openings of the nostrils appear during the second half of the second month. A little elevation, the nose, appears between these openings, and the nasal cavity begins to be separated from the mouth. The lips are distinct during the third month, and the tongue first appears in the course of the seventh week.

When, by an arrest of development, the superior maxilla on one side fails to unite with the side of the incisor process, there is the very common deformity known as single harelip. If this union fail on both sides, there is double harelip, when the incisor process usually is more or less projecting. As a very rare deformity, it is sometimes observed that the two sides of the incisor process have failed to unite with each other, leaving a fissure in the median line.

The palatine arch is developed by two processes, which arise on either side, from the incisor process, pass backward and upward and finally meet and unite in the median line. The union of these forms the plane of separation between the mouth and the nares; and want of fusion of these processes, from arrest of development, produces the malformation known as cleft palate, in which the fissure is always in the median line. At the same time a vertical process forms in the median line, between the palatine arch and the roof of the nasal cavity, which separates the two nares.

Development of the Teeth.—The first appearance of the organs for the development of the teeth is marked by the formation of a cellular projection extending the entire length of the rounded border of either jaw, which forms a rounded band above and dips down somewhat into the subjacent structure. This band is readily separated by maceration, and the removal of the portion that dips into the maxilla leaves a groove. This band extends the entire length of the jaws, without interruption. Its superior surface is rounded, and that portion which dips into the subjacent mucous structure is wedge-shaped, so that its section has the form of a V.

As soon as this primitive band is formed, which occurs at the sixth or seventh week, a flat band projects from its internal surface, near the mucous structure, which is called the epithelial band. This also extends over the entire length of the jaws. It is thin, flattened, with its free edge curved inward and toward the jaw, and is composed at first of a central layer of polygonal cells, covered by a layer of columnar epithelium.

At certain points—these points corresponding to the situation of the true, dental bulbs—there appear rounded enlargements at the free margin of the epithelial band just described. Each one of these is developed into one of the structures of the perfect tooth. The mechanism of the formation of this, which is called the enamel-organ, and of the dental bulb is as follows:

A rounded enlargement appears at the margin of the epithelial band. This soon becomes directed downward—adapting the description to the lower jaw—and dips into the mucous structure, being at first connected with the epithelial band, by a narrow pedicle, which soon disappears, leaving the enlargement enclosed completely in a follicle. This is the dental follicle, and it has no connection with the wedge-shaped band described first. While

this process is going on, a conical bulb appears at the bottom of the follicle. The enamel-organ, formed from the epithelial band, becomes excavated, or cup-shaped, at its under surface, and fits over the dental bulb, becoming united to it.

The tooth at this time consists of the dental bulb, with the enamel-organ closely fitted to its projecting surface. The enamel-organ is developed into

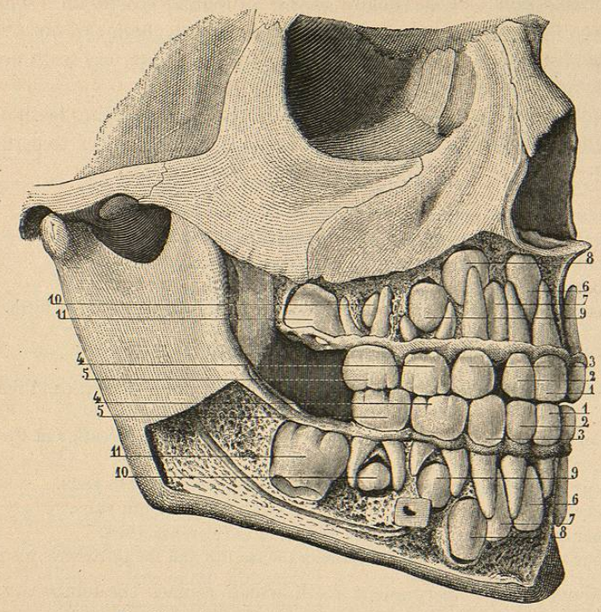

FIG. 310.—*Temporary and permanent teeth* (Sappey).
1, 1, temporary central incisors; 2, 2, temporary lateral incisors; 3, 3, temporary canines; 4, 4, temporary anterior molars; 5, 5, temporary posterior molars; 6, 6, permanent central incisors; 7, 7, permanent lateral incisors; 8, 8, permanent canines; 9, 9, permanent first bicuspids; 10, 10, permanent second bicuspids; 11, 11, first molars.

the enamel; the dental bulb, which is provided with vessels and nerves, becomes the tooth-pulp; and upon the surface of the dental bulb, the dentine is developed in successive layers. The cement is developed by successive layers, upon that portion of the dentine which forms the root of the tooth. As these processes go on, the tooth projects more and more, the upper part of the wall of the follicle gives way and the tooth finally appears at the surface.

The permanent teeth are developed beneath the follicles of the temporary, or milk-teeth. The first appearance is a prolongation or diverticulum from the enamel-organ of the temporary tooth, which dips more deeply into the mucous structure. This becomes the enamel-organ of the permanent tooth; and the successive stages of development of the dental follicles and the dental pulp progress in the same way as in the temporary teeth. As the permanent teeth increase in size, they gradually encroach upon the roots

of the temporary teeth. The roots of the latter are absorbed, the permanent teeth advance more and more toward the surface, and the crown of each temporary tooth is finally pushed out. The number of the temporary teeth is twenty, and there are thirty-two permanent teeth. Thus there are three permanent teeth on either side of both jaws, which are developed *de novo* and are not preceded by temporary structures.

The first dental follicles usually appear in regular succession. The follicles for the internal incisors of the lower jaw appear first, this occurring at about the ninth week. All of the follicles for the temporary teeth are completely formed at about the eleventh or twelfth week.

The temporary teeth appear successively, the corresponding teeth appearing a little earlier in the lower jaw. The usual order, subject to certain exceptional variations, is as follows (Sappey):

The four central incisors appear six to eight months after birth.
The four lateral incisors appear seven to twelve months after birth.
The four anterior molars appear twelve to eighteen months after birth.
The four canines appear sixteen to twenty-four months after birth.
The four posterior molars appear twenty-four to thirty-six months after birth.

The order of eruption of the permanent teeth is as follows:

The two central incisors of the lower jaw appear between the sixth and the eighth years.
The two central incisors of the upper jaw appear between the seventh and the eighth years.
The four lateral incisors appear between the eighth and the ninth years.
The four first bicuspids appear between the ninth and the tenth years.
The four canines appear between the tenth and the eleventh years.
The four second bicuspids appear between the twelfth and the thirteenth years.

The above are the permanent teeth which replace the temporary teeth. The permanent teeth which are developed *de novo* appear as follows:

The first molars appear between the sixth and the seventh years.
The second molars appear between the twelfth and the thirteenth years.
The third molars appear between the seventeenth and the twenty-first years.

Development of the Genito-Urinary Apparatus.

The genital and the urinary organs are developed together and are both preceded by the appearance of two large, symmetrical structures, known as the Wolffian bodies, or the bodies of Oken. These are sometimes called the false, or the primordial kidneys. They appear at about the thirtieth day, develop very rapidly on either side of the spinal column and are so large as to almost fill the cavity of the abdomen. Fig. 311 shows how large these bodies are in the early life of the embryon, at which time their office is undoubtedly very important.

Very soon after the Wolffian bodies have made their appearance, there appear at their inner borders, two ovoid bodies, which are finally developed into the testicles, for the male, or the ovaries, for the female. At their external borders, are two ducts on either side, one of which, the internal, is

called the duct of the Wolffian body. This finally disappears in the female, but it is developed into the vas deferens in the male. The other duct, which is external to the duct of the Wolffian body, disappears in the male, but it becomes the Fallopian tube in the female. This is known as the duct of Müller. Behind the Wolffian bodies, are developed the kidneys and the suprarenal capsules.

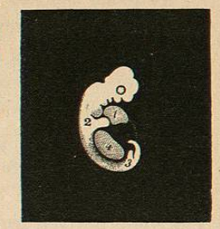

Fig. 311.—*Fœtal pig, $\frac{5}{8}$ of an inch (15·9 mm.) long.* From a specimen prepared by Dalton.
1, heart; 2, anterior extremity; 3, posterior extremity; 4, Wolffian body.
The abdominal walls have been cut away, in order to show the position of the Wolffian bodies.

As the development of the Wolffian bodies attains its maximum their structure becomes somewhat complex. From their proper ducts, which are applied directly to their outer borders, tubes make their appearance at right angles to the ducts, which extend into the substance of the bodies and become somewhat convoluted at their extremities. These tubes communicate directly with the ducts, and the ducts themselves open into the lower part of the intestinal canal, opposite to the point of its communication with the allantois. The tubes of the Wolffian bodies are simple, terminating in single, somewhat dilated, blind extremities, are lined with epithelium, and are penetrated at their extremities, by blood-vessels, which form coils or convolutions in their interior. These are undoubtedly organs of depuration for the embryon and take on the office to be afterward assumed by the kidneys; but in the female they are temporary structures, disappearing as development advances, and having nothing to do with the development of the true, urinary organs.

The testicles or ovaries are developed at the internal and anterior surface of the Wolffian bodies, first appearing in the form of small, ovoid masses. Beginning just above and passing along the external borders of the Wolffian bodies, are the tubes called the ducts of Müller. These at first open into the intestine, near the point of entrance of the Wolffian ducts. In the female their upper extremities remain free, except the single fimbria which is connected with the ovary. Their inferior extremities unite with each other, and at their point of union they form the uterus. When this union is incomplete there is the malformation known as double uterus, which may be associated with a double vagina. The Wolffian bodies and their ducts disappear, in the female, at about the fiftieth day. A portion of their structure, however, persists in the form of a collection of closed tubes constituting the parovarium, or organ of Rosenmüller.

In the female the ovaries pass down no farther than the pelvic cavity; but the testicles, which are at first in the abdomen of the male, finally descend into the scrotum. As the testicles descend they carry with them the Wolffian duct, that portion of the Wolffian body which is permanent constituting the head of the epididymis. At the same time a cord appears, attached to the lower extremity of the testicle and extending to the symphysis pubis. This is called the gubernaculum testis. It is at first muscular, but the muscular fibres disappear during the later periods of utero-gestation. It

is not known that its muscular structure takes any part, by contractile action, in the descent of the testicle in the human subject. The epididymis and the vas deferens are formed from the Wolffian body and the Wolffian duct.

At about the end of the seventh month the testicle has reached the internal abdominal ring; and at this time a double tubular process of peritoneum, covered with a few fibres from the lower portion of the internal oblique muscle of the abdomen, gradually extends into the scrotum. The testicle descends, following this process of peritoneum, which latter become eventually the visceral and parietal portions of the tunica vaginalis. The canal of communication between the abdominal cavity and the cavity of the scrotum is finally closed, and the tunica vaginalis is separated from the peritoneum. The fibres derived from the internal oblique constitute the cremaster muscle.

At the eighth or the ninth month the testicles have reached the external abdominal ring and then soon descend into the scrotum. The vas deferens passes from the testicle, along the base of the bladder, to open into the prostatic portion of the urethra; and as development advances, two sacculated diverticula from these tubes make their appearance, which are attached to the bladder and constitute the vesiculæ seminales.

As the ovaries descend to their permanent situation in the pelvic cavity, there appears, attached to the inner extremity of each, a rounded cord, analogous to the gubernaculum testis. A portion of this, connecting the ovary with the uterus, constitutes the ligament of the ovary; and the inferior portion forms the round ligament of the uterus, which passes through the inguinal canal and is attached to the symphysis pubis.

Development of the Urinary Apparatus.—Behind the Wolffian bodies, and developed entirely independently of them, the kidneys, suprarenal capsules and ureters make their appearance. The kidneys are developed in the form of little, rounded bodies, composed of short, blind tubes, all converging toward a single point, which is the hilum. These tubes increase in length, branch, become convoluted in a certain portion of their extent, and they finally assume the structure and arrangement of the renal tubules, with their Malpighian bodies, blood-vessels etc. They all open into the hilum. At the time that the kidneys are undergoing development the suprarenal capsules are formed at their superior extremities. These bodies, the uses of which are unknown, are relatively so much larger in the fœtus than in the adult that they have been supposed to be peculiarly important in intraüterine life, though nothing definite is known upon this point. The kidneys are relatively very large in the fœtus. Their proportion to the weight of the body, in the fœtus, is 1 to 80, and in the adult, 1 to 240. The ureters undoubtedly are developed as tubular processes from the kidneys, which finally extend to open into the bladder. This fact is shown by certain cases of malformation, in which the ureters do not reach the bladder, but terminate in blind extremities. The development of the genito-urinary apparatus can be readily understood, after the discription just given, by a study of Fig. 312.

Development of the External Organs of Generation.—The external organs of generation begin to be developed at about the fifth week. At the infe-

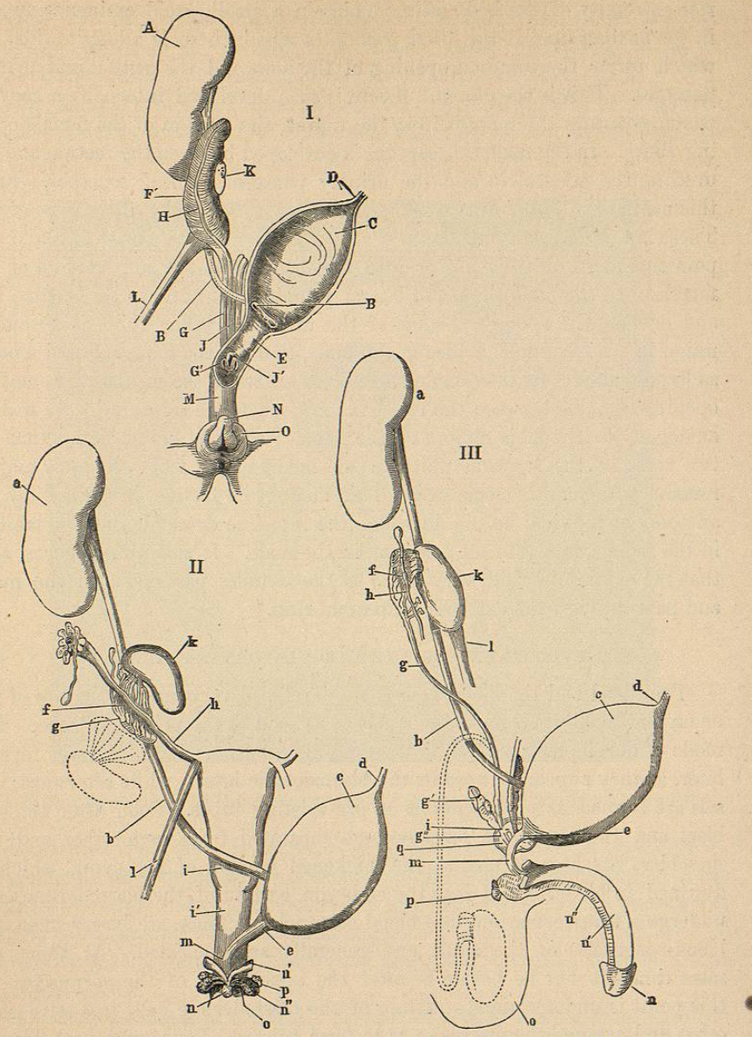

Fig. 312.—*Diagrammatic representation of the genito-urinary apparatus* (Henle).

I, embryonic condition, in which there is no distinction of sex; II, female form; III, male form. The dotted lines in II and III represent the situations which the male and female genital organs assume after the descent of the ovaries and testicles. The small letters in II and III correspond to the capital letters in I.

Fig. 312, I.—A, kidney; B, ureter; C, bladder; D, urachus, developed into the median ligament of the bladder; E, constriction which becomes the urethra; F′, Wolffian body; G, Wolffian duct, with its opening below, G′; H, duct of Müller, united below, from the two sides, into a single tube, J, which presents a single opening, J′, between the openings of the Wolffian ducts; K, ovary or testicle; L, gubernaculum testis or round ligament of the uterus; M, genito-urinary sinus; N, O, external genitalia.

Fig. 312, II (female).—a, kidney; b, ureter; c, bladder; d, urachus; e, urethra; f, remains of the Wolffian body (parovarium); g, remnant of the Wolffian duct; h, Fallopian tube; i, uterus; i′, vagina; k, ovary; l, round ligament of the uterus; m, extremity of the urethra; n, clitoris; n′, corpus cavernosum of the clitoris; n″, bulb of the vestibule; o, external genital opening; p, excretory duct of the gland of Bartholinus.

Fig. 312, III (male).—a, kidney; b, ureter; c, bladder; d, urachus; e, m. urethra; f, epididymis; g, vas deferens; g′, seminal vesicle; g″, ejaculatory duct; h, i, remains of the duct of Müller; k, testicle; l, gubernaculum testis; n, n′, n″, urethra and penis; o, scrotum; p, gland of Cowper; q, prostate.

rior extremity of the body of the embryon a small, ovoid eminence appears in the median line, at the lower portion of which there is a longitudinal slit, which forms the common opening of the anus and the genital and urinary passages. This is the cloaca. There is soon developed internally a septum, which separates the rectum from the vagina, the urethra of the female opening above. In the male this septum is developed between the rectum and the urethra, the generative and the urinary passages opening together. From this median prominence two lateral, rounded bodies make their appearance. These are developed, with the median elevation, into the glans penis and corpora cavernosa of the male or into the clitoris and the labia minora of the female. In the male these two lateral prominences unite in the median line and enclose the spongy portion of the urethra. When there is a want of union in the cavernous bodies in the male, there is the malformation known as hypospadias. In the female there is no union in the median line, and an opening remains between the two labia minora. The scrotum in the male is analogous to the labia majora of the female; the distinction being that the two sides of the scrotum unite in the median line, while the labia majora remain permanently separated. This analogy is farther illustrated by the anatomy of inguinal hernia, in which the intestine descends into the labium, in the female, and into the scrotum, in the male. It sometimes occurs, also, that the ovaries descend, very much as the testicles pass down in the male, and pass through the external abdominal ring.

Development of the Circulatory Apparatus.

The blood and the blood-vessels are developed very early in the life of the ovum and make their appearance nearly as soon as the primitive trace. The mode of development of the first vessels differs from that of vessels formed later, as they appear *de novo* in the blastodermic layers, while afterward, vessels are formed as prolongations of pre-existing tubes. Soon after the epiblast and the hypoblast have become separated from each other and the mesoblast has been formed at the thickened portion of the ovum, which is destined to be developed into the embryon, certain of the blastodermic cells undergo a transformation into blood-corpuscles. These are larger than the blood-corpuscles of the adult and generally are nucleated. At about the same time—it may be before or after the appearance of the corpuscles, for this point is undetermined—certain of the blastodermic cells fuse with each other and arrange themselves so as to form vessels. Leucocytes probably are developed in the same way as the red corpuscles. The vessels thus formed constitute the area vasculosa, which is the beginning of what is known as the first circulation.

According to His and Waldeyer, the cells of the mesoblast do not take part in the formation of the blood and blood-vessels, as indicated above, but cells penetrate at the edges, between the epiblast and the hypoblast, and these, which are called parablastic cells, are developed into blood-vessels and blood-corpuscles. The connective tissue is also supposed to be developed from parablastic cells. According to this view—which, however, is not generally

adopted—the parablastic cells are to be distinguished from the cells of the mesoblast, which latter are called archiblastic cells. According to Rindfleisch the so-called parablastic cells are derived from the area opaca.

The First, or Vitelline Circulation.—In the development of oviparous animals, the first, or vitelline circulation is very important; for by these vessels the contents of the nutritive yelk are taken up and carried to the em-

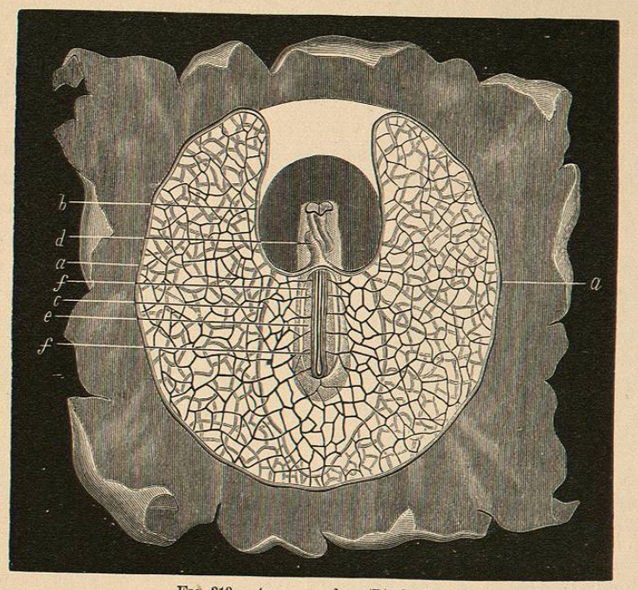

Fig. 313.—*Area vasculosa* (Bischoff).
a, *a*, *b*, sinus terminalis; *c*, omphalo-mesenteric vein; *d*, heart; *e*, *f*, *f*, posterior vertebral arteries.

bryon, constituting the only source of material for its nutrition and growth. In mammals, however, nutritive matter is absorbed almostly exclusive from the mother, by simple endosmosis, before the placental circulation is established, and by the placental vessels, at a later period. The vitelline circulation is therefore not important, and the vessels dissappear with the atrophy of the umbilical vesicle.

The area vasculosa in mammals consists of vessels coming from the body of the embryon, forming a nearly circular plexus in the substance of the vitellus, around the embryon. The vessels of this plexus open into a sinus at the border of the area, called the sinus terminalis.

In examining the ovum when the area vasculosa is first formed, the embryon is seen lying in the direction of the diameter of the nearly circular plexus of blood-vessels. The plexus surrounds the embryon, except at the cephalic extremity, where the terminal sinuses of the two sides curve downward toward the head, to empty into the omphalo-mesenteric veins. As the umbilical vesicle is separated from the body of the embryon, it carries the plexus of vessels of the area vasculosa with it, the vessels of communication

with the embryon being the omphalo-mesenteric arteries and veins. As these processes are going on, the great, central vessel of the embryon becomes enlarged and twisted upon itself, at a point just below the cephalic enlargement of the embryon, between the inferior extremity of the pharynx and the superior *cul-de-sac* of the intestinal canal. The excavation which receives this vessel is called the fovea cardiaca. Simple, undulatory movements take place in the heart of the chick at about the middle of the second day; but there is not at that time any regular circulation. At the end of the second day or the beginning of the third, the currents of the circulation are established. The time of the first appearance of the circulation in the human embryon has not been accurately determined.

In the arrangement of the vessels for the first circulation in the embryon, the heart is situated exactly in the median line and gives off two arches which curve to either side and unite into a single central trunk at the spinal column below. These are the two aortæ, and the single trunk formed by their union becomes the abdominal aorta. The two aortic arches, only one of which is permanent, are sometimes called the inferior vertebral arteries. These vessels give off a number of branches, which pass into the area vasculosa. Two of these branches, however, are larger than the others, pass to the umbilical vesicle and are called the omphalo-mesenteric arteries. In the embryon of mammals, there are at first four omphalo-mesenteric veins, two superior, which are the larger, and two inferior; but as development advances, the two inferior veins are closed, and there are then two omphalo-mesenteric arteries and two omphalo-mesenteric veins. At about the fortieth day one artery and one vein disappear, leaving one omphalo-mesenteric artery and one vein. Soon after, as the circulation becomes established in the allantois, the vessels of the umbilical vesicle and the omphalo-mesenteric vessels are obliterated, and the first circulation is superseded by the second.

As the septum between the two ventricles makes its appearance, that division of the right aortic arch which constitutes the vascular portion of one of the branchial arches disappears and loses its connection with the abdominal aorta; a branch, however, persists during the whole of intraüterine life and constitutes the ductus arteriosus, and another branch is permanent, forming the pulmonary artery.

The Second, or Placental Circulation.—As the omphalo-mesenteric vessels disappear and as the allantois is developed to form the chorion, two vessels (the hypogastric arteries) are given off, first from the abdominal aorta; but afterward, as the vessels going to the lower extremities are developed, the branching of the abdominal aorta is such that the vessels become connected with the internal iliac arteries. The hypogastric arteries pass to the chorion, through the umbilical cord, and constitute the two umbilical arteries. At first there are two umbilical veins; but one of them afterward disappears, and there is finally but one vein in the umbilical cord. It is in this way—the umbilical arteries carrying the blood to the tufts of the fœtal placenta, which is returned by the umbilical vein—that the placental circulation is established.

Corresponding to the four visceral arches, which have been described in connection with the development of the face, are four vascular arches. One of these disappears, and the remaining three undergo certain changes, by which they are converted into the vessels going to the head and the superior extremities. The anterior arches on the two sides are converted into the carotids and subclavians; the second, on the left side, is converted into the permanent aorta, and the right is obliterated; the third, on either side, is converted into the right and left pulmonary arteries.

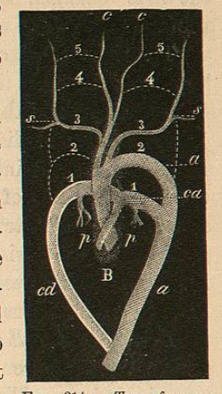

FIG. 314. — *Transformation of the system of aortic arches into permanent arterial trunks, in the mammalia* (Von Baer).

B, aortic bulb: 1, 2, 3, 4, 5, on either side, the five pairs of aortic arches; 5, 5, the earliest in their appearance; 1, 1, the most recent; *c*, *c*, the two carotids, still united, which are separated at a later period; *s*, *s*, the two subclavians, the right arising from the arteria innominata; *a*, *a*, the aorta; *p*, *p*, the pulmonary arteries; *ca*, the ductus arteriosus; *cd*, the left artieral canal, which is finally obliterated.

The changes of the branchial arches are illustrated in the diagrammatic Fig. 314. In this figure the three branchial arches that remain and participate in the development of the upper portion of the vascular system are 1, 2, 3, on either side. The two anterior (3, 3) become the carotids (*c*, *c*) and the subclavians (*s*, *s*). The second (2, 2) is obliterated on the right side, and becomes the arch of the aorta on the left side. The third (1, 1), counting from above downward, is converted into the pulmonary arteries of the two sides. Upon the left side there is a large, anastomosing vessel (*ca*), between the pulmonary artery of that side and the arch of the aorta, which is the ductus arteriosus. The anastomosing vessel (*cd*), between the right pulmonary artery and the aorta, is obliterated.

The mode of development of the veins is very simple. Two venous trunks make their appearance by the sides of the spinal column, which are called the cardinal veins, and run parallel with the superior vertebral arteries, or the two aortæ, emptying finally into the auricular portion of the heart, by two canals, which are called the canals of Cuvier. These veins change their relations and connections as the first circulation is replaced by the second. The omphalo-mesenteric vein opens into the heart, between the two canals of Cuvier. As development advances, the liver is formed in the course of this vessel, a short distance below the heart, and the vein ramifies in its substance; so that the blood of the omphalo-mesenteric vein passes through the liver before it goes to the heart. The omphalo-mesenteric vein is obliterated as the umbilical vein makes its appearance. The blood from the umbilical vein is at first emptied directly into the heart; but this vessel soon establishes the same relations with the liver as the omphalo-mesenteric vein, and its blood passes through the liver before it reaches the central organ of the circulation. As the omphalo-mesenteric vein atrophies, the mesenteric vein, bringing the blood from the intestinal canal, is developed, and this penetrates the liver, becoming finally the portal vein.

As the lower extremities are developed, the inferior vena cava makes its appearance, between the two inferior cardinal veins. This vessel receives an