the septum transversum, joins with the vitelline vein and forming a common channel called the *vitello-umbilical vein,* opens into the ventral aorta. A vein appears in the cephalic region on each side called the *precardinal* vein and is joined by another vein appearing in the caudal region called the *postcardinal* vein forming a common trunk known as the *duct of Cuvier.* This opens into the vitello-umbilical vein.

A pair of stem arteries called the primitive aortæ appear in the ventral region of the pericardial area which is situated at the extreme cephalic end of the embryo. Each primitive aorta extends caudally on each side of the notochord and gives origin to the umbilical artery ventrally.

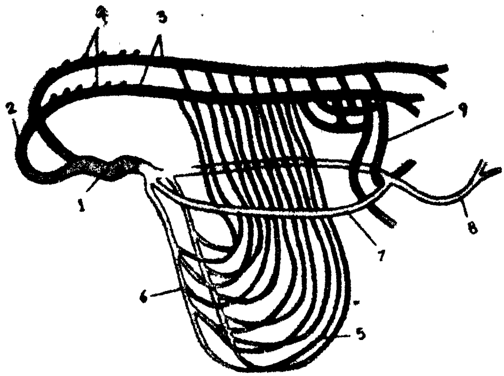

FIG. 30.—DIAGRAM SHOWING THE LATERAL VIEW OF BLOOD VESSELS IN A 2 MM. HUMAN EMBRYO. (AFTER FELIX.)

1. Heart, 2. First aortic arch, 3. Dorsal aortæ, 4. Dorsal intersegmental arteries, 5. Vitelline arteries, 6. Vitelline veins, 7. Umbilical vein, 8. Vena umbilicalis impar, 9. Umbilical artery.

As the embryo is folded upon itself the primitive aortæ in the cephalic region get bent and each results in a ventral aorta, a dorsal aorta and the bend which is called the first aortic arch. The caudal portion of the ventral aortæ fuse together to form a single heart tube, into the caudal portion on which the veins open. The dorsal aortæ fuse from the level of the fourth thoracic to the fourth lumbar vertebræ and form the descending aorta. The middle sacral artery has been supposed to be the direct continuation of the aorta but it is doubtful as to whether it is so.

Five additional arches appear between the ventral and the dorsal aortæ.

THE HEART

The cephalic ends of the primitive aortæ lie ventral to the mesodermal area which forms the pericardium. The folding of the embryo brings about a reversal of the pericardium, which was dorsal to the aortæ to begin with, becomes ventral. The heart tube begins to grow rapidly in length and so it is bent with its convexity forwards, and then gets twisted. As the heart tube is bent forwards it pushes the mesoderm before it. The portion of the mesoderm which is in contact with the heart tube becomes the visceral pericardium.

Constrictions appear in the heart tube and divide it into five portions called from the cephalic to the caudal region the *truncus arteriosus*, *the bulbus cordis*, *the ventricle*, *the atrium* and the *sinus venosus.* The ventral aortæ arise from the truncus arteriosus while the vitelline, the umbilical, and the cardinal veins join the sinus venosus.

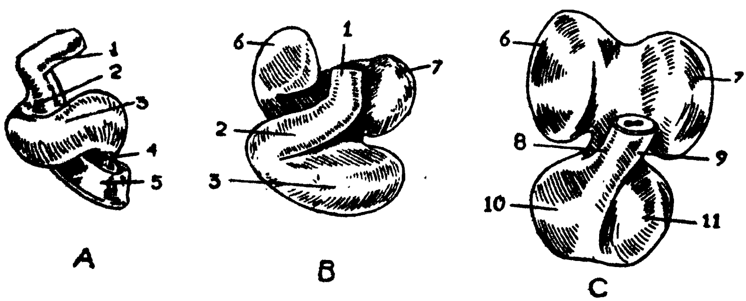

FIG. 31.—THE DEVELOPMENT OF THE HEART, AS SEEN EXTERNALLY. VENTRAL VIEW. (FROM A MODEL BY ZIEGLER AFTER HIS.)

A. Embryo 2·15 mm. long, B. Embryo 4·3 mm. long, C. Embryo 10 mm. long.

1. Truncus arteriosus, 2. Bulbus cordis, 3. Ventricle, 4. Atrium, 5. Sinus venosus, 6. Right atrium, 7. Left atrium, 8. Pulmonary artery, 9. Aorta, 10. Right ventricle, 11. Left ventricle.

The heart tube gets twisted in such a manner that the sinus venosus and the atrium occupy a dorsal position, the sinus venosus being the most caudal; the ventricles, the bulbus cordis and the truncus arteriosus occupy a ventral position, the truncus being the most cephalic. The heart thus gives off the ventral aorta cephalically from the truncus and receives the veins caudally into the sinus venosus.

The sinus venosus becomes crescentic in shape and receives the vitelline vein, the umbilical vein and the duct of Cuvier in each horn of its crescent. The sinus venosus develops further and opens into the right side of the atrium. The right horn increases considerably in size and forms the greater portion of the right atrium known as the *sinus venarum.* The fully developed atrium is thus formed of the sinus venosus and the primitive atrium, and the two divisions are marked inside by a vertical ridge called the *crista terminalis (His).* The right vitelline vein develops into the inferior vena cava and opens together with the right duct of Cuvier into the dorsal part of the atrium. The left horn lags behind in development, becomes narrow, receives only the left duct of Cuvier and forms the coronary sinus which opens into the right horn. The right horn forms a portion of the right atrium. Three openings are seen at this stage in the dorsal wall of the right atrium, the superior vena cava derived from the right duct of Cuvier above, the coronary sinus formed of the left horn in the middle, and the inferior vena cava formed of the right vitelline vein below.

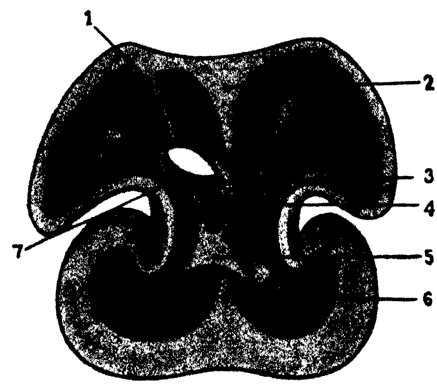

FIG. 32.—THE INTERIOR OF THE DORSAL HALF OF THE HEART OF A HUMAN EMBRYO ABOUT THIRTY DAYS OLD. (FROM A MODEL BY ZIEGLER AFTER HIS.)

1. Septum spurium, 2. Septum primum, 3. Opening of the sinus venosus, 4. Right venous valve, 5. Septum intermedium, 6. Septum inferius, right venous valve.

The opening of the sinus venosus into the right atrium is guarded by two valves called the right and left venous valves; these meet above and form a fold called the septum spurium which degenerates into a ridge called the crista terminalis referred to above. The valves fuse below to form an elevation called the *spina vestibuli*. The intermediate portion of the right valve develops into the valve of the inferior vena cava and the valve of the coronary sinus, while the intermediate portion of the left valve atrophies.

The constriction between the atrium and the ventricle is called the *atrial canal*. This is soon overlapped by the overgrowth of the atria round the bulbus cordis. Two elevations called the *anterior* and the *posterior endocardial cushions* appear in the primitive atrial canal and join together to form a partition called the *septum intermedium* which divides the primitive atrial canal into the right and the left atrioventricular orifices.

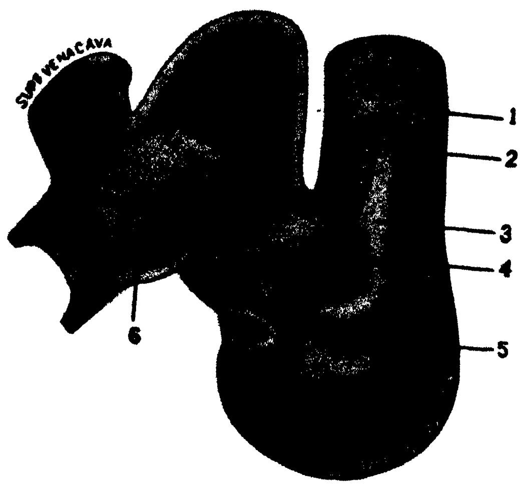

FIG. 33.—HEART OF A HUMAN EMBRYO ABOUT THIRTY-FIVE DAYS OLD, OPENED ON THE RIGHT SIDE. (FROM A MODEL BY ZIEGLER, AFTER HIS.)

1. Truncus arteriosus, 2. Probe in the aorta, 3. Aortopulmonary Septum, 4. Septum intermedium, 5. Septum inferius, 6. Coronary sinus.

A partition called the *septum primum* grows ventrally from the dorsal wall of the atrium and eventually joins the septum intermedium, dividing the primitive atrium into the right and left atria, but before the communication between the atria called the *ostium primum* (*Born*) is closed, perforations appear in the septum primum and fuse together to form the *ostium secundum* (*Born*) commonly known as the *foramen ovale*. Another septum called the *septum secundum* grows from the dorsal and cephalic part of the atrium on the right side of the septum primum and as it grows it overlaps the foramen ovale and thus a flap-valve is formed of the septum primum and allows blood to flow only in one direction, *i.e.*, from the right to the left. After birth the septum secundum and the septum primum fuse and the foramen ovale is closed

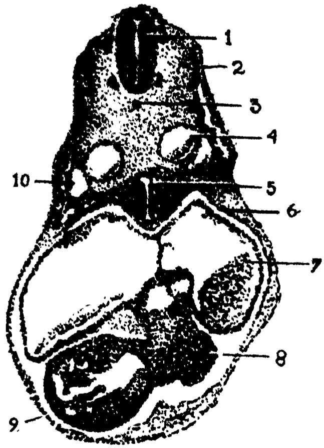

FIG. 34.—TRANSVERSE SECTION OF A 9 MM. PIG EMBRYO.

1. Medulla spinalis, 2. Myotome, 3. Notochord, 4. Descending aorta, 5. Pharynx, dividing into the larynx and œsophagus, 6. Pericardial cavity, 7. Left atrium, 8. Left ventricle, 9. Somatopleure, 10. Anterior cardinal vein.

A crescentic septum called the *septum inferius* grows upwards from the lower portion of the ventral wall of the ventricle and divides the ventricle into the right and left ventricles. These are connected for a time with each other by the interventricular foramen between the two horns of the crescentic septum. The posterior horn of the septum inferius joins the dorsal endocardial cushion which forms the pars membranacea of the interventricular septum. The septum inferius forms the main muscular part of the fully developed interventricular septum. The primitive ventricle and the bulbus cordis form the ventricles, the bulbus cordis becoming the infundibulum of the right ventricle.

The truncus arteriosus is divided longitudinally by means of a spiral septum into the ascending aorta and the pulmonary artery. The septum splits subsequently and separates the two vessels from each other.

Four elevations called the endocardial cushions appear in the bulbus cordis near the truncus arteriosus and form the valves of the aorta and of the pulmonary artery. The right and left endocardial cushions meet and form a central septum which fuses above with the aorto-pulmonary septum and below with a septum which appears in the bulbus cordis and joins with the crescentic margin of the interventricular septum separating the right from the left ventricle completely. The two divisions of the truncus arteriosus, *i.e.*, the pulmonary artery and the ascending aorta thus communicate with the right and the left ventricles respectively.

The septum formed from the right and the left endocardial cushions divides these cushions into an anterior and a posterior pair; the anterior pair together with the anterior endocardial cushion develop into three semilunar flaps of the pulmonary valve; the two posterior pairs together with the posterior endocardial cushion develop into the semilunar flaps of the aortic valve. The atrioventricular valves are developed from the septum intermedium and the invagination of the atrial canal into the ventricles; the former develops into the medial cusp and the latter into the lateral cusp.

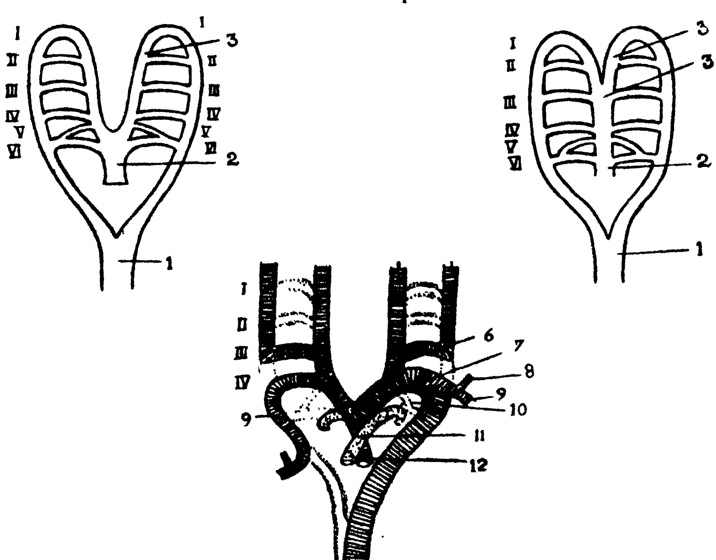

FIG 35.—SCHEMATA OF THE AORTIC ARCHES AND THEIR TRANSFORMATION.

I. First arch, II. Second arch, III. Third arch, IV. Fourth arch, V. Fifth arch, VI. Sixth arch.

1. Fused dorsal aorta, 2. Truncus arteriosus, 3. Ventral aorta, 4. External carotid, 5. Internal carotid, 6. Common carotid, 7. Arch of aorta, 8. Vertebral artery, 9. Subclavian artery, 10. Ductus arteriosus, 11. Pulmonary artery, 12. Ascending aorta.

THE ARTERIES

The first aortic arch or the bend of the primitive aorta passes through the first visceral (mandibular) arch; five arterial arches grow subsequently and run through their respective visceral arches. The second arch joins the ventral with the dorsal aorta and gives off the stapedial artery which passes through the foot of the stapes and persists in some animals such as rats but disappears in man. The third and the fourth arches join the truncus arteriosus with the dorsal aorta. The fifth arch joins the truncus with the dorsal end of the sixth arch. The sixth arch runs between the truncus arteriosus and the dorsal aorta. As the dorsal aorta keeps pace with the elongation of the neck, the third and the fourth arches run between the ventral and the dorsal aortæ.

The portions of the aorta between two arches are called roots. Modification of the aorta and aortic arches results in the formation of the arteries of the head and neck, superior extremity, the lungs and the arch of the aorta. The first, second and fifth arches entirely disappear in man. The third arch together with the dorsal aorta above it forms the internal carotid artery. The right fourth arch together with the right dorsal aorta down to the seventh segmental artery forms the proximal portion of the right subclavian artery; its distal portion is formed of the seventh segmental artery. The left subclavian artery is formed of the left seventh segmental artery only. The left fourth arch forms a portion of the arch of the aorta. The portion of the dorsal aorta between the left third and fourth arches disappears. The left sixth arch gives origin to the pulmonary arteries and forms the ductus arteriosus. The right sixth arch disappears. The right ventral aorta becomes the innominate up to the fourth arch, the common carotid up to the third, and the external carotid artery beyond that.

On the left side the ventral aorta becomes part of the aortic arch between the innominate and the left common carotid arteries; further up the ventral aorta becomes the left common carotid up to the third arch and the left external carotid arteries beyond that. The aortic arch is therefore formed of the truncus arteriosus from the beginning of the arch to the origin of the innominate artery, of the left ventral aorta between the innominate and the left common carotid artery, of the fourth arch and of the cephalic portion of the left dorsal aorta. The right dorsal aorta from the third arch to the point of fusion of the two primitive dorsal aortæ disappears, except for a small portion which forms a part of the right subclavian artery.

As the pericardium together with the developing heart descends into the thorax the arteries also descend, the right subclavian artery to the root of the neck and the aortic arch into the thoracic cavity. The recurrent laryngeal nerve, which passes under the sixth arch to supply the muscles of the larynx, is also carried down. The left nerve hooks round the ductus arteriosus which represents the left sixth arch, and the right nerve hooks round the subclavian artery which represents the left fourth arch, the left fifth and sixth arches having disappeared.

The dorsal aortæ give off a dorsal, a lateral and a ventral series of arteries. The ventral arteries are at first paired, but as the dorsal aortæ fuse each pair becomes a single artery; these are called the splanchnic arteries and supply the abdominal viscera. Out of these only the cœliac artery, the superior mesenteric artery and the inferior mesenteric artery persist. The lateral arteries pass laterally and supply the Wolffian body. Of these only the arteries to the gonads (testicle or ovary) and the three suprarenal arteries persist. The superior suprarenal gives off the inferior phrenic while the inferior suprarenal gives off the renal artery. As the diaphragm and the kidneys develop the inferior phrenic and the renal arteries attain a large size and become the main arteries; consequently the superior and the inferior suprarenal arteries become secondary and appear to arise from the inferior phrenic and the renal respectively. The middle suprarenal, however, retains its origin from the descending aorta. The dorsal segmental arteries pass at first laterally and then forwards and each gives off a dorsal and a lateral branch. The arteries that retain their segmental character are the intercostal and the lumbar arteries. Longitudinal anastomoses of the segmental arteries form fresh arteries, such as the internal mammary in front of the thorax and the vertebral artery in the neck; the proximal portion of the vertebral artery is, however, derived from the dorsal branch of the seventh segmental artery.

The arteries of the limbs are probably segmental and anastomose very freely. In the case of the superior extremity only the seventh segmental artery persists and continues as the subclavian, the axillary, the brachial, the volar interosseus and the median artery, the radial and the ulnar being lateral offsprings. As the radial and the ulnar arteries develop the median artery atrophies. Rarely the median artery persists and its pulsation can be felt next to the median nerve.

Recent investigations by Senior show that the main or the *axis artery* of the lower limb is derived from the dorsal root of the umbilical artery and runs along the dorsal surface of the thigh, knee and leg and ends in a *rete plantare;* one of its branches passes through the sinus tarsi and forms the *rete dorsale.* The femoral artery is formed later, passes ventral to the thigh and is connected with the axis artery. Portions of the axis artery disappear but the root persists as the inferior gluteal artery, the part behind the knee persists as the proximal part of the popliteal artery and a part near the ankle persists as part of the peroneal artery. The rete plantare develops into the plantar arch and the rete dorsale forms the arteries of the dorsum of the foot.

THE VEINS

The development of the veins has been followed as far as the formation of the vitelline and the umbilical veins on the one hand and the precardinal and the postcardinal veins, and the duct of Cuvier on the other. The two vitelline veins run along the sides of the vitelline ducts through the septum transversum to the sinus venosus. The septum transversum later on develops into the central tendon of diaphragm and the ventral mesogastrium into which the liver develops. As the liver grows, the vitelline veins which pass through it get broken up and open into spaces called *sinusoids* (Minot). Each vitelline vein is thus divided into a vein leading into the liver, called *vena advehens* and a vein carrying blood away from the liver called *vena revehens.* The left vena revehens passes to the right and opens into the right vena revehens which ultimately forms the upper part of the inferior vena cava.

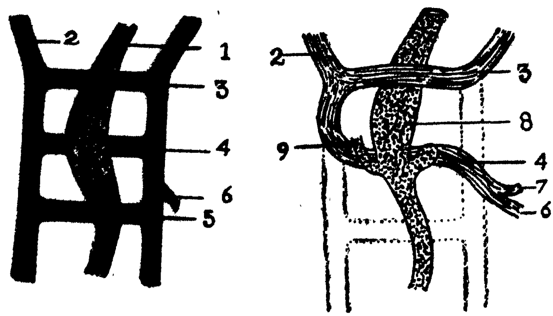

FIG. 36.—SCHEMATA, SHOWING THE DEVELOPMENT OF THE PORTAL VEIN.

1. Primitive gut, 2. Right vitelline vein, 3. Cephalic ventral anastomosis, 4. Dorsal cross anastomosis, 5. Caudal ventral cross anastomosis, 6. Superior mesenteric vein, 7. Splenic vein, 8. Stomach, 9. Bile duct.

The Portal Vein.—As the vitelline veins run on each side of that part of the primitive gut which is going to form the duodenum, they are connected by three transverse anastomoses. The upper and the lower anastomoses are ventral and the middle one is dorsal. Meanwhile a fresh vein called the superior mesenteric vein appears which carries blood from the intestines and joins the left vitelline vein just distal to the dorsal cross anastomosis. The splenic vein which brings in blood from the spleen also opens at the same spot. The portal vein is evolved cephalic to the entry to the superior mesenteric vein, and is formed by the portion of the left vitelline between the superior mesenteric vein and the dorsal anastomosis, the dorsal anastomosis itself and the right vitelline vein cephalic to the dorsal anastomosis. The right branch of the portal vein is formed of the right vena advehens, and the left is formed of the cephalic (ventral) anastomosis and the left vena advehens.

The veins from the placenta fuse into a single trunk called the vena umbilicalis impar which runs through the umbilical cord. As it passes through the umbilical opening into the body, it divides into a right and a left umbilical vein. The right umbilical vein disappears quite early. The left umbilical vein opens at first into the sinus venosus, then into the sinusoids of the liver as the latter develops, and lastly into the left vena advehens. Another channel called the ductus venosus springs between the left vena advehens and the right vena revehens which forms the inferior vena cava. Blood from the placenta therefore passes by the left umbilical vein and the left vena advehens to the inferior vena cava by two routes, one through the liver and the other through the ductus venosus. After birth the left umbilical vein and the ductus venosus shrink and become the ligamentum teres of the liver and the ligamentum venosum respectively.

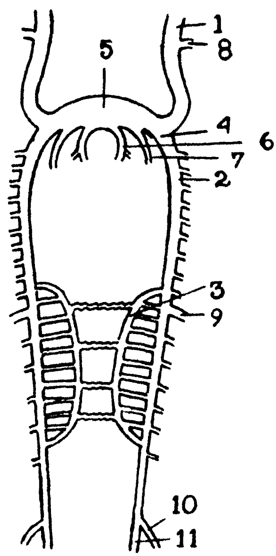

FIG. 37.—DIAGRAM OF THE EARLY ARRANGEMENT OF THE PARIETAL VEINS.

1. Precardinal, 2. Postcardinal, 3. Subcardinal, 4. Duct of Cuvier, 5. Sinus venosus, 6. Vitelline, 7. Umbilical, 8. Subclavian, 9. Left renal, 10. External iliac, 11. Hypogastric.

The precardinal vein which receives blood from the head, and the postcardinal vein from the trunk open by means of a common channel called the duck of Cuvier into the sinus venosus. The postcardinal vein which lies dorsal to the Wolffian body receives the external iliac and the hypogastric veins. A third pair called the subcardinal veins makes its appearance ventromedial to the Wolffian body. The postcardinal and the subcardinal veins are joined together by a series of transverse channels; two of these channels develop and become the left renal vein and the left common iliac vein respectively.

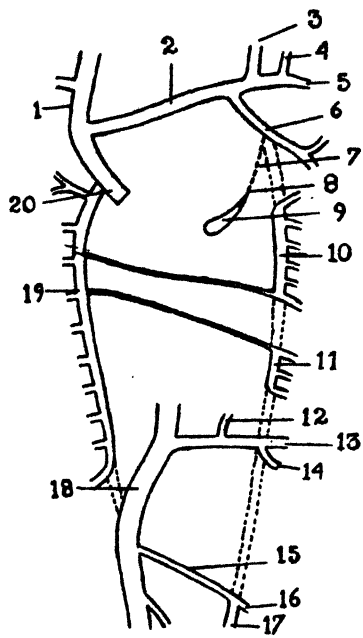

FIG. 38.—DIAGRAM OF THE COMPLETE DEVELOPMENT OF THE PARIETAL VEINS.

1. Right innominate, 2. Left innominate, 3. Internal jugular, 4. External jugular, 5. Left subclavian, 6. Left superior intercostal, 7. Ligament of left vena cava, 8. Oblique vein, 9. Coronary sinus, 10. Accessory hemiazygos, 11. Hemiazygos, 12. Left suprarenal, 13. Left renal, 14. Left testicular, 15. Left common iliac, 16. External iliac, 17. Hypogastric, 18. Inferior vena cava, 19. Azygos, 20. Superior vena cava.

Development of a fourth pair of veins called the *supracardinal veins* dorsal to the postcardinal has been described by some of the recent observers.

The Inferior Vena Cava.—Developmentally, the inferior vena cava has been divided into five parts, the extrahepatic portion situated above the liver, the hepatic portion lying behind the liver, the prerenal portion, the renal portion and the postrenal portion. The extrahepatic portion is formed of the right vena revehens. The hepatic portion is the caudal prolongation of the right vena revehens to the right subcardinal vein. The prerenal portion is formed of the right subcardinal vein. The renal portion is developed from the anastomosis between the subcardinal and the postcardinal veins. The postrenal portion was supposed to be formed of the postcardinal vein but recent investigations point to its formation from the lower part of the supracardinal vein.

The Postcardinal Vein.—The cephalic portion of the right postcardinal becomes the azygos vein which communicates with the accessory hemiazygos and hemiazygos veins by transverse channels. The left postcardinal becomes the hemiazygos, the accessory hemiazygos and the distal part of the left superior intercostal vein. Some of the cross anastomoses between the postcardinal veins become the left lumbar veins and open into the inferior vena cava, as the caudal portion of the left postcardinal vein disappears.

The Precardinal Vein forms from above downwards, the internal jugular vein, the right innominate vein up to the junction of the left innominate, and the superior vena cava to the level of the entry of the azygos vein. The left innominate vein is developed from a transverse anastomosis between the two precardinal veins. The left precardinal vein below the left innominate vein becomes the proximal portion of the left superior intercostal vein. The left duct of Cuvier which is sometimes known as the left superior vena cava atrophies and becomes the *ligament of the left vena cava* (vestigial fold of Marshall) and the *oblique vein* (Marshall) of the left atrium.

The Superior Vena Cava.—The extrapericardiac portion of the superior vena cava is formed of the caudal portion of the right precardinal vein and the intrapericardiac portion is formed of the right duct of Cuvier.

The Supracardinal Vein (Huntingdon & McClure).—A vein dorsal to the postcardinal vein appears and anastomoses with its fellow of its opposite side, with the subcardinal and with the postcardinal forming a transverse venous ring called the circumaortic ring surrounding the aorta and a longitudinal ring on each side through which the ureter passes. These rings get broken up after the formation of the permanent veins. The upper part of the supracardinal vein takes part in the formation of the vena azygos and the hemiazygos, and the lower part forms the postrenal part of the inferior vena cava. The lower part of the right postcardinal vein disappears.

THE VEINS OF THE HEAD

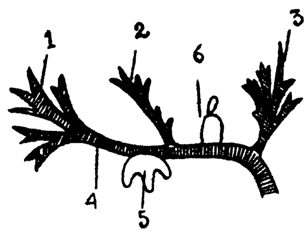

FIG. 39.—VEINS OF THE HEAD. (AFTER STREETER.)

1. Anterior plexus, 2. Middle plexus, 3. Posterior plexus, 4. Primary head vein, 5. Semilunar ganglion, 6. Auditory vesicle.

According to Streeter the veins of the head are developed from a plexus which gives rise to a primary head vein on each side. The vein passes dorsally medial to the semilunar ganglion and lateral to the auditory capsule, continues distally as the

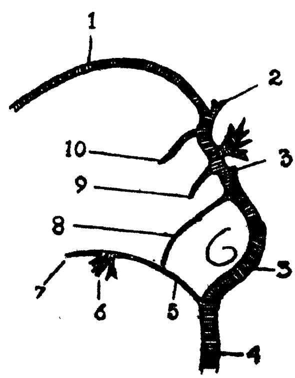

FIG. 40.—VEINS OF THE HEAD. (AFTER STREETER.)

1. Superior sagittal sinus, 2. Anterior and middle plexus, 3. Transverse sinus, 4. Internal jugular vein, 5. Inferior petrosal sinus, 6. Cavernous sinus, 7. Ophthalmic vein, 8. Superior petrosal sinus, 9. Inferior cerebral vein, 10. Straight sinus.

precardinal vein and opens into the duct of Cuvier. In the later stage, the plexus is differentiated into an anterior, a middle and a posterior secondary plexus; each of these joins the primary head vein by a stem. The anterior plexus receives a vein called the ophthalmic vein from the region of the eye. A fresh channel connecting the middle and the posterior plexuses develops dorsal to the auditory capsule and forms a portion of the transverse sinus; the original portion of the head vein lateral to the auditory capsule disappears. The anterior part of the primary head vein, however, develops, forms the cavernous sinus and receives the ophthalmic vein above mentioned.

The Transverse Sinus.—The transverse sinus develops from the stem of the anterior plexus, its connection with the middle plexus, the fresh channel dorsal to the auditory vesicle, and the stem of the posterior plexus opening into the internal jugular vein which is developed from the cephalic portion of the precardinal vein.

As the cranium and the membranes of the brain develop from the mesoderm round the brain stem the plexus of veins is divided into a superficial portion which drains the surface of the head and a deep portion which drains the brain stem. The three secondary plexuses remain in connection with the dura mater. The channel by which the middle plexus joins the primary head vein undergoes atrophy but later develops into the superior petrosal sinus. A small portion of the venous plexus between the cavernous sinus and the internal jugular vein develops into the inferior petrosal sinus. The anterior and middle plexuses extend anteriorly to the developing hemisphere where they unite and form the sagittal plexus. A portion of the venous plexus hangs between the growing hemispheres in the region of the falx cerebri and develops into the superior sagittal sinus in the upper part and the inferior sagittal sinus and the straight sinus in the lower free margin of the falx cerebri. The superior sagittal sinus when completed opens usually in the right transverse sinus. The backward growth of the hemispheres carries the superior sagittal sinuses and the straight sinuses with them; these open into the confluens sinuum. The posterior plexus becomes connected with the confluens sinuum, loses its connection with the transverse sinus and becomes the occipital sinus.

The external jugular vein drains the post-auricular region, and is connected with the lingual and facial veins which open into the precardinal vein. Later on the facial veins also open into the external jugular vein. The cephalic vein which originally opened into the external jugular vein is transferred later on to the axillary vein. The former arrangement occasionally persists and if it does the cephalic vein passes superficial to the clavicle and joins the external jugular vein.

THE FŒTAL CIRCULATION

The fœtal heart consists of two atria imperfectly separated from each other and communicating through the foramen ovale, and the two ventricles which are entirely separated from one another. The termination of the arch of the aorta is connected to the pulmonary artery by a channel called the *ductus arteriosus.* Blood is received into the right atrium from three sources, the superior vena cava, the coronary sinus, and the inferior vena cava. Blood from the superior vena cava is poured into the right auricle together with blood from the coronary sinus and passes into the right ventricle. From the inferior vena cava the blood passes into the right atrium and is directed by the valve of the inferior vena cava into the left atrium through the foramen ovale. From the left atrium the blood passes through the left atrioventricular orifice into the left ventricle, thence to the aorta the branches of which distribute the greater portion of the blood to the head and upper limbs, a small quantity of blood may find its way into the descending aorta. After circulating in the head and the upper limbs the blood is brought back by the superior vena cava into the right atrium, whence it passes into the right ventricle and thence to the pulmonary artery. Only a small quantity, however, goes to the lungs as they are inactive, the greater portion of the blood passes into the arch of the aorta by the ductus arteriosus. A portion of the blood travels to the lower limbs but a large quantity is carried over to the placenta by the umbilical arteries; here exchange of gases and nutrition takes place and the blood is carried to the fœtus by the umbilical veins. These unite to form the vena umbilicalis impar which enters the body and divides into the two umbilical veins. The right umbilical vein disappears but the left persists till birth and degenerates into the ligament teres after birth. The left umbilical vein passes into the liver and is connected with the inferior vena cava by the ductus venosus. The inferior vena cava therefore receives blood from the liver which in turn is supplied by the portal vein and the left umbilical vein, and from the left umbilical vein directly through the ductus venosus. The blood from the lower extremity and the abdominal wall also passes into the inferior vena cava.

It will thus be seen that there is an admixture of blood throughout the fœtal circulation; first the blood from the umbilical vein gets mixed in the inferior vena cava with that from the inferior extremity, abdominal wall, and the liver; secondly, there is a mixture of blood from the superior and the inferior vena cava in the right atrium ; thirdly, the blood passing through the pulmonary veins from the inactive lungs mixes in the left atrium with that from the right atrium; and fourthly, the blood passing through the aorta is mixed with that from the pulmonary artery passing through the ductus arteriosus.

When the child is born it cries and takes a deep breath. Blood rushes from the pulmonary arteries into the expanding lungs, the placental circulation ends at this stage and the pulmonary circulation begins. The blood from the superior vena cava and the inferior vena cava enters the right auricle and passes down into the right ventricle which pumps the blood through the pulmonary arteries into the lungs which are now active. Here exchange of gases takes place and the blood is returned to the left auricle by the pulmonary veins. The blood next passes into the left ventricle which pumps it into the aorta which distributes it throughout the system. After it has circulated in the system it is returned to the right auricle by the superior and the inferior vena cava. The ductus arteriosus subsequently atrophies into a cord known as the *ligamentum arteriosum*. The foramen ovale closes, the left umbilical vein and the ductus venosus atrophy and become the round ligament of the liver and the ligamentum venosum respectively. The part of the hypogastric artery which extends from the bladder to the umbilicus also atrophies and forms a fold known as the *lateral umbilical ligament.*

The Lymphatic System

ACCORDING to Lewis and others the lymphatic system is an offshoot of the venous system and is developed by the confluence of the venous capillaries which lose their connections with the veins to begin with, but ultimately join them. The lymph vessels have therefore an endothelial lining. The confluence of veins forms six sacs in the human embryo; two jugular lymph sacs each appearing at the junction of the subclavian and precardinal veins, two posterior lymph sacs at the junction of the iliac with the postcardinal veins, the retroperitoneal in the root of the mesentery at the level of the suprarenal glands, and the cisterna chyli opposite the third and the fourth lumbar vertebræ. From these sacs lymphatic vessels grow along the course of the embryonic blood vessels. The thoracic duct is probably formed by channels between the jugular sac and the cisterna chyli. With the exception of the upper portion of the cisterna chyli, the lymph sacs are broken up by bridges of connective tissue, and by the aggregation of lymphocytes are transformed into groups of lymph glands. The lower portion of the cisterna chyli undergoes the same fate, but the upper portion remains as the cisterna chyli.

The Lymph Glands.—Some lymph glands appear directly in the region of the axilla and the iliac region at about the third month. Others are formed from lymph sacs as mentioned above and appear later. While undergoing development the lymph glands possess both the blood vascular and the lymphatic network. Ordinary lymph gland is formed by the growth of lymphatic network, on the other hand preponderance of blood network results in the appearance of red colour in the glands which are called *hœmal glands*. From the observations of Harrison and Swale Vincent it appears that hœmal glands are rudimentary forms of lymph glands.

The Urogenital System

THE urinary system and the genital system develop from a common origin from the intermediate cell mass which is the constricted portion of the mesoderm lying between the paraxial and the lateral mesoderm.

A series of transverse rods which become tubular are formed of the intermediate cell mass, beginning in the region of the neck and extending caudally. The first series appear in the third week and is called the *pronephros.* A second series called the mesonephros or the *Wolffian body* develops as the first series begin to atrophy. A third series called the *metanephros* develops more caudally. A longitudinal rod which also becomes tubular develops at the same time and is called the *Wolffian duct.* It opens into the ventral portion of the entodermal cloaca. The transverse tubules open into the Wolffian duct by one end, and into the cœlomic cavity by the other.

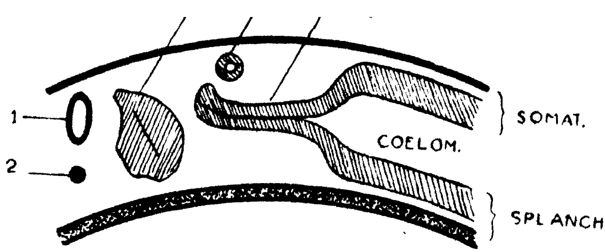

FIG. 41. –DIAGRAM OF THE DEVELOPMENT OF THE MESONEPHROS

1. Neural tube, 2. Notochord, 3. Myotome, 4. Wolffian duct, 5. Intermediate cell mass forming the transverse tubes, SOMAT. somatopleure, splanchnopleure.

On one side of the tubule a dilatation is formed which becomes flattened and concave and receives a tuft of capillaries. The structure is collectively known as the *glomerulus.*

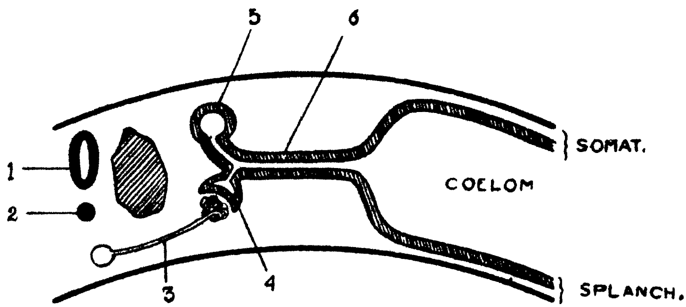

FIG. 42.—DIAGRAM SHOWING THE DEVELOPMENT OF THE UROGENITAL TUBULES.

1. Neural tube, 2. Notochord, 3. Artery, 4. Glomerulus, 5. Wolffian duct, 6. Transverse tube, SOMAT. somatopleure, SPLANCH. splanchnopleure.

Another longitudinal tube called the *Mullerian duct* develops on the lateral side of the Wolffian duct by the invagination of the cœlomic epithelium and forms the greater part of the genital apparatus in the female.

The Pronephros.—The transverse tubules of the pronephros develop in the cervical region and as the development extends into the thoracic region the cervical tubules atrophy. The tubules join the Wolffian duct, the upper part of which in the lower animals forms the *pronephric duct.* In man, however, the pronephros atrophies.

The Mesonephros.—In the fishes and amphibia the mesonephros forms the permanent kidney. In the higher animals a greater portion of it disappears. In man the remaining part of the mesonephros gives rise to the *vasa efferentia* (efferent ducts), *coni vasculosi*, *vasa aberrantia* (aberrant duct) and the paradidymis (organ of Giraldes) in the male; the *epoophoron* (organ of Rosennüller) and the *paroophoron* in the female.

The Wolffian Duct.—In the male the Wolffian duct gives rise to the *epididymis*, the *deferent duct* and the *ejaculatory duct.* A tubular diverticulum from the lower end of the Wolffian gives rise to the *seminal vesicle.* In the female the Wolffian duct gives rise to the *longitudinal duct of epoophoron* (duct of Gartner) and the *appendices vasculosi* (stalked hydatid). The ureter and a part of the kidney grow as a diverticulum from the Wolffian duct in both the sexes. The remaining portion of the kidney develops from the metanephros.

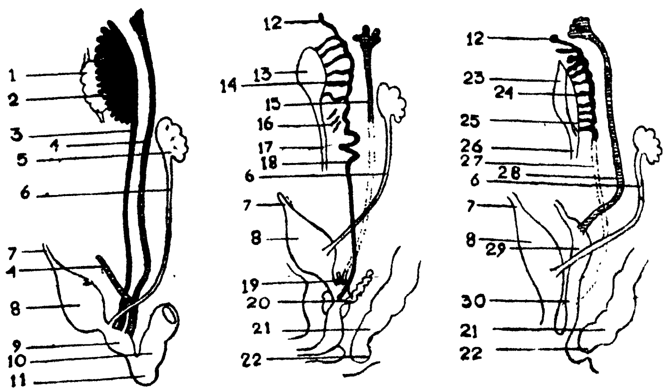

FIG. 43.—DIAGRAM TO SHOW THE DEVELOPMENT OF THE GENITAL ORGANS.

1. Sex gland, 2. Wolffian body, 3. Wolffian duct, 4. Mullerian duct, 5. Kidney, 6. Ureter. 7. Urachus, 8. Bladder, 9. Urogenital sinus. 10. Intestine, 11. Cloaca, 12. Stalked hydatid, 13. Testis, 14. Epididymis, 15. Unstalked hydatid. 16. Paradidymis, 17. Gubernaculum, 18. Ductus deferens, 19. Prostate, 20. Seminal vesicle, 21. Rectum, 22. Anus 23. Ovary, 24. Epoophoron, 25. Paroophoron, 26. Round ligament, 27. Duct of Gartner, 28. Uterine tube. 29. Uterus, 30. Vagina.

The Mullerian Ducts.—In the female the Mullerian duct gives rise to the uterine tube, the uterus and the vagina. In the male it degenerates and forms the appendices of the testes, (unstalked hydatid) and the utriculus prostaticus. The Mullerian duct crosses the Wolffian duct from the lateral to the medial position. The two Wolffian ducts situated laterally and the two Mullerian ducts are collectively called the *genital cord.*

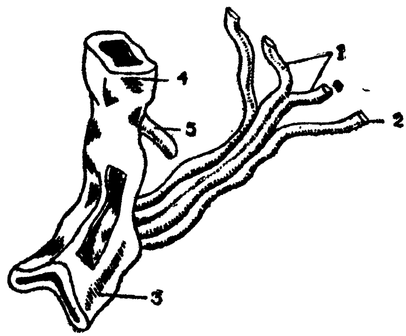

FIG. 44.—UROGENITAL SYSTEM OF A FEMALE EMBRYO ABOUT NINE WEEKS OLD. (FROM A MODEL BY ZIEGLER AFTER KEIBEL.)

1. Mullerian ducts, 2. Wolffian duct, 3. Urogenital sinus, 4. Bladder, 5. Ureter.

The Uterus and the Vagina.—The caudal portions of the Mullerian ducts fuse together, extend to the entodermal cloaca and become hollow; the septum between the two tubes is absorbed and the fused portion forms the uterus while the extension forms the vagina. A fold appears at the opening of the vagina and forms the Hymen. The cephalic portions of the Mullerian ducts remain separate and form the uterine tubes, which open into the cœlomic cavity by an opening called the *abdominal ostium.*

Various abnormalities are found due to the failure of fusion of the two Mullerian ducts or to the persistence of the septum between the two. The principal abnormalities are *uterus bicornis* which results from the former and *uterus septus* due to the latter.

Metanephros.—The transverse tubules of the metanephros do not open directly into the Wolffian duct but are connected to a diverticulum from it. The cœlomic opening of the tubule is closed, a part of it atrophies and the glomerulus arises from one of its ends.

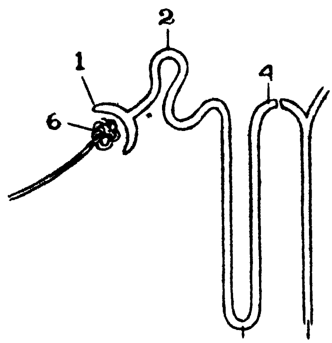

FIG. 45.—DIAGRAM OF THE URINARY TUBULES.

1. Glomerulus, 2. Convoluted tubule, 3. Loop of Henle, 4. Junctional tubule, 5. Collecting tubule.

The tubule which forms the secretory portion of the kidney becomes elongated and is differentiated as the convoluted tubule, the loop of Henle and the junctional tubule. The last opening into the excretory portion of the kidney which is developed from the diverticulum from the Wolffian duct.

The Ureter and the Kidney.—At about the fourth week a diverticulum is given off from the distal end of the Wolffian duct just before it enters the entodermal cloaca. The diverticulum passes dorsally, in the cephalic direction and gives rise

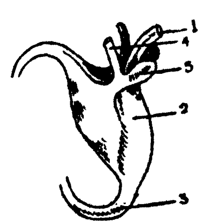

FIG. 46.—CLOACA OF AN EMBRYO THIRTYFIVE DAYS OLD. (FROM A MODEL BY ZIEGLER AFTER KEIBEL.)

1. Intestine, 2. Cloaca, 3. Postanal gut, 4. Wolffian duct, 5. Ureter diverticulum.

to the ureter proximally and the excretory portion of the kidney distally. The distal portion of the Wolffian duct from which the diverticulum arises, dilates, and is incorporated with the cloaca forming the urinary bladder. In this way the diverticulum (ureter) and the Wolffian duct (ejaculatory duct) open separately into the cloaca (bladder). The distal (cephalic) portion of the diverticulum becomes dilated and branched, and forms the pelvis and the calyces of the kidney. Further branching results in the formation of the collecting tubules. Into these the secreting tubules of the metanephros open. The mesoderm round the tubules becomes the connective tissue of the kidney. Lobulated condition of the kidney is found in the early fœtus and some of the lower animals, and may even be present in the fully developed kidney.

Abnormalities.—Absence of one or both the kidneys is very rare, one of the kidneys may be very small but fully developed. The two kidneys may be united across the vertebral column and form a horse-shoe kidney. The kidney may have a double ureter. The two portions of the kidney, *i.e.*, the secretory and the excretory parts may very rarely fail to unite and result in a congenital cystic kidney.

The Bladder.—The bladder is developed from two sources. The greater part is developed from the entodermal cloaca (entoderm), and the remaining from the Wolffian ducts (mesoderm). The cephalic portion of the ventral part of the entodermal cloaca forms the greater portion of the bladder. The Wolffian ducts which open dorsally into the cloaca dilate so that the ureters that originally arise as diverticula from the Wolffian ducts open into the cloaca. The portion of the dilated Wolffian ducts is incorporated with the entodermal cloaca and forms the trigone of the bladder. The upper or cephalic part of the bladder is considerably elongated and is continuous with the allantois at the umbilicus. Later on this portion is obliterated and forms the medial umbilical ligament (urachus).

The Genital Glands.—The genital glands in both sexes are developed medial to the mesonephros from an elevation of the cœlomic epithelium called the genital ridge. This ridge extends from the level of the sixth thoracic to the second sacral segment. The upper portion of the ridge however disappears and only the lower portion gives rise to the genital gland. The cœlomic epithelium covering the genital ridge is called the germinal epithelium because it was supposed to give rise

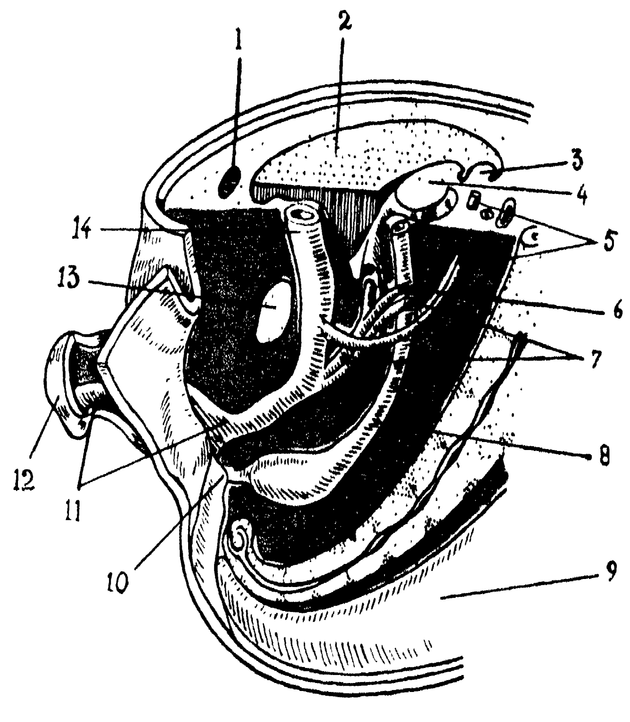

FIG 47.—THE CAUDAL END OF A HUMAN EMBRYO ABOUT NINE WEEKS OLD. (FROM A MODEL BY ZIEGLER AFTER KEIBEL.)

1. Rectus muscle, 2. Liver, 3. Mesonephros, 4. Genital gland. 5. Ureter, 6. Mullerian duct, 7 Wolffian duct, 8. Rectum, 9. Spinal medulla, 10. Anal membrane, 11. Urethra, 12. Glans penis, 13. Symphysis, 14. Bladder.

to the germinal cells. It has however been found that the generative cells are differentiated in a very early zygote and migrate into the genital ridge ; some of these cells may be scattered about, giving rise to abnormal growths such as the dermoid cyst. The germinal cells sink deep into the genital ridge and are arranged in rods which form a plexiform arrangement, and form the epithelial cells of the seminiferous tubules in the male and the primitive ova in the female. The genital ridge has, to begin with, a mesentery common to it and the mesonephros, but later the mesentery separates and forms the mesorchium in the male and the mesovarium in the female.

In the male the germ cells form solid cords which arrange themselves in a plexiform manner and form the seminiferous tubules, the tubuli recti, and the rete testes. The efferent ducts of the mesonephros get connected with the rete testes and thus carry the contents of the seminiferous tubules to the Wolffian duct. The mesoderm covering the tubules becomes condensed to form the tunica albuginea, and that between the tubules becomes the septa between the tubules. Each solid cord acquires a lumen quite late and begins to function at puberty. Some of the lining cells of the tubules become the sperm cells, while others become the supporting cells.

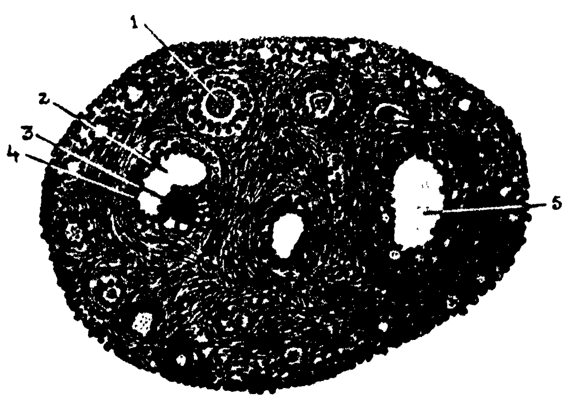

FIG. 48.—OVARY OF A RABBIT, T. S.

1. Premordial ovum, 2. Ovarian follicle, 3. Cumulus oophori, 4. Stratum granulosum, 5 Corpus luteum.

In the female, the germ cells sink into the substance of the genital ridge and give rise to primitive ova. These are surrounded by other cells and become follicles. A fluid called liquor folliculi appears in the follicle which gradually rises to the surface of the ovary, becomes ripe and is known as the ovarian follicle. Probably on account of the tension of the fluid and thinning of the peripheral portion of the follicle, it ruptures letting the ovum free in the peritoneal cavity.

Descent of the Ovary and the Testis.—The genital gland is developed in the lumbar region whence it descends by the aid of a band of fibrous tissue and involuntary muscle called the *gubernaculum.*

The ovary descends to its adult position by the third month, the gubernaculum of the ovary is attached by one end to the ovary and by the other to the uterus and to the labium majus. The portion of gubernaculum between the ovary and the uterus forms the ligament of the ovary and that between the uterus and the labium forms the round ligament of the uterus.

The testis occupies the position of the abdominal inguinal ring at the third month, lies in the inguinal canal at the sixth month, reaches the subcutaneous inguinal ring by the ninth month and descends into the scrotum at birth. The gubernaculum of the testis anchors itself to the bottom of the scrotal sac and exerts a pull on the testis with the result that the testis together with its duct (ductus deferens), blood vessels and lymphatics which collectively constitute the spermatic cord, and which are covered over by the peritoneum descend into the scrotum pushing the various layers of the abdominal wall before them. The testis thus derives its various coverings; the peritoneal extension is called the *processus vaginalis;* its lower end forms the *tunica vaginalis* and its upper end is obliterated. The passage in the abdominal wall through which the testis descends forms the inguinal canal. This soon closes round the spermatic cord and the passage is obliterated.

Abnormalities.—If the passage through which the testis descends is not obliterated *oblique* inguinal hernia results.

Sometimes the testis does not descend but remains in the lumbar region; such a condition is known as the *retained testis.* If the testis descends only partially and lodges in the inguinal canal it is called the *imperfectly descended testis.* If the testis instead of descending into the scrotum descends into other positions such as the symphysis pubis, the upper part of the thigh or the perineum it is called *ectopia testis.* Such conditions are due to faulty development and abnormal attachment of the gubernaculum. It has been observed that an undescended testis does not functionate.

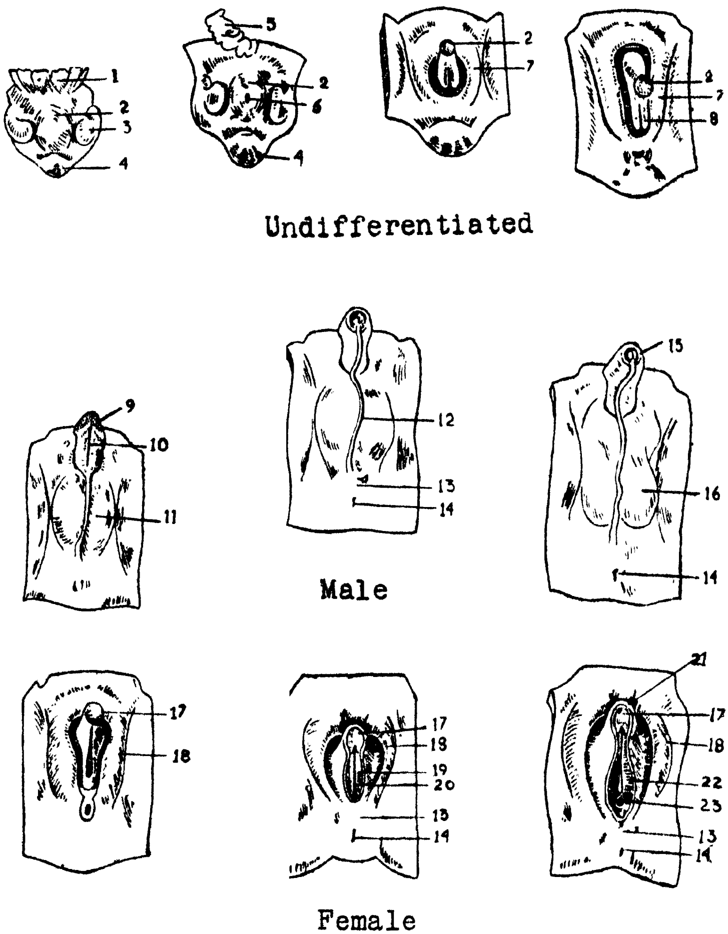

FIG. 49.—STAGES IN THE DEVELOPMENT OF THE EXTERNAL SEXUAL ORGANS. (FROM ZIEGLER'S MODELS.)

1. Bodystalk, 2. Genital tubercle, 3. Lower limb bud, 4. Tail, 5. Umbilical cord, 6. Cloaca, 7. Genital swelling, 8. Labio-scrotal fold, 9. Glans penis, 10. Cavernous urethra, 11. Scrotal swelling, 12. Raphe, 13. Perineum, 14. Anus, 15. Prepuce, 16. Scrotum, 17. Glans clitoridis, 18. Labium majus, 19. Labium minus, 20. Opening of urogenital 21. Preputium clitoridis, 22. Vestibule, 23. Vaginal orifice.

The Prostate arises at about the third month as a series of solid buds on each side of the urethra. The buds become hollow and form glands. Extension from these buds in the middle line constitutes the middle lobe. The muscular tissue of the prostate is derived from the musculature of the urethra. In the female these glands are not well developed. They are called para-urethral glands.

The Bulbourethral Glands arise as buds at the same time as the prostate from the epithelium of the urethra.

External Genital Organs.—The ectodermal cloaca extends from the umbilicus to the coccyx and is separated from the entodermal cloaca by the cloacal membrane. The mesoderm which forms the musculature of the abdominal wall extends caudally below the umbilicus and gives rise to an eminence called the genital tubercle. Another elevation surrounds the genital tubercle above forming the mons pubis and extends backwards as the labial or scrotal folds. No difference can be noted in the two sexes before the embryo is two months old, but after that, the external genital organs begin to differentiate.

In the male the genital tubercle develops into the penis, the terminal end of which forms the glans. The musculature derived from the mesoderm is at first solid, but becomes cavernous later on. The entodermal cloaca extends below the under surface of the genital tubercle, and elongates with it and extends as far as the glans. Invagination of the ectoderm of the glans from below and front towards the entodermal urethra forms that portion of the urethra which is situated in the glans. The scrotal folds extend backwards, unite in the middle line and form the scrotum. A horse-shoe shaped plate grows superficially into the glans and splits, the superficial portion forms the prepuce.

Abnormalities.—Arrest in the development of the urethra results in *hypospadius*, a condition in which the urethra is only represented by a groove on the under surface of the penis; the groove is usually limited to the glans but sometimes extends back and may pass through the scrotum which remains un-united. Another condition in which the urethra forms a groove on the dorsum of the penis is called *epispadius;* this is frequently associated with *ectopia vesicæ* in which the anterior wall of the bladder, and the lower portion of the anterior abdominal wall is not developed and the ureters open on the surface.

In the female the genital tubercle develops into the clitoris; the development of which is similar to that of the penis with this difference that the clitoris is small in size and the urethra opens independently below it. The labial folds extend backwards, do not unite but form the labia majora. Further ingrowths of the labia majora form the labia minora.

The Organs of Special Senses

THE EYE

THE optic bud grows out as a hollow vesicle on each side of the front part of the forebrain and is called the *optic vesicle.* The distal portion of the optic vesicle is dilated to form the *optic bulb.* The proximal portion is elongated to form the optic stalk which develops into the optic nerve. The optic nerve is prolonged backward and comes in contact with the nerve of the opposite side forming the optic chiasma. Here a part of the nerve decussates and passes to the opposite side; the two nerves grow back and become connected with the optic thalami and the midbrain. The optic bulb is depressed in front and becomes cup-shaped. A groove which is called the chorioidial fissure appears below. The outer layer of the optic cup becomes pigmented and forms the outer layer of the retina called the pigmented layer. The inner layer of the optic cup develops in the various layers of the retina. Extension of mesoderm takes place in the chorioidial fissure and an artery known as the central artery of the retina is formed. The fissure generally disappears, but may persist in rare instances and produce the condition known as *congenital coloboma*, a condition in which the iris is deficient below.

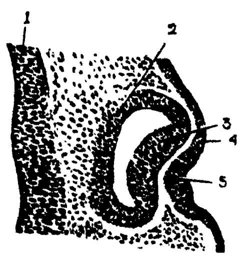

FIG. 50.—THE EYE OF A 9 MM. PIG EMBRYO.

1. Forebrain, 2. Pigment layer, 3. Retinal layer, 4. Ectoderm, 5. Rudiment of lens.

While the optic cup develops by the indentation of the front portion of the optic vesicle, the surface ectoderm also gets depressed to form a vesicle which ultimately forms the crystalline lens. The vesicle soon separates from the parent ectoderm by a cavity which is filled with fluid and is called the aqueous chamber. The edges of the optic cup overlap the lens vesicle and form the *pars iridica retinæ.* The vitreous humour is formed of the cells lying between the lens and the optic cup; a membrane called the *hyaloid membrane* encloses the vitreous humour. The central artery of the retina passes through a canal through this membrane to supply the capsule of the lens. The artery atrophies but the canal persists as the *hyaloid canal.* The outer coats of the eyeball, *i.e.*, the sclerotic and the choroid are developed from the mesoderm surrounding the optic cup.

The eyelids are formed by the invagination of the ectoderm above and below. The invagination forms the conjunctiva and the fornix. The eyelids to begin with are adherent to the conjunctiva but by the sixth month of fœtal life they become separable.

The lacrimal glands arise as solid outgrowths from the upper fornix; the outgrowths arrange themselves into an upper and a lower group, acquire lumen and become the upper and lower portions of the gland. The lacrimal sac and duct are developed from the ectoderm in the furrow between the lateral nasal process and the maxillary process of the developing face.

THE EAR

The internal ear develops as a thickening known as the *auditory plate* in the ectoderm in the region of the hind-brain just above the first branchial cleft. A depression called the *auditory pit* appears in the auditory plate and develops into a vesicle known as the *auditory vesicle* or the *otocyst;* this forms the epithelial lining of the membranous labyrinth. The otocyst soon separates from the ectoderm and gets surrounded by mesoderm and gives rise to a number of diverticula which form the various parts of the membranous labyrinth. A diverticulum in the middle becomes the saccus endolymphaticus. A second diverticulum is given off ventrally which becomes elongated, gets coiled on itself and forms the cochlea or the auditory apparatus. The proximal extremity of the vesicle gets constricted and forms the canalis reunion.

Diverticula given off behind form the semicircular canals which are the apparatus for equilibrium. The vesicle itself forms the vestibule and the saccule.

The mesoderm covering the otocyst and its diverticula becomes cartilagenous, then bony and ultimately forms the bony labyrinth. Nerve cells which are derived either from the nerve crest similar to the spinal ganglia or from the cells of the otocyst send their processes to the vestibule and cochlea on the one hand and to the hind-brain on the other and form the auditory nerve.

The external auditory meatus is developed from the first branchial cleft situated between the mandibular and the hyoid arches. Nodules appear outside and develop into the auricle.

The tympanic cavity and the auditory tube, according to Frazer, are formed of the recess between the first and the third branchial arches, called the *tubotympanic recess*, the floor of which is formed of the first and the second branchial arches and the first and the second branchial pouches. The ossicles of the ear are developed from the cartilages of the first and second arches. The malleus and incus develop from the cartilage of the mandibular arch and the stapes develops from the cartilage of the hyoid arch. A branch from the artery of the second arch called the *stapedial artery* passes through the ring of the stapes. This persists in rats but disappears in man. The ossicles are attached by means of the stapes to the labyrinth medially and by means of the malleus to the tympanic membrane laterally, the incus being situated between the two ossicles. The tympanic membrane is formed of the floor of the tubotympanic recess.

The Chromaffin System

THE neural tube which is formed by a depression in the thickening of the ectoderm in the mid-dorsal region, develops a number of cells in its dorsal aspect deep to the ectoderm. These cells are called the neural crest and migrate ventrally on each side, lose their connection with the neural tube and lie loose on each side of it as masses of cells. The cells differentiate themselves into a dorsal portion which develops into the spinal and cerebral ganglia and a ventral

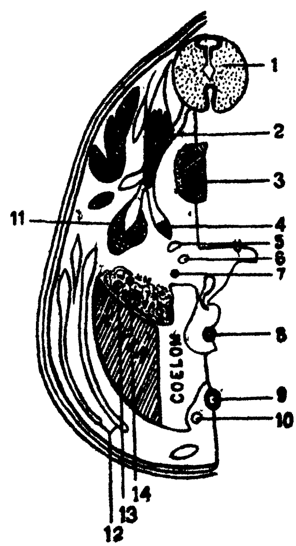

FIG. 51.—TRANSVERSE SECTION THROUGH A HUMAN EMBRYO ABOUT NINE WEEKS OLD. (FROM A MODEL BY ZIEGLER AFTER KEIBAL.)

1. Medulla spinalis, 2. Spinal ganglion, 3. Notochord, 4. Sympathetic ganglion, 5. Inferior vena cava, 6. Common iliac artery, 7. Ureter, 8. Intestine, 9. Bladder, 10. Umbilical artery, 11. Chromaffin cells, 12. Abdominal muscles, 13. Wolffian duct, 14. Mullerian duct.

portion called sympathetic chromaffin cells. The last group again differentiates into a medial portion forming the sympathetic cells and a lateral portion forming the chromaffin cells. The sympathetic cells are smaller in size. They detach themselves from the chromaffin cell mass and migrate to the side of the aorta to form the ganglia of the sympathetic trunk. Some of the cells migrate further and form the ganglia of the prevertebral region and the visceral plexus.

The chromaffin cells are larger in size and give rise to the paraganglia, glomus caroticum, aortic bodies, glomus coccygeum and the medulla of the suprarenal gland.

The paraganglia are associated with the sympathetic trunk and plexus. The glomus caroticum is situated at the bifurcation of the carotid artery. The glomus coccygeum is situated in front of the tip of the coccyx in relation to the medial sacral artery.

THE SUPRARENAL GLAND

The gland consists of a cortical portion and a medullary portion. The cortex is derived from the mesoderm of the cœlomic epethelium, which is thickened into a ridge called the suprarenal ridge and is situated between the mesonephros and the root of the mesentery. The cells of the ridge proliferate and get loose. The chromaffin cells which form the medulla migrate into the cortical cells and fuse.

The suprarenal gland is of a comparatively large size in the embryo. Each gland is supplied by three arteries derived directly from the aorta. The inferior phrenic arises from the superior suprarenal and the renal from the inferior suprarenal. On account of the development of the diaphragm and the kidney the inferior phrenic and the renal arteries develop and become the main arteries and the superior and the inferior suprarenal are given off from them. It is interesting to know that the cortical and medullary portions are quite separate in the elasmobranchs. In the frog the medullary and the cortical portions lie close together while in the mammals the chromaffin cells migrate into the substance of the cortical portion and fuse.

The Embryos and Foetuses at Different Periods

AS a general rule the ovum is fertilised in the uterine tube and undergoes segmentation while it passes along the tube into the uterus in about a week. Bryce and Teacher have accurately described an ovum of about fourteen days which was embedded in the uterine wall with a trophoblast externally, the amniotic cavity and archenteron internally. In the third week the embryo is quite distinguishable with the cephalic and the caudal folds; the neural tube is formed and about seven pairs of primitive segments may be seen. In the fourth week, the brain vesicle is formed in the cephalic end of the neural tube and the otocyst makes its appearance. In the fifth week the embryo is 5 mm. long and from this period to the end of the eighth week it increases 1 mm. every day: the limb buds appear, the mesonephros is developed and the branchial arches can be distinguished. In the sixth week the second branchial or hyoid arch overdevelops and forms

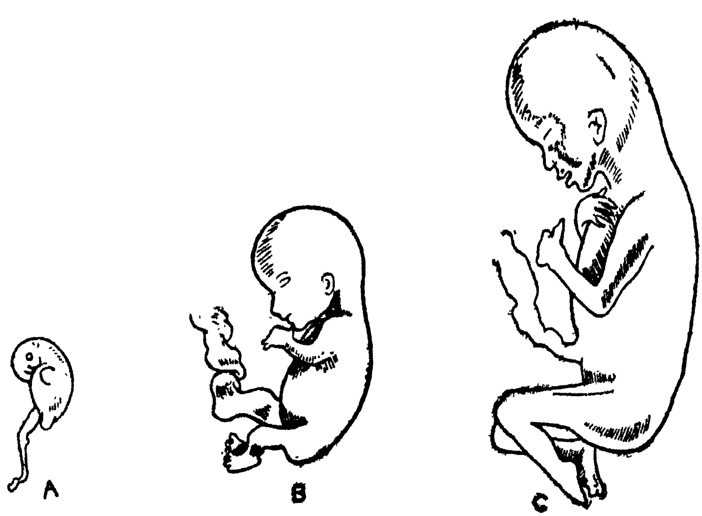

FIG. 52.—EMBRYO AND FŒTUS. (NATURAL SIZE.)

A. 11 mm. of about six weeks (stunted).

B. 40 mm. of about 9 weeks.

CC. 80 mm. of about 11 weeks.

an operculum overlapping the third and the fourth arches which recede resulting in a pit called the *cervical sinus;* the limbs show signs of segmentation. In the last embryonic period, *i.e.*, in the seventh and eighth week the face and ears are formed, the embryo becomes a fœtus and the crown rump length is 25 mm.

In the third lunar month the head of the fœtus is extended, nails appear on the digits and the external genital organs are differentiated so that the sex is distinguishable. In the sixth month fine hair called lanugo appear on the body, there is a considerable deposit of *vernix caseosa*, and the testes descend into the inguinal canal. In the seventh month the eyelids open. In the eighth month lanugo begins to disappear and subcutaneous fat develops. In the ninth month the testes are situated at the subcutaneous inguinal ring and at birth descend into the scrotum.

According to Mall and Scammon the length and height at the different periods are as follows:—

3 weeks embryo	·5	mm.	crown rump length.
4 „ „	2·5	„	„ „ „
5 „ „	5·5	„	„ „ „
6 „ „	11	„	„ „ „
7 „ „	17	„	„ „ „
2nd lunar month fœtus	25	„	„ „ „
3rd „ „ „	100	„	crown heel height.
4th „ „ „	180	„	„ „ „
5th „ „ „	250	„	„ „ „
6th „ „ „	315	„	„ „ „
7th „ „ „	370	„	„ „ „
8th „ „ „	425	„	„ „ „
9th „ „ „	470	„	„ „ „
Full term fœtus	500	„	„ „ „

INDEX