extremities, and the thigh, leg and foot, for the lower extremities. At the end of each extremity, there are, finally, divisions into the fingers and toes, with the various cartilages and bones of all of these parts, and their articulations.

Very early in intraüterine life the skeleton begins to ossify, from little bony points which appear in the cartilaginous structure. The first points appear at nearly the same time—about the beginning of the second month—in the clavicle and the upper and the lower jaw. Similar ossific points, which gradually extend, are also seen in other parts, the head, ribs, pelvis, scapula, metacarpus and metatarsus, and the phalanges of the fingers and toes. At birth the carpus is entirely cartilaginous, and it does not begin to ossify until the second year. The same is true of the tarsus, except the calcaneum and astragalus, which ossify just before birth. The pisiform bone of the carpus is the last to take on osseous transformation, this occurring between the twelfth and the fifteenth years. As ossification progresses, the deposits in the various ossific points gradually extend until they reach the joints, which remain incrusted with the permanent, articular cartilage.

While the skeleton is thus developing, the muscles are formed from the outer layer of the mesoblast, and the visceral plates close over the thorax and abdomen in front, leaving an opening for the umbilical cord. The various tissues of the external parts, particularly the muscles, begin to be distinct at the end of the second month. The deep layers of the dorsal muscles are the first to be distinguished; then successively, the long muscles of the neck, the anterior straight muscles of the head, the straight and transverse muscles of the abdomen, the muscles of the extremities, the superficial muscles of the back, the oblique muscles of the abdomen and the muscles of the face.

The skin appears at about the beginning of the second month, when it is very delicate and transparent. At the end of the second month the epidermis may be distinguished. The sebaceous follicles are developed at the third month; and at about the fifth month the surface is covered with their secretion mixed with desquamated epithelium. This cheesy substance constitutes the vernix caseosa. At the third month the nails make their appearance, and the hairs begin to grow at about the fifth month. The sudoriparous glands first appear at about the fifth month, by the formation of flask-like processes of the true skin, which are gradually elongated and convoluted, until they are fully developed only a short time before birth.

Development of the Nervous System.

It has been seen, in studying the development of the spinal column, how the dorsal, or medullary plates close over the groove for the neural canal. In the interior of this canal, the cerebro-spinal axis is developed, by cells which gradually encroach upon its caliber, until there remains only the small, central canal of the spinal cord, communicating with the ventricles of the brain. As the nervous tissue is developed in the interior of the neural canal, there is a separation of the histological elements at the surface, to form the membranes. The dura mater and the pia mater are formed first, appearing

at about the end of the second month, while the arachnoid is not distinct until the fifth month. The nerves are not produced as prolongations from the cord into the various tissues nor do they extend from the tissues to the cord, but they are developed in each tissue by a separation of histological elements from the cells of which the parts are originally constituted. The nerves of the sympathetic system are developed in the same way.

The mode of development of the spinal cord is thus sufficiently simple; but with the growth of the embryon dilatations are observed at the superior and at the inferior extremities of the neural canal. The cord is nearly uniform in size in the dorsal region, marked only by the regular enlargements at the sites of origin of the spinal nerves; but there soon appears an ovoid dilatation below, which forms the lumbar enlargement, from which the nerves are given off to the inferior extremities, and the brachial enlargement above, where the nerves of the superior extremities take their origin. At the same time there is a more marked dilatation of the canal at its cephalic extremity. Here a single enlargement appears, which is soon divided into three vesicles, called the anterior, middle and posterior cerebral vesicles. These become more and more distinct as development advances. The formation of these parts is shown in Fig. 303. This figure, in C, shows the projections, on either side, of the vesicles which are eventually developed (*o*, Fig. 303, C) into the nervous portions of the organ of vision.

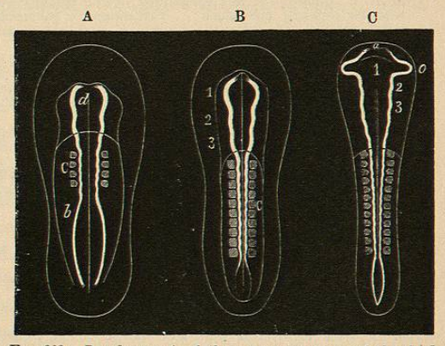

Fig. 303.—*Development of the nervous system of the chick* (Longet, after Wagner).

A, the two primitive halves of the nervous system, twenty-four hours after incubation; B, the same, thirty-six hours after; C, the same, at a more advanced stage. *c*, the protovertebræ; *b*, posterior dilatation (the lumbar enlargement); *d*, anterior dilatation of the neural canal; 1, 2, 3, anterior, middle and inferior cerebral vesicles; *a*, slight flattening of the anterior cerebral vesicle; *o*, formation of the ocular vesicles.

The three cerebral vesicles now undergo farther changes. The superior, or the first primitive vesicle, is soon divided into two secondary vesicles, the anterior of which becomes the cerebral hemispheres, and the posterior, the optic thalami, which are eventually covered by the greater relative development of the hemispheres. The middle, or second primitive vesicle, does not undergo division and is developed into the tubercula quadrigemina. The posterior, or third primitive vesicle, is divided into two secondary vesicles, the anterior of which becomes the cerebellum, and the posterior, which is covered by the anterior, the medulla oblongata and the pons Varolii. While this division of the primitive cerebral vesicles is going on, the entire chain of encephalic ganglia becomes curved from behind forward, forming three prominent angles. The first of these angles or prominences (*e*, Fig. 304, A, B, C), counting from before backward, is formed by a projection of the tubercula quadrigemina, which at this time constitute the most projecting

portion of the encephalic mass; the second prominence (*c*, Fig. 304), situated behind the tubercula quadrigemina, is formed by the projection of the cerebellum; the third (*d*, Fig. 304, A, B, C), is the bend of the superior portion of the spinal cord. These projections and the early formation of certain parts of the encephalon in the human subject are illustrated in Fig. 304.

The cerebrum is developed from the anterior division of the first primitive cerebral vesicle. The development of this part is more rapid in its lateral portions than in the median line, which divides the cerebrum imperfectly into two lateral halves, forming in this way the great longitudinal fissure. At the same time, by the rapid development of the posterior portion, it extends over the optic thalami, the corpora quadrigemina and the cerebellum. Until the end of the fourth month, the hemispheres are smooth on their surface; but they then begin to present large depressions, following folds of the pia mater, which are the first convolutions, these increasing rapidly in number and complexity, especially after the seventh month. The septum lucidum is then formed, by an elevation of nervous matter from the base, which divides the lower portion of the space left between the hemispheres as they ascend, and forms the two lateral ventricles. At the base of these, are developed the corpora striata. The septum lucidum is formed of two laminæ, with a small space between them, which is the cavity of the fifth ventricle. The posterior division of this first primitive vesicle forms the optic thalami. These become separated in front into two lateral halves, but they remain connected together at their posterior portion, which becomes the posterior commissure. The central canal of the cord is prolonged upward between the optic thalami, and forms the third ventricle, which is covered by the hemispheres.

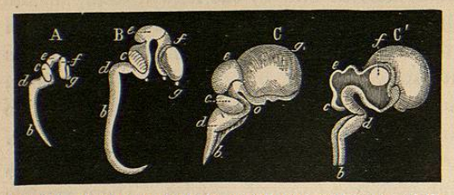

FIG. 304.—*Development of the spinal cord and brain of the human subject* (Longet, after Tiedemann).

A, brain and spinal cord of an embryon of seven weeks; lateral view.

B, the same, from an embryon farther advanced in development; *b*, spinal cord; *d*, enlargement of the spinal cord, with its anterior curvature; *c*, cerebellum; *e*, tubercula quadrigemina; *f*, optic thalamus; *g*, cerebral hemispheres.

C, brain and spinal cord of an embryon of eleven weeks; *b*, spinal cord; *d*, enlargement of the spinal cord, with its anterior curvature; *c*, cerebellum; *e*, tubercula quadrigemina; *g*, cerebral hemispheres; *o*, optic nerve of the left side.

C′, the same parts in a vertical section in the median line, from before backward; *b*, membrane of the spinal cord, turned backward; *d*, second curvature of the upper portion of the spinal cord, which has become thickened and constitutes the peduncles of the cerebrum; *e*, tubercula quadrigemina; *f*, optic thalami, covered by the hemispheres.

The second, or middle cerebral vesicle, becomes filled with medullary substance, extends upward and forms the peduncles of the cerebrum, the upper portion being divided to form the tubercula quadrigemina.

The anterior portion of the third primitive vesicle is developed into the cerebellum, the convolutions of which appear at about the fifth month. Its posterior portion forms the medulla oblongata, in the substance of which is the fourth ventricle, communicating with the third ventricle, by the aqueduct of Sylvius, which is left in the development of the middle vesicle. At

about the fourth month there is a deposition of nervous matter in front and above, forming the pons Varolii.

In Fig. 304 (C, *o*), it is seen that the vesicles for the organs of vision appear very early, as lateral offshoots of the anterior cerebral vesicle. These gradually increase in size and advance anteriorly, as development of the other parts progresses. The eyes are situated at first at the sides of the head, gradually approaching the anterior portion. At the extremity of each of these lateral prolongations, a rounded mass appears, which becomes the globe of the eye. The superficial portions of the globe are developed into the sclerotic and the cornea, which seem to be formed of a process from the dura mater. The pedicle attached to the globe becomes the optic nerve. The iris is developed at about the seventh week, and is at first a simple membrane, without any central opening. As the pupil appears, it is closed by a vascular membrane—which probably belongs to the capsule of the crystalline lens—called the pupillary membrane. This membrane gradually disappears, by an atrophy extending from the centre to the periphery. It attains its maximum of development at the sixth month and disappears at the seventh month. The vitreous humor is formed of the fluid contents of the optic vesicle. The crystalline lens is regarded as a product of the epiblast. At the tenth week there is the beginning of the formation of the eyelids. These meet at about the fourth month and adhere together by their edges. In many mammals the eyelids remain closed for a few days after birth; but they become separated in the human subject in the later periods of fœtal life.

It is probable that the vesicle which becomes developed into the internal ear is formed independently; at least cases have been observed in which there was congenital absence of the auditory nerves, the parts of the internal ear being perfect. Soon after the formation of the auditory vesicle, however, it communicates with the third primitive cerebral vesicle, the filament of communication being developed into the auditory nerve.

The auditory vesicle, which appears later than the organ of vision, is eventually developed into the vestibule. The next formations are the arches, or diverticula, which constitute the semicircular canals. The membranous labyrinth appears long before the osseous labyrinth; and it has been found perfectly developed at three months. The bones of the middle ear, which have no connection, in their development, with the nervous system, but which it is convenient to mention here, are remarkable for their early appearance. They appear at the beginning of the third month and are as large in the fœtus at term as in the adult. A remarkable anatomical point with relation to these structures is the existence of a cartilage, attached to the malleus on either side and extending from this bone along the inner surface of the lower jaw, the two cartilages meeting and uniting in the median line, to form a single cord. "This cartilage now ossifies, although, in the commencement, it forms most of the mass of the bone; it disappears at the eighth month" (Meckel). This structure is known as the cartilage of Meckel.

There are no special points for description in the development of the

olfactory lobes, which is very simple. These are offshoots from the first cerebral vesicle, appearing at the inferior and anterior part of the cerebral hemispheres, a little later than the parts connected with vision and audition. The vesicles themselves become filled with ganglionic matter and constitute the olfactory bulbs, their pedicles being the so-called olfactory nerves, or olfactory commissures.

As far as the action of the nervous system of the fœtus is concerned, it is probable that it is restricted mainly to reflex phenomena depending upon the spinal cord, and that perception and volition hardly exist. It is probable that many reflex movements take place in utero. When a fœtus is removed from the uterus of an animal, even during the early months of pregnancy, movements of respiration occur; and it is well known that efforts of respiration sometimes take place within the uterus. These are due to the want of oxygen-carrying blood in the medulla oblongata when the placental circulation is interrupted.

Development of the Digestive Apparatus.

The intestinal canal is the first formation of the digestive system. This is at first open in the greatest part of its extent, presenting, at either extremity of the longitudinal gutter, in front of the spinal column, a rounded, blind extremity, which is closed over in front for a short distance. The closure of the visceral plates then extends laterally and from the two extremities of the intestine, until only the opening remains for the passage of the umbilical cord and the pedicle of the umbilical vesicle. There is at first an open communication between the lower part of the intestinal tube and the allantois, which forms the canal known as the urachus; but that portion of this communication which remains enclosed in the abdominal cavity becomes separated from the urachus, is dilated and eventually forms the urinary bladder. When the bladder is first shut off, it communicates with the lower portion of the intestine, which is called the cloaca; but it finally loses this connection and presents a special opening, the urethra.

Fig. 305.—*Fœtal pig, showing a loop of intestine, forming an umbilical hernia* (Dalton).

From the convexity of the loop, a thin filament is seen passing to the umbilical vesicle, which is here flattened into a leaf-like form.

As development advances, the intestine grows rapidly in length and becomes convoluted. It is held loosely to the spinal column by the mesentery, a fold of the peritoneum, this membrane being reflected along the walls of the abdominal cavity. In the early stages of development, a portion of the intestine protrudes at the umbilicus, where the first intestinal convolution appears; and sometimes there is a congenital hernia of this kind at birth, which usually disappears under the influence of gentle and continued pressure. An illustration of this is given in Fig. 305. This protrusion, in the normal process of development, is gradually returned into the abdomen, as

the cavity of the pedicle of the umbilical vesicle is obliterated, at about the tenth week.

At the upper part of the abdominal cavity the alimentary canal presents two lateral projections, or pouches. The one on the left side, as it increases in size, becomes the greater pouch of the stomach, and the one on the right side, the lesser pouch.

At a short distance below the attachment of the pedicle of the umbilical vesicle to the intestine, there appears a rounded diverticulum, which is eventually developed into the cæcum. The cæcum gradually recedes from the neighborhood of the umbilicus, which is its original situation, and finally becomes fixed, by a shortening of the mesentery, in the right iliac region. As the cæcum is developed it presents a conical appendage, which is at first as large as the small intestine and is relatively longer than in the adult. During the fourth week this appendage becomes relatively smaller and more or less twisted, forming the appendix vermiformis. At the second month the cæcum is at the umbilicus, and the large intestine extends in a straight line toward the anus; at the third month it is situated at about the middle of the abdomen; and it gradually descends, until it reaches the right iliac region at about the seventh month. Thus at the second month, there is only a descending colon; the transverse colon is formed at the third month; and the ascending colon, at the fifth month. The ileo-cæcal valve appears at the third month; the rectum, at the fourth month; and the sigmoid flexure of the colon, at the fifth month. During this time the large intestine increases more rapidly in diameter than the small intestine, while the latter develops more rapidly in its length.

In the early stages of development the internal surface of the intestines is smooth; but villi appear upon its mucous membrane during the latter half of intraüterine existence. These are found at first both in the large and the small intestine. At the fourth month they become shorter and less abundant in the large intestine, and they are lost at about the eighth month, when the projections which bound the sacculi of this portion of the intestinal canal make their appearance. The valvulæ conniventes appear, in the form of slightly elevated, transverse folds, in the upper portion of the small intestine. The villi of the small intestine are permanent.

The mesentery is first formed of two perpendicular folds, attached to the sides of the spinal column. As the intestine undergoes development a portion of the peritoneal membrane extends in a quadruple fold from the stomach to the colon, to form the great omentum, which covers the small intestine in front.

As the head undergoes development a large cavity appears, which is eventually bounded by the arches that are destined to form the different parts of the face. This is the pharynx. It is entirely independent, in its formation, of the intestinal canal, the latter terminating in a blind extremity, at the stomach; and between the pharynx and the stomach there is at first no channel of communication. The anterior portion of the pharynx presents, during the sixth week, a large opening, which is afterward partially

closed in the formation of the face. The rest of this cavity remains closed until a communication is effected with the œsophagus. The œsophagus appears in the form of a tube, which finally opens into the pharynx above and into the stomach below. At this time there is really no thoracic cavity, the upper part of the stomach is very near the pharynx, the œsophagus is short, the rudimentary lungs appear by its sides and the heart lies just in front. As the thorax is developed, however, the œsophagus becomes longer, the lungs increase in size, and finally the diaphragm shuts off its cavity from the cavity of the abdomen. The growth of the diaphragm is from its periphery to the central portion, which latter gives passage to the vessels and the œsophagus. When this closure is incomplete there is the malformation known as congenital diaphragmatic hernia.

The development of the anus is very simple. At first the intestine terminates below in a blind extremity; but at about the seventh week a longitudinal slit appears below the external organs of generation, by which the rectum opens. This is the anus. It is not very unusual to observe an arrest in the development of this opening, the intestine terminating in a blind extremity, a short distance beneath the integument. This constitutes the malformation known as imperforate anus, a deformity which usually can be relieved, without much difficulty, by a surgical operation, if the distance between the rectum and the skin be not too great. The opening of the anus appears about a week after the opening of the mouth, at or about the seventh week.

The rudiments of the liver appear very early, and, indeed, at the end of the first month this organ has attained a large size. Two projections, or buds, appear on either side of the intestine, which form the two principal lobes of the liver. This organ is at first symmetrical, the two lobes being of nearly the same size, with a median fissure. One of these prolongations from the intestine becomes perforated and forms the excretory duct, of which the gall-bladder, with its duct, is an appendage. During the early part of fœtal life the liver occupies the greatest part of the abdominal cavity. Its weight, in proportion to the weight of the body at different ages, is as follows: At the end of the first month, 1 to 3; at term, 1 to 18; in the adult, 1 to 36 (Burdach). Its structure is very soft during the first months. As development advances and as the relative size of the liver gradually diminishes, its tissue becomes more solid.

The pancreas appears at the left side of the duodenum, by the formation of two ducts leading from the intestine, which branch and develop glandular structure at their extremities. The spleen is developed, about the same time, at the greater curvature of the stomach, and becomes distinct during the second month.

There is no reason to believe that any of the digestive fluids are secreted during intraüterine life. At birth the intestine contains a peculiar substance, called meconium, which will be described farther on. Cholesterine, an important constituent of the bile, is found in large quantity in the meconium.

Development of the Respiratory System.

On the anterior surface of the membranous tube which becomes the œsophagus, an elevation appears, which soon presents an opening into the œsophagus, the projection forming at this time a single, hollow *cul-de-sac*. This opening becomes the rima glottidis, and the single tube with which it is connected is developed into the trachea. At the lower extremity of this tube, a bifurcation appears, terminating first in one and afterward in several *culs-de-sac*. The bifurcated tube constitutes, after the lungs are developed, the primitive bronchia, at the extremities of which are the branches of the bronchial tree. As the bronchia branch and subdivide, they extend downward into what becomes eventually the cavity of the thorax. The pulmonary vesicles are developed before the trachea (Burdach). The lungs contain no air at any period of intraüterine life and receive but a small quantity of blood; but at birth they become distended with air, are increased thereby in volume and receive all the blood from the right ventricle. This process of development is illustrated in Fig. 306. The lungs appear, in the human embryon, during the sixth week. The two portions into which the original bud is bifurcated constitute the true pulmonary structure, and the formation of the trachea and bronchial tubes occurs afterward and is secondary.

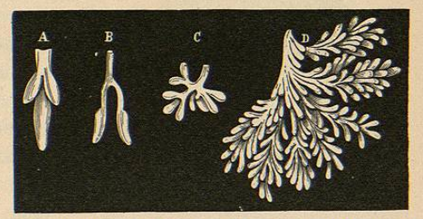

Fig. 306.—*Formation of the bronchial ramifications and of the pulmonary cells.—A, B, development of the lungs, after Rathke; C, D, histological development of the lungs, after J. Müller* (Longet).

Development of the Face.

The anterior portion of the embryon remains open in front long after the medullary plates have met at the back and enclosed the neural canal. The common cavity of the thorax and abdomen is closed by the growth of the visceral plates, which meet in front. At the time that the visceral plates are closing over the thorax and abdomen, four distinct, tongue-like projections appear, one above the other, by the sides of the neck. These are called the visceral arches, and the slits between them are called the visceral clefts. The first three arches, enumerating them from above downward, correspond, in their origin, to the three primitive cerebral vesicles. The fourth arch—which is not enumerated by some authors, who recognize but three arches—corresponds to the superior cervical vertebræ. Of these four arches, the first is the most important, as its development, in connection with that of the frontal process, forms the face and the malleus and incus of the middle ear. The second arch forms the lesser cornua of the hyoid bone, the stapes and the styloid ligament. The third arch forms the body and the greater cornua of the hyoid. The fourth arch forms the larynx. The first cleft, situated between the first and the second arch, is finally closed in front, but an opening

remains by the side, which forms, externally, the external auditory meatus, and internally, the tympanic cavity and the Eustachian tube. The other clefts become obliterated as the arches advance in their development.

From the above sketch, it is seen that the face and the neck are formed by the advance and closure in front of projections from behind, in the same way as the cavities of the thorax and abdomen are closed; but the closure of the first visceral arch is complicated by the projection, from above downward, of the frontal, or intermaxillary process, and by the formation of several secondary projections, which leave certain permanent openings, forming the mouth, nose etc.

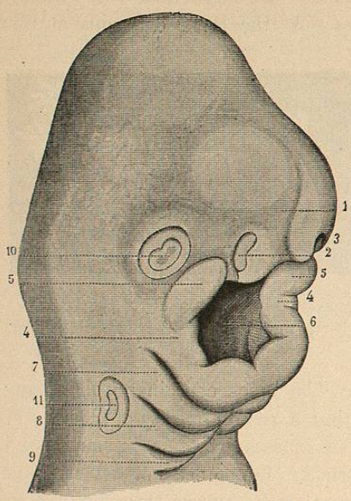

FIG. 307.—*Mouth of a human embryon of twenty-five to twenty-eight days; magnified* 15 *diameters* (Coste).

1, median or frontal process, the inferior portion of which is considerably enlarged; 2, right nostril; 3, left nostril; 4, 4, inferior maxillary processes, already united in the median line; 5, 5, superior maxillary processes, which have become quite prominent and have descended to the level of the slope of the frontal process; 6, mouth; 7, first visceral arch; 8, second visceral arch; 9, third visceral arch; 10, eye; 11, ear.

In the very first stages of development of the head there is no appearance of the face. The cephalic extremity consists simply of the cerebral vesicles, the surface of this enlarged portion of the embryon being covered, in front as well as behind, by the epiblast. During the sixth week, after the cavity of the pharynx has appeared, the membrane gives way in front, forming a large opening, which may be called the first opening of the mouth. At this time, however, the face is entirely open in front, as far back as the ears. The first, or the superior visceral arch, now appears as a projection of the mesoblast, extending forward. This is soon marked by two secondary projections, the upper projection forming the superior maxillary portion of the face, and the lower, the inferior maxilla. The two projections which form the lower jaw soon meet in the median line, and their superior margin is the lower lip. At the same time there is a projection from above, extending between the two superior projections, which is called the frontal, or intermaxillary process. This extends from the forehead—that portion which covers the front of the cerebrum—downward. The superior maxillary projections then advance forward, gradually passing to meet the frontal process, but leaving two small openings on either side of the median line, which are the openings of the nostrils. The upper portion of the frontal process thus forms the nose; but below, is the lower end of this process, which is at first split in the median line, projects below the nose, and forms the incisor process, at the lower border of which are finally developed the incisor teeth. As the superior maxillary processes advance forward, the eyes are moved, as it were, from the

sides of the head and present anteriorly, until finally their axes become parallel. These processes advance from the two sides, come to the sides of the incisor process, beneath the nose, unite with the incisor process on either side, and their lower margin, with the lower margin of the incisor process, forms the upper lip; but before this, the two lateral halves of the incisor process have united in the median line. At the bottom of the cavity of the mouth a small papilla makes its appearance, which gradually elongates and forms the tongue.

While this process of development of the anterior portion of the first visceral arch is going on, at its posterior portion, the malleus and incus are developing, the former being at first connected with the cartilage of Meckel, which extends along the inner surface of the inferior maxilla, the cartilages from either side meeting at the chin. The cleft between the first and the second visceral arch has closed, except at its posterior portion, where an opening is left for the external auditory meatus, the cavity of the tympanum and the Eustachian tube.

At the same time the second visceral arch advances and forms the stapes, the styloid ligament and the lesser cornua of the hyoid bone. The third arch advances in the same way; and the arches from the two sides meet, become united in the median line and form the body and the greater cornua of the hyoid bone. The clefts between the second and the third and between the third and fourth arches are finally obliterated.

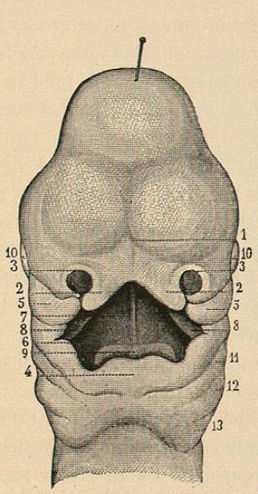

FIG. 308.—*Mouth of a human embryon of thirty-five days* (Coste).

1, frontal process, widely sloped at its inferior portion; 2, 2, incisor processes produced by this sloping; 3, 3, nostrils; 4, lower lip and maxilla, formed by the union of the inferior maxillary processes; 5, 5, superior maxillary processes, contiguous to the incisor process; 6, mouth, still confounded with the nasal fossæ; 7, first appearance of the closure of the nasal fossæ; 8, 8, first appearance of the two halves of the palatine arch; 9, tongue; 10, 10, eyes; 11, 12, 13, visceral arches.

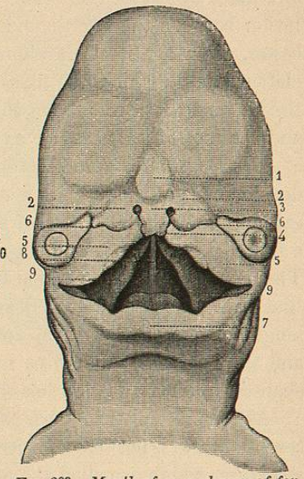

FIG. 309.—*Mouth of an embryon of forty days* (Coste).

1, first appearance of the nose; 2, 2, first appearance of the alæ of the nose; 3, appearance of the closure beneath the nose; 4, middle, or median portion of the upper lip, formed by the approach and union of the two incisor processes, a little notch in the median line still indicating the primitive separation of the two processes; 5, 5, superior maxillary processes, forming the lateral portions of the upper lip; 6, 6, groove for the development of the lachrymal sac and the nasal canal; 7, lower lip; 8, mouth; 9, 9, the two lateral halves of the palatine arch, already nearly approximated to each other in front, but still widely separated behind.

The fourth arch forms the sides of the neck and the larynx, the arytenoid cartilages being developed first. In front of the larynx and just behind the tongue, is a little elevation, which is developed into the epiglottis. The